DRAFT NORTH FRONT AVENUE
INTERIM SOURCE CONTROL MEASURE WORK PLAN
RP - PORTLAND SITE

July 10, 2007

Submitted to:

Oregon Department of Environmental Quality
Northwest Region
2020 S.W. 4th Avenue, Suite 400
Portland, Oregon 97201

Prepared for:

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0-61M-107030/Phase 80/T2

July 10, 2007

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Tom Roick
Oregon Department of Environmental Quality
2020 S.W. 4th Avenue
Portland, Oregon 97201

Dear Mr. Roick:

Re: Draft North Front Avenue Interim Source Control Measure Work Plan
Request for Approval
RP - Portland Site

On behalf of SLLI, AMEC Earth & Environmental, Inc., is submitting to the Oregon Department of Environmental Quality (DEQ) the referenced Work Plan for review and approval. As part of a broader remediation strategy, SLLI plans to implement the proposed Interim Source Control Measure (ISCM) to improve the quality of deep groundwater before it migrates to the bank of the Willamette River.

Recently, SLLI completed a bioremediation pilot study in the Lake Area of the former Rhône-Poulenc (RP) Property that injected air and hydrogen peroxide into the groundwater to reduce target constituent concentrations. The findings of the pilot study triggered consideration of alternative technologies. As we have previously advised you, this Work Plan describes why in-situ chemical oxidation using persulfate injection was selected and how it will be used to treat the deep groundwater. The Work Plan presents a summary of the recent pilot study, evaluates a range of alternatives, identifies persulfate injection as the best alternative, and presents the 60% design and installation plan.

The Work Plan includes 60% design engineering drawings, which are provided as Appendix A. To reach the 90% (final) design stage necessary to release contract bid packages, additional data collection activities are planned. Results from these activities will be submitted to DEQ as supplements to this Work Plan. In order to implement the ISCM during fall 2007, SLLI requests Work Plan approval at this current 60% design stage. Timely approval from DEQ is necessary to avoid substantial delays in achieving access from affected property owners. Specific conditions of approval identified by DEQ can be incorporated into the final design.

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Eight bound copies and one compact disk of the Work Plan are being delivered to DEQ at today's meeting. We look forward to our discussions. In the meantime, if you have any questions, following the meeting, please call Roger Gresh or Jim Feild at (503) 639-3400.

Sincerely,

AMEC Earth & Environmental, Inc.

James B. Feild, R.G.
Associate Hydrogeologist

Roger T. Gresh, P.G.
Project Manager

Attachments: Draft North Front Avenue Interim Source Control Measure Work Plan

JBF/lp

c: S. Dearden, sanofi-aventis, US, Inc
R. Ferguson, SLLI
J. Benedict, CHBH&L

Table of Contents

Page

LIST OF ACRONYMS AND ABBREVIATIONS iv

1.0 INTRODUCTION 1
- 1.1 Purpose 1
- 1.2 Purpose of ISCM 2
- 1.3 Work Plan Organization 3
- 1.4 ISCM Location 5

2.0 RESULTS OF JSCS SCREENING AND SELECTION OF TARGET CONSTITUENTS 5

3.0 REMEDIAL ACTION OBJECTIVE 6

4.0 BACKGROUND 6
- 4.1 Site Location and History 6
- 4.2 Geology and Hydrogeology 8
  - 4.2.1 Geologic CSM 8
  - 4.2.2 Hydrogeologic CSM 9

5.0 CURRENT CONDITIONS IN THE DEEP GRAVEL ZONE 13
- 5.1 Target Constituents in Groundwater 13
- 5.2 Soil and Groundwater Geochemistry 14
  - 5.2.1 Oxygen, Oxidation-Reduction Potential, Nitrate, and Nitrite 14
  - 5.2.2 Iron and Manganese 14
  - 5.2.3 Sulfate, Sulfide, Methane, Ethene, and Ethane 15
  - 5.2.4 Microbial Activity and Nutrients 15
  - 5.2.5 Summary of Geochemical Conditions for the Deep Gravel Zone 15
  - 5.2.6 Groundwater Fate and Transport Model Summary 16
- 5.3 Summary of Pilot Study Results 17
  - 5.3.1 Hydrogeology Assessment 17
  - 5.3.2 Air Injection 17
  - 5.3.3 Hydrogen Peroxide Injection 19
  - 5.3.4 Pilot Study Summary 19

6.0 REMEDIAL TECHNOLOGY SCREENING 20
- 6.1 Description of Remedial Approaches and Introduction of Remedial Technologies 20
  - 6.1.1 In-Situ Treatment Technologies 21
  - 6.1.2 In-Situ/Ex-Situ Treatment Technologies 23
  - 6.1.3 Remedial Technology Screening Summary 23
- 6.2 Screening of Remedial Alternatives 24
  - 6.2.1 Aerobic In-Situ Bioremediation Remedial Alternatives 24
  - 6.2.2 In-Situ Chemical Oxidation Remedial Alternatives 27
  - 6.2.3 Air Sparging/Soil Vapor Extraction Remedial Alternative 29
  - 6.2.4 Groundwater Extraction and Treatment Remedial Alternative 30
  - 6.2.5 Remedial Alternative Screening Summary 30
- 6.3 Evaluation of Remedial Alternatives by Balancing Factor Approach 31
  - 6.3.1 Evaluation Results for Each Remedial Alternative 32
  - 6.3.2 Comparing Evaluation Results for Remedial Alternatives 36

6.4 Alternative Selection 38

7.0 ISCM SYSTEM DESIGN AND INSTALLATION OVERVIEW 38

8.0 BASIS FOR DEQ APPROVAL 39

9.0 INSTALLATION AND CONSTRUCTION 41
9.1 Site Preparation 41
9.2 Drilling Methodology 41
9.3 Site Access, Utilities, and Remediation Compounds 42
9.4 Baseline Sampling 43
9.5 System Startup 43

10.0 OPERATION AND MAINTENANCE 43
10.1 Groundwater Sampling 43
10.2 In-Situ Chemical Oxidation System Maintenance 44
10.3 Remedial Process Optimization 44

11.0 REMEDIATION WASTE MANAGEMENT 44

12.0 REPORTING 46
12.1 Installation Report 46
12.2 Progress Reports 46

13.0 SITE ACCESS 46

14.0 HEALTH AND SAFETY 47

15.0 SCHEDULE 47

REFERENCES 48

LIMITATIONS 52

List of Tables

Table 1 Target Constituent Comparison to JSCS SLVs
Table 2 2006 Groundwater Geochemistry Data Summary
Table 3 2006 Soil Geochemistry Data Summary
Table 4 Summary of SF_6 Tracer Test Data, LA Pilot Study Array
Table 5 Identification of Potential Remedial Technologies for Control of Plume in DGZ
Table 6 Screening of Potential Remedial Alternatives for Control of Plume in DGZ
Table 7 Assessment of Technology Balancing Factors for Remedial Alternatives

List of Figures

Figure 1 North Front Avenue Interim Source Control Measure Location
Figure 2 North Front Avenue ISCM Utility Location Map
Figure 3 Lithologic Cross Section Locations
Figure 4 Lithologic Cross Section C-C'
Figure 5 Lithologic Cross Section E-E'
Figure 6 Lithologic Cross Section F-F'
Figure 7 Lithologic Cross Section G-G'
Figure 8 Lithologic Cross Section J-J'
Figure 9 Basalt Elevation Contour Map
Figure 10 1,2-Dichlorobenzene Distribution in Groundwater, 2004-2006, Fill Zone
Figure 11 1,2-Dichlorobenzene Distribution in Groundwater, 2004-2006, Aullivum Zone
Figure 12 1,2-Dichlorobenzene Distribution in Groundwater, 2004-2006, Deep Gravel Zone
Figure 13 1,2-Dichlorobenzene Distribution in Groundwater, 2004-2006, Basalt Zone
Figure 14 North Front Avenue Interim Source Control Measure with DGZ & Basalt Zone Groundwater Elevations (Nov. 2006) & Approximate 1,2-Dichlorobenzene 130 µg/L Contour in the DGZ (Most Recent)
Figure 15 North Front Avenue Interim Source Control Measure First Line Performance Monitoring Well Locations
Figure 16 Preliminary North Front Avenue Interim Source Control Measure Schedule

List of Appendices

Appendix A North Front Avenue ISCM System Design and Installation Plan
Appendix B Groundwater Monitoring Field Sheet

LIST OF ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
1,2-DCB	1,2-dichlorobenzene
1,4-DCB	1,4-dichlorobenzene
2,4-D	2,4-dichlorophenoxyacetic acid
2,4-DB	4-(2,4-dichlorophenoxy)butyric acid
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
Alluvium	Alluvium Geologic Zone
Alluvium Zone	Alluvium Hydrogeologic Zone
AMEC	AMEC Earth & Environmental, Inc.
ARAR	Applicable or Relevant and Appropriate Requirement
Arkema	Arkema, Inc.
AS/SVE	Air Sparging and Soil Vapor Extraction
Basalt Zone	Basalt Hydrogeologic Zone
Basalt	Basalt Geologic Zone
bgs	below ground surface
BNSF	BNSF Railway Company
CB	chlorobenzene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfu/mL	colony forming units per milliliter
COP	City of Portland
CRBG	Columbia River Basalt Group
CSM	Conceptual Site Model
DAG	Deep Alluvial Gravel Geologic Zone
DEQ	Oregon Department of Environmental Quality
DGZ	Deep Gravel Hydrogeologic Zone
DO	dissolved oxygen
DOT	United States Department of Transportation
EPA	United States Environmental Protection Agency
ESCO	ESCO Corporation

Fe^{2+}	ferrous iron
Fe^{3+}	ferric iron
Fill Zone	Fill Hydrogeologic Zone
ft/d	feet per day
GAC	granular activated carbon
GET	Groundwater Extraction and Treatment
Gould	Gould Electronics
HA	Herbicide Area
HASP	Health and Safety Plan
IA	Insecticide Area
ISCM	Interim Source Control Measure
ISCO	In-Situ Chemical Oxidation
JSCS	Joint Source Control Strategy
LA	Lake Area
LAHI	Lake Area Hydrologic Investigation
LWG	Lower Willamette Group
MCL	Maximum Contaminant Level
MCPA	4-chloro-2-methylphenoxyacetic acid
mg/L	milligrams per liter
MGP	Manufactured Gas Plant
MNA	Monitored Natural Attenuation
mV	millivolts
NDL	North Doane Lake
NFA	North Front Avenue
NPDES	National Pollutant Discharge Elimination System
O&M	Operation and Maintenance
ORP	Oxidation-Reduction Potential
PPE	personal protective equipment
psi	pounds per square inch
PTB	Permeable Treatment Barrier
PVC	polyvinyl chloride

RAO	Remedial Action Objective
Redox	oxidation-reduction
RI	Remedial Investigation
River	Willamette River
ROD	Record of Decision
ROW	right of way
RP	Rhône-Poulenc
RPO	Remedial Process Optimization
RW	remediation waste
SCAA	Source Control Alternatives Analysis
SCDD	Source Control Decision Document
SCE	Source Control Evaluation
scfm	standard cubic feet per minute
Schnitzer	Schnitzer Investment Corporation
SCP	Source Control Program
SF_6	sulfur hexafluoride
Siltronic	Siltronic Corporation
SLV	screening level value
SO_4^{2+}	sulfate
SOP	standard operating procedure
TOC	total organic carbon
UIC	Underground Injection Control
USGS	United States Geological Survey
VC	vinyl chloride
WDL	West Doane Lake
Work Plan	NFA ISCM Work Plan
WTP	Water Treatment Plant

1.0 INTRODUCTION

1.1 Purpose

On behalf of SLLI, AMEC Earth & Environmental, Inc. (AMEC) is submitting to the Oregon Department of Environmental Quality (DEQ) this North Front Avenue (NFA) Interim Source Control Measure (ISCM) Work Plan (Work Plan) for review and approval. The Work Plan provides the rationale and 60% design for constructing and operating an ISCM to treat Rhône-Poulenc (RP) Portland Site (RP Site) target constituents in the Deep Gravel Hydrogeologic Zone (DGZ) between the RP Property and the Willamette River (River) (Figure 1). The NFA ISCM will be located along an approximately 1,100-foot-long transect that runs along the BNSF Railway Company (BNSF) right of way (ROW) on the north side of the railroad embankment, and within the NW Front Avenue ROW on the south side of the railroad embankment (Figure 2). The area beneath the BNSF railroad embankment is included in the transect and will be treated via angled borings.

The NFA ISCM is one of several planned RP Site source control measures to be implemented, and it has been designed as one component of an integrated Site-wide remedy. The purpose of the NFA ISCM is to reduce the concentrations of target constituents in the groundwater in the DGZ before in-water remediation is implemented for the Portland Harbor Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site. As detailed in Section 2.0, the target constituents are chlorobenzene (CB), 1,2-dichlorobenzene (1,2-DCB), 1,4-dichlorobenzene (1,4-DCB), and vinyl chloride (VC).

The Work Plan includes 60% design engineering drawings, which are provided as Appendix A. To reach the 90% (final) design stage necessary to release contract bid packages, additional data collection activities are planned. Results from these activities will be submitted to DEQ as supplements to this Work Plan. Because SLLI's objective is to initiate implementation of the ISCM during fall 2007, SLLI requests Work Plan approval at this current 60% design stage on or before July 24, 2007.

In addition to presenting the 60% design, the Work Plan provides the remedial action objectives (RAOs) and a screening of remedial technologies and alternatives which identifies persulfate injection as the preferred ISCM alternative. The Work Plan also presents: an overview of ISCM installation and construction activities; a summary of operations and maintenance tasks; a discussion on closure determination; and details regarding the activities planned (Section 8.0) to fill remedial design data gaps

associated with hydraulic characteristics, groundwater flow rates and velocities, and oxidant demand by the aquifer matrix.

1.2 Purpose of ISCM

The purpose of the NFA ISCM is to reduce the concentrations of target constituents in the groundwater in the DGZ before the groundwater migrates to the riverbank. Target constituents include CB, 1,2-DCB, 1,4-DCB, and VC as identified in our Source Control Evaluation (SCE) activities (discussed below).

The timing of the installation and operation is to allow demonstration of effective treatment in advance of the predicted 2010 Portland Harbor CERCLA Record of Decision (ROD) to meet the goal of the Final Joint Source Control Strategy (JSCS) document that addressed the need to control ongoing sources of contamination to the River before remediation of the Portland Harbor Site (DEQ/EPA, 2005).

The NFA ISCM has been designed to treat both the known and potential DGZ pathway on both sides of the railroad embankment, (the presence of a complete migration pathway south of the railroad bridge has not been determined).

Evaluation of potential groundwater pathways to the riverbank on the south side of the BNSF railroad tracks will not be finished until completion of the Stage I SCE. As is discussed in Section 4.2.2 and Section 5.0 below, information has already been collected and evaluated for the DGZ groundwater pathway to the riverbank on the north side of the BNSF railroad tracks through various means as part of the lower Willamette Group's (LWG's) transition zone water discharge study, and SLLI's Stage 1 and Stage 2 SCE investigations completed on Siltronic Corporation (Siltronic) property.

SCE efforts conducted to date have included development and implementation of a Final Stage 1 SCE Work Plan (AMEC, 2005c; DEQ, 2005b and 2005c), and the Draft Stage 2 SCE Work Plan (AMEC, 2006a; DEQ, 2006a). Due to delays by Arkema in providing property access, the beach area portion of the Stage 1 SCE has not yet been completed. However, Arkema recently granted access and now the remainder of the Stage 1 SCE scope of work is anticipated to be completed in summer and fall 2007.

In addition to Stage 1 and 2 SCE activities, two focused RI groundwater monitoring events were also completed in 2006, one in winter and one in summer (AMEC, 2006b and 2007b). A Lake Area Hydrologic Investigation (LAHI) conducted in 2006 included the installation and groundwater monitoring of new monitoring well clusters on the RP,

ESCO Corporation (ESCO), and BNSF properties (AMEC, 2007a). All of these activities were designed to compliment the SCE.

An interim SCE Report will be submitted to DEQ in late 2007. This report will include the evaluation of identified or potential pathways by which RP constituents might migrate to the riverbank based on investigations conducted to date. However, this report will not include the results of the remaining Stage 1 SCE field work which will be completed in late 2007. A supplemental SCE Report will be submitted to document the remaining Stage 1 SCE results. The results of the remaining Stage 1 SCE activities and other SCE investigations will be considered in development of the Source Control Alternatives Analysis (SCAA) in 2008. The Source Control Decision Document (SCDD) is scheduled to be completed in 2009.

In order to meet a 2010 goal of achieving substantial control in the DGZ at the riverbank it is necessary to implement the NFA ISCM in late 2007, before agency approval of the final SCDD. SLLI, therefore, intends to implement the NFA ISCM on an at-risk, interim basis. As described in Section 5.2.6, numerical groundwater fate and transport modeling indicates that the time required for the treated groundwater to reach the riverbank from a central portion of the NFA ISCM location is approximately 2 to 4 years, or slightly less or more depending on its origination along the ISCM location.

1.3 Work Plan Organization

The remaining sections of this report are organized as follows:

Section 2.0, Results of JSCS Screening and Selection of Target Constituents, presents the basis for selecting target constituents for the ISCM treatment.

Section 3.0, Remedial Action Objectives, describes the NFA ISCM objectives.

Section 4.0, Background, briefly summarizes the operational history and hydrogeologic characteristics of the Site.

Section 5.0, Current Conditions in the Deep Gravel Zone, summarizes the current chemical conditions, including target constituent concentrations, in the DGZ where ISCM treatment is planned, and presents a summary of the results of the Lake Area (LA) Pilot Study.

Section 6.0, Remedial Technology Screening, screens remedial technologies, using DEQ balancing factors, by their ability to attain the RAOs in the DGZ, and identifies persulfate injection as the preferred ISCM alternative.

Section 7.0, ISCM System Design and Installation Overview, presents the 60% design for implementing in-situ chemical oxidation with persulfate injection as the ISCM (also Appendix A).

Section 8.0, Basis for DEQ Approval, summarizes the basis for requesting DEQ approval of persulfate injection for the ISCM and outlines the plan for implementing the ISCM.

Section 9.0, Installation and Construction, presents NFA ISCM preparation activities, drilling methodology, permitting, utilities, compound installation, baseline sampling, and system start-up.

Section 10.0, Operation and Maintenance, discusses activities associated with groundwater sampling, in-situ chemical oxidation system maintenance, and Remedial Process Optimization.

Section 11.0, Remediation Waste Management, describes the procedures for sampling, handling, and disposal of the remediation waste generated during the installation, and operation and maintenance of the NFA ISCM.

Section 12.0, Reporting, discusses the components of the Installation Report, Progress Reports, and the Final Decommissioning Report.

Section 13.0, Site Access, discusses the steps necessary to obtain property access from adjacent property owners, as well as site access for installation equipment.

Section 14.0, Health and Safety, references the Site-specific Health and Safety Plan, which will include job safety analyses prepared for project tasks implemented since June 2005.

Section 15.0, Schedule, presents a Gantt Chart illustrating the tentative schedule for various components of the NFA ISCM implementation.

This Work Plan will be implemented according to installation and monitoring procedures outlined in the NFA ISCM System Design and Installation Plan (Appendix A), and the Site-Specific Health and Safety Plan (HASP) dated June 24, 2005 (AMEC, 2005b), including more recent job safety analyses prepared for new project tasks since June 2005. Groundwater monitoring field sheets are included in Appendix B.

1.4 ISCM Location

The NFA ISCM will be located on the BNSF ROW on the north side of the railroad embankment, and within the NW Front Avenue ROW on the south side of the railroad embankment (Figure 2). The system is designed to target the DGZ, which is defined as the hydrogeologic zone in the alluvial gravels and the uppermost portion of the weathered basalt as presented in Section 4.2.2.

The system location was based on distribution of target constituents (CB, 1,2-DCB, 1-4-DCB, and VC) in groundwater and transition zone water as presented in Section 2.0. Furthermore, the NFA ISCM location was based on time of travel to the riverbank, the estimated ROD date of November 2010, and implementation limitations from surface features including the railroad tracks and embankment, North Doane Lake (NDL), underground utilities, and the upcoming planned remedial actions at West Doane Lake (WDL).

This NFA ISCM is one of several planned RP Site source control measures to be implemented, and has been designed as one component of an integrated Site-wide remedy.

2.0 RESULTS OF JSCS SCREENING AND SELECTION OF TARGET CONSTITUENTS

The target constituents for the NFA ISCM, CB, 1,2-DCB, 1,4-DCB, and VC, were selected based on the following rationale:

- These constituents are present in riverbank wells on Siltronic property, and were detected in transition zone water samples collected by the Lower Willamette Group (LWG) from the relatively transmissive offshore discharge zone in the River identified as part of the Portland Harbor Round 2 data collection activities. The target constituents were detected at concentrations that exceed the most conservative JSCS Screening Level Value (SLV) for fish consumption or drinking water (based only on the United States Environmental Protection Agency [EPA] Maximum Contaminant Level [MCL]). Table 1 provides a summary of the JSCS SLVs for the target constituents.
- The DGZ represents a complete pathway for these constituents between the RP Property and certain areas of the riverbank.

As described below, the objectives of the NFA ISCM relate to reduction of target constituent concentration in the DGZ.

3.0 REMEDIAL ACTION OBJECTIVE

The NFA ISCM is designed to treat target constituents in the DGZ (Section 4.2.2). Design and installation of the NFA ISCM are strategic components of, and compatible with, the anticipated RP Site-wide remedy. The RAO for the NFA ISCM is:

- Reduce concentrations of target constituents in groundwater within the DGZ to Site-specific risk-based cleanup levels protective of human health and the environment at the riverbank compliance wells.

In addition to achieving this RAO, the NFA ISCM is expected to minimize the potential for target constituents to discharge from the DGZ to the alluvium/sediment interface in the River at concentrations above Site-specific risk-based cleanup levels. Furthermore, although it is questionable whether or not any facilitated transport of dioxins or other recalcitrant compounds in the DGZ is actually occurring, the NFA ISCM also is anticipated to minimize the potential for future facilitated transport by interrupting the transport mechanisms.

To accomplish this RAO, a variety of treatment approaches and technologies were evaluated and are discussed in Section 6.0. Based on this evaluation, in-situ chemical oxidation treatment using persulfate injection was selected to achieve the above-listed RAO, as presented in Section 6.4.

4.0 BACKGROUND

This section describes the RP facility location and operational history, summarizes the geologic and hydrogeologic conceptual site models (CSMs) for the RP Site and the NFA ISCM location, and sets the geologic and hydrogeologic framework for the ISCM treatment zone.

4.1 Site Location and History

The RP Property comprises approximately 17 acres and is located in Section 13 of Range 1 West, Township 1 North of the Willamette Meridian. The RP Property is located in the Guild's Lake Industrial Sanctuary (City of Portland, 2001), which is a heavily industrialized area northwest of Portland and southwest of the River. Adjacent and nearby properties are owned by the City of Portland (COP), Siltronic, Schnitzer Investment Corporation (Schnitzer), Arkema, Inc. (Arkema), ESCO, Gould Electronics (Gould), Metro, and BNSF. The Gould, ESCO, and Schnitzer properties, along with

the LA portion of the RP Property, were part of the Gould Superfund Site. The RP Property and vicinity are depicted on Figure 1.

The former RP Property facility was operational from 1943 to 1990. The property historically has been separated, for the purpose of investigation, into three areas identified as the Insecticide Area (IA), the Herbicide Area (HA), and the LA (Figure 1). Manufacturing of herbicides occurred primarily in the HA; formulation of insecticides occurred in the IA. A general production chronology for the HA and IA ("Plant Area") is summarized below:

- Early production included: formulation of railroad ROW treatments, fertilizers and inorganic pesticides, and sodium arsenite liquids;
- Early 1950s: added formulation of organochlorine insecticides and chlorophenoxy herbicides;
- Expanded in 1956 to include manufacture of 2,4-dichlorophenoxyacetic acid (2,4-D) and its esters;
- 1960: added manufacture of 4-chloro-2-methylphenoxyacetic acid (MCPA) and its esters, and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) esters from purchased 2,4,5-T;
- 1964: added manufacture of 4-(2,4-dichlorophenoxy)butyric acid (2,4-DB) and esters;
- 1969: discontinued formulation of all insecticides;
- 1971: bromoxynil products were added to production;
- 1976: discontinued production of MCPA; and
- 1980: discontinued production of 2,4-D and 2,4-DB.
- 1990: discontinued production of all products at facility.

The RP Site is currently undergoing a Remedial Investigation (RI) under a 1999 Consent Order with DEQ. Extensive soil and groundwater sampling have been conducted at and in the vicinity of the RP Property. Remedial actions to date include an ongoing groundwater extraction system, soil capping in the former plant area, and repair of a COP Outfall 22B storm sewer to mitigate groundwater infiltration.

4.2 Geology and Hydrogeology

The geologic and hydrogeologic framework for the RP Site and surrounding properties has been characterized through a number of complimentary investigations. Recently, the hydrogeologic framework for the Site was updated to incorporate geologic and hydrogeologic data collected as part of the Stage 1 SCE, Stage 2 SCE, and the LAHI. The geologic and hydrogeologic CSMs for the RP Site and surrounding properties were presented in the Stage 2 SCE Technical Memorandum dated June 21, 2007. Brief discussions of the geologic and hydrogeologic CSMs are provided below. The NFA ISCM is designed to reduce concentrations of target constituents present in the DGZ.

To aid in the discussion of the geologic and hydrogeologic framework of the NFA ISCM, five lithologic cross sections (C-C', E-E', F-F', G-G', and J-J') at the RP Site relative to the location of the NFA ISCM are provided. This information is presented in a cross section location map showing the location of the five cross sections (Figure 3), C-C' (Figure 4), E-E' (Figure 5), F-F' (Figure 6), G-G' (Figure 7), and J-J' (Figure 8). Cross section C-C' parallels the River from the northwestern portion of the Siltronic property to the southeastern portion of the Arkema property. Cross section E-E' roughly parallels the River approximately halfway between the River and Highway 30. Cross section F-F' extends from Highway 30 (on the north side of NDL) to the River. Cross section G-G' extends from the south side of Highway 30 (to the south of NDL) north to the River. Cross section J-J' represents the subsurface conditions along the transect of the planned NFA ISCM location, as does the southeastern portion of E-E'.

4.2.1 Geologic CSM

The geologic CSM was developed to understand the Site geologic framework and was based on a review of lithologic boring logs completed in the area. The geologic CSM is comprised of the Alluvium, Deep Alluvial Gravel, and Basalt Geologic Zones. Descriptions of these zones are summarized below:

- Alluvium Geologic Zone (Alluvium) consists of unconsolidated fill material and alluvially-deposited silty sand, sandy silt, and clay. Both the fill and alluvial material contain silty sand, sandy silt, and clay; distinguishing the fill material from the alluvial material is aided by the presence of debris (i.e., bricks, gravel, battery casings, etc.). Fill material extends to depths of approximately 20 to 30 feet below ground surface (bgs), and is comprised of variable amounts of sand, silt, clay, organic material, gravel, and miscellaneous debris used to infill the former Doane Lake and the western bank of the River. The alluvial material underlying the fill is

comprised of sediments deposited by the River. The alluvium is broadly characterized as silty sand and sandy silt extending to depths ranging from 55 feet bgs on the RP Property to at least 205 feet bgs on the Siltronic property. Silty clay and clay with an average thickness of 15 feet is observed at approximately 25 feet bgs beneath the former Doane Lake area.

- The Deep Alluvial Gravel Geologic Zone (DAG) underlies the Alluvium beneath much of the RP Site, and consists of subrounded to rounded colluvial and alluvial gravels with cobble-sized clasts in a sand matrix. The DAG ranges from approximately 5 to 40 feet thick, and has bottom depths ranging from 60 feet bgs on the RP Property to at least 205 feet bgs on some areas of the Siltronic property. In general, the thickness of the DAG increases with proximity to the River and decreases with proximity to the Tualatin Mountains. At the RP property, the DAG is present primarily in the LA. Underlying the ESCO property, the DAG appears to be present in a relatively uniform layer (less than 10 feet thick) at the base of the Alluvium. At Arkema Lots 1 and 2, the DAG is present in a thin layer (less than 10 feet) on the western portion of the property and a small isolated deposit near the River at well cluster W-19. Observations to date indicate the greatest thickness of the DAG is approximately 40 feet bgs and its greatest depth is approximately 205 feet bgs, at RP-07 and SIL-01 respectively, both on Siltronic property.
- The Basalt Geologic Zone (Basalt) underlies the alluvial deposits of the Alluvium and, where present, the DAG. The Basalt beneath the Site is part of the Columbia River Basalt Group (CRBG). In the general vicinity of the Site, the Columbia River Basalt is at least 700 feet thick and consists of a series of lava flows separated by discontinuous layers of interflow tuff and sediment. At the Site, the uppermost portion of the basalt is observed as highly fractured to massive and highly weathered to fresh. The Basalt elevation contour map is presented as Figure 9.

4.2.2 Hydrogeologic CSM

The hydrogeologic CSM was developed to evaluate groundwater fate and transport at the RP Site, and consists of four hydrogeologic zones distinguished by groundwater elevation, aquifer permeability, and solute concentrations. The hydrogeologic CSM is comprised of the Fill, Alluvium, Deep Gravel, and Basalt Hydrogeologic Zones. Below is a summary of each of the hydrogeologic zones to illustrate the rationale behind the location and design of the NFA ISCM. Decision criteria for selecting the appropriate zone for each monitoring well zone designation were presented in the Stage 2 SCE TM (AMEC, 2007c).

Fill Hydrogeologic Zone

The Fill Hydrogeologic Zone (Fill Zone), part of the Alluvium Geologic Zone, consists of saturated fill material (e.g., dredge sand and silt, gravel, debris) associated with the infilling of former Doane Lake and a low-lying marshy area north of the BNSF railroad tracks. The Fill Zone is discontinuous and is distinguished from the Alluvium, Deep Gravel, and Basalt Hydrogeologic Zones by:

- Relatively high groundwater elevations; and
- Groundwater flow direction toward WDL south of the BNSF railroad tracks, toward NDL north of the BNSF railroad tracks, and toward the River near the River shore north and south of the BNSF railroad tracks.

The upper boundary of the Fill Zone is the water table; therefore, groundwater in the Fill Zone is unconfined (Freeze and Cherry, 1979). The depth to groundwater in the Fill Zone is generally less than 15 feet bgs. Groundwater elevations in the Fill Zone do not exhibit tidal fluctuation; therefore, the Fill Zone does not appear to be hydraulically connected to the River (URS, 2000).

Water enters the Fill Zone on the south side of the BNSF tracks by precipitation and leakage from the northern portion of WDL. Water leaves the Fill Zone on the south side of the BNSF tracks by discharge to the southern portion of WDL and to the underlying Alluvium Hydrogeologic Zone, which flows toward the River (AMEC, 2005a). Water enters the Fill Zone on the north side of the BNSF tracks by precipitation and leakage from the northern portion of NDL. Water leaves the Fill Zone on the north side of the BNSF tracks by groundwater discharge to the southern and western portions of NDL and to the underlying Alluvium Hydrogeologic Zone, which flows toward the River (AMEC, 2005a).

RP Site groundwater flow in the Fill Zone consists of a horizontal component toward WDL and NDL, and a vertical component toward the underlying Alluvium Zone caused by downward vertical hydraulic gradients (i.e., greater than 0.1 feet/feet) between the Fill and Alluvium Zones.

The average hydraulic conductivity of the Fill Zone is similar to that of the Alluvium Zone, is at least an order of magnitude less than that of the DGZ, and is slightly less than that of the Basalt Zone. Nine slug tests conducted at monitoring wells screened in the Fill Zone indicate that hydraulic conductivity ranges from 0.08 feet/day (ft/d) to 13.40 ft/d, with a geometric mean of 0.97 ft/d.

Alluvium Hydrogeologic Zone

The Alluvium Hydrogeologic Zone (Alluvium Zone) consists of saturated native silty sand and sandy silt. The Alluvium Zone is distinguished from the Deep Gravel and Basalt Hydrogeologic Zones by its lithology and low permeability. The Alluvium Zone is part of the Alluvium Geologic Zone.

Groundwater in the Alluvium Zone occurs under both unconfined and semi-confined conditions, but not under confined conditions. Unconfined conditions occur in the upper portion of the Alluvium Zone when the overlying Fill Zone is absent and the upper boundary of the Alluvium Zone is the water table (Freeze and Cherry, 1979). The Alluvium Zone exhibits semi-confined conditions when the overlying Fill Zone is present, or when shallow portions of the Alluvium Zone (which contain a higher percentage of silt) confine deeper portions of the Alluvium Zone (which contain a higher percentage of sand). Evidence for semi-confined conditions in the deeper portion of the Alluvium Zone includes:

- Groundwater elevations that rise above the bottom of the overlying Fill Zone, indicating that groundwater in the Alluvium Zone is pressurized, which is a property of semi-confined groundwater (Fetter, 1994);
- Drawdown observed in piezometers during a 24-hour pumping test at RP-03-52 indicate semi-confined conditions (Fetter, 1994); and
- According to data collected by URS (2000), groundwater elevations in the Alluvium Zone potentially exhibit tidal fluctuation as far inland as the W-11 well cluster on ESCO property; therefore, the Alluvium Zone potentially appears to be semi-confined and hydraulically connected to the River.

Water recharges the Alluvium Zone by infiltration from precipitation (where the Fill Zone is not present), leakage from the overlying Fill Zone (where present), leakage from the underlying Deep Gravel and Basalt Hydrogeologic Zones, and lateral inflow from the Tualatin Mountains. Groundwater in the Alluvium Zone generally flows northeast, from the Tualatin Mountains toward the River. Groundwater elevations in the Alluvium Zone are similar to groundwater elevations in the Deep Gravel and Basalt Hydrogeologic Zones, and are lower than groundwater elevations in the Fill Zone.

The average hydraulic conductivity of the Alluvium Zone is similar to that of the Fill Zone, but is at least an order of magnitude less than that of the DGZ, and is slightly less than that of the Basalt Zone. Thirty-nine slug tests conducted at monitoring wells

screened in the Alluvium Zone indicate that hydraulic conductivity in the Alluvium Zone ranges from 0.01 ft/d to 10.70 ft/d, with a geometric mean of 0.89 ft/d.

Deep Gravel Hydrogeologic Zone

The DGZ consists of transmissive alluvial gravel, colluvial gravel, and weathered basalt that has hydrogeologic properties similar to the DAG. The DGZ is distinguished from the Fill, Alluvium, and Basalt Hydrogeologic Zones by its relatively high permeability, and by the gravel and weathered basalt lithology. The DGZ is comprised of the DAG and the uppermost weathered portion of the Basalt.

The evidence for groundwater in the DGZ existing under semi-confined, but not confined, conditions includes:

- Groundwater elevations that rise above the top of the DGZ, indicating that groundwater in the DGZ is pressurized, which is a property of semi-confined groundwater (Fetter, 1994); and
- According to data collected by URS (2000), groundwater elevations in the DGZ potentially exhibit tidal fluctuation; therefore, the DGZ appears to be semi-confined and hydraulically connected to the River.

Groundwater enters the DGZ by lateral inflow from the Tualatin Mountains, leakage from the overlying Alluvium Zone, and leakage from the underlying Basalt Hydrogeologic Zone. Groundwater in the DGZ flows northeast, from the Tualatin Mountains toward the River.

Average hydraulic conductivity of the DGZ is at least one order of magnitude greater than that of the Fill, Alluvium, and Basalt Zones. Thirty-two slug tests conducted at monitoring wells screened in the DGZ indicate that hydraulic conductivity ranges from 0.68 ft/d to 263 ft/d, with a geometric mean of 11.96 ft/d.

Basalt Hydrogeologic Zone

The Basalt Hydrogeologic Zone (Basalt Zone) consists of weathered basalt exhibiting hydrogeologic properties that differ from the DGZ, and competent basalt. The Basalt Zone is distinguished from the Alluvium and DGZ by its relatively low permeability and basalt lithology. The Basalt Zone is contained entirely within the Basalt Geologic Zone.

Groundwater in the Basalt Zone is semi-confined, as indicated by:

- Groundwater elevations that rise above the top of the Basalt Zone, indicating that groundwater in the Basalt Zone is pressurized, which is a property of semi-confined groundwater (Fetter, 1994); and
- Groundwater elevations in the Basalt Zone exhibit tidal fluctuation as far inland as the W-11 well cluster on ESCO property; therefore, the Basalt Zone appears to be semi-confined and hydraulically connected to the River (URS, 2000).

Groundwater enters the Basalt Zone by lateral inflow from the Tualatin Mountains and leakage from the overlying DGZ, where present. Groundwater in the Basalt Zone flows northeast, from the Tualatin Mountains toward the River.

Average hydraulic conductivity of the Basalt Zone is one order of magnitude less than that of the DGZ, and is slightly greater than that of the Fill and Alluvium Zones. Three slug tests conducted at monitoring wells screened in the Basalt Zone indicate that hydraulic conductivity ranges from 1.70 ft/d to 8.0 ft/d, with a geometric mean of 3.20 ft/d.

5.0 CURRENT CONDITIONS IN THE DEEP GRAVEL ZONE

Soil and groundwater have been sampled as part of RI activities at the RP Site. In addition to groundwater sampling and water level monitoring activities that occurred in the 1990s, groundwater at the RP Site was monitored approximately annually from 2000 to 2005, and semi-annually during 2006. A general summary of target constituent concentrations in groundwater, and a summary of soil and groundwater geochemistry, are presented below. These are followed by summaries of the groundwater fate and transport model and the LA Pilot Study results.

5.1 Target Constituents in Groundwater

Concentrations of 1,2-DCB in wells screened in the four hydrogeologic zones in the vicinity of the NFA ISCM location from 2004 through 2006 are presented on Figures 10 through 13. In the NFA ISCM target area, concentrations of 1,2-DCB are present at greater concentrations in the DGZ wells at given well clusters. Where detected in the shallower hydrogeologic zones, 1,2-DCB concentrations typically do not exceed the JSCS SLVs.

In general, concentrations of target constituents at monitoring wells in the vicinity of the proposed location of the NFA ISCM have varied less than an order of magnitude during the seven-year monitoring period from 2000 through 2006. This allows for predictability in ISCM treatment expectations and design. Based on Site-wide data,

the proposed ISCM location is strategically located to act as a treatment barrier to DGZ groundwater flowing toward the riverbank (Figure 14).

5.2 Soil and Groundwater Geochemistry

Several monitoring well clusters (RP-19, W-11, RP-18, and MW, 03) located in the vicinity of the proposed NFA ISCM were used to evaluate soil and groundwater geochemistry in the DGZ. Geochemistry determines: 1) whether the aquifer matrix is reductive or oxidative in character; 2) at what steps on the oxidation-reduction (redox) ladder the aquifer material is poised; 3) the potential for past, present, and future biological activity; and 4) the availability of electron accepting anions and redox active metals. Selected physical, chemical, geochemical, and biological parameters were evaluated and are presented on Tables 2 and 3.

The redox conditions were inferred from field data (oxidation-reduction potential [ORP], dissolved oxygen [DO], pH, and ferrous iron [Fe^{2+}]) and geochemical data (nitrate, total/dissolved iron, total/dissolved manganese, sulfate, sulfide, and methane). Many of the geochemical species measured can be characterized as either electron acceptors or reduced products as one moves down the steps of the redox ladder: DO (electron acceptor), nitrate (electron acceptor), nitrite (reduced product), Fe^{2+} (reduced product), dissolved iron and dissolved manganese (reduced products), sulfate (electron acceptor), sulfide (reduced product), and methane (reduced product). Bacterial counts, alkalinity (as indirect measure of carbon dioxide), total organic carbon (TOC), and nutrients were measured to evaluate the potential for microbial activity at the Site.

5.2.1 Oxygen, Oxidation-Reduction Potential, Nitrate, and Nitrite

Generally, DO and ORP data indicate anoxic to reducing conditions are prevalent in the DGZ in the vicinity of the NFA ISCM location. DO concentrations are generally less than 0.5 milligrams per liter (mg/L) and ORP values are less than +50 millivolts (mV). There is little spatial variability in these conditions in the DGZ in the ISCM vicinity. Nitrate and nitrite are not detected.

5.2.2 Iron and Manganese

The redox-active metals iron and manganese are useful indicators of redox state. In general, a high proportion of the dissolved metal concentrations were nearly equivalent to the total metal concentrations, indicating that the iron and manganese present were dissolved. Fe^{2+} was detected throughout the ISCM vicinity. The elevated levels of

Fe^{2+}, dissolved iron, and dissolved manganese in groundwater are indicative of reducing conditions.

5.2.3 Sulfate, Sulfide, Methane, Ethene, and Ethane

Relationships of sulfate, sulfide, methane, ethene, and ethane concentration are useful indicators of conditions at the more reducing end of the redox spectrum. Sulfate (SO_4^{2-}) is present at varying levels in the DGZ groundwater in the vicinity of the ISCM location, but sulfide, the reduced species of sulfate, is generally not detected (Table 2). This indicates that the groundwater environment is not strongly anaerobic. Soil collected from the DGZ in the ISCM vicinity occasionally contains sulfide in excess of sulfate (Table 3).

Methane is present at concentrations at or below 1.6 mg/L. Of 12 samples, 10 contained 0.66 mg/L or less of methane, with methane results ranging down to non-detection levels at 0.0006 mg/L. Methanogenesis is at the most reducing end of naturally occurring redox conditions. The presence of widely varying amounts of dissolved methane indicates that the environment is not uniformly strongly anaerobic.

Ethane, a potential product of reductive dehalogenation of vinyl chloride, has been detected at a few wells.

5.2.4 Microbial Activity and Nutrients

Heterotrophic bacteria counts varied in groundwater in the ISCM vicinity. Microbial activity appears to fluctuate with time and with location. The occasional presence of aerobic microbes in the range of 10E+04 colony forming units per milliliter (cfu/mL) indicate that microbial activity can be stimulated in the DGZ, given appropriate conditions. Nutrients to support microbial growth are limited (e.g., orthophosphate). TOC concentrations were variable and fairly low, generally below 3 mg/L. The microbial counts were depressed where nitrogen (as either ammonia or as total Kjeldahl nitrogen) was below the typical nitrogen/TOC ratio of 1:10 necessary for aggressive microbial growth. Orthophosphate was generally at or below detection limits. Oxygen and nutrient sources would need to be augmented to promote optimal aerobic microbial growth.

5.2.5 Summary of Geochemical Conditions for the Deep Gravel Zone

The typical DGZ groundwater in the NFA ISCM vicinity is at a redox state characterized by low DO and slightly negative ORP values, the presence of reduced iron and reduced manganese, the continuing presence of sulfate, and a very limited

presence of ethane and methane (Table 2). Soil collected from the DGZ in the ISCM vicinity occasionally contains sulfide in excess of sulfate (Table 3). Heterotrophic bacteria are found in the groundwater. Collectively, the data indicate an aquifer medium typically at slightly reducing conditions that is amenable to either oxygenation (to stimulate aerobic microbial activity) or oxidation (to oxidize target constituents).

5.2.6 Groundwater Fate and Transport Model Summary

A numerical two-dimensional cross-sectional groundwater fate and transport model was internally constructed for the RP Site in fall 2006. The numerical groundwater model was designed primarily for estimating constituent travel time within the DGZ from the NFA ISCM location to the River. The results of the groundwater model supports the location of the NFA ISCM, while meeting the objectives of the RP Site-wide SCP.

The model construction was based on outputs from the previous three-dimensional numerical groundwater flow model developed for the RP Site (AMEC, 2005a). The United States Geological Survey (USGS) block-centered, finite difference groundwater code MODFLOW (McDonald and Harbaugh, 1988; Harbaugh et al., 2000) was used to simulate steady-state groundwater flow conditions at the RP Site. MT3D99 (a three-dimensional transport module for multiple chemical species transport) was used to simulate transient constituent migration. Visual MODFLOW version 4.1 software was used as a pre- and post-processor to aid in groundwater flow model development and presentation of model output.

The two-dimensional model input parameters included lithology, TOC, porosity, retardation factors, hydraulic conductivity, bulk density, specific storage, specific yield, aerial recharge, and dispersivity.

Of the four target constituents, 1,2-DCB has the most extensive spatial and temporal data record. Therefore, in all constituent transport simulations, 1,2-DCB was used as a surrogate for the other target constituents. Transport of 1,2-DCB was simulated with a steady-state concentration at monitoring well W-06, near the source area. A MT3D99 transport model run period of approximately 20 years was used to simulate current constituent distributions.

Model simulations indicated that the time required for treated groundwater to reach the River from a central portion in the NFA ISCM location was approximately 2 to 4 years, under a conservative assumption of zero biological decay. Thus, instantaneous constituent destruction at the ISCM location should deliver a clean water front to the

River over a period of 2 to 4 years. However, the time required for treated groundwater to reach the River may be slightly less or more than 2 to 4 years, depending on its origination point along the NFA ISCM. The time of travel for the constituents from the LA to the River was approximately 5 to 7 years. Thus the proposed ISCM location is approximately halfway along the travel path from the RP property to the River.

5.3 Summary of Pilot Study Results

Remediation pilot study activities have been underway in the DGZ of the RP Site LA since late 2006. The LA Pilot Study is located approximately 900 feet upgradient of the NFA ISCM location (Figure 1). The LA Pilot Study system consists of 14 wells: 2 are designed for air and water injection and 12 are designed as observation points. Eleven of the observation wells are arrayed downgradient of the injection points. One observation well is located upgradient of the injection points. The injection and observation wells are constructed with 5-foot screen intervals placed in the DAG geologic zone of the DGZ. A summary of the LA Pilot Study observations to date is presented in the following sections.

5.3.1 Hydrogeology Assessment

Hydraulic slug tests and a Rhodamine dye tracer test were conducted to evaluate hydraulic conductivity and groundwater velocities in the LA DGZ. Groundwater velocities calculated from the slug test results range from 0.29 to 1.25 ft/d, and tracer test results indicated a groundwater velocity ranging from 19 to 32 ft/d.

During initial testing of air injection, changes in water table elevations were measured using down-hole pressure transducers in six of the observation wells. A pressure response of similar magnitude was observed in all observation wells nearly simultaneously, suggesting that the tighter, siltier sand formation overlying the DGZ acts as a semi-confining layer.

5.3.2 Air Injection

Air was injected into the DGZ starting on December 8, 2006. The system was monitored on a periodic basis and adjusted in response to observations and system performance. AMEC adjusted the amount of injected air by adjusting both the flow rate and injection duration, typically set at 5 standard cubic feet per minute (scfm) for 30 minutes on and 60 minutes off. Very limited changes in dissolved oxygen and other geochemical indicators were observed over a 2-month period of monitoring. These

data suggested that air injection was not effectively delivering oxygen to the subsurface.

A sulfur hexafluoride (SF_6) tracer test was subsequently conducted in order to evaluate whether the lack of change in groundwater geochemistry was a result of oxygen being quickly consumed or a problem with oxygen delivery. SF_6 tracer testing is a common technique used to assess air distribution and oxygen delivery rate to the subsurface during in-situ air injection. SF_6 is a conservative, non-reactive gas tracer with partitioning properties similar to oxygen.

On February 27, 2007, SF_6 was injected over a 24-hour period during a sparge cycle of 30 minutes on and 60 minutes off. Following the 24-hour injection period, both vapor and groundwater samples were immediately collected at all LA Pilot Study observation wells, and collected again at intervals of 24, 48, and 120 hours after air injection ceased. The SF_6 data are summarized in Table 4.

SF_6 was detected in the groundwater at all observation wells directly following the tracer injection. The SF_6 detections were highest at observation well OW-1, the up-gradient monitoring location (Table 4). SF_6 concentrations decreased in groundwater at all monitoring locations over time with the exception of OW-1. The vapor samples showed similar results, with the highest SF_6 detection at OW-1. Based on the location and relative percentages of SF_6 detections, and the lack of increase in oxygen concentration at OW-1 during the air injection phase of pilot testing, it appeared that oxygen was being consumed faster than oxygen could transfer from the gaseous phase to the groundwater.

The observed conditions indicate that the coarse nature of the lithology, in combination with the buoyancy of the injected air, caused the injected air to travel to the top of the DAG. At the top of the DAG, small air bubbles may have gathered at the contact with the siltier semi-confining layer noted earlier, aggregated to form large bubbles with limited surface area available for oxygen phase transfer, and migrated up the dip-slope formed by the gravel/semi-confining layer contact. In this case, air migrating along the dip slope and against the groundwater gradient and flow, could have lead to the observed concentrations of SF_6 at the upgradient well OW-1.

Based on these results, AMEC determined that air injection would have limited effectiveness with use in the DGZ, and the oxygen demand could not easily be met by the oxygen mass flux delivered by air injection. Therefore, AMEC modified the LA Pilot Study infrastructure to deliver oxygen to the DGZ using dilute hydrogen peroxide.

5.3.3 Hydrogen Peroxide Injection

A total of 450 gallons of hydrogen peroxide solution (5%) was injected periodically (in five increments over a 7-day period) through the two injection wells in alternating tests. Initially, the peroxide solution was allowed to gravity-flow into the injection well. Ten gallons of the gravity-fed solution was delivered to the well screen for approximately 5.5 minutes, at which point flow stopped due to backpressure in the aquifer. A pump was then employed to inject approximately 50 gallons of peroxide solution into the first injection well over a period of 74 seconds, at which point backpressure increased to 29 pounds per square inch (psi), and bubbling could be heard in the well boring. (The head pressure in the DGZ is typically 25 psi.)

Following this step, approximately 50 gallons of peroxide solution was injected once a day in each injection well, over a period of 90 to 150 seconds. This injection program yielded higher backpressures of 42 to 48 psi. Injection was stopped when peroxide solution was seen to break the soil surface near one of the injection wells. The injections of hydrogen peroxide did not lead to measurable increases in DO in DGZ groundwater, although an increase in ORP was noted (from approximately -100 mV to approximately +30 mV) at a few nearby wells. The handling and delivery challenges, combined with the lack of appreciable increase in DO, indicated that peroxide injection would require a great deal of further development to evaluate whether this approach could meet the need for oxygen delivery.

5.3.4 Pilot Study Summary

As described in the preceding sections, neither air injection nor hydrogen peroxide injection resulted in appreciable elevation of DO levels in LA Pilot Study observation wells. Lithologic conditions in the area of the LA Pilot Study appeared to result in injected air being preferentially delivered upgradient of the LA Pilot Study location. Peroxide injection resulted in high backpressures and possibly vapor lock. In either case, oxygen delivery to the DGZ was not enough to overcome oxygen demand. Given improvement of injection techniques and a significant amount of time to perform injection to overcome aquifer oxygen/oxidant demand, either air injection or hydrogen peroxide injection might function to deliver oxygen to the DGZ in the LA Pilot Study area, or in the NFA ISCM area. Because groundwater treatment at the ISCM location is needed in the near term, SLLI evaluated alternative technologies. The results of the alternative remedial technology screening for the NFA ISCM are presented in Section 6.0.

6.0 REMEDIAL TECHNOLOGY SCREENING

This section identifies and screens remedial technologies, using DEQ balancing factors (DEQ, 1998), that may be combined into remedial action alternatives to meet the RAOs identified in Section 3.0. The RAOs for the NFA ISCM were to mitigate target constituent migration in DGZ groundwater. Remedial technologies are presented and screened on Table 5. Retained remedial technologies are divided into specific remedial alternatives on Table 6, and the specific alternatives are screened. Retained alternatives are carried forward to Table 7, where they are assessed on the basis of the five balancing factors: effectiveness, reliability, implementability, implementation risk, and reasonableness of cost.

6.1 Description of Remedial Approaches and Introduction of Remedial Technologies

Remedial approaches and related technologies considered for the DGZ are shown on Table 5. In selecting remedial technologies for evaluation, the EPA Technology Screening Matrix (http://www.frtr.gov/matrix2/section3/matrix.html) (EPA, 2006) was consulted, and AMEC's professional judgment and experience with various cleanup technologies were also considered. Five remedial approaches were selected for evaluation: bioremediation, destructive permeable barriers, adsorptive permeable barriers, chemical degradation, and physical removal (Table 5). Under these five approaches, eight technologies were identified for the initial screening evaluation. The eight technologies are considered solely in-situ or combined in-situ/ex-situ remedial technologies and consist of the following:

In-Situ Treatment Technologies

1. Monitored Natural Attenuation (MNA)
2. Aerobic Bioremediation
3. Anaerobic Bioremediation
4. Permeable Treatment Barriers (PTBs) - Destructive and Adsorptive
5. In-Situ Chemical Oxidation (ISCO)
6. In-Situ Chemical Reduction

In-Situ/Ex-Situ Treatment Technologies

7. Air Sparging and Soil Vapor Extraction (AS/SVE)

8. Groundwater Extraction and Treatment (GET)

The eight technologies are described in the following sections.

6.1.1 In-Situ Treatment Technologies

Monitored Natural Attenuation. MNA reduces target constituent concentrations through natural processes such as biodegradation, diffusion, dispersion, hydrolysis, and sorption (EPA, 1998). Typical goals for MNA are demonstrated reductions in mass, toxicity, mobility, volume, or concentrations. Progress toward MNA goals is evaluated through groundwater monitoring, and fate and transport modeling. On the basis of the current RP Site data, it can be inferred that MNA alone is not currently able to meet the second RAO, which is to minimize migration of target constituents through the DGZ to the River. MNA may serve as a complement to other potential technologies and is, therefore, retained for further consideration.

Aerobic Bioremediation. The target constituents are aerobically biodegradable. Based on several years of monitoring, the RP Site groundwater tends to be slightly anaerobic (oxygen deficient), and limited in nutrients that support microbial growth. Therefore, addition of oxygen to the groundwater would be necessary to stimulate aerobic bioremediation in the DGZ. Oxygen addition can be accomplished through a variety of physical and chemical means. The addition of nutrients such as nitrogen and phosphorus may also be necessary to facilitate in-situ bioremediation. The technology is broadly adaptable to typical geologic and hydrogeologic conditions, and typically relatively easy to install. Operation and maintenance (O&M) of aerobic bioremediation systems is considered fairly routine. Aerobic conditions can also help lower dissolved metal concentrations through formation of less soluble metal oxides. Therefore, aerobic bioremediation is retained for further consideration as an ISCM.

Anaerobic Bioremediation. Anaerobic bioremediation can occur in the presence of microbes that use electron acceptors such as nitrate, sulfate, iron, manganese, and carbon. Based on several years of monitoring, the RP Site groundwater generally tends to be anaerobic, though to variable degrees depending on location. In the vicinity of the NFA ISCM, the DGZ is only slightly anaerobic. Anaerobic bioremediation is often enhanced by the addition of a carbon source and/or nutrients to the groundwater. Anaerobic biodegradation proceeds at a slower rate than aerobic biodegradation processes, and probably would not achieve cleanup within the travel distance/time to the riverbank compliance wells. Additionally, enhancing anaerobic

conditions within the aquifer could leach more of the naturally occurring metals such as arsenic, manganese, and iron. Therefore, anaerobic bioremediation is not retained for further consideration as an ISCM.

Permeable Treatment Barriers - Destructive and Adsorptive. PTBs use reactive and passive media, such as zero-valent iron for chemical reduction and activated carbon for adsorption, respectively, to intercept and treat groundwater target constituents. A PTB typically is installed by excavating a trench across the flow path of a groundwater plume and backfilling the trench with the treatment medium of choice or by specialized injection through deep wells. The groundwater is treated as it passes through the PTB. Both the depth of the DGZ, and the need for periodic replacement or amendment of the reactive media that would be required for target constituent treatment, lead to technological infeasibility. PTBs are not retained for further consideration.

Chemical Oxidation. ISCO may be achieved by the injection of a strong chemical oxidant into the groundwater to oxidize target constituents. ISCO has been proven to be a successful remediation technology for dissolved phase target constituents in soil and groundwater at numerous sites. Groundwater extraction and injection technologies can be used to enhance subsurface mixing and delivery of the oxidants to specific areas of saturated soils. Under certain conditions where high levels of TOC or dissolved-phase target constituents are present, chemical oxidation is less effective because copious amounts of the chemical oxidizer are required to neutralize the scavenging capacity of the soil and groundwater. In the DGZ, the relatively low TOC and target constituent content, and the permeable nature of the aquifer materials, are conditions that are favorable for the implementation of ISCO. The ISCO technology is, therefore, retained for further consideration as an ISCM.

Chemical Reduction. Chemical reduction can be enhanced by the injection of ferrous nanoscale iron or a mixed iron/carbon reducing agent. This reaction will push the environment into a deeply anaerobic state, thus stimulating anaerobic biodegradation and direct chemical reduction of target constituents. In-situ reduction by injection of nanoscale iron is not an established technology, and the actual field efficacy of the technique is largely unproven. Advanced delivery systems may be needed. The rate of anaerobic treatment for many target constituents is slow in comparison to aerobic treatment. The anaerobic character would lead to increased leaching of the naturally occurring metals such as arsenic, manganese, and iron. Thus, chemical reduction is not retained for further ISCM consideration.

6.1.2 In-Situ/Ex-Situ Treatment Technologies

Two technologies for consideration involve in-situ physical capture of the target constituents, followed by ex-situ target constituent treatment.

Air Sparging and Soil Vapor Extraction. The AS/SVE technology consists of a high pressure and high volume injection of air into the groundwater, increasing the surface area of groundwater exposed to air and resulting in volatilization of the target constituents. The injected air migrates upward through groundwater and dissolved constituents volatilize into the air stream. Soil vapor extraction removes soil gas from the subsurface, under induced vacuum, through wells screened in the vadose zone. The major limiting factors are the transfer (by volatilization) of target constituent mass from the dissolved phase in groundwater to the vapor phase and the effective capture of vapors near the surface. Captured vapors are commonly treated ex-situ by adsorption onto granular activated carbon (GAC) or through thermal destruction technologies. A secondary benefit of AS/SVE is that oxygen introduced to the groundwater and soil induces aerobic bioremediation. AS/SVE is an effective method for removing volatile target constituents from groundwater, and inducing target constituent biodegradation in the groundwater. The AS/SVE technology is retained for further consideration as an ISCM.

Groundwater Extraction and Treatment. GET is a traditional remedial technology that extracts target constituent-impacted groundwater from the subsurface for ex-situ treatment via air stripping or adsorption onto GAC. Generally, treated water is discharged into sanitary sewers or storm sewers, to water bodies under a National Pollutant Discharge Elimination System (NPDES) permit, or re-injected into the subsurface under an Underground Injection Control (UIC) permit. The potential presence of recalcitrant constituents with very low treatment standards in these types of water discharges may present difficulties for water treatment and agency permitting. Traditional GET provides containment of target constituents in groundwater. The DGZ appears to have low TOC levels and the aquifer materials are relatively permeable, and GET should be able to reasonably achieve target constituent containment. The GET can also complement other technologies by providing mass/hydraulic containment on site. This technology is retained for further consideration as an ISCM.

6.1.3 Remedial Technology Screening Summary

The remedial technologies that were eliminated include anaerobic bioremediation, PTBs, and chemical reduction. These technologies were eliminated based on inability to meet the RAOs and, more specifically, due to slow treatment times, high costs, or

unsuitability to the proposed location or nature of the DGZ. Remedial technologies retained include: aerobic in-situ bioremediation, ISCO, AS/SVE, and GET. MNA also is retained as a compliment to the four retained primary technologies.

6.2 Screening of Remedial Alternatives

Each of the four remedial technologies retained from the preliminary screening on Table 5 are further developed into sets of specific remedial alternatives, as presented and screened on Table 6.

Treatment system components will be installed within the system alignment (Figure 2) to approximate depths of 78 to 119 feet bgs to target the preferential groundwater flow paths within the DGZ. Monitoring wells will be installed at downgradient locations to evaluate the remedial system performance. System infrastructure (utility runs and housing units) will be installed in the BNSF ROW and the NW Front Avenue ROW.

Each of the remedial alternatives will act as a treatment “barrier” within the system alignment. Through remedial alternative implementation at the barrier, a “clean water” front that migrates toward the riverbank will be produced. The “clean water” front will cause a lowering of target constituent concentrations to below site-specific risk-based cleanup goals at the downgradient compliance wells.

In some cases, MNA may be relied upon to achieve treatment to the site-specific risk-based cleanup goals at the downgradient compliance points. Therefore, MNA will be considered a secondary component of each remedial alternative.

6.2.1 Aerobic In-Situ Bioremediation Remedial Alternatives

Creating an aerobic environment can enhance the rate of biodegradation of organic constituents and reduce, or potentially eliminate, their transport through the subsurface. If a nutrient limitation is inhibiting microbial growth rates, this process may be augmented with nutrient injection.

The delivery of oxygen may be limited by site geologic factors, such as heterogeneity that preferentially channels oxygen to certain parts of the aquifer. Other limitations include inorganic aquifer material that may consume more oxygen than can be delivered, and may slow or limit the spread of oxygen to the entire DGZ from the system to the riverbank.

The three aerobic bioremediation oxygenation alternatives chosen for screening are: the injection of air; the injection of either a dilute hydrogen peroxide solution or of a

material that generates hydrogen peroxide (sodium percarbonate); and the injection of an oxygen slow-release material (such as calcium peroxide). The successful use of these oxygen amendment systems has been well documented at other sites.

Biosparging and Soil Vapor Extraction

This process consists of injecting compressed air into the groundwater. Air is injected at low volumetric flow rates (typically 3 to 5 scfm) through a series of injection wells. Alternatively, pure oxygen can be injected directly or introduced into the ambient air stream through the injection well.

The biosparging pilot test results in the LA demonstrated that migration of injected air to the surface may occur, even at the low air injection volumes (Section 5.3). Therefore, a SVE component would be included in this system to maintain vapor capture and maintain protectiveness. The LA Pilot Study demonstrated that Alluvium/DAG Geologic Zone contact guides buoyancy-driven air bubbles up dip and away from treatment locations. This was confirmed by a tracer study. In addition, elevated levels of DO in the DGZ groundwater were not observed, suggesting that oxygen consumption was rapid.

Based on these observations, a biosparging system would require a great deal of continued optimization, and would likely have effectiveness limitations. Therefore, biosparging is not retained for further consideration as an ISCM.

Dilute Hydrogen Peroxide Injection

Aerobic conditions may also be enhanced through the injection of dilute hydrogen peroxide. The hydrogen peroxide disproportionates to introduce oxygen into the groundwater. Dilute aqueous hydrogen peroxide injection is advantageous because the oxygen source is already in solution and releases oxygen directly into the groundwater. Injected peroxide solution also may follow higher permeability paths in the aquifer, remaining in contact with the groundwater transporting the highest mass flux.

During bioremediation applications, injection solutions typically contain hydrogen peroxide at concentrations of between 0.5 and 6%. Solutions higher in hydrogen peroxide can be injected, if necessary. Concentrations of hydrogen peroxide toxic to microorganisms reportedly can range from 5 mg/L to 50,000 mg/L (5%) in groundwater. The reasons for this wide concentration range have not been fully elucidated (Watts and Teel, 2005). In aquifer materials exposed to peroxide concentrations that initially diminish microbial counts, microbial counts reportedly often

rebound to levels higher than original levels within days to weeks. Relatively inaccessible soil pores may shield some microbes from the initial toxicity of the peroxide. The microbes may then thrive on the degraded organic materials and high oxygen levels present after the peroxide has reacted (Watts and Teel, 2005).

The oxygen produced from the disproportionation of hydrogen peroxide may be rapidly consumed by organic and inorganic aquifer materials. In addition, hydrogen peroxide may degrade soil humic materials that bind target constituents, potentially causing an initial release of target constituents to the groundwater. Low carbon content within the DGZ should limit the quantity of hydrogen peroxide required, and limit the potential initial release of target constituents.

Hydrogen peroxide is hazardous, and poses health and safety concerns for storage and handling. Safety measures and the cost of hydrogen peroxide would add to system O&M costs. The system would require optimization of hydrogen peroxide injection rates and nutrient conditions.

The hydrogen peroxide injection in the LA Pilot Study did not lead to measurable increases in DO in DGZ groundwater (Section 5.3). In addition, the peroxide reacted strongly with the aquifer, causing bubbling, air lock, and substantial backpressures within injection wells. As a result of handling issues and the lack of appreciable increase in DO, dilute hydrogen peroxide injection is not retained for further consideration as an ISCM.

Slow Release Oxygen Product

Aerobic conditions may also be enhanced through the introduction of solid peroxide, such as calcium peroxide. Solid peroxide dissolves slowly to release oxygen into the groundwater. The solid peroxide would be delivered to the DGZ for the NFA ISCM either in slurry form by an injection well network or encased in socks within wells. Slurry form injection requires delivery of enough material to sustain adequate groundwater oxygen concentrations.

The system and its components are proven to be reliable, including the long-term treatment of aerobically biodegradable constituents. The slow release characteristic of solid peroxide products limits the oxygen flux that can be delivered to the aquifer. The system requires optimizing injection rates of solid peroxide to overcome aquifer oxygen demands.

The solid nature of the material leads to labor- and time-intensive handling and multiple applications to the subsurface. The solid peroxide has a relatively high cost, and equipment to pump/deliver the high viscosity slurry is not commonly available.

The potential application and cost challenges associated with high volume delivery of slow release oxygen products to the subsurface lead to elimination of this technology from the list of NFA ISCM candidates.

6.2.2 In-Situ Chemical Oxidation Remedial Alternatives

Permanganate, sodium persulfate, and hydrogen peroxide (Fenton reagent) are examples of chemical oxidizers that transform constituents into carbon dioxide, chloride, and water. ISCO would be implemented at the NFA ISCM location by direct injection of oxidant solutions at permanent injection points. Oxidant injections at approximately 74 injection points in the DGZ at approximately 15-foot spacing would form a treatment zone through which groundwater would flow. The chemical injection would take place in continuous rounds, with time intervals based on groundwater flow and oxidant reaction times with the target constituents.

Hydrogen Peroxide Injection

Hydrogen peroxide in the presence of an iron catalyst degrades to form highly reactive hydroxyl radicals that react with and cause significant chemical destruction of the target constituents (Huling and Pivetz, 2006). The aquifer contains iron in the groundwater and soil, in dissolved and mineral form. Hydrogen peroxide would react with this natural iron catalyst to form hydroxyl radicals. In fact, naturally occurring metal oxide minerals are now viewed as preferable catalysts for these types of treatment because the mineral catalysts impart the slowest rate of hydrogen peroxide decomposition and allow for maximum downgradient transport of the hydrogen peroxide (Watts and Teel, 2005). Iron catalyst would be added to the system as needed to optimize oxidation performance. The use of chelated iron catalyst of either the Fe^{+2} (ferrous) or Fe^{+3} (ferric) oxidation states can have varying effects on the rate and efficiency of hydroxyl radical formation.

Hydrogen peroxide solutions would be injected into the DGZ. The chemical reaction would cause a buildup of heat and gas, as the peroxide interacts with organic and inorganic components of the aquifer materials. Each peroxide addition to the subsurface during the LA Pilot Study (Section 5.3) led to a strong reaction with the aquifer, causing the aquifer to temporarily refuse further infiltration. A longer injection period likely would have neutralized the available iron mineral in the injection vicinity.

The DGZ aquifer materials have relatively high permeability and flow, and relatively low organic carbon content; therefore, the peroxide should be able to readily spread once the area around the well was exposed to enough peroxide.

A portion of the hydrogen peroxide will decompose to oxygen that would enhance aerobic biodegradation of target constituents. As already noted, in aquifer materials exposed to peroxide concentrations that initially diminish microbial counts, microbial counts reportedly often rebound to levels higher than original levels within days to weeks.

Concentrated hydrogen peroxide is a costly, hazardous material, and poses health and safety concerns for storage and handling. Optimization of hydrogen peroxide injection technique would be required to mitigate system operation challenges and to minimize costs and potential safety issues.

The ability to optimize peroxide activity within the DGZ through the use of various catalysts and stabilizers has not been fully explored. Oxidation with hydrogen peroxide has the added benefit of increasing oxygen content to stimulate bioremediation activity. Therefore, direct oxidation via peroxide injection is retained for further consideration as an ISCM.

Persulfate Injection

Persulfate salts dissociate in water to form persulfate anions, which form strongly oxidizing sulfate radicals in the presence of catalytic agents (Block, et al., 2004). The anions and free radicals react with target constituents in the groundwater, resulting in significant chemical destruction of target constituents. CBs and VC have been treated using persulfate.(Block, et al., 2004; FMC, 2006; Smith, et al., 2005).

This method would be implemented at the NFA ISCM by means of direct injection of persulfate along with catalytic additives such as hydrogen peroxide, calcium carbonate (raises pH), dissolved iron, or heat. Persulfate and catalyst additives would be injected at a series of wells transecting the plume. The injection quantity and interval would be evaluated based on the target constituent concentrations, oxidant persistence in groundwater, and travel times of oxidant and target constituents.

Persulfate is more selective for dissolved target constituents than many other strong oxidants, as it is much less reactive with naturally occurring organic and inorganic matter (Brown, 2004; Huling and Pivetz, 2006). This selectivity allows persulfate to be transported and dispersed within the groundwater and yet maintain target constituent oxidation activity. The effective delivery of the persulfate and catalytic additives to the

subsurface are the chief challenges to the use of this method. For reasons of oxidant selectivity, and ease of use, target constituent oxidation by persulfate is retained for further consideration as an ISCM.

Permanganate Injection

When injected into the groundwater, permanganate generates ions that strip electrons from double bonds in alkene compounds. The permanganate ion oxidizes organic constituents, preferring non-aromatic alkenes. Manganese dioxide is the residue left by the permanganate.

The effectiveness of permanganate on aromatic target constituents is questionable because of lower oxidation potential (Clayton, et al., 2000; Huling and Pivetz, 2006). Permanganate also is known to be a relatively non-selective oxidant that reacts strongly with natural organic matter (Brown, 2004). The relative weakness and non-selectivity of the permanganate as an oxidant would lead to the injection of large and costly quantities of permanganate. Manganese dioxide, a by-product of permanganate reaction, could clog aquifer pore spaces, reducing the permeability and effectiveness of the remediation with time. Production of dissolved manganese from the reaction may not be tolerable because of the existing background manganese levels.

Because permanganate cannot efficiently oxidize the majority of the target constituent mass, reacts non-selectively with naturally occurring organic matter, and adds manganese to the aquifer, oxidation by permanganate is eliminated from further consideration as an ISCM.

6.2.3 Air Sparging/Soil Vapor Extraction Remedial Alternative

The AS/SVE technology is a physical process that facilitates the in-situ partitioning of volatile target constituents from an aqueous phase into a vapor phase that is removed through vapor capture and extraction. The AS/SVE system would be designed to operate continuously, with periodic shutdown associated with the maintenance of the equipment and carbon change out.

This technology relies on the ability to evenly distribute air within the groundwater aquifer and also to recover the air stream, including vapor phase constituents, over the extent of the treatment area. The less permeable soil containing layers of silt, clay, and alluvium above the DGZ would probably result in a limited radius of influence for each SVE well, and limited reliability of vapor capture. As demonstrated by the LA Pilot Study results to date, migration of injected air is also unpredictable. Thus, a robust and expansive SVE system would be needed to control potential vapor

exposure to system maintenance workers, occupational workers at nearby facilities, and other members of the public at the ground surface.

The robust and expansive SVE system needed to reliably capture high-volumes of vapor would be quite costly (due to high drilling expenses) and is not considered feasible in the limited footprint available for the ISCM. Therefore, AS/SVE is not retained for further consideration as an ISCM.

6.2.4 Groundwater Extraction and Treatment Remedial Alternative

GET is a traditional remedial technology that extracts target constituent-impacted groundwater from the subsurface for ex-situ treatment via target constituent adsorption onto GAC. The goal of the GET system would be the capture and treatment of groundwater in the DGZ.

This method would include extraction wells to pump groundwater from the DGZ. The pumping wells would be screened in the DGZ. The extracted water from the wells would be directed to an equipment compound via subsurface polyvinyl chloride (PVC) conduit and accumulated in a collection tank. The accumulated water would then be processed through GAC vessels.

The equipment associated with the GET would consist of submersible pumps, a collection tank, GAC vessels, electrical control panels, and other miscellaneous piping, valves, and sensors. The GET alternative has high O&M costs due to treating large volumes of water with low contaminant concentrations, high costs of maintaining significant infrastructure, plus difficulty of treating and obtaining a discharge permit for PBTs. Other constraints associated with this method include an aboveground infrastructure footprint that potentially could interfere with Siltronic or BNSF property operations. For these reasons, GET is eliminated from further consideration as an ISCM.

6.2.5 Remedial Alternative Screening Summary

During this step of review, the aerobic bioremediation, AS/SVE, and GET remedial alternatives were eliminated. Remedial alternatives retained for balancing factor evaluation include: 1) oxidation by hydrogen peroxide injection and 2) oxidation by persulfate injection. MNA is retained as a complementary component of each remedial alternative.

6.3 Evaluation of Remedial Alternatives by Balancing Factor Approach

In this section, balancing factor criteria presented in the DEQ Final Guidance for Conducting Feasibility Studies (DEQ, 1998) are used to qualitatively evaluate the remedial technology methods retained in the previous section. The evaluation criteria also are used to compare the retained remedial alternatives against one another. The results of the remedial alternative balancing factor evaluation are presented in Table 7.

Brief descriptions of the balancing factors follow:

Effectiveness - In general, effectiveness measures the performance of the technology up to the time when RAOs are achieved and remedy implementation is complete. Whether the technology can maintain these objectives over the long-term is assessed by the balancing factor of reliability.

Reliability - A remedy's reliability is based on the ability of the treatment technology to meet and maintain cleanup levels, and if using engineering or institutional controls, on its reliability to manage residual risks. Reliability is also influenced by uncertainties associated with potential long-term risk management. For purposes of this ISCM evaluation, the control of upgradient sources would occur over a 15-year time frame. Thus, the NFA ISCM would need to treat target constituents reliably for 15 years.

Implementability - A remedy's implementability is evaluated on the basis of difficulty associated with construction, implementation, and O&M. Implementability also depends on the ability to measure the remedy's effectiveness and its consistency with regulatory requirements, including applicable or relevant and appropriate requirements (ARARs).

Implementation Risk - Implementation risk evaluates the risk posed by the remedy during implementation (including construction and O&M), based on potential impacts to the community, workers, and the environment, and the effectiveness and reliability of protective or mitigating measures. Implementation risk also considers the time needed to implement the remedy.

Reasonableness of Cost - A remedy's reasonableness of cost is based on:

- Capital costs, annual O&M costs, and total project cost calculations for comparison;
- The degree to which the costs are proportionate to the benefits of human health and the environment created by risk reduction;

- The degree to which the costs are proportionate to the benefits created through restoration or protection of groundwater beneficial use; and
- The degree of sensitivity and uncertainty of the costs.

Treatment system components will be installed within the system alignment (Figure 2) to approximate depths of 79 to 118 feet bgs to target the DGZ. Performance monitoring wells will be installed at downgradient locations to evaluate the remedial system performance. Surface infrastructure will be installed in utility runs and compounds in the BNSF ROW and the NW Front Avenue ROW.

Each of the remedial alternatives will act as a treatment "barrier" within the system alignment. Through remedial alternative implementation at the barrier, a "clean water" front that migrates toward the riverbank will be produced. The "clean water" front will reduce target constituent concentrations to below negotiated cleanup goals at the riverbank compliance wells.

It may not be feasible to fully treat the target constituents with each of the remedial alternatives to below the cleanup goals at all locations along the NFA ISCM barrier. In some cases, MNA may be relied upon to achieve treatment to the site-specific risk based cleanup goals at the downgradient compliance points. Therefore, MNA will be considered a secondary component of each remedial alternative.

6.3.1 Evaluation Results for Each Remedial Alternative

The remedial alternatives and the evaluation are presented on Table 7. As presented on Table 7, evaluation by each factor is semi-quantitative, ranging from 1 to 5, with 5 being the highest mark, and incorporates information derived from literature, past experience, and Site constraints.

Oxidation through Hydrogen Peroxide Injection

Hydrogen Peroxide Injection Effectiveness. Hydrogen peroxide is considered an effective oxidant for treatment of the target constituents (Huling and Pivetz, 2006). Oxidation is an aggressive technique that should treat the groundwater in a much faster time frame than either natural attenuation or bioremediation. The effectiveness would be strongly tied to the ability to physically deliver the peroxide and iron catalyst to the DGZ. Hydrogen peroxide tends to break down rapidly in the environment due to catalytic effects of minerals, and to autocatalytic effects of peroxide itself. Effective oxidation using hydrogen peroxide relies on the ability to slow and control the peroxide

degradation rate in-situ. The use of various catalytic and stabilization agents would moderate the peroxide degradation rate.

Hydrogen Peroxide Injection Reliability. The reliability of hydrogen peroxide use is generally high because it is an aggressive approach that readily degrades the target constituents. Hydrogen peroxide injection involves the use of accessible and reliable chemical and mechanical components with a moderate level of field management. Because there is a continuing source of target constituent mass upgradient, completion of this remedy would rely on further Site-wide remedial action. Bench and pilot testing would resolve some question as to catalyst reliability.

Hydrogen Peroxide Injection Implementability. Many aspects of hydrogen peroxide injection are readily implementable. The practical and unknown factors associated with this in-situ oxidation remedy are related to safely, thoroughly, and effectively delivering the peroxide and catalyst throughout the DGZ before the peroxide decays. An adequate monitoring network and plan imparts a strong ability to monitor effectiveness of the technique. The necessary materials, services, equipment, and specialists to implement oxidation with hydrogen peroxide injection are all available locally. The hydrogen peroxide system would be installed and operational within several months of initiating field construction. The use of an appropriate form of iron catalyst would improve the implementability. Bench and pilot testing would resolve some question as to implementability using various catalysts.

Permitting for the addition of hydrogen peroxide or catalyst to the groundwater would be relatively straightforward.

Hydrogen Peroxide Injection Implementation Risk. Based on the hydrogeological character of the DGZ, the time to achieve the RAOs using this technology would be approximately 2 to 4 years. While the ISCM would be one part of a Site-wide remedy, target constituent oxidation with hydrogen peroxide likely would be able to reduce target constituent concentrations at the riverbank to below acceptable levels over the 2 to 4 year period, and then maintain those levels pending continuing source management. Target constituent oxidation/biodegradation would lower the long-term risk at the Site. The long-term management of hydrogen peroxide injection consists of a monitoring plan, an amendment plan, and periodic reassessment of enhanced in-situ oxidation effectiveness and ease of use.

The implementation of hydrogen peroxide injection would require the generation of small quantities of drill spoils during well installation and the withdrawal of impacted groundwater during monitoring events. The potential for migration of related catalytic

agents (iron) to the riverbank would need to be considered and monitored. These proposed activities are standard and well developed.

Preparation and addition of potentially hazardous hydrogen peroxide is a larger challenge. Hydrogen peroxide poses health and safety concerns for storage and handling. Significant optimization of hydrogen peroxide injection technique would be required to mitigate known system operation challenges (such as bubbling, vapor lock, and high pressure buildup). Careful design of injection wells, other system components, and handling protocols would be necessary.

Hydrogen Peroxide Injection Reasonableness of Cost. The total estimated cost for implementation of oxidation with hydrogen peroxide over a 15-year period of operation is $36.4 million. The cost effectiveness of this option is viewed as fair.

Oxidation through Persulfate Injection

Fast and effective oxidation using persulfate relies on the formation of radical sulfur species. The radical species formation can be catalyzed by several factors, including iron addition, hydrogen peroxide addition, adjustment of groundwater to pH 10, or by heating groundwater to a temperature of 35 degrees Celsius (ºC) to 45ºC. These potential catalytic factors are evaluated on Table 7 and in the text.

Persulfate Injection Effectiveness. Persulfate has been proven to degrade the target constituents in bench and field application (Block, et al., 2004; FMC, 2006). The relatively low organic carbon content of the DGZ should limit persulfate demand. Oxidation is an aggressive technique that should treat the groundwater in a much faster time frame than either natural attenuation or bioremediation. The effectiveness of each of the catalysts should be nearly equivalent. The relatively longer lifetime for persulfate compared to many other oxidants should allow for increased contact with, and destruction of, target constituents.

Persulfate Injection Reliability. The controls necessary to manage current risk are reliable. The long-term management of persulfate injection consists of a monitoring plan, an amendment plan, and periodic reassessment of enhanced in-situ oxidation effectiveness and ease of use. The reliability of persulfate injection is high because it is an aggressive approach that readily degrades the target constituents. Persulfate injection involves the use of readily accessible and reliable chemical and mechanical components with a moderate level of field management. Because there is a continuing source of target constituent mass upgradient, completion of this remedy would rely on further Site-wide remedial action. The use of catalytic iron or pH

adjustment would likely provide higher reliability than the use of heat or peroxide, given delivery challenges. Bench and pilot testing would resolve some question as to catalyst reliability.

Persulfate Injection Implementability. All aspects of persulfate and nutrient injection are readily implementable. An adequate monitoring network and plan imparts a strong ability to monitor effectiveness of the technique. The necessary materials, services, equipment, and specialists to implement oxidation with persulfate injection are all available locally. The persulfate system would be installed and operational within several months of authorization. The use of catalytic iron or pH adjustment would provide higher implementability than the use of heat or peroxide. Peroxide has delivery and safety challenges. Heating a fast moving water flow at a significant depth would require a large amount of infrastructure and high levels of power. Bench and pilot testing would resolve some question as to implementability using various catalysts. Permitting for the addition of persulfate or catalyst to the groundwater would be relatively straightforward.

Persulfate Injection Implementation Risk. Based on the hydrogeological character of the DGZ, the time to achieve the RAOs using this technology would be approximately 2 to 4 years. While the NFA ISCM would be one part of a Site-wide remedy, target constituent oxidation with persulfate likely would be able to reduce target constituent concentrations at the riverbank to below target levels over the 2 to 4 year period, and then maintain those levels pending continuing source management. Target constituent oxidation/biodegradation would lower the long-term risk at the Site.

The implementation of persulfate injection would require the generation of small quantities of drill spoils during well installation and the withdrawal of impacted groundwater during monitoring events. The potential for migration of related anions (sulfate) or catalytic agents (iron or base) to the riverbank would need to be considered and monitored. These proposed activities are standard and well developed.

The preparation and addition of potentially hazardous chemical additives (persulfate, and especially hydrogen peroxide as catalyst) pose health and safety concerns for storage and handling. Significant optimization of the hydrogen peroxide injection technique would be required to mitigate known hazards (such as bubbling, vapor lock, and high pressure buildup). Careful design of injection wells, other system components, and of handling protocols would be especially necessary if a hydrogen peroxide catalyst is used. A higher risk ensues from the heating catalysis option for persulfate due to the potential waste handling/management associated with heating system installation. Heating system operation would also involve high voltage power

and hot water/steam production. The use of iron or base as catalysts present less significant handling and delivery challenges.

Dilute Persulfate Injection Reasonableness of Cost. The total estimated cost for implementation of oxidation with persulfate over a 15-year period of operation is $30.7 to $35.9 million, for base and iron as a catalyst, respectively. The cost effectiveness of this option is viewed as fair. Iron and base injection as a catalyst have the lowest cost due to limited infrastructure. Costs for a peroxide catalyst is a little higher due to the need for separate infrastructure. Costs associated with heating would be significantly higher due to significant infrastructure and power requirements.

6.3.2 Comparing Evaluation Results for Remedial Alternatives

The five remedial technologies are presented on Table 7 (hydrogen peroxide injection and persulfate injection with four activation alternatives) and evaluated for effectiveness, reliability, implementability, implementation risk, and reasonableness of cost, as discussed in Section 6.3.1. The summary evaluations for each technology are compared below.

Effectiveness

All of these remedial alternatives appear to be effective in achieving the RAOs within the approximately 2 to 4 year target constituent travel time to the riverbank. All of the remedial alternatives would be one part of a Site-wide remedy for the RP Site. The use of persulfate injection with catalysts to cause oxidizing conditions that destroy target constituents holds more immediate promise of target constituent treatment than the use of hydrogen peroxide. Persulfate appears to have a higher degree of effectiveness due to its longer lifetime in the subsurface, enabling better mixing and contact with the target constituents in the DGZ. In simultaneous applications, persulfate has reportedly outperformed hydrogen peroxide in CB degradation (Smith, et al., 2005).

Reliability

Because there currently is a continuing source of target constituent mass upgradient of the NFA ISCM location, completion of any remedy relies on further Site-wide remedial action. Both systems require the use of readily accessible and reliable mechanical components and technician skill-sets. The peroxide addition system would require a higher level of field management than the persulfate system due to higher peroxide reactivity with the aquifer material. The use of iron or pH adjustment for persulfate catalysis would likely provide higher reliability than the use of heat or peroxide, given

delivery challenges. The field management should be relatively straightforward under either scenario, given implementation of appropriate operating procedures.

Implementability

The installation of the subsurface components (injection wells and associated piping) is relatively straightforward for both of the systems. Once the subsurface components are installed, completing the aboveground components of the systems is performed with relative ease. The necessary services, equipment, materials, and specialists to implement the systems are all available locally. Permitting for the addition of peroxide, or persulfate, and catalyst to the groundwater would be relatively straightforward.

The hydrogen peroxide system has a lower implementability due to the need for infrastructure to safely handle and deliver the peroxide and catalyst to the DGZ. The implementability of oxidation by persulfate using either iron or base catalyst is viewed as higher than the implementability of oxidation by persulfate with either peroxide or heat catalysis. The implementability of the persulfate systems is viewed as higher than the implementability of the peroxide system.

Implementation Risk

The time to meet the RAOs will be the travel time for target constituents from the treatment system to the riverbank, which has been estimated to be 2 to 4 years. Oxidation and natural attenuation of target constituents will lower the long-term risk at the Site.

The potential for migration of anions (sulfate) or catalyst (iron or basic water) to the riverbank would need to be considered and monitored.

The implementation of the systems requires the generation of small quantities of drill spoils during well installations, preparation and addition of potentially hazardous chemical additives (especially hydrogen peroxide), and the withdrawal of impacted groundwater during performance monitoring events. The proposed activities are standard and well developed.

The risk of hydrogen peroxide handling is slightly higher than the risk of persulfate and iron or base catalyst handling. A higher risk also ensues from the heating catalysis option for persulfate due to greater waste handling/management, and the presence of high voltage power and hot water/steam during operation.

Reasonableness of Cost

Overall, the total estimated costs for implementation of remedies over an assumed 15-year period of operation ranks persulfate injection with iron or base catalyst in the highest position. The design, permitting, and installation costs for either persulfate injection scenario are comparable. In terms of O&M, persulfate injection is slightly less costly due to lowered annual material and handling costs.

6.4 Alternative Selection

The target constituent mass is readily oxidized by either hydrogen peroxide or activated persulfate through radical exchange mechanisms. Of the retained remedial alternatives, oxidation through persulfate injection with catalysis by either iron or base earns the highest total score, at 21. Use of heat or peroxide to catalyze oxidation by persulfate earns scores of 17 and 18, respectively. Oxidation by hydrogen peroxide earns a score of 17.

The persulfate scenarios provide effective, reliable, implementable, and relatively low risk remediation. Based on the screening and relative ranking of technologies, oxidation by persulfate catalyzed by either iron or base is selected as the remedial alternative for the NFA ISCM.

7.0 ISCM SYSTEM DESIGN AND INSTALLATION OVERVIEW

Based on the results of the technology screening, ISCO was selected as the NFA ISCM technology. An overview of the ISCM design, construction, and startup activities is discussed below. These activities and the 60% design set are presented in detail in Appendix A.

The ISCO system design consists of 74 dual-completion wells that will deliver oxidant to the DGZ. The system will consist of two main well arrays each consisting of 35 well locations, with two screened intervals per location. To treat groundwater flux beneath the railroad embankment, four wells will be installed using angled drilling techniques (either sonic or air rotary). These four wells will be co-located, at the surface, with the eastern-most well of the northern leg and the northernmost well of the south leg of the ISCM.

Each array will have a separate control panel to operate the two systems. The control panel will manage electrical supply distribution and remote telemetry/alarm monitoring. The daily quantity of oxidant injected into the wells will be adjustable and easily

programmed through the control panel user interfaces. Injection adjustments include the ability to program the injection time, duration, frequency, and/or volume. This flexibility will allow the operator to focus on particular areas or cover large areas, as needed. Two separate compounds will be constructed to house and protect all of the aboveground equipment for each main system. Twenty-four performance monitoring wells will be installed to monitor system performance. At this time, the locations of ten performance monitoring wells have been identified, as the first line of monitoring closest to the NFA ISCM location, within the BNSF and COP ROWs (Figure 15). The locations of the remaining 14 performance monitoring wells will be identified and submitted to the DEQ as a supplement to this Work Plan.

8.0 BASIS FOR DEQ APPROVAL

Over the next 2 to 4 years, SLLI plans to reduce target constituent concentrations in groundwater in the DGZ before the groundwater migrates to the River. Pending DEQ approval, this work will be completed through the NFA ISCM, as part of a broader Site-wide remediation strategy. The specific RAOs for the NFA ISCM are the following:

- Reduce concentrations of target constituents in groundwater within the DGZ to Site-specific risk-based cleanup levels protective of human health and the environment at the riverbank compliance wells; and
- Minimize potential for target constituent discharge from the DGZ to the River above Site-specific risk-based cleanup levels by reducing target constituent concentrations.

To attain these RAOs, SLLI plans to implement the NFA ISCM by injecting persulfate into the DGZ by means of injection wells arrayed across flowpaths leading to the River (Figure 14). Treatment effectiveness will be monitored in an array of nearby downgradient monitoring wells (Figure 15).

As detailed earlier in this Work Plan, persulfate injection was selected as the ISCM technology for the following reasons: it is effective, reliable, and readily implementable; it has acceptable and manageable implementation risks; and it is of reasonable cost.

In order to implement the NFA ISCM in the desired timeframe, SLLI developed the ISCM design to the 60% level and is requesting approval from DEQ for this Work Plan at this time. To reach the 90% final design stage necessary to release contract bid packages, additional data collection activities, discussed below, are planned. Results from these activities will be submitted to DEQ as supplements to this Work Plan.

Specific conditions of approval identified by DEQ can be incorporated into the final design.

The ISCM 90% final design, including details of well spacing, injection and performance monitoring schedules, and injection dosages will be completed after SLLI obtains key additional data pertaining to hydraulic characteristics, groundwater flow rates and velocities, and oxidant demand by the aquifer matrix. These data gaps will be filled by completing the following work:

- Complete a monitoring well in weathered basalt in order to collect weathered basalt for chemical testing and to develop additional data regarding target constituent occurrence;
- Complete a bench test of persulfate treatment in order to estimate oxidant demand, dosing concentration, and rate;
- Conduct pumping tests at the LA Pilot Study area and conduct slug tests in order to develop hydraulic conductivity data to use in designing injection well spacing and injection rates;
- Conduct a transducer study in order to develop continuous hydraulic gradient data for use in improving numerical groundwater flow model; and
- Complete numerical groundwater flow modeling in order to help design injection well spacing.

In order to meet the RAOs rapid implementation of the NFA ISCM is necessary. ISCM construction is scheduled to begin on November 1, 2007. To meet this schedule, SLLI plans to obtain the additional data proposed in the five mentioned data gap studies and complete the NFA ISCM design by September 1, 2007.

Since the NFA ISCM will provide direct benefits to DGZ groundwater quality, SLLI believes that DEQ approval of this Work Plan at the current 60% design stage is justified, with the understanding that the NFA ISCM is part of a broader Site-wide remediation strategy. To allow for sufficient time to obtain access approval from multiple property owners and to conduct contract bidding, SLLI requests that DEQ approve this Work Plan by July 24, 2007.

In order to provide DEQ with greater certainty as to the efficacy of the proposed ISCM design, a summary discussion of the installation, construction, operation and maintenance, and closure activities is provided below. For additional details, please refer to Appendix A.

9.0 INSTALLATION AND CONSTRUCTION

Installation and construction activities will take approximately 6 months. This work will be performed by licensed contractors under the supervision of engineers licensed in the State of Oregon.

9.1 Site Preparation

The NFA ISCM will be located on BNSF ROW on the north side of the railroad embankment, and within the NW Front Avenue ROW on the south side of the embankment (Figure 2). An access road will be placed on the north side of the embankment to allow installation, and O&M activities to occur. AMEC will maintain BNSF access.

Access to the NW Front Avenue portion of the ISCM will be from NW Front Avenue. Brush clearing and minimal site grading near the railroad embankment will be necessary to allow construction. The existing turnaround near the sanitary lift station will be maintained and accessible.

9.2 Drilling Methodology

A total of 24 performance monitoring wells and 74 ISCO wells will be installed using sonic drilling techniques, in accordance with standard operating procedures (SOPs). More specific information regarding well construction is provided in Appendix A, and SOPs are included in Appendix A-2. Locations for the ten first line performance monitoring wells are shown on Figure 15.

Each ISCO well location will be drilled 5 feet into weathered basalt at anticipated depths ranging from approximately 79 to 118 feet bgs. Due to the variability in subsurface conditions, the final depths of the wells will be determined in the field. Because Manufactured Gas Plant (MGP) waste has been encountered in shallow fill in the vicinity and near the proposed location of the ISCM, telescoping drilling methods will be used to seal off approximately the upper 40 feet, as determined by field observations. The wells will be drilled using 12-inch casing from ground surface to approximately 40 feet bgs, and stepped down to a 10-inch casing from 40 feet bgs to the total well depth. The upper casing will be sealed off using hydrated bentonite chips.

Once total depth is reached, a 10-foot screen section (deep well designation) will be set and backfilled with filter pack to 5 feet above the top of the screen. A second 5-

foot length of screen (upper well designation) will be set in the upper two-thirds of the DGZ, as determined at the time of drilling. Bentonite grout will be placed between the two wells to separate the screened intervals and filter pack will be placed around the upper screen to 5 feet above the top of the screen. The remaining borehole will be backfilled to just below the surface with bentonite grout.

Performance monitoring wells will be constructed of 2-inch diameter Schedule 80 PVC with a 10-foot-long, 0.010-inch screen interval placed at the bottom of the boring. Boring depth will be determined in the field. Each borehole will be backfilled with filter-pack sand around the screen to 5 feet above the screen, as detailed in Appendix A. To provide a protective seal around the well casing above the sand pack, a bentonite grout will be used from the sand pack up to just below the ground surface.

Well completion will be in accordance with local and state regulations. All 74 ISCO wells will be terminated in traffic-rated, concrete, pre-cast well vaults installed slightly above the final surface grade.

The performance monitoring and ISCO wells will be developed to minimize infiltration of silt or other particles and to reduce the creation of subsurface conduits for groundwater. At least 24 hours following installation, the wells will be developed by pumping approximately 5 to 10 well volumes from each well. In addition, the wells will be surged using a surge block. Each well will be developed according to AMEC's SOP - 14 (Appendix A-2). The wells will be allowed to set for at least 48 hours following development, prior to groundwater sampling.

9.3 Site Access, Utilities, and Remediation Compounds

This Work Plan assumes that access for NFA ISCM installation, construction, and regular O&M events will be unhindered and available, whenever required. Access agreements will be required for the placement of the ISCM system and performance monitoring wells on BNSF and COP properties, which will be negotiated prior to construction activities (Section 13.0).

Prior to drilling or other ISCM field activities, public and private utility locates will be conducted, and information regarding on-site utilities will need to be determined. All efforts will be made to not disrupt or impact utilities during the installation and construction of the ISCM system, including those within the BNSF ROW, the Siltronic utility corridor, the COP Outfall 22C storm sewer line, or the NW Front Avenue ROW (Figure 2). At this time, it is expected that electrical power will be provided to the two

systems along aboveground power poles. Aside from borings, none of the excavations required to install the NFA ISCM will be greater than 4 feet bgs.

The system compounds will be enclosed within a secure fence, will have exterior lighting, and will house the system mechanical equipment.

9.4 Baseline Sampling

Baseline groundwater sampling in the DGZ near the NFA ISCM location will be conducted prior to system startup to determine baseline target constituent concentrations, redox state, and geochemical indicator concentrations. Baseline monitoring wells will include: 1) riverbank wells RP-07-84, RP-07-119, RP-24-73, and RP-24-85; wells W-09-116, W-11-D(91), W-11-B(122), RP-18-111, and RP-18-125 upgradient from the NFA ISCM location; 3) every third ISCO injection well; and 4) the first line performance monitoring wells (Figure 15). Sampling and analysis procedures are included in the SOPs included in Appendix A-2.

9.5 System Startup

Following baseline sampling, system startup operations will be completed. Specific startup operations are described in the System Design and Installation Plan (Appendix A). Specific performance criteria will be monitored in each of the performance monitoring wells.

10.0 OPERATION AND MAINTENANCE

The O&M for the NFA ISCM will consist of a baseline groundwater sampling event as described in Section 9.4, followed by post-startup groundwater sampling as described in 10.1. Field observations and groundwater sampling field measurements will be documented on a Groundwater Sampling Field Sheet for each well monitored (Appendix B). System maintenance and remedial process optimization are discussed in Sections 10.2 and 10.3, respectively.

10.1 Groundwater Sampling

Following system startup, the performance monitoring wells will be sampled weekly for the first month of system operation, once during the second month, and then quarterly. Quarterly groundwater samples will be analyzed for geochemical parameters and target constituents. Additional parameters may be collected from these wells during Site-wide groundwater monitoring events.

Groundwater sampling will be conducted in accordance with SOPs established for the RP Site. Full data validation will be performed for the baseline and each subsequent quarterly sampling event.

10.2 In-Situ Chemical Oxidation System Maintenance

The main systems are designed to inject a limited and metered quantity of oxidant to each well. O&M activities will be conducted as necessary to ensure the system is functioning as specified and to make necessary adjustments.

10.3 Remedial Process Optimization

Remedial Process Optimization (RPO) will be conducted on an ongoing basis to optimize the process. The goals of any RPO program are established to: 1) ensure that existing remediation systems remain protective of human health and the environment; 2) facilitate the re-evaluation of cleanup goals; 3) track and report remedial progress; 4) reduce operating and monitoring costs (e.g., oxidant usage); and 5) accelerate system closure.

The RPO evaluation will track the expected performance versus actual performance of the ISCM. To facilitate this tracking, groundwater data from a network of performance monitoring wells will be reviewed regularly to evaluate the continuing effectiveness and protectiveness of the ISCM. General types of groundwater data may include target constituent concentration, geochemical data, and elevation measurements. Based on the RPO evaluation, the existing remediation system may be optimized with a more effective operational approach.

Additionally, groundwater and system monitoring can be significant cost items in the annual O&M budget. RPO evaluation will consider whether the existing monitoring points have continued usefulness in tracking ISCM performance.

Additional optimization efforts may be guided by the performance of the LA Pilot Study (AMEC, 2007a) or other applicable data.

11.0 REMEDIATION WASTE MANAGEMENT

Remediation Waste (RW) generated during construction and installation of the NFA ISCM remediation system will be managed in accordance with SOP - 13 (Appendix A-2) and United States Department of Transportation (DOT) manifesting, labeling, and transportation requirements. It is anticipated that the RW may consist of:

- Soil excavated from the utility trenching;
- Soil cuttings from ISCO treatment well and performance monitoring well installation;
- Water and soil from decontamination of drilling equipment and construction equipment;
- Water from development and purging of the ISCO treatment wells and performance monitoring wells; and
- Personal protective equipment (PPE) and miscellaneous debris.

AMEC assumes that soil excavated during trenching activities will not have to be treated as hazardous waste and will be placed back in the excavation trench. If field conditions indicate otherwise, the soil will be placed in lined and secured waste storage bins located near the ISCM location and moved to the RP Site staging area when full, pending characterization and disposal. If hazardous, the soil will be transported to and disposed of at either the Chemical Waste Management Subtitle C Landfill (Arlington, Oregon) or the Clean Harbors incinerator at Aragonite, Utah.

Surface soil excavated or scraped for relocating or construction of access roadways will be stockpiled on the property for reuse or distribution as determined by the property owner.

Water generated during system installation activities, decontamination procedures, well development, and well sampling will be contained in secure temporary poly-containers near the location of the ISCM and moved to the RP Site when full. It is anticipated that the water will be disposed of in the RP water treatment plant (WTP).

Solid waste generated during construction, well installation, well development, and system startup will include PPE and miscellaneous trash (plastic sheeting, tubing, electrical wire, PVC pipe, etc.). This material will be contained in heavy-duty plastic trash bags and transported to the RP Site for storage in either drums or a container pending characterization and disposal.

RW generated during O&M activities and performance monitoring well sampling events will consist of minimal amounts of purge water, debris, and PPE. The waste will be stored in drums or containers at the RP Site pending characterization and disposal. It is anticipated that PPE and debris will be transported to and disposed of at the Chemical Waste Management Subtitle C Landfill (Arlington, Oregon), and purge water will go to the RP WTP.

12.0 REPORTING

Reporting will include an initial startup and construction report, an O&M manual, progress reports, and reporting related to system decommissioning activities. Regular communication with DEQ will occur throughout the project, including weekly status memos for the first year and optional on-site meetings.

12.1 Installation Report

The installation and startup report will include the ISCM system schematic, layout, and detailed as-built drawings stamped by a Professional Engineer. The installation and startup report will also incorporate results from baseline groundwater sampling, including field observations and field sheets from performance monitoring well sampling, analytical results, data validation, a Site figure with sampling locations, and the initial daily O&M field sheets from system startup. The report will include a narrative of field activities. An O&M manual will also be developed, and is discussed in Appendix A.

12.2 Progress Reports

Results of O&M activities and groundwater sampling will be provided to the DEQ on a quarterly basis for the first year of system operation. The quarterly reports will consist of field observations and field sheets from well sampling, analytical results, data validation, a Site figure with sampling locations, field sheets from system O&M activities, and a brief narrative. Other activities related to the system, such as RPO (Section 10.3) or system modifications conducted during the quarter, will be included in the quarterly reports. Following the first year of operation, progress reports will be submitted to the DEQ on an annual basis and will contain information similar to the quarterly reports.

13.0 SITE ACCESS

Legal access for implementation and monitoring of the NFA ISCM will be required from BNSF and the COP. A DEQ-approved Work Plan often is required before property owners will grant access. In addition, physical access issues due to overhead power lines and underground utilities, as well as the railroad embankment, will need to be addressed for the portion of the NFA ISCM along NW Front Avenue and the utility corridor. SLLI is currently working with property owners and utility companies to facilitate access; however, implementation of this ISCM as proposed, is entirely dependent on SLLI's ability to obtain legal and physical access.

In addition to access from BNSF and the COP for the NFA ISCM system installation and performance monitoring well installation, it is currently anticipated that the access requested will include ongoing access for the following: construction and maintenance of an access road, and continued access for system O&M and performance monitoring on BNSF property; and continued access for system O&M and performance monitoring on COP property.

14.0 HEALTH AND SAFETY

The RP HASP will be updated to incorporate any additional activities proposed for the NFA ISCM construction and O&M.

Currently, the PPE requirements for subcontractors and AMEC personnel are anticipated to be modified Level D.

15.0 SCHEDULE

Implementation of the NFA ISCM will follow DEQ's approval of this Work Plan, completion of the planned activities to fill data gaps, and securing property access. Construction is anticipated to begin in late 2007. Duration of the ISCM installation and construction is estimated to be approximately 6 months. Baseline groundwater sampling and startup of the system should begin by first-quarter 2008. The operational life of the system is anticipated to be approximately 15 years, and long-term monitoring is anticipated to continue for approximately 5 years following system shutdown. A Gantt chart of the tentative NFA ISCM schedule is provided as Figure 16.

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LIMITATIONS

This report was prepared exclusively for SLLI by AMEC Earth & Environmental, Inc. (AMEC). The quality of information, conclusions, and estimates contained herein is consistent with the level of effort involved in AMEC services and based on:
i) information available at the time of preparation; ii) data supplied by outside sources; and iii) the assumptions, conditions, and qualifications set forth in this report. This Draft North Front Avenue Interim Source Control Measure Work Plan is intended to be used by SLLI for the RP - Portland Site, 6200 N.W. St. Helens Road, Portland, Oregon only, subject to the terms and conditions of its contract with AMEC. Any other use of, or reliance on, this report by any third party is at that party's sole risk.

TABLES

TABLE 1
Target Constituent Comparison to JSCS SLVs
Siltronic Riverbank MWs and LWG TZ Water Samples
Maximum Detected Concentrations (2000-2006)
RP - Portland Site

Sample Location	Hydrogeologic Zone	Sample Date	Analyte (Detections Only)	Concentration (µg/L)	Screening Level Values (µg/L)									Exceedance Ratio[1]				
					Human Health						Ecological Receptors			Human Health		Ecological Receptors		
					Fish Consumption				Drinking Water					Fish Consumption	Drinking Water			
					EPA's 2006 NRWQC (Organism Only) [2]	Portland Harbor Specific Fish Consumption Rate [2]	DEQ's 2004 AWQC (organism only) [3]	Portland Harbor Specific Fish Consumption Rate [3]	MCL [4]	Tap Water PRG [5]	EPA's 2006 NRWQC (chronic) [3]	DEQ's 2004 AWQC (chronic) [3]	Oak Ridge National Laboratory's (Tier II SCV) [3]	Portland Harbor Specific Fish Consumption Rate	MCL	EPA's 2006 NRWQC (chronic)	DEQ's 2004 AWQC (chronic)	Oak Ridge National Laboratory's (Tier II SCV)
RP-07-84	DGZ	08/07/06	1,2-Dichlorobenzene	800	1,300	130	1,300	130	600	370	~	763	14.0	6.15	1.33		1.05	
RP-07-84	DGZ	08/07/06	1,4-Dichlorobenzene	250	190	19.0	190	19.0	75.0	0.500	~	763	15.0	13.2	3.33			16.7
RP-07-84	DGZ	08/07/06	Chlorobenzene	140	1,600	160	1,600	160	100.0	110	~	50.0	64.0		1.40		2.80	
RP-07-84	DGZ	04/13/04	Vinyl chloride	16.3	2.40	0.240	2.40	0.240	2.00	0.0200	~	~	~	67.9	8.15			
RP-07-119	DGZ	04/29/02	1,2-Dichlorobenzene	987	1,300	130	1,300	130	600	370	~	763	14.0	7.59	1.65		1.29	
RP-07-119	DGZ	04/29/02	1,4-Dichlorobenzene	310	190	19.0	190	19.0	75.0	0.500	~	763	15.0	16.3	4.13			20.7
RP-07-119	DGZ	04/29/02	Chlorobenzene	95.1	1,600	160	1,600	160	100.0	110	~	50.0	64.0				1.90	
RP-07-119	DGZ	04/29/02	Vinyl chloride	11.6	2.40	0.240	2.40	0.240	2.00	0.0200	~	~	~	48.3	5.80			
RP-11-216	DGZ	11/21/05	1,2-Dichlorobenzene	210	1,300	130	1,300	130	600	370	~	763	14.0	1.62				15.0
RP-11-216	DGZ	11/21/05	1,4-Dichlorobenzene	58.0	190	19.0	190	19.0	75.0	0.500	~	763	15.0	3.05				3.87
RP-11-216	DGZ	08/14/06	Vinyl chloride	3.10 J	2.40	0.240	2.40	0.240	2.00	0.0200	~	~	~	12.9	1.55			
RP-24-85	DGZ	11/21/06	1,2-Dichlorobenzene	480	1,300	130	1,300	130	600	370	~	763	14.0	3.69				34.3
RP-24-85	DGZ	11/21/06	1,4-Dichlorobenzene	130	190	19.0	190	19.0	75.0	0.500	~	763	15.0	6.84	1.73			8.67
RP-24-85	DGZ	11/21/06	Vinyl chloride	8.50 J	2.40	0.240	2.40	0.240	2.00	0.0200	~	~	~	35.4	4.25			
RP02ETR	30 cm	10/27/05	1,2-Dichlorobenzene	26	1,300	130	1,300	130	600	370	~	763	14.0					1.86
RP02ETR	150 cm	10/27/05	1,2-Dichlorobenzene	44	1,300	130	1,300	130	600	370	~	763	14.0					3.14
RP02ETR	30 cm	10/27/05	Chlorobenzene	55	1,600	160	1,600	160	100.0	110	~	50.0	64.0				1.10	
RP02ETR	30 cm	10/27/05	Vinyl chloride	3	2.40	0.240	2.40	0.240	2.00	0.0200	~	~	~	12.5	1.50			
RP02ETR	150 cm	10/27/05	Vinyl chloride	0.67	2.40	0.240	2.40	0.240	2.00	0.0200	~	~	~	2.79				
RP03CTR	30 cm	10/28/05	1,2-Dichlorobenzene	640	1,300	130	1,300	130	600	370	~	763	14.0	4.92	1.07			45.7
RP03CTR	150 cm	10/28/05	1,2-Dichlorobenzene	310	1,300	130	1,300	130	600	370	~	763	14.0	2.38				22.1
RP03CTR	30 cm	10/28/05	1,4-Dichlorobenzene	240	190	19.0	190	19.0	75.0	0.500	~	763	15.0	12.6	3.20			16.0
RP03CTR	150 cm	10/28/05	1,4-Dichlorobenzene	180	190	19.0	190	19.0	75.0	0.500	~	763	15.0	9.47	2.40			12.0
RP03CTR	30 cm	10/28/05	Chlorobenzene	210	1,600	160	1,600	160	100.0	110	~	50.0	64.0	1.31	2.10		4.20	
RP03CTR	150 cm	10/28/05	Chlorobenzene	310	1,600	160	1,600	160	100.0	110	~	50.0	64.0	1.94	3.10		6.20	
RP03CTR	30 cm	10/28/05	Vinyl chloride	6.4	2.40	0.240	2.40	0.240	2.00	0.0200	~	~	~	26.7	3.20			
RP03CTR	150 cm	10/28/05	Vinyl chloride	15	2.40	0.240	2.40	0.240	2.00	0.0200	~	~	~	62.5	7.50			
RP03ETR	30 cm	10/27/05	1,2-Dichlorobenzene	270	1,300	130	1,300	130	600	370	~	763	14.0	2.08				19.3
RP03ETR	90 cm	10/27/05	1,2-Dichlorobenzene	98	1,300	130	1,300	130	600	370	~	763	14.0					7.00
RP03ETR	30 cm	10/27/05	1,4-Dichlorobenzene	88	190	19.0	190	19.0	75.0	0.500	~	763	15.0	4.63	1.17			5.87
RP03ETR	90 cm	10/27/05	1,4-Dichlorobenzene	36	190	19.0	190	19.0	75.0	0.500	~	763	15.0	1.89				2.40
RP03ETR	30 cm	10/27/05	Chlorobenzene	55	1,600	160	1,600	160	100.0	110	~	50.0	64.0				1.10	
RP03ETR	30 cm	10/27/05	Vinyl chloride	7.9	2.40	0.240	2.40	0.240	2.00	0.0200	~	~	~	32.9	3.95			
RP03ETR	90 cm	10/27/05	Vinyl chloride	3.2	2.40	0.240	2.40	0.240	2.00	0.0200	~	~	~	13.3	1.60			
R2RP01TR	30 cm	10/26/05	Vinyl chloride	0.82	2.40	0.240	2.40	0.240	2.00	0.0200	~	~	~	3.42				

Notes:

µg/L = micrograms per liter
~ = no screening value available
MCL = maximum contaminant level
PRG = preliminary remediation goal
DGZ = deep gravel zone hydrogeologic zone
cm = centimeters
SLV = screening level value
NRWQC = National Recommended Water Quality Criteria
AWQC = Ambient Water Quality Criteria

1 = Exceedance ratios were calculated only for those constituents exceeding their most appropriate JSCS SLVs as described in Section 3.0 of the **Portland Harbor Joint Source Control Strategy (JSCS), December 2005**.
2 = Screening values were taken from **EPA document** titled **National Recommended Water Quality Criteria, 2006**; Portland Harbor Specific Fish Consumption Rates are the **NRWQC (Organism Only)** value divided by 10.
3 = Screening values were taken from **Portland Harbor Joint Source Control Strategy, December 2005**; Portland Harbor Specific Fish Consumption Rates are the **DEQ's 2004 AWQCs** divided by 10.
4 = MCL screening values from **EPA Office of Water (4606M), EPA 816-F-03-016, June 2003.**
5 = PRG screening values from EPA Region 9, **PRG Table Version 9, October 2004.** In some cases these values appear to differ slightly from **JSCS** SLVs due to rounding differences.

TABLE 2
2006 Groundwater Geochemistry Data Summary
North Front Avenue ISCM WP
RP - Portland Site

Location ID	Sample Date	Field pH	Dissolved Oxygen	Oxidation-Reduction Potential	Nitrate as Nitrogen	Nitrite as Nitrogen	Dissolved Manganese	Total Manganese	Ferrous Iron	Dissolved Iron	Total Iron	Sulfate	Sulfide	Methane	Ethene	Ethane	Chemical Oxygen Demand	Electrical Conductivity	Field Temperature	Field Turbidity	Total Dissolved Solids	Total Suspended Solids	Chloride	Total Organic Carbon	Total Kjeldhal Nitrogen	Ammonia as Nitrogen	Orthophosphorus	Total Alkalinity	Biological Oxygen Demand	Heterotrophic Plate Count
		SU	mg/L	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	uS/cm	deg c	ntu	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	cfu/mL
MW-03-137	11/17/06	7.00	0.33	-87.4	0.0110 U	0.0150 U	4.39	4.31	2.5	2.38	2.36	19.4	0.49 U	NT	NT	NT	10 U	914	11.91	0.39	512	5.8	155	0.72 U	NT	0.26	0.00107 U	221	NT	210
MW-03-141	11/17/06	7.15	0.17	-100.4	0.0110 U	0.0150 U	1.46	1.46	2.0	1.45	1.54	11.2	0.49 U	NT	NT	NT	10 U	575	11.80	1.53	321	4.7	69.8	2.5	NT	0.57	0.00107 U	185	NT	24000
RP-06-87	3/27/06	6.26	0.31	-61	0.0150 U	0.113 U	31	31	3.4	6.2	6.4	100	0.0050 U	0.65	0.0004 U	0.0016 J	150	3878	12.57	3.55	NT	NT	1300	2.7	0.57	0.080	0.00433 J	420	0.307 U	2
RP-06-87	7/26/06	6.35	0.35	-53.6	0.0150 U	1.13 U	32.8	32.4	3.5	5.78	6.04	127	0.49 U	0.24	0.001 U	0.0012 U	74.4	4004	13.35	2.63	251	13.2	1460	2.1	0.15 U	0.39	0.00107 U	449	0.307 U	297
RP-06-87	8/24/06	6.44	0.32	-61.8	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	3040	12.87	1.62	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
RP-06-87	11/27/06	6.60	0.37	-73.7	0.0110 U	0.150 U	30.9	31.2	3.6	4.46 J	4.55	129	0.49 U	NT	NT	NT	59.2	3185	11.76	0.43	2480	10.0	1320	4.9	NT	0.025 U	0.00107 U	438	NT	210
RP-06-95	11/27/06	6.74	0.27	-61.4	0.0110 U	0.150 U	13.1	12.8	1.1	3.41	3.34	151	0.49 U	NT	NT	NT	30.5	3250	12.11	2.48	2140	18.8	1110	5.4	NT	0.025 U	0.00107 U	469	NT	310
RP-07-119	3/23/06	6.28	0.27	50	0.0900 J	0.113 U	0.18	0.18	0.5	0.12 J	0.24	30	0.0050 U	0.0006 U	0.0004 U	0.0003 U	8.6	1885	14.13	1.11	NT	NT	470	1.2	0.50 U	0.11	0.0184	140	0.307 U	12000
RP-07-119	8/4/06	6.63	0.15	-25.5	0.0150 U	0.113 U	0.11	0.101	2.2	0.33	0.327	50.4	0.49 U	0.00051 U	0.001 U	0.0012 U	25.6	1718	15	0.23	1060	0.50 U	485	1.1	0.15 U	0.025 U	0.0334	141	0.307 U	1200
RP-17-145	9/18/06	6.59	0.30	-54.7	0.150 U	1.13 U	10.6	10.8	3.4	3.31	3.4	146	0.49 U	NT	NT	NT	33.7	2061	14.55	1.05	NT	NT	496	2.4	NT	0.056	0.00107 U	404	NT	5100
RP-17-145	11/20/06	6.76	0.44	-86.8	0.0110 U	1.50 U	11.2	10.8	3.8	3.74	15.9	162	0.49 U	0.17	0.001 U	0.0044	38.7	2355	13.91	60.2	1480	264	509	2.7	0.23	1.0	0.00107 U	397	0.307 U	43000
RP-18-111	9/20/06	6.49	0.49	-48.3	0.015 U	1.13 U	14.2	14.4	3.4	3.9	3.84	326	0.49 U	NT	NT	NT	56.1	3213	14.22	4.35	NT	NT	862	2.9	NT	0.17	0.00107 U	407	NT	1200
RP-18-125	9/18/06	6.51	0.31	-32.5	0.015 U	1.13 U	14.2	14.3	3.6	3.33	3.78	323	0.49 U	NT	NT	NT	48	3153	14.62	3.95	NT	NT	840	2.5	NT	0.5	0.00107 U	409	NT	2900
RP-19-129	9/21/06	8.17	0.44	-167.9	0.015 U	0.0113 U	0.2	0.199	1.1	0.972	1.14	5.1	0.49 U	NT	NT	NT	21.5	526	14.24	NT	NT	NT	48.4	0.72 U	NT	0.26	0.00107 U	172	NT	13000
RP-19-90	9/20/06	6.80	0.41	-99.5	0.015 U	0.0113 U	13.9	13.6	4.4	11.9	11.9	7.4	0.49 U	NT	NT	NT	48	892	14.40	3.61	NT	NT	14.9	3.9	NT	0.53	0.00107 U	493	NT	78000
W-08-74	8/30/06	6.65	0.6	-86.1	0.0150 U	0.0113 U	NT	5.3	2.8	6.05	6.03	3.0	0.49 U	1.6	0.001 U	0.0012 U	10 U	799	13.32	1.11	72.0	18.1	66.5	2.6	0.27	0.16	0.221	324	6.62	10
W-09-116	4/3/06	6.08	0.37	7.1	0.0150 U	0.113 U	10	12	U	1.1	1.4	56	0.0050 U	1.3	0.0004 U	0.00032 J	13	1985	12.69	8.06	NT	NT	650	3.3	0.84	0.34	0.00494 J	370	2.84 J	8
W-09-116	8/10/06	6.34	0.53	29	0.0150 U	0.113 U	9.59	9.53	0.9	1.09	NT	62.9	0.49 U	0.66	NT	0.0012 U	31.7	2106	15.01	2.59	1590	3.0	695	1.6	0.15 U	0.30	0.0208	377	4.04	8
W-11-B(122)	3/29/06	7.08	0.32	-127.6	0.0150 U	0.150 U	0.58	0.5	U	8.9	8.3	120	0.0050 U	0.37	0.0004 U	0.0021	13	2468	12.9	10.5	NT	NT	700	1.1	0.78	0.10	0.00341 J	320	0.307 U	270
W-11-B(122)	7/28/06	7.34	0.61	-118.4	0.150 U	0.113 U	0.56	0.574	3.2	NT	9.2	139	0.49 U	0.22	0.001 U	0.0012 U	27.6	2383	14.86	2.42	1500	25.7	713	1.4	0.40	0.11	0.00107 U	329	0.307 U	19 U
W-11-B(122)	8/24/06	7.3	0.63	-135.9	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	26.53	15.78	2.08	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
W-11-D(91)	3/29/06	6.66	0.21	8.4	0.0150 U	0.150 U	14	14	1.6	1.9	5.4	240	0.0050 U	0.24	0.0004 U	0.014	20	3429	12.98	62.6	NT	NT	840	3.3	0.50 U	0.082	0.0150	420	0.307 U	43
W-11-D(91)	8/1/06	7.07	2.58	23.6	0.0150 U	0.113 U	NT	NT	0.2	NT	NT	NT	NT	NT	NT	NT	NT	3592	14.62	3.44	NT	NT	NT	NT	NT	NT	0.00107 U	430	0.307 U	56
W-11-D(91)	8/25/06	NT	NT	NT	NT	NT	15.5	15.6	NT	2.42	5.27	259	0.49 U	0.08	0.001 U	0.0055	35.8	NT	NT	NT	2180	86.3	805	2.9	0.15 U	0.17	NT	NT	NT	NT

Notes:

This data is not validated, with the exception of the metals (Fe and Mn)
U = not detected at or above method reporting limit
cfu/ml = colony forming units per milliliter
deg C = degrees entigrade
mg/L = milligrams per Liter
mV = millivolts
NT= not tested
ntu = nephelometric turbidity units
SU = standard units
µS/cm = microSiemens per centimeter

TABLE 3
2006 Soil Geochemistry Data Summary
North Front Avenue ISCM WP
RP - Portland Site

Location ID	Sample Date	Start Depth	End Depth	pH	Nitrate as Nitrogen	Nitrite (as N)	Manganese	Iron	Sulfate	Sulfide	Chemical Oxygen Demand	Total Organic Carbon	Ammonia as Nitrogen	Orthophosphorus	Total Alkalinity	Chloride	Hetero-trophic Plate Count
		feet	feet	SU	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	cfu/mL
MW-03-137	10/04/2006	131.5	136.5	8.71	0.186 U	0.201 U	365	33400	4.6	7.9 U	541	839	NT	0.0103 U	850	19.0	30
MW-03-141	10/02/2006	136	141	8.83	0.181 U	0.195 U	245	28700	5.2	19.3	705	551 U	NT	0.812	350	5.2	10 U
RP-06-95	10/30/2006	90	95	8.15	0.150 U	0.113 U	373	22900	14.3	7.9 U	178	562 U	NT	0.146	300	107	10 U
RP-17-145	08/02/2006	140	145	8.92	0.172 U	0.186 U	NT	NT	33.6	5.72 U	55.4	501 U	0.17 U	1.84	250 U	89.1	10
RP-18-111	08/17/2006	102	107	8.44	0.216 U	0.233 U	NT	NT	123	7.1 U	784	730 J	1.44	1.55	900	292	60
RP-18-111	08/17/2006	107	112	8.96	0.176 U	0.19 U	NT	NT	58.4	5.75 U	867	540 J	0.177 U	0.628	1200	90.3	220
RP-18-125	08/15/2006	120	125	8.75	0.168 U	0.181 U	NT	NT	41	279 U	603	501 U	0.166 U	1.55	1200	52.7	30
RP-19-129	08/24/2006	125	130	8.34	0.178 U	0.193 U	NT	NT	1.26 U	61.5	363	2000	0.173 U	0.228	2400	0.234 U	10 U
RP-19-90	08/24/2006	80	90	7.66	0.223 U	0.241 U	NT	NT	1.57 U	6.77 U	794	501 U	0.742	0.662	980	0.292 U	10

Notes:
This data is not validated, with the exception of the metals (Fe and Mn)
U = not detected at or above method reporting limit
cfu/ml = colony forming units per milliliter
deg C = degrees entigrade
ID = identification
mg/kg = milligrams per kilogram
mV = millivolts
NT= not tested
ntu = nephelometric turbidity units
SU = standard units
µS/cm = microSiemens per centimeter

TABLE 4
Summary of Sulfur Hexafluoride Tracer Test Data
North Front Avenue ISCM Work Plan
RP - Portland Site

Observation Well	Groundwater Samples % Saturation of SF_6 - 24, 48, and 120 Hours after Injection*			Vapor Samples % of Injection Concentration
	24 hours	48 hours	120 hours	24 hours
OW1	26.3	38.2	72	47
OW2	16.6	9.1	5	25.5
OW3	6.4	2.9	3.3	0.1
OW4	2.4	0.8	1	0.1
OW5	1	0.6	0.6	0
OW6	1.4	0.6	0.6	0.1
OW7	1.1	0.9	1.1	0
OW8	4.7	2.2	1.8	0
OW9	0.9	0.6	0.4	0
OW10	0.3	0.3	0.2	0
OW11	1	1.2	0.2	0.2
OW12	3.9	2	0.6	0

Notes:
SF6 = sulfur hexafluoride
* Injection began on February 27, 2007.

TABLE 5
Identification of Potential Remedial Technologies for Control of Plume in Deep Gravel Zone
North Front Avenue ISCM Work Plan
RP - Portland Site

Approach	Remedial Technology	Technology Description	Retain or Eliminate?	Reason for Retention or Elimination
Bioremediation	Monitored Natural Attenuation	Natural attenuation occurs via a variety of natural physical, chemical, or biological processes that, under favorable conditions, act to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ processes include biodegradation, diffusion, dispersion, hydrolysis, and sorption.	**Retain**	• While the current rate of natural attenuation alone does not attain RAOs at riverbank compliance point, MNA will be an integral component of most remedial alternatives.
	Aerobic In-Situ Bioremediation	Addition of oxygen to groundwater for stimulation of aerobic microorganisms to biodegrade target constituents in-situ. Goal of obtaining harmless chemicals as end products.	**Retain**	• Most of the constituent mass is aerobically biodegradable. • Generally adaptable to geology, hydrogeology, and varying depths. • Relatively easy to install. Degrades target constituents in-situ. • Aerobic conditions can help lower dissolved metal concentrations through formation of less soluble metal oxides. • O&M is fairly routine.
	Anaerobic In-Situ Bioremediation	Addition of readily degradable carbon compounds (hydrogen/electron source) to groundwater to stimulate anaerobic target constituent biodegradation. Goal of obtaining harmless chemicals as end products.	Eliminate	• Rate of constituent degradation too slow to reach RAOs at compliance point. • Most constituent mass is not readily anaerobically treatable. • Increased anaerobic character in aquifer could leach more of the naturally occurring metals such as arsenic, manganese, and iron, which currently exceed screening levels. • Some target constituents may transform to more toxic byproducts.
Permeable Barrier Destructive	In-Situ Permeable Treatment Barrier	Emplaced treatment media degrade constituents. Media are emplaced perpendicular to groundwater flow in-situ using either trenching, direct injection, or soil fracture planes. The media intercept the groundwater flow and interact with the dissolved target constituents. Typical treatment media include redox active metals (such as Zero-Valent Iron) to dechlorinate certain constituents.	Eliminate	• Reaction rates with target constituents are likely too slow to provide effective treatment in high velocity groundwater environment. • Media have relatively limited life span (typically 2 to 10 years) and cannot be feasibly recovered or changed out in-situ.
Permeable Barrier Adsorptive	In-Situ Permeable Treatment Barrier	Emplaced treatment media adsorb constituents. Media are emplaced perpendicular to groundwater flow in-situ using either trenching, direct injection, or soil fracture planes. The media intercept the groundwater flow and interact with the dissolved target constituents. Typical treatment media include a passive media (such as activated carbon) to adsorb constituents.	Eliminate	• Reaction rates with target constituents are likely too slow to provide effective treatment in high velocity groundwater environment. • Media have relatively limited life span (typically 2 to 10 years) and cannot be feasibly recovered or changed out in-situ.
Chemical Degradation	In-Situ Chemical Oxidation	In-situ application of oxidants (such as hydrogen peroxide, persulfate, or permanganate) to groundwater to cause rapid chemical transformation of the target constituents to harmless end products.	**Retain**	• Adaptable to geology, hydrogeology, and varying depths. • Relatively easy to install. • Effectively degrades target constituents quickly in-situ. • May require large amounts of oxidant to overcome oxidant demand of aquifer materials.
	In-Situ Chemical Reduction	Injection of ferrous nanoscale iron, or injection of mixed iron/carbon reducing agent that acts to directly dechlorinate certain constituents. The iron and carbon would push the environment into an anaerobic state and spur anaerobic microorganisms to biodegrade constituents in-situ with the goal of obtaining harmless chemicals as end products.	Eliminate	• Rate of constituent degradation too slow to reach RAOs at compliance point. • Most constituent mass is not readily anaerobically treatable. • Increased anaerobic character in aquifer could leach more of the naturally occurring metals such as arsenic, manganese, and iron that currently exceed screening levels. • Some target constituents may transform to more toxic byproducts.
Physical Removal	Air Sparging and Soil Vapor Extraction	High pressure/high volume injection of air into groundwater partitions volatile target constituents by exposing contaminated water to large quantities of air. Volatilized target constituents are entrained in an air stream that moves to the vadose zone, where soil vapor extraction provides target constituent capture. Target constituents are typically either transferred to the atmosphere, to a filter medium, or are thermally treated. Oxygen stimulates aerobic microorganisms to biodegrade target constituents in-situ with the goal of obtaining harmless chemicals as end products.	**Retain**	• Relatively easy to install. • Many target constituents are volatile and most of the constituent mass is aerobically biodegradable. • O&M is fairly routine. • Air sparging component adaptable to geology, hydrogeology, and varying depths. • Aerobic conditions can help lower dissolved metal concentrations through formation of less soluble metal oxides.
	Groundwater Extraction and Treatment	Groundwater pumping into extraction wells or trenches to capture groundwater and associated constituents, then treatment facility removes constituents from water. Pumping may provide containment of contaminated groundwater and prevent constituent migration. Captured groundwater is treated ex-situ, typically using carbon for constituent removal.	**Retain**	• Adaptable to geology, hydrogeology, and varying depths. • May capture dissolved target constituents. • O&M is fairly routine. • Requires pumping large volume of water. • Treatment of water to discharge limits may be very difficult and expensive. • Transfers target constituents to another media which requires disposal.

Notes:
O&M: Operation and Maintenance
RAO: Remedial Action Objective
Shaded cells indicate technology retained and carried over to Table 6.

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TABLE 6
Screening of Potential Remedial Alternatives for Control of Plume in Deep Gravel Zone
North Front Avenue ISCM Work Plan
RP - Portland Site

Remedial Technology	Remedial Alternative	Remedial Alternative Description	Retain or Eliminate?	Reason for Retention or Elimination
Aerobic In-Situ Bioremediation complemented by MNA	Biosparging, Soil Vapor Extraction with Nutrient Addition, complemented by MNA	Air is introduced into the groundwater at a low flow rate of 3 to 5 scfm, imparting oxygen to the groundwater to stimulate aerobic microorganism growth. Nutrients may also be added as a growth stimulant. The microorganisms use oxygen as an electron acceptor as they biodegrade target constituents in-situ. Unknowns: target constituent half-lives. Ability to propagate oxygen across entire treatment zone. Migration pathways and surface release points for injected air.	Eliminate	• Air flow in subsurface is unpredictable and hard to capture • Air does not phase transfer enough oxygen to the groundwater to overcome oxygen demand. This may be either a physical (bubbles aggregate and move upward) or a chemical limitation (high demand)
	Dilute Hydrogen Peroxide Injection with Nutrient Addition, complemented by MNA	Technical-grade hydrogen peroxide is diluted and then injected into groundwater. Disproportionation of the peroxide introduces oxygen to the groundwater, stimulating microorganism growth and target constituent biodegradation. Nutrients may also be added as a growth stimulant. Unknowns: target constituent half-lives. Ability to propagate oxygen across entire treatment zone. Injection rate of hydrogen peroxide needed to produce necessary condition.	Eliminate	• Large amount of peroxide must be delivered to overcome natural aquifer oxidant demand. • Handling and delivery of peroxide is challenging and fairly costly. • Relatively high uncertainly of bioremediation success, spatially and temporally, coupled with the challenges of peroxide delivery.
	Oxygen Slow Release Product Injection with Nutrient Addition, complemented by MNA	A solid peroxide (such as calcium peroxide) is injected into the groundwater via an installed injection well network The solid slowly dissolves and releases oxygen to the groundwater. Nutrients may also be added as a growth stimulant. The oxygen stimulates microorganism growth and target constituent biodegradation. Unknowns: target constituent half-lives. Ability to propagate oxygen across entire treatment zone. Lifetime of oxygen release material and steady state oxygen concentration that can be achieved in groundwater. Ability to effectively deliver oxygen release product to subsurface.	Eliminate	• Handling and subsurface delivery of solid material is problematic at treatment zone depths. • Capital and labor costs for repeated mobilizations to field to add solid are prohibitive. • Groundwater velocity and oxygen dilution outstrips ability of solid to deliver oxygen to the subsurface.
In-Situ Chemical Oxidation complemented by MNA	Hydrogen Peroxide Injection, complemented by MNA	Concentrated hydrogen peroxide is injected into the groundwater. In the presence of naturally occurring iron (dissolved and mineral forms) the hydrogen peroxide disproportionates to form highly reactive hydroxyl radicals that react with, and cause the chemical destruction of, many target constituents. May be able to achieve high treatment efficiencies. Unknowns: Ability to effectively deliver oxidant throughout treatment zone by injection at depth in the given lithology. Lifetime of oxidant.	**Retain**	• Generally adaptable, easy to install • Degrades target constituents in-situ, does not transfer to other media. • Peroxide addition system is easily mechanized. • Operation and maintenance, while challenging initially, can be optimized and made routine. • Has added benefit of stimulating aerobic bioremediation
	Persulfate Injection, complemented by MNA	Persulfate is injected into the groundwater. The persulfate salts dissociate in water to persulfate anions and, in the presence of catalytic agents, to sulfate free radicals. The anions and radicals react with the constituents in groundwater and cause the chemical destruction of target constituents. May be able to achieve high treatment efficiencies. Unknowns: Ability to effectively deliver oxidant throughout treatment zone by injection at depth in the given lithology. Lifetime of oxidant.	**Retain**	• Persulfate has been used to degrade chlorobenzenes, other aromatic and alkyl constituents • Persulfate is more selective than other strong oxidants, and is not as highly consumed by naturally occurring organic matter • Iron catalyst is already present in the form of iron minerals in the aquifer. Catalysis can also be implemented using pH adjustment (to pH 10), heating, or hydrogen peroxide
	Permanganate Injection, complemented by MNA	Permanganate is injected into the groundwater. The permanganate ion acts to oxidize organic constituents, preferring non-aromatic alkenes. Unknowns: Effectiveness of the oxidant on the target constituents. Ability to effectively deliver oxidant throughout treatment zone by injection at depth in the given lithology. Lifetime of oxidant.	Eliminate	• Permanganate not considered very effective against aromatic constituents. • Manganese dioxide solid produced during reaction may clog aquifer pore spaces.
Air Sparging/Soil Vapor Extraction complemented by MNA	High Pressure Ambient Air Injection, and Vacuum Recovery of Vapors, complemented by MNA	Air is compressed and introduced to the groundwater at aggressive flows of 10 to 15 scfm. Volatile organics are partitioned from groundwater by greatly increasing the surface area of the contaminated water exposed to air. Aeration is typically paired with soil vapor extraction, in which the volatilized gas is extracted from the subsurface using soil vapor extraction technology. Volatile gases are treated using carbon or thermal destruction systems. Air leaves oxygen in the groundwater to induce aerobic microorganism growth. The microorganisms biodegrade volatile and non-volatile target constituents in-situ. Unknowns: Ability to propagate air stream across entire treatment zone. Ability to predictably propagate air stream to surface for recovery at known locations.	Eliminate	• Effective vapor capture at predictable locations is reliant on permeable soils with a large soil vapor extraction radius of influence. • The presence of low permeability silt in the top 30 feet of the water column, as well as other soil heterogeneities, makes reliable vapor capture infeasible. • Aggressive volatilization of target constituents, in the absence of reliable vapor capture, is infeasible in the vicinity of occupational workers (such as at the Siltronic facility).
Groundwater Extraction and Treatment complemented by MNA	Groundwater Pumping, Extraction, Treatment and Discharge, complemented by MNA	Through groundwater pumping, dissolved target constituents are extracted from the subsurface. In certain-situations, pumping may provide containment of contaminated groundwater to prevent migration. Extracted water is then treated ex-situ, typically using carbon for target constituent removal. Unknowns: Ability to establish an effective and efficient region of water and target constituent capture in a high flux treatment zone.	Eliminate	• Pumping from within a diffuse, high flux plume is not considered an efficient remediation method. • Requires significant investment in surface/subsurface infrastructure and permitting that may interfere with Siltronic or BNSF property operation. • Difficult to treat water so that it meets surface water discharge limits. • Target constituents transferred to new media at surface during treatment and not in-situ degraded.

Notes:
O&M: Operation and Maintenance
RAO: Remedial Action Objective
scfm: Standard cubic feet per minute

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TABLE 7
Assessment of Technology Balancing Factors for Remedial Alternatives
North Front Avenue ISCM Work Plan
RP - Portland Site

Remedial Alternative	Effectiveness 5 = high effectiveness		Reliability 5 = high reliability		Implementability 5 = high implementability		Implementation Risk 5 = low risk		Reasonableness of Cost 5 = most reasonable		Overall		Total Score
											Potential Advantages	Potential Disadvantages	
In-Situ Oxidation using Hydrogen Peroxide Injection Activated by Iron, complemented by MNA	4	• Target constituent oxidation occurs in a relatively short timeframe, so treatment can occur with relatively little contact time to be effective. A treated water front can be initiated within a short period of time. • Hydrogen peroxide delivery across treatment zone at injection line can be optimized by adjusting well spacing and pumping rates. • Hydrogen peroxide degradation will release oxygen to aquifer, thus promoting aerobic biodegradation.	4	• Proven at other sites, but site-specific field tests indicate that much optimization is required, • System must work for 2 to 4 years to achieve cleanup at riverbank compliance monitoring point. Absent upgradient source remediation, system must work indefinitely to maintain treatment barrier. • Requires moderate maintenance.	3	• Site-specific field tests indicate that much optimization is required. • Good physical access. • Easily automated • Requires monitoring well network to measure progress. • Design and implementation expertise and materials readily available locally and nationally.	3	• Target constituent oxidation occurs in a very short time, thus quickly leading to lowered constituent concentration. • Hydrogen peroxide is hazardous and large quantities of concentrated solutions will be handled and secured. • Degradation of soil humic material by hydrogen peroxide may cause initial release of target constituents to groundwater.	2	Design, Permit, Install - $5,875,000 O&M first year - $2,530,000 O&M each ensuing year - $2,000,000 Total Cost - $36,405,000 for 15 years	• Peroxide will oxidize target constituents. • Minimal surface profile. • Dissolved peroxide should move some oxygen to wherever groundwater flows.	• Peroxide is highly reactive with site aquifer material, requiring high peroxide volumes • Heightened health and safety requirements. • Potential for system fouling. • Requires site visits at a moderate to high frequency over the long term.	16
In-Situ Oxidation using Persulfate Injection Activated by Iron, complemented by MNA	5	• Target constituent oxidation occurs in a relatively short timeframe, so treatment can occur with relatively little contact time to be effective. A treated water front can be initiated within a short period of time. • Hydrogeologic conditions in DGZ appear to be conducive for oxidant delivery. Persulfate delivery across treatment zone at injection line can be optimized by adjusting well spacing and pumping rates • Persulfate is a strong oxidizer that is stable toward soil natural organic matter and toward carbonate.	5	• Proven at other sites. • Depending on oxidant depletion rates, treatment may continue for some time after each application. Persulfate has a higher oxidation specificity (thus a longer lifetime) in soil and groundwater than many other oxidants. • System must work for 2 to 4 years to achieve cleanup at riverbank compliance monitoring point. Absent upgradient source remediation, system must work indefinitely to maintain treatment barrier. • Requires moderate maintenance.	5	• Good physical access. • Easily automated • Requires monitoring well network to measure progress. • Design and implementation expertise and materials readily available locally and nationally.	4	• Target constituent oxidation occurs in a very short time, thus quickly leading to lowered constituent concentration. • Persulfate solutions are hazardous and large quantities of concentrated solutions will be handled and secured.	2	Design, Permit, Install - $5,863,000 O&M first year - $2,530,000 O&M each ensuing year - $1,960,000 Total Cost - $35,875,000 for 15 years	• Oxidizes target constituents in short time. • Small surface profile. • Treated water front is produced within short time.	• Heightened health and safety requirements. • Potential for system fouling. • Requires site visits at a moderate to high frequency over the long term.	21
In-Situ Oxidation using Persulfate Injection Activated by Hydrogen Peroxide, complemented by MNA	5	• Target constituent oxidation occurs in a relatively short timeframe, so treatment can occur with relatively little contact time to be effective. A treated water front can be initiated within a short period of time. • Hydrogeologic conditions in DGZ appear to be conducive for oxidant delivery. Persulfate delivery across treatment zone at injection line can be optimized by adjusting well spacing and pumping rates. • Hydrogen peroxide releases oxygen to aquifer, promoting aerobic biodegradation. • Persulfate is a strong oxidizer that is stable toward soil natural organic matter and toward carbonate.	4	• Proven at other sites, but site-specific field tests indicate that much optimization of hydrogen injection is required. • Depending on oxidant depletion rates, treatment may continue for some time after each application. Persulfate has a longer lifetime (and higher oxidation specificity) in soil and groundwater than many other oxidants. • System must work for 2 to 4 years to achieve cleanup at riverbank compliance monitoring point. Absent upgradient source remediation, system must work indefinitely to maintain treatment barrier. • Requires moderately high maintenance.	4	• Site-specific field tests indicate that much optimization is required for hydrogen peroxide injection • Good physical access. • Easily automated • Requires monitoring well network to measure progress. • Design and implementation expertise and materials readily available locally and nationally.	3	• Target constituent oxidation occurs in a very short time, thus quickly leading to lowered constituent concentration. • Hydrogen peroxide and persulfate solutions are hazardous and large quantities of concentrated solutions will be handled and secured. • Degradation of soil humic material by hydrogen peroxide may cause initial release of target constituents to groundwater.	2	Design, Permit, Install - $6,875,000 O&M first year - $2,100,000 O&M each ensuing year - $1,125,000 Total Cost - $36,570,000 for 15 years	• Oxidizes target constituents in short time. • Small surface profile. • Treated water front is produced within short time	• Heightened health and safety requirements. • Potential for system fouling. • Requires site visits at a moderate to high frequency over the long term.	18

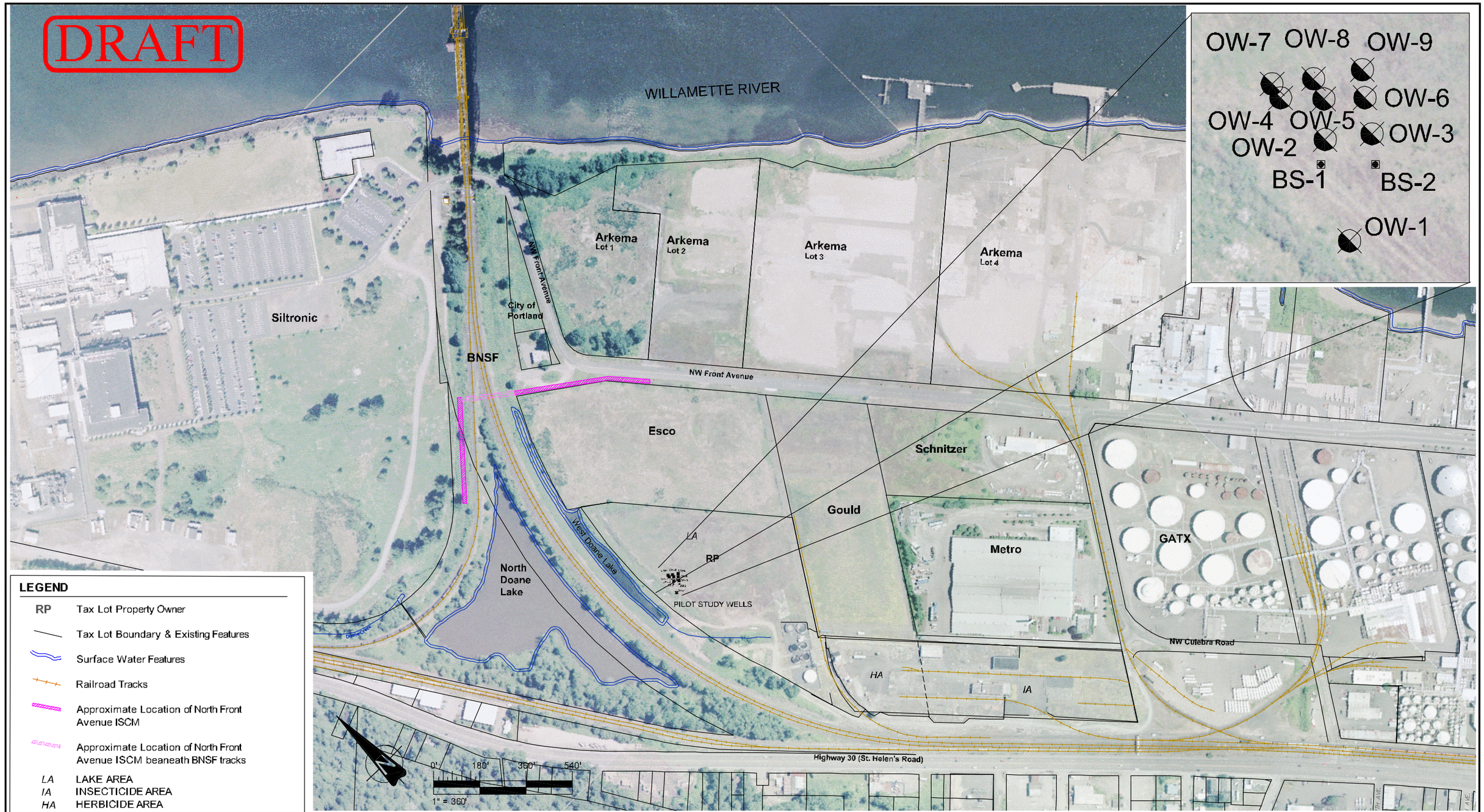
DRAFT

TABLE 7
Assessment of Technology Balancing Factors for Remedial Alternatives
North Front Avenue ISCM Work Plan
RP - Portland Site

Remedial Alternative	Effectiveness 5 = high effectiveness		Reliability 5 = high reliability		Implementability 5 = high implementability		Implementation Risk 5 = low risk		Reasonableness of Cost 5 = most reasonable		Overall		Total Score
											Potential Advantages	Potential Disadvantages	
In-Situ Oxidation using Persulfate Injection Activated by Base Addition to pH 10, complemented by MNA	5	• Target constituent oxidation occurs in a relatively short timeframe, so treatment can occur with relatively little contact time to be effective. A treated water front can be initiated within a short period of time. • Hydrogeologic conditions in DGZ appear to be conducive for oxidant delivery. Persulfate delivery across treatment zone at injection line can be optimized by adjusting well spacing and pumping rates. • Persulfate is a strong oxidizer that is stable toward soil natural organic matter and toward carbonate.	5	• Proven at other sites. • Depending on oxidant depletion rates, treatment may continue for some time after each application. Persulfate has a higher oxidation specificity (thus a longer lifetime) in soil and groundwater than many other oxidants. • System must work for 2 to 4 years to achieve cleanup at riverbank compliance monitoring point. Absent upgradient source remediation, system must work indefinitely to maintain treatment barrier. • Requires moderate maintenance.	5	• Good physical access. • Easily automated • Requires monitoring well network to measure progress. • Design and implementation expertise and materials readily available locally and nationally.	4	• Target constituent oxidation occurs in a very short time, thus quickly leading to lowered constituent concentration. • Caustic and persulfate solutions are hazardous and large quantities of concentrated solutions will be needed, handled and secured.	3	Design, Permit, Install - $5,875,000 O&M first year - $1,950,000 O&M each ensuing year - $1,632,000 Total Cost - $30,660,000 for 15 years	• Oxidizes target constituents in short time. • Small surface profile. • Treated water front is produced within short time	• Heightened health and safety requirements. • Potential for system fouling. • Requires site visits at a moderate to high frequency over the long term.	22
In-Situ Oxidation using Persulfate Injection Activated by Heating Aquifer to 35º to 45ºC, complemented by MNA	5	• Target constituent oxidation occurs in a relatively short timeframe, so treatment can occur with relatively little contact time to be effective. A treated water front can be initiated within a short period of time. • Hydrogeologic conditions in DGZ appear to be conducive for oxidant delivery. Persulfate delivery across treatment zone at injection line can be optimized by adjusting well spacing and pumping rates. • Persulfate is a strong oxidizer that is stable toward soil natural organic matter and toward carbonate.	4	• Proven at other sites. • Depending on oxidant depletion rates, treatment may continue for some time after each application. Persulfate has a higher oxidation specificity (thus a longer lifetime) in soil and groundwater than many other oxidants. • System must work for 2 to 4 years to achieve cleanup at riverbank compliance monitoring point. Absent upgradient source remediation, system must work indefinitely to maintain treatment barrier. • Requires moderate to high level of ongoing maintenance, especially with added heating infrastructure.	3	• Good physical access. • Heating requires complex infrastructure with frequent operation oversight and maintenance • Requires monitoring well network to measure progress. • Design and implementation expertise and materials readily available locally and nationally.	3	• Target constituent oxidation occurs in a very short time, thus quickly leading to lowered constituent concentration. • Persulfate solution is hazardous and large quantities of concentrated solutions will be needed, handled and secured. • Heated water and/or steam, and high power requirements introduce health and safety risk	1	Design, Permit, Install - $12,000,000 O&M first year - $3,000,000 O&M each ensuing year - $2,000,000 Total Cost - $43,000,000 for 15 years	• Oxidizes target constituents in short time. • Treated water front is produced within short time	• Heightened health and safety requirements. • Potential for system fouling. • Requires site visits at a moderate to high frequency over the long term. • Heating system requires larger surface profile, and significantly higher installation and O&M costs.	16

Notes:
O&M: Operation and Maintenance
DGZ: deep gravel hydrogeologic zone

FIGURES



NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL NORTH FRONT AVENUE ISCM WORK PLAN DATED _____.

NOTE: 2005 Aerial from **Metro Data Resource Center**

CLIENT:	SLLI
DWN BY:	LM
CHK'D BY:	JF
DATUM:	NAD83
PROJECTION:	OR SP N. Int Ft
SCALE:	1" = 360'
PROJECT:	RP - PORTLAND SITE
TITLE:	NORTH FRONT AVENUE INTERIM SOURCE CONTROL MEASURE LOCATION
DATE:	JUNE 2007
PROJECT NO:	061M-107030-P80
REV. NO.:	8
FIGURE No.	1

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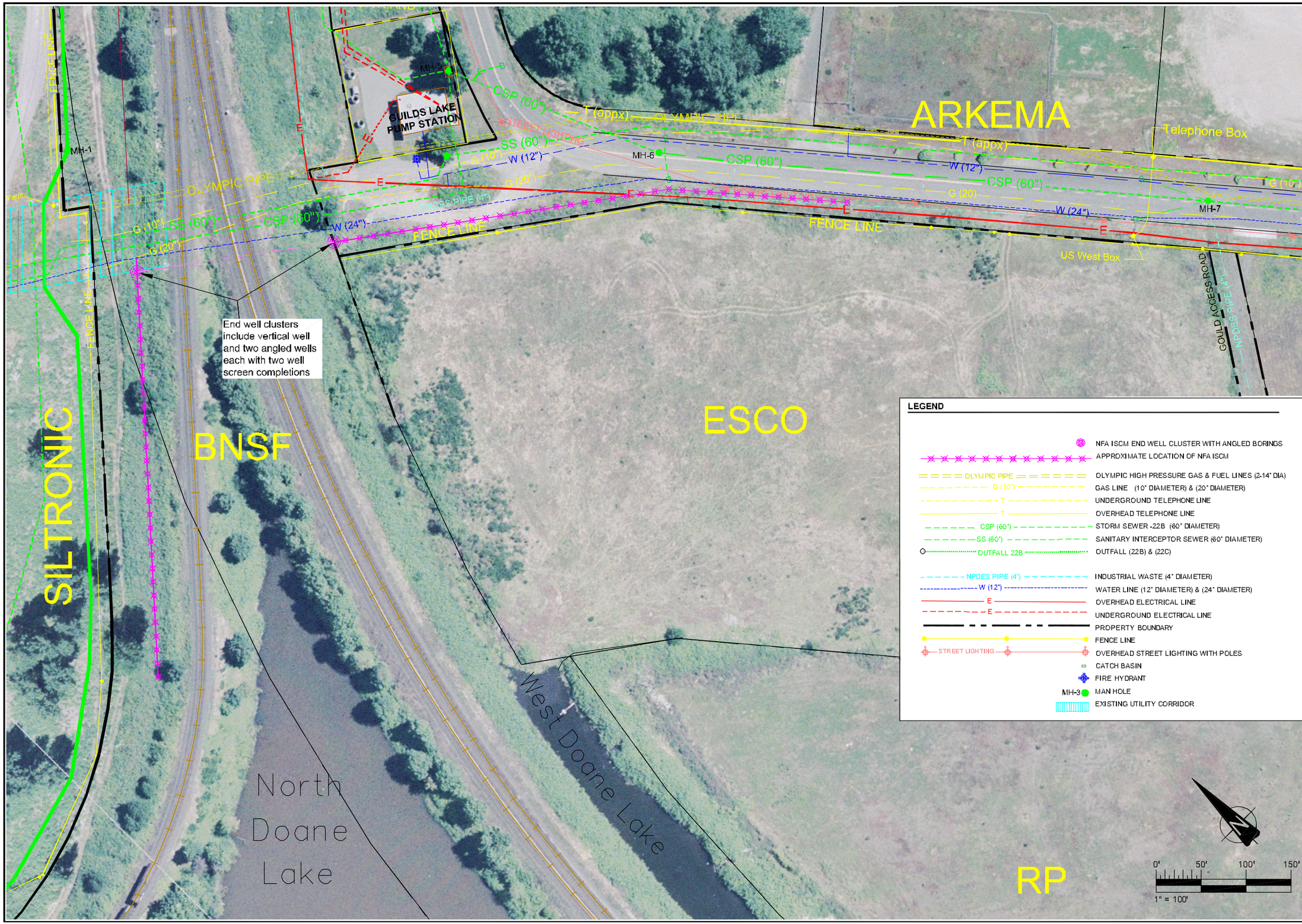
K:\10000\10700\10703\Phase 80 North Front Ave ISCM\WP\Figures\Figure_01_Site_Vicinity_Map.dwg – 11X17 – Jul. 09, 2007 2:38pm – doug.davis



REV. NO.:	JUNE 2007
DATE:	061M107030 P80 T2
PROJECT NO:	3
FIGURE No.	2

PROJECT: RP - PORTLAND SITE

TITLE: NORTH FRONT AVENUE ISCM UTILITY LOCATION MAP

DWN BY:	DD
CHK'D BY:	TJ/JF
DATUM:	NAD83
PROJECTION:	OR SP N. Int.Ft.
SCALE:	1" = 100'

CLIENT: SLLI

amec

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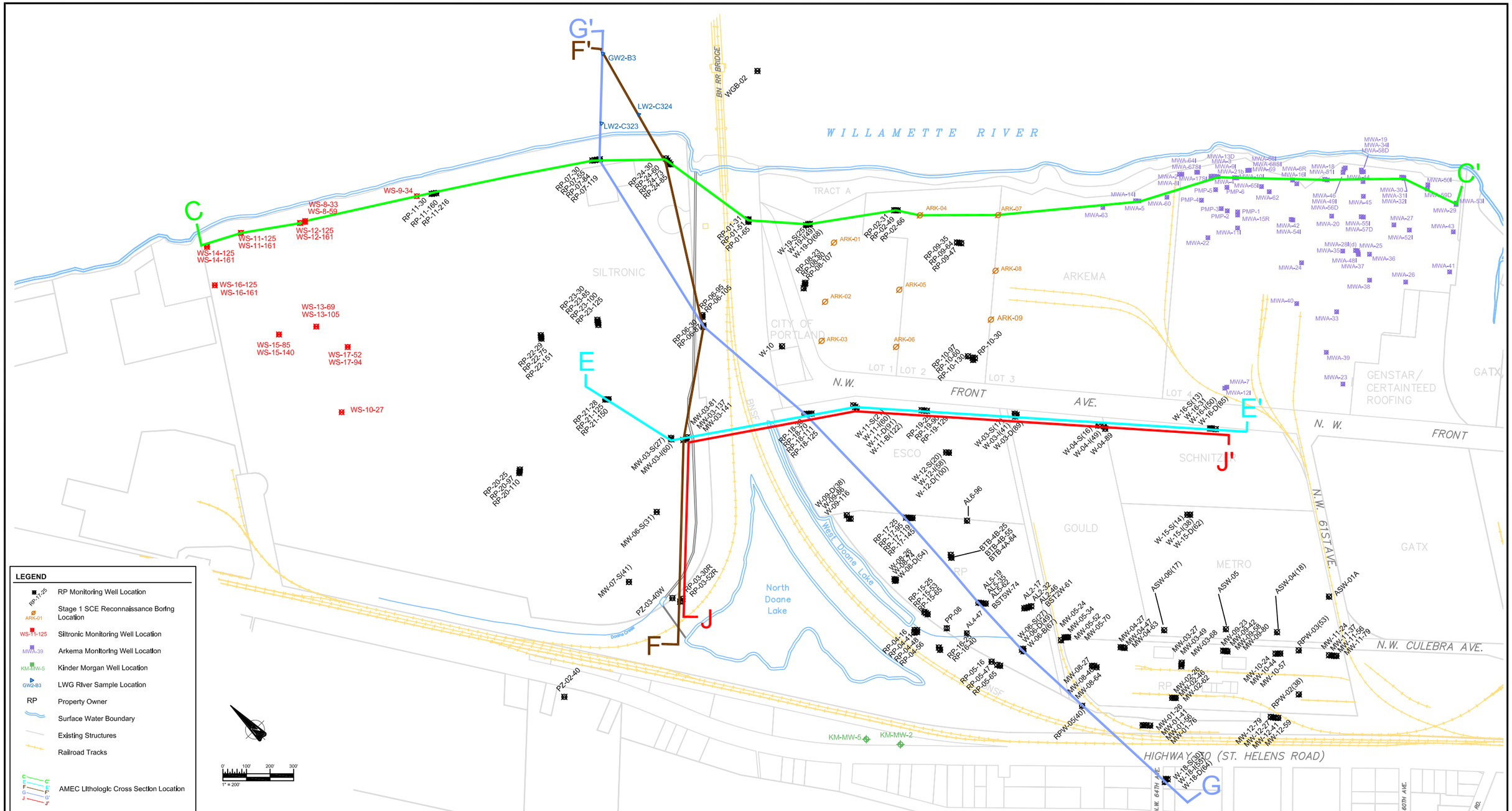
Portland, OR. U.S.A. 97224

DRAFT

K:\10000\10700\10703\Phase 80 North Front Ave ISCM\WP\Figures\Figure_02.dwg – NFA ISCM – Jul. 09, 2007 2:41pm – doug.davis



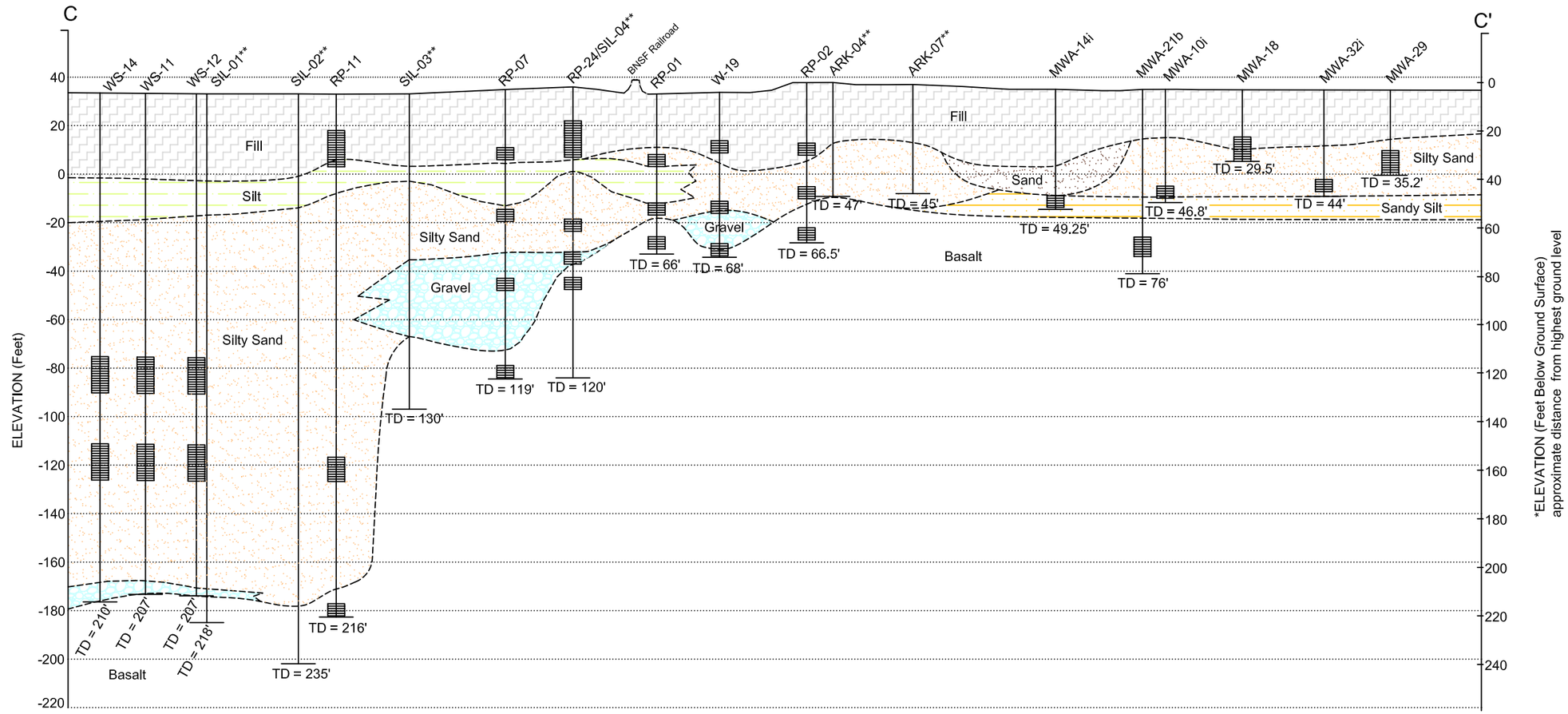
NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL NORTH FRONT AVENUE ISCM WORK PLAN DATED _____.

DRAFT

CLIENT: SLLI	DWN BY: LM	PROJECT: RP - PORTLAND SITE	DATE: JUNE 2007
	CHK'D BY: CJ/RJ		PROJECT NO: 0-61M-107030-P80
AMEC Earth & Environmental 7376 S.W. Durham Road Portland, OR U.S.A. 97224	DATUM: NAD83	TITLE: LITHOLOGIC CROSS SECTION LOCATIONS	REV. NO.: 2
	PROJECTION: OR SP N. Int Ft.		FIGURE No. 3
	SCALE: Verify Scale with Bar 1" = 200'		

K:\10000\10700\10703\Phase 80 North Front Ave ISCM\WP\Figures\Figure_03_Lithologic_Cross-Sections.dwg – D-Sized – Jul. 09, 2007 2:46pm – doug.davis

(VIEW TO THE EAST)



VERTICAL SCALE: 1" = 25'

HORIZONTAL SCALE: 1" = 250'

DRAFT

LEGEND

SIL-02 — TD = 235' — Exploratory Boring and Identifier (TD=Total Boring Depth Below Ground Surface)

RP-07 — TD = 119' — Monitoring Well Cluster, Identifier, and Screen Interval (TD=Total Boring Depth Below Ground Surface)

INFERRED LITHOLOGIC CONTACT

**DENOTES A RECONNAISSANCE BORING LOCATION

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL NORTH FRONT AVENUE ISCM WORK PLAN DATED _____.

NOTE: STRATIGRAPHY BETWEEN DEPICTED BORINGS INTERPRETED FROM ADDITIONAL BORINGS NOT SHOWN ON THIS CROSS SECTION.

CLIENT:	SLLI
DWN BY:	LM
CHK'D BY:	CJ
DATUM:	City of Portland
PROJECTION:	-
SCALE:	AS NOTED
PROJECT:	RP - PORTLAND SITE
TITLE:	LITHOLOGIC CROSS SECTION FROM C-C'
DATE:	JUNE 2007
PROJECT NO:	061M-107030-P80 T2
REV. NO.:	3
FIGURE No.	4

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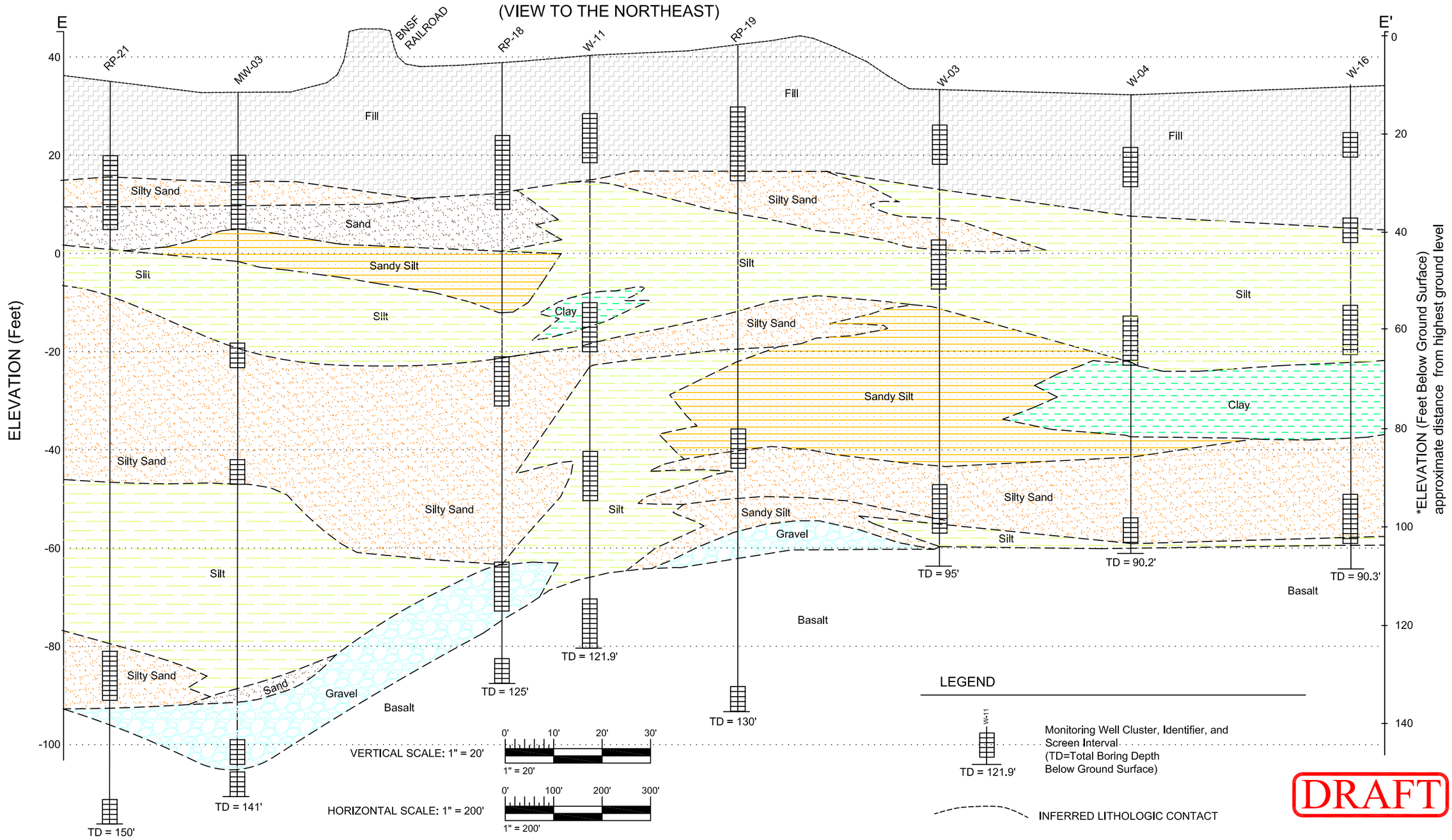
Portland, OR. U.S.A. 97224

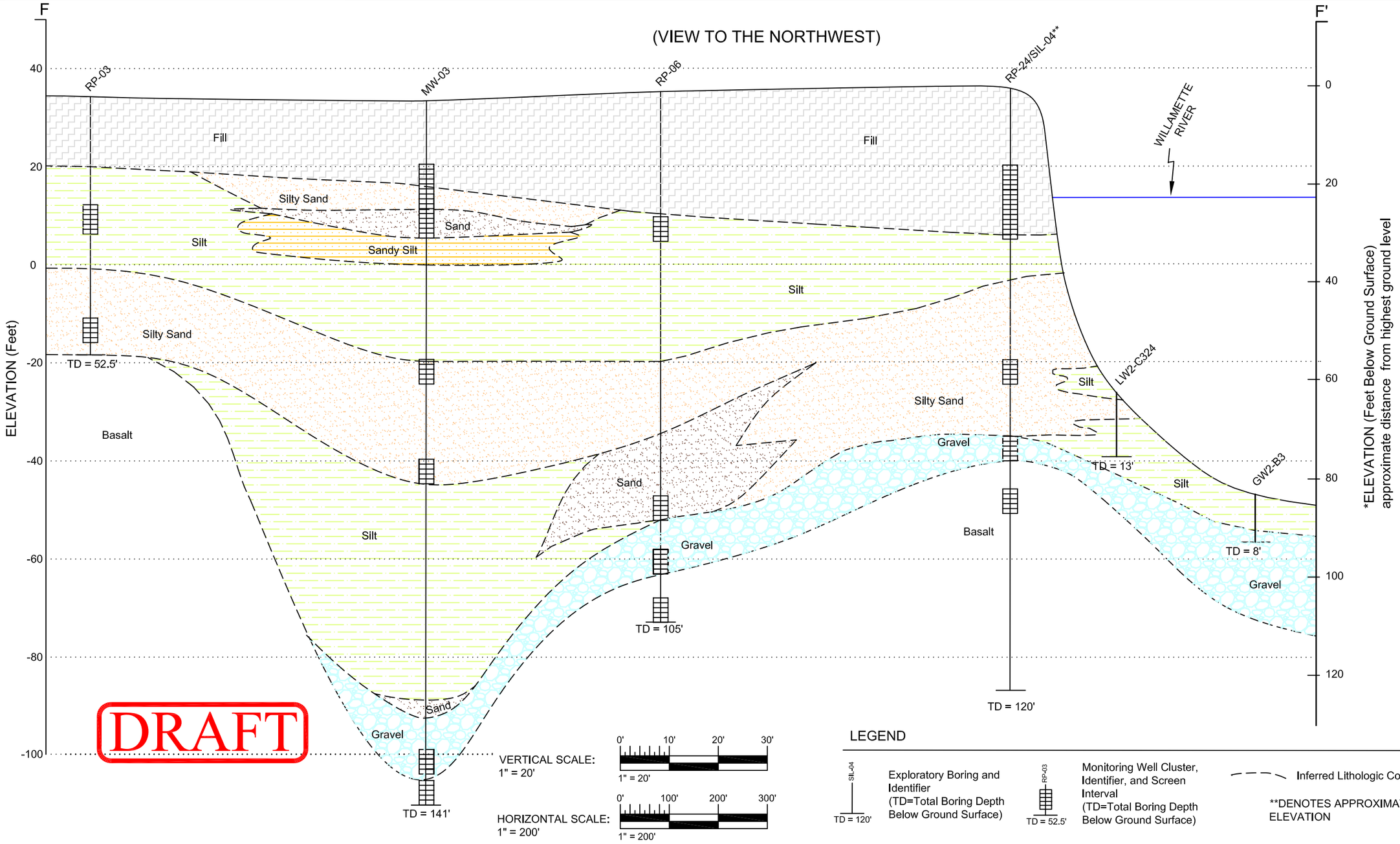


NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL NORTH FRONT AVENUE ISCM WORK PLAN DATED _____.

NOTE: STRATIGRAPHY BETWEEN DEPICTED BORINGS INTERPRETED FROM ADDITIONAL BORINGS NOT SHOWN ON THIS CROSS SECTION.

CLIENT: SLLI	DWN BY: LM	PROJECT: RP - PORTLAND SITE	DATE: JUNE 2007
	CHK'D BY: CJ		PROJECT NO: 061M-107030-P80
AMEC Earth & Environmental 7376 S.W. Durham Road Portland, OR. U.S.A. 97224	DATUM: City of Portland	TITLE: LITHOLOGIC CROSS SECTION FROM E-E'	REV. NO.: 2
	PROJECTION: -		FIGURE No. 5
	SCALE: AS NOTED		

K:\10000\10700\10703\Phase 80 North Front Ave ISCM\WP\Figures\Figure_05_Cross_Section_E-E'.dwg – 11x17 – Jul. 09, 2007 2:48pm – doug.davis

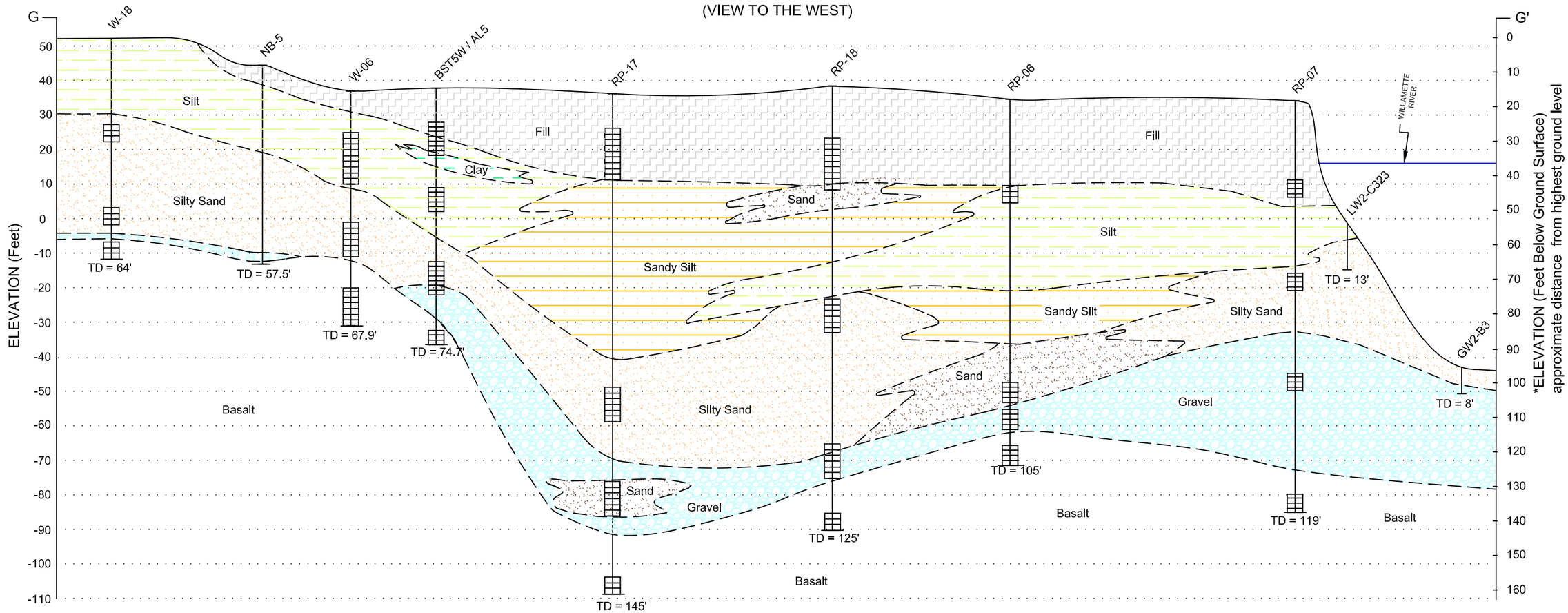


NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL NORTH FRONT AVENUE ISCM WORK PLAN DATED _____.

NOTE: STRATIGRAPHY BETWEEN DEPICTED BORINGS INTERPRETED FROM ADDITIONAL BORINGS NOT SHOWN ON THIS CROSS SECTION.

CLIENT: SLLI	DWN BY: LM	PROJECT: RP - PORTLAND SITE	DATE: JUNE 2007
	CHK'D BY: CJ		PROJECT NO: 061M-107030-P80
AMEC Earth & Environmental 7376 S.W. Durham Road Portland, OR. U.S.A. 97224	DATUM: City of Portland PROJECTION: - SCALE: AS NOTED	TITLE: LITHOLOGIC CROSS SECTION FROM F-F'	REV. NO.: 2 FIGURE No. 6

K:\10000\10700\10703\Phase 80 North Front Ave ISCM\WP\Figures\Figure_06_Cross_Section_F-F'.dwg – Layout1 – Jul. 09, 2007 2:49pm – doug.davis



DRAFT

VERTICAL SCALE: 1" = 30'

HORIZONTAL SCALE: 1" = 300'

LEGEND

Exploratory Boring and Identifier (TD=Total Boring Depth Below Ground Surface)

Monitoring Well Cluster, Identifier, and Screen Interval (TD=Total Boring Depth Below Ground Surface)

**DENOTES APPROXIMATED ELEVATION

Inferred Lithologic Contact

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL NORTH FRONT AVENUE ISCM WORK PLAN DATED _____.

NOTE: STRATIGRAPHY BETWEEN DEPICTED BORINGS MAY HAVE BEEN INTERPRETED FROM ADDITIONAL BORINGS NOT SHOWN ON THIS CROSS SECTION.

CLIENT:	SLLI
DWN BY:	LM
CHK'D BY:	CJ
DATUM:	City of Portland
PROJECTION:	-
SCALE:	AS NOTED
PROJECT:	RP - PORTLAND SITE
TITLE:	LITHOLOGIC CROSS SECTION FROM G-G'
DATE:	JUNE 2007
PROJECT NO:	061M-107030-P80
REV. NO.:	2
FIGURE No.	7

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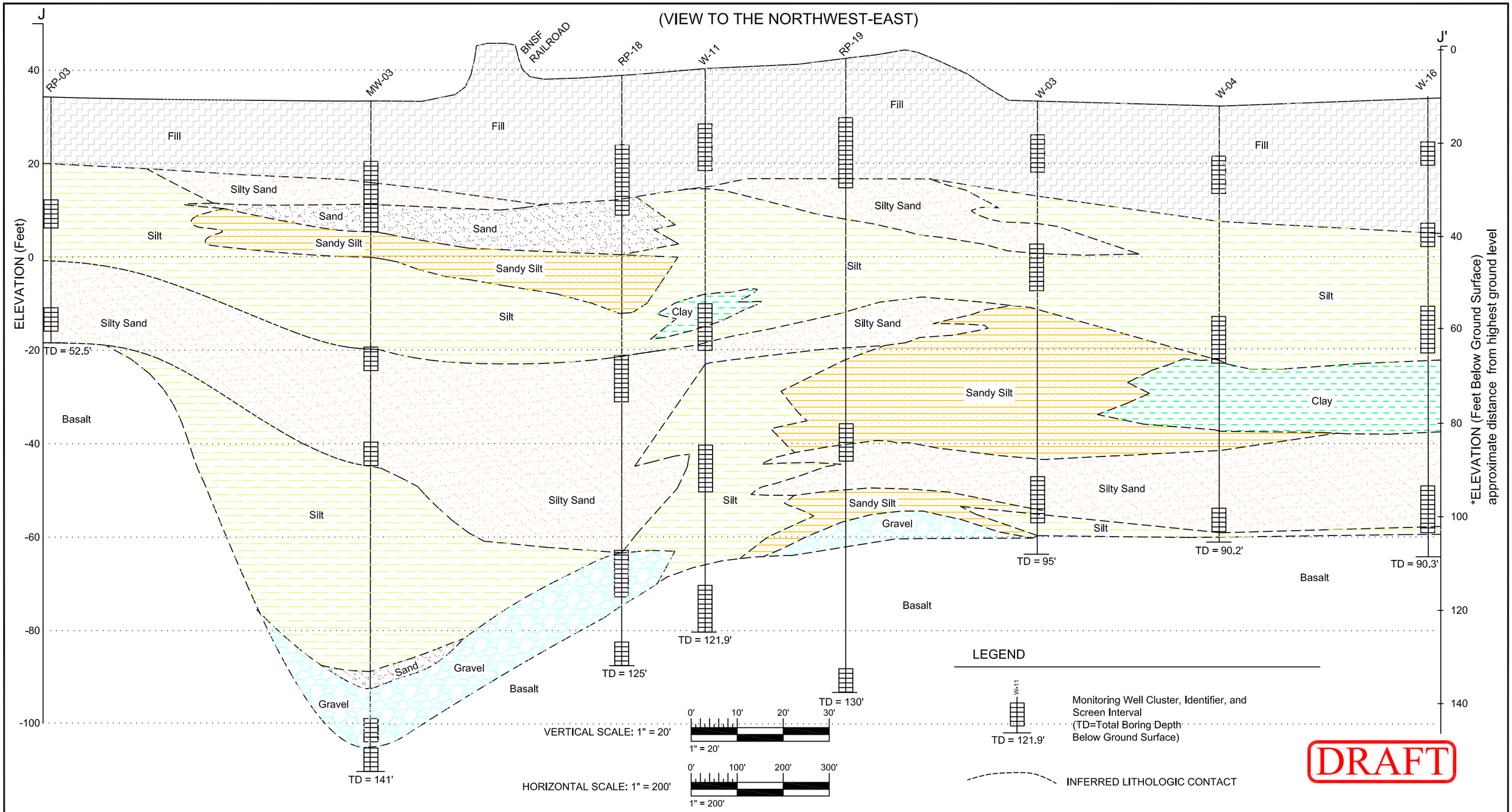
K:\10000\10700\10703\Phase 80 North Front Ave ISCM\WP\Figures\Figure_07_Cross_Section_G-G'.dwg – 11x17 – Jul. 09, 2007 2:50pm – doug.davis

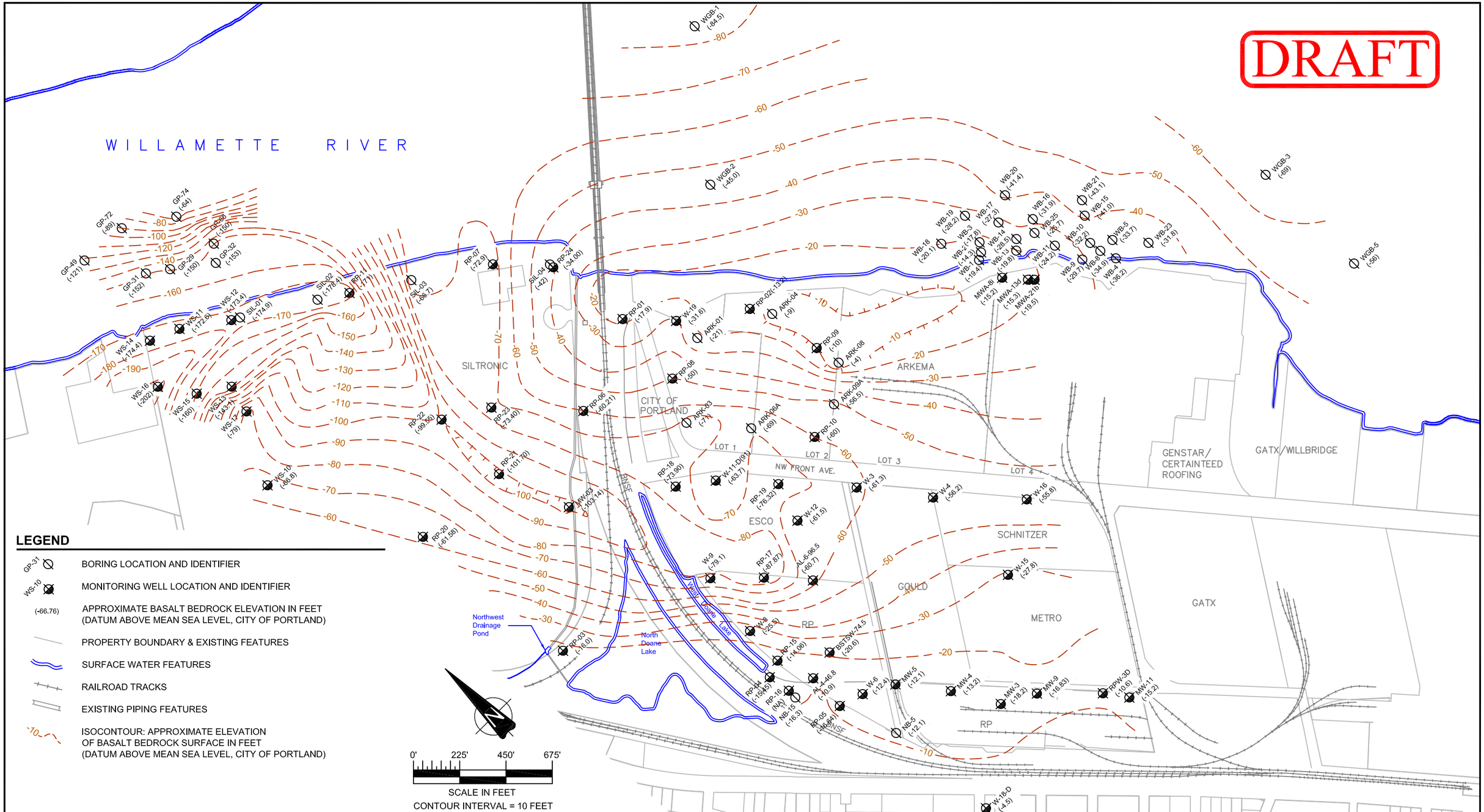


NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL NORTH FRONT AVENUE ISCM WORK PLAN DATED _____.

NOTE: STRATIGRAPHY BETWEEN DEPICTED BORINGS INTERPRETED FROM ADDITIONAL BORINGS NOT SHOWN ON THIS CROSS SECTION.

CLIENT: SLLI	DWN BY: DD	PROJECT: RP - PORTLAND SITE	DATE: JUNE 2007
	CHK'D BY: CJ		PROJECT NO: 061M-107030-P80
AMEC Earth & Environmental, 7376 S.W. Durham Road, Portland, OR. U.S.A. 97224	DATUM: City of Portland	TITLE: LITHOLOGIC CROSS SECTION FROM J-J'	REV. NO.: 2
	PROJECTION: -		FIGURE No. 8
	SCALE: AS NOTED		

K:\10000\10700\10703\Phase 80 North Front Ave ISCM\WP\Figures\Figure_08_Cross_Section_J-J'.dwg – 11x17 – Jul. 09, 2007 2:50pm – doug.davis

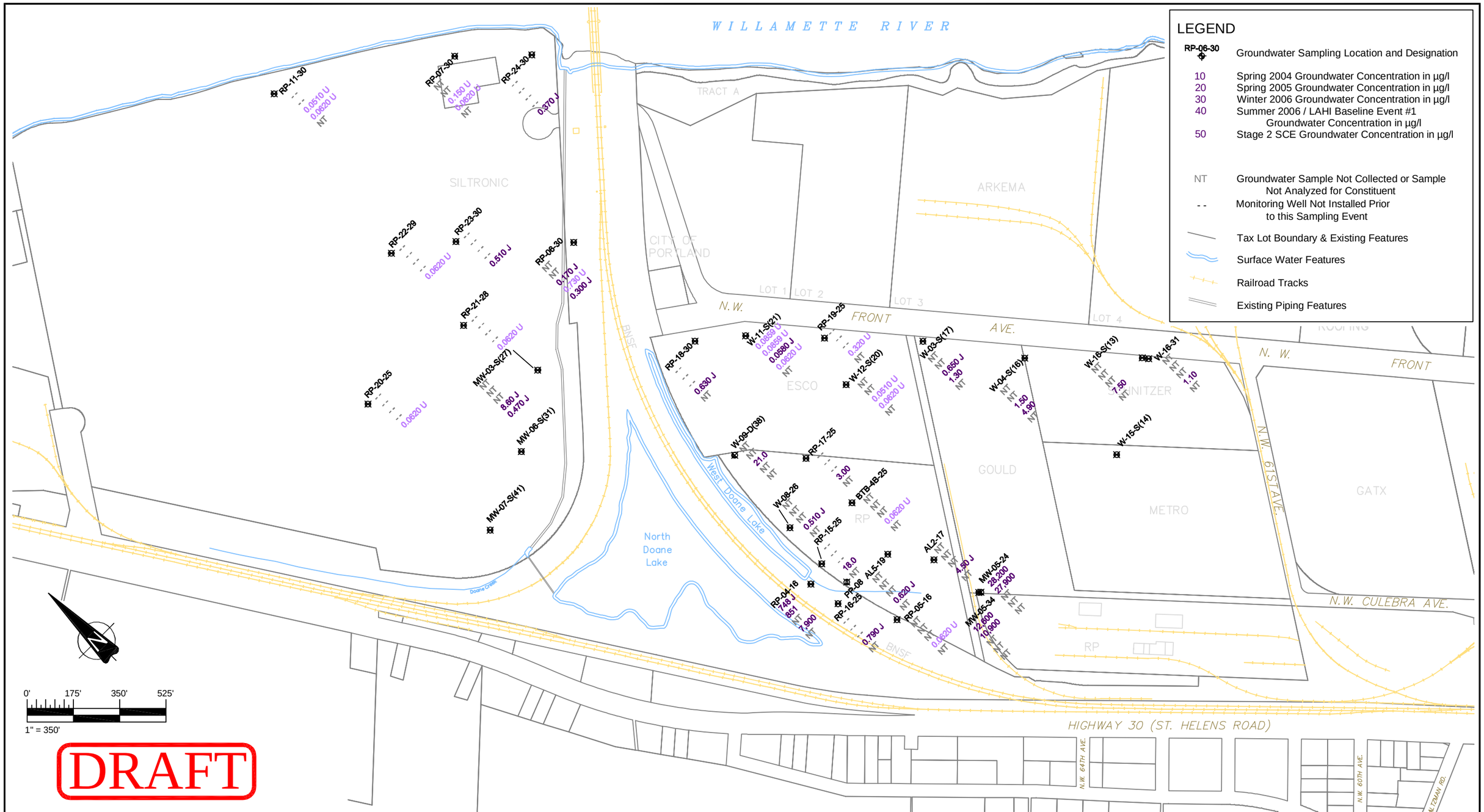


NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL NORTH FRONT AVENUE ISCM WORK PLAN DATED _____.

NOTE:
BORING LOGS FOR OFFSITE PROPERTIES WERE OBTAINED FROM OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY PUBLIC RECORDS.

CLIENT: SLLI	DWN BY: LM	PROJECT: RP - PORTLAND SITE	DATE: JUNE 2007
	CHK'D BY: CJ		PROJECT NO: 061M-107030-P80
AMEC Earth & Environmental, 7376 S.W. Durham Road, Portland, OR U.S.A. 97224	DATUM: City of Portland	TITLE: BASALT ELEVATION CONTOUR MAP	REV. NO.: 3
	PROJECTION: OR SP North Intl Ft		FIGURE No. 9
	SCALE: As Shown		

K:\10000\10700\10703\Phase 80 North Front Ave ISCM\WP\Figures\Figure_09_Basalt_Elevation_Contours_Dec06.dwg – Layout1 – Jul. 09, 2007 2:51pm – doug.davis



NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL NORTH FRONT AVENUE ISCM WORK PLAN DATED _____.

NOTE: The constituent concentrations presented represent validated analytical results from the specified groundwater characterization events. Data qualifier definitions are provided on the associated groundwater characterization event tables.

See list of acronyms and abbreviations on page vi for acronym definitions.

CLIENT:	SLLI
DWN BY:	BRJ
CHK'D BY:	CJ
DATUM:	NAD83
PROJECTION:	OR SP N. Int Ft.
SCALE:	1" = 350'
PROJECT:	RP - PORTLAND SITE
TITLE:	1,2-DICHLOROBENZENE DISTRIBUTION IN GROUNDWATER, 2004-2006 FILL ZONE
DATE:	JUNE 2007
PROJECT NO:	061M107030-P80-T2
REV. NO.:	2
FIGURE No.	10

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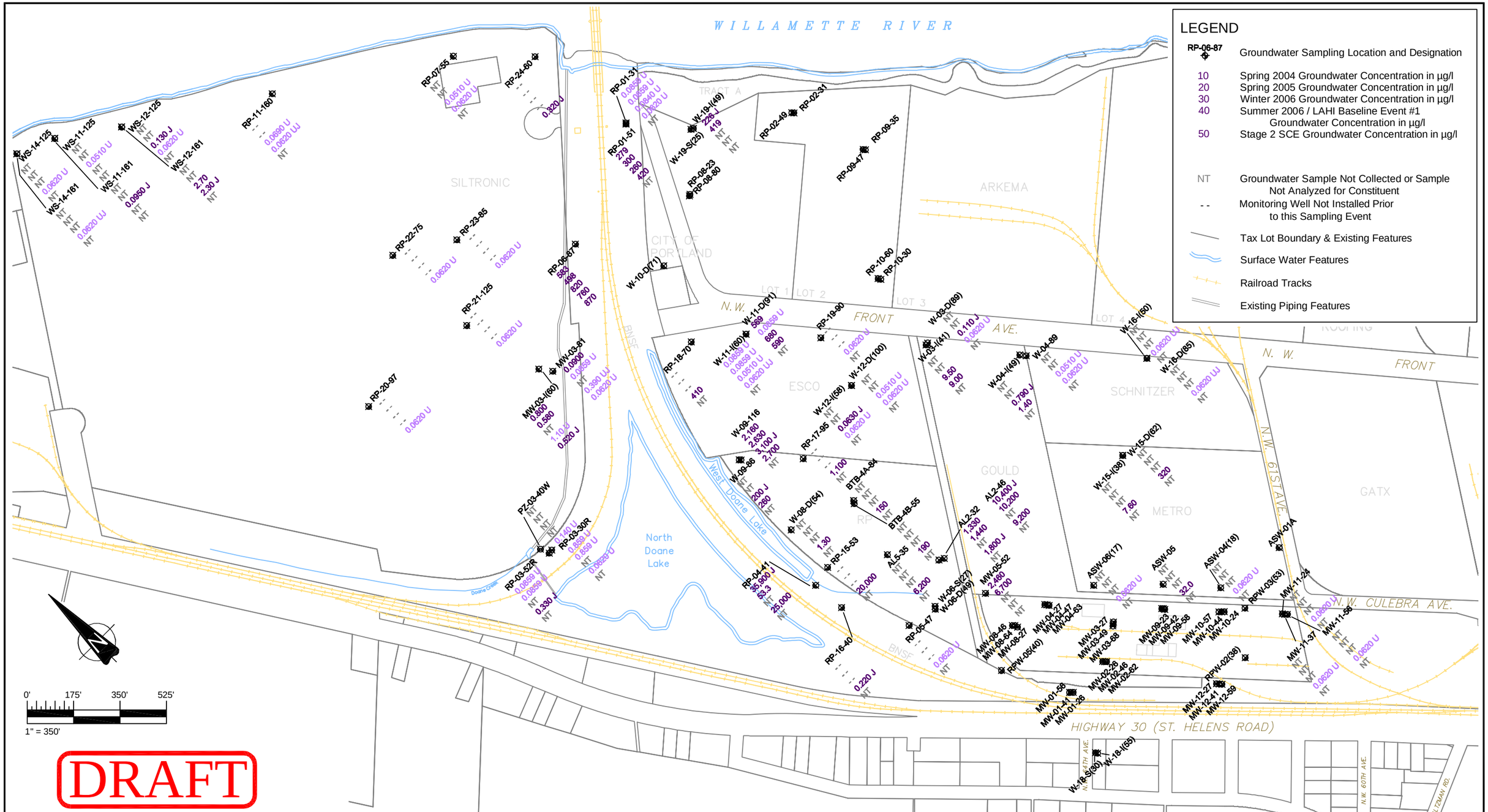
K:\10000\10700\10703\Phase 80 North Front Ave ISCM\WP\Figures\Figures_10-13_ 12DCB_in_GW_(2004-2006).dwg - Fill - Jul. 09, 2007 4:05pm - patrick.mccarthy



NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL NORTH FRONT AVENUE ISCM WORK PLAN DATED _____.

NOTE: The constituent concentrations presented represent validated analytical results from the specified groundwater characterization events. Data qualifier definitions are provided on the associated groundwater characterization event tables.

See list of acronyms and abbreviations on page vi for acronym definitions.

CLIENT:	SLLI
DWN BY:	BRJ
CHK'D BY:	CJ
DATUM:	NAD83
PROJECTION:	OR SP N. Int Ft.
SCALE:	1" = 350'
PROJECT:	RP - PORTLAND SITE
TITLE:	1,2-DICHLOROBENZENE DISTRIBUTION IN GROUNDWATER, 2004-2006 ALLUVIUM ZONE
DATE:	JUNE 2007
PROJECT NO:	061M107030-P80T2
REV. NO.:	1
FIGURE No.	11

AMEC Earth & Environmental
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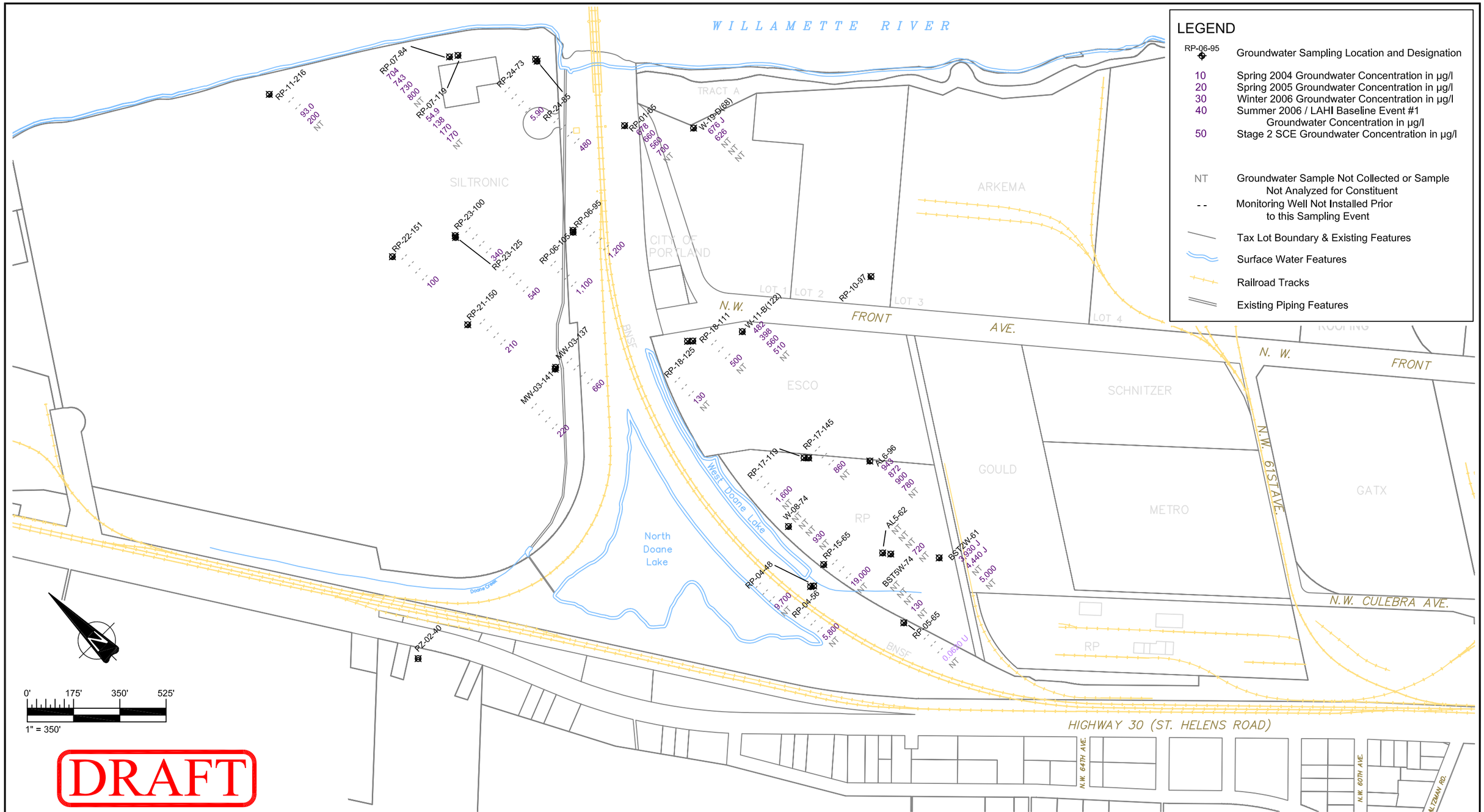
Portland, OR U.S.A. 97224

K:\10000\10700\10703\Phase 80 North Front Ave ISCM\WP\Figures\Figures_10-13_ 12DCB_in_GW_(2004-2006).dwg - Alluvium - Jul. 09, 2007 4:06pm - patrick.mccarthy



NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL NORTH FRONT AVENUE ISCM WORK PLAN DATED _____.

NOTE: The constituent concentrations presented represent validated analytical results from the specified groundwater characterization events. Data qualifier definitions are provided on the associated groundwater characterization event tables.

See list of acronyms and abbreviations on page vi for acronym definitions.

CLIENT:	SLLI
DWN BY:	BRJ
CHK'D BY:	CJ
DATUM:	NAD83
PROJECTION:	OR SP N. Int Ft.
SCALE:	1" = 350'
PROJECT:	RP - PORTLAND SITE
TITLE:	1,2-DICHLOROBENZENE DISTRIBUTION IN GROUNDWATER, 2004-2006 DEEP GRAVEL ZONE
DATE:	JUNE 2007
PROJECT NO:	061M107030-P 80 T2
REV. NO.:	2
FIGURE No.	12

AMEC Earth & Environmental
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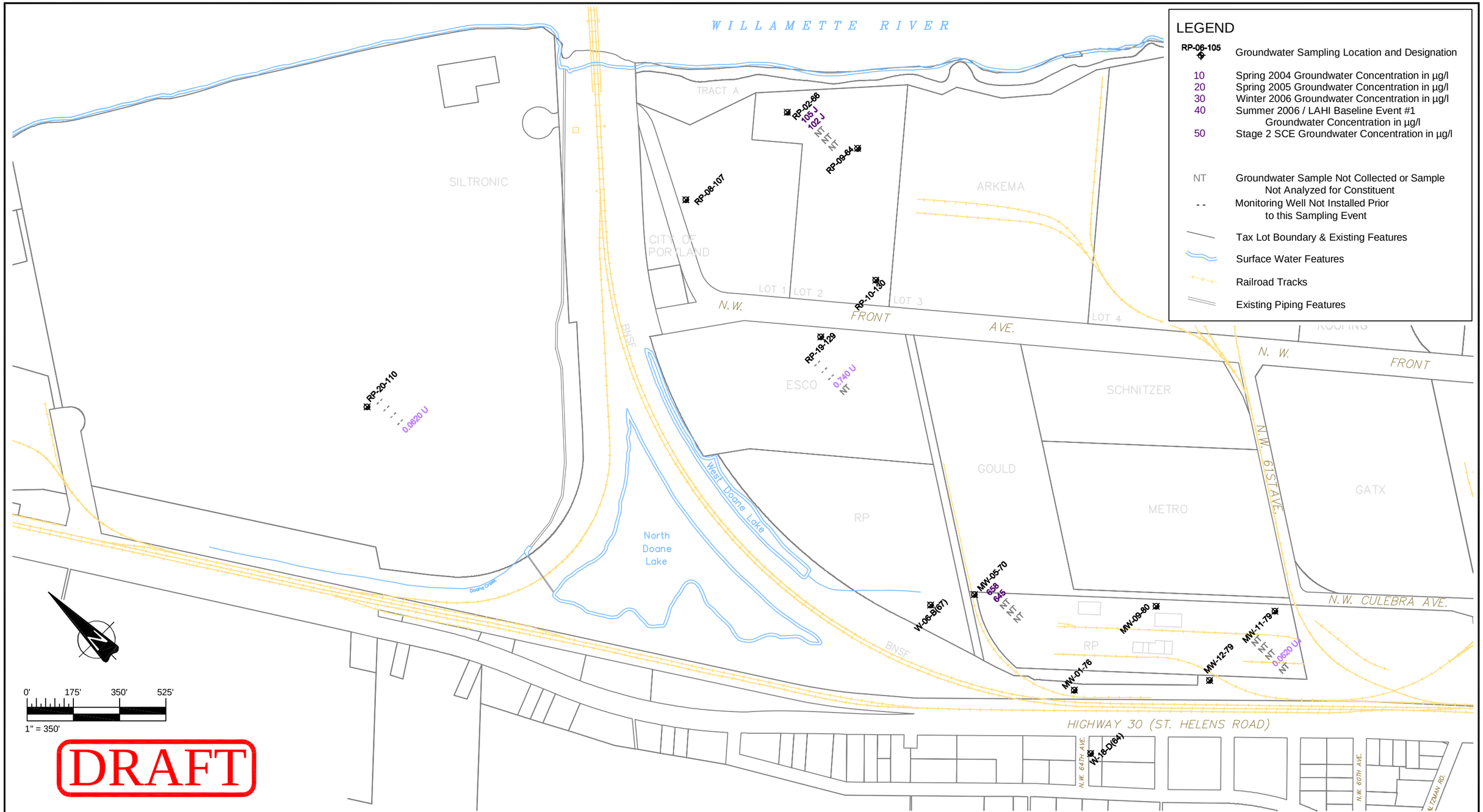
Portland, OR U.S.A. 97224

K:\10000\10700\10703\Phase 80 North Front Ave ISCM\WP\Figures\Figures_10-13_ 12DCB_in_GW_(2004-2006).dwg – Deep Gravel – Jul. 09, 2007 2:58pm – doug.davis



NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL NORTH FRONT AVENUE ISCM WORK PLAN DATED _____.

NOTE: The constituent concentrations presented represent validated analytical results from the specified groundwater characterization events. Data qualifier definitions are provided on the associated groundwater characterization event tables.

See list of acronyms and abbreviations on page vi for acronym definitions.

CLIENT: SLLI

AMEC Earth & Environmental
7376 S.W. Durham Road
Portland, OR U.S.A. 97224

DWN BY:	BRJ
CHK'D BY:	CJ
DATUM:	NAD83
PROJECTION:	OR SP N. Int Ft.
SCALE:	1" = 350'

PROJECT: RP - PORTLAND SITE

TITLE: 1,2-DICHLOROBENZENE DISTRIBUTION IN GROUNDWATER, 2004-2006 BASALT ZONE

DATE:	JUNE 2007
PROJECT NO:	061M107030-P80-T2
REV. NO.:	1
FIGURE No.	13

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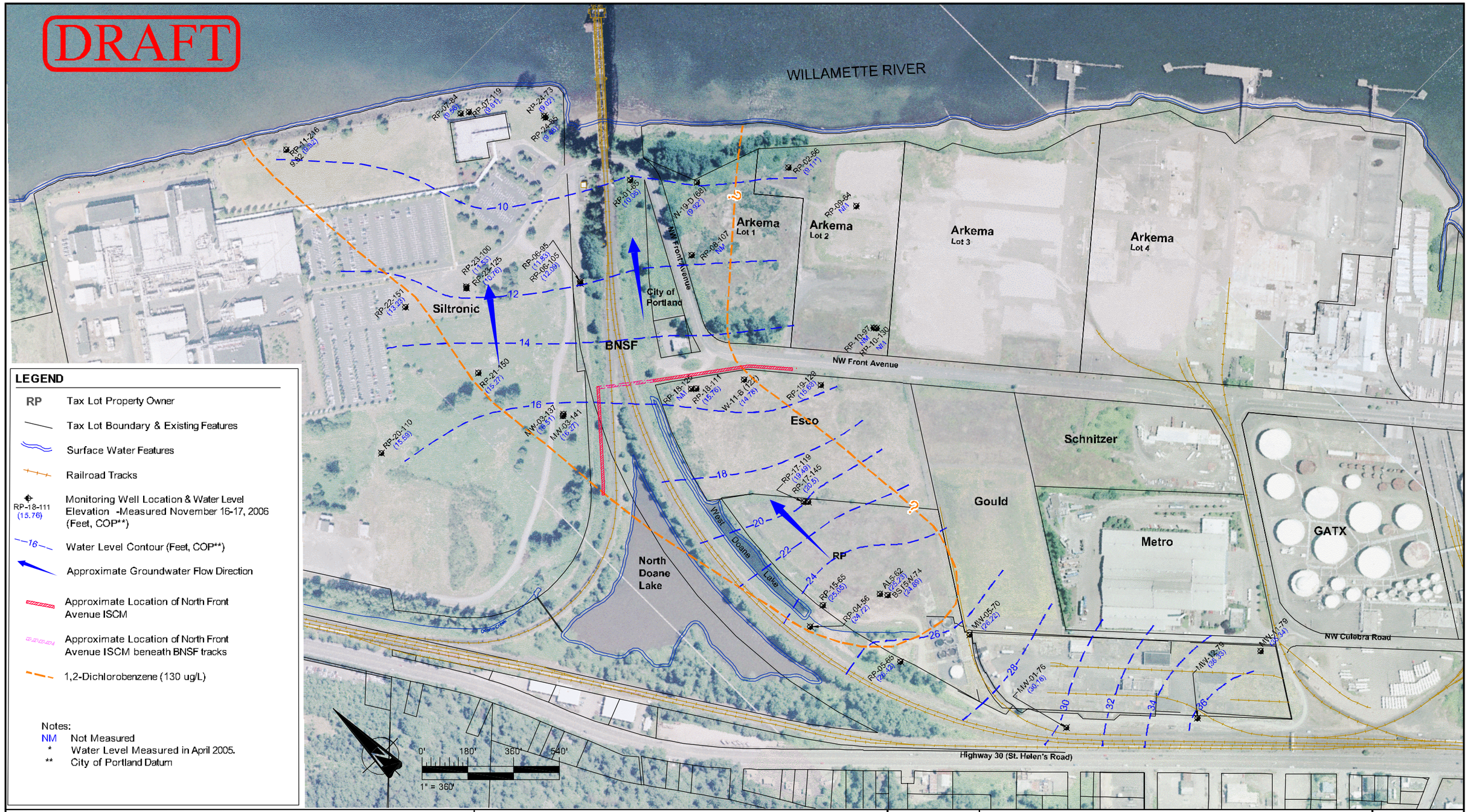

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL NORTH FRONT AVENUE ISCM WORK PLAN DATED _____.

NOTE: 2005 Aerial from **Metro Data Resource Center**

CLIENT: SLLI

AMEC Earth & Environmental
7376 S.W. Durham Road
Portland, OR. U.S.A. 97224

DWN BY:	LM
CHK'D BY:	RJ/JF
DATUM:	NAD83
PROJECTION:	OR SP N. Int Ft
SCALE:	1" = 360'

PROJECT: RP - PORTLAND SITE

TITLE: NORTH FRONT AVENUE INTERIM SOURCE CONTROL MEASURE WITH DGZ & BASALT ZONE GROUNDWATER ELEVATIONS (NOV 2006) & APPROXIMATE 1,2-DICHLOROBENZENE 130 ug/L CONTOUR IN THE DGZ (MOST RECENT)

DATE:	JUNE 2007
PROJECT NO:	061M-107030-P80
REV. NO.:	6
FIGURE No.	14

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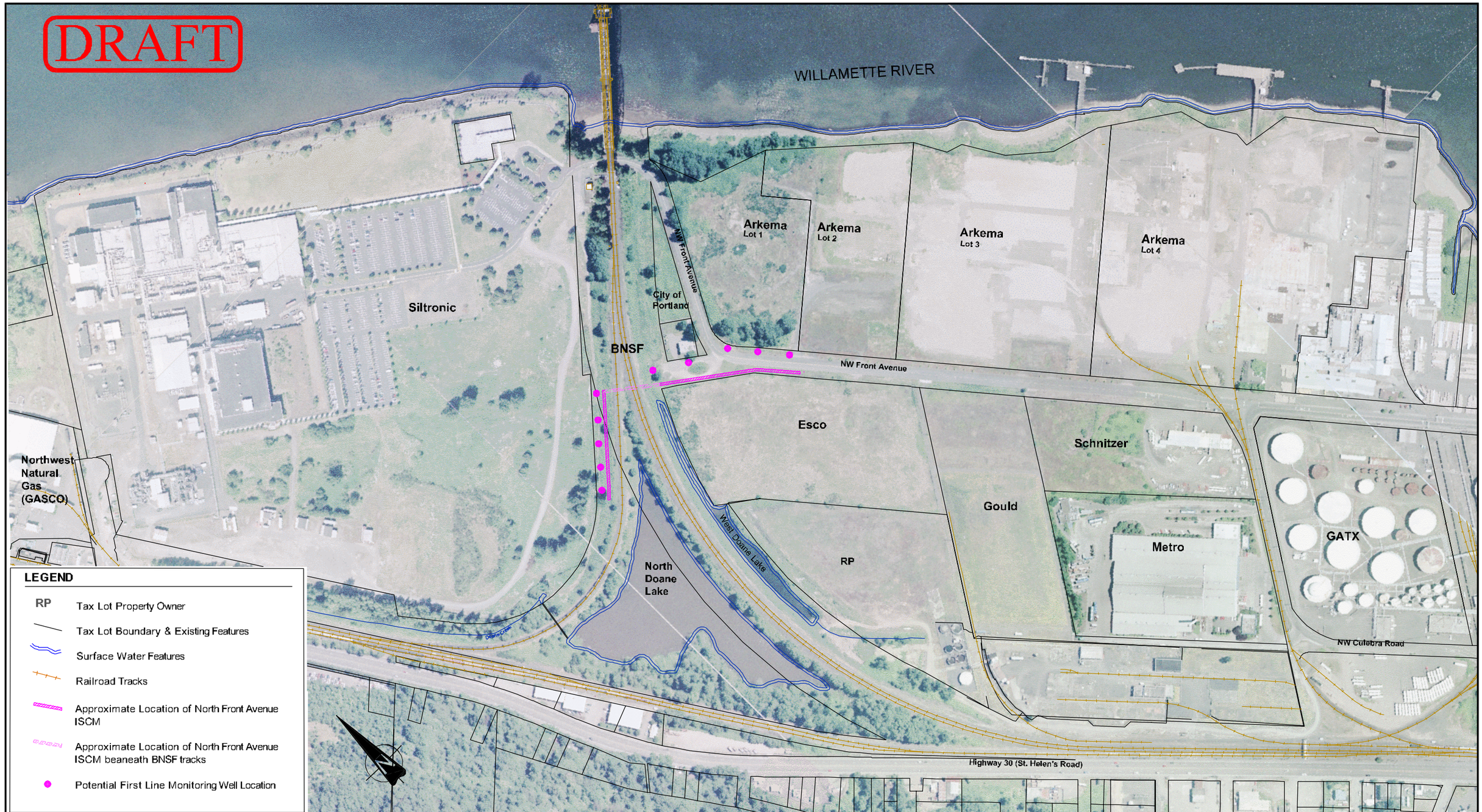

NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL NORTH FRONT AVENUE ISCM WORK PLAN DATED _____.

NOTE: 2005 Aerial from **Metro Data Resource Center**

0' 180' 360' 540'
1" = 360'

CLIENT: SLLI

AMEC Earth & Environmental
7376 S.W. Durham Road
Portland, OR. U.S.A. 97224

DWN BY:	DD
CHK'D BY:	RJ/JF
DATUM:	NAD83
PROJECTION:	OR SP N. Int Ft
SCALE:	1" = 360'

PROJECT: RP - PORTLAND SITE

TITLE: NORTH FRONT AVENUE INTERIM SOURCE CONTROL MEASURE FIRST LINE PERFORMANCE MONITORING WELL LOCATIONS

DATE:	JUNE 2007
PROJECT NO:	061M-107030-P80
REV. NO.:	1
FIGURE No.	15

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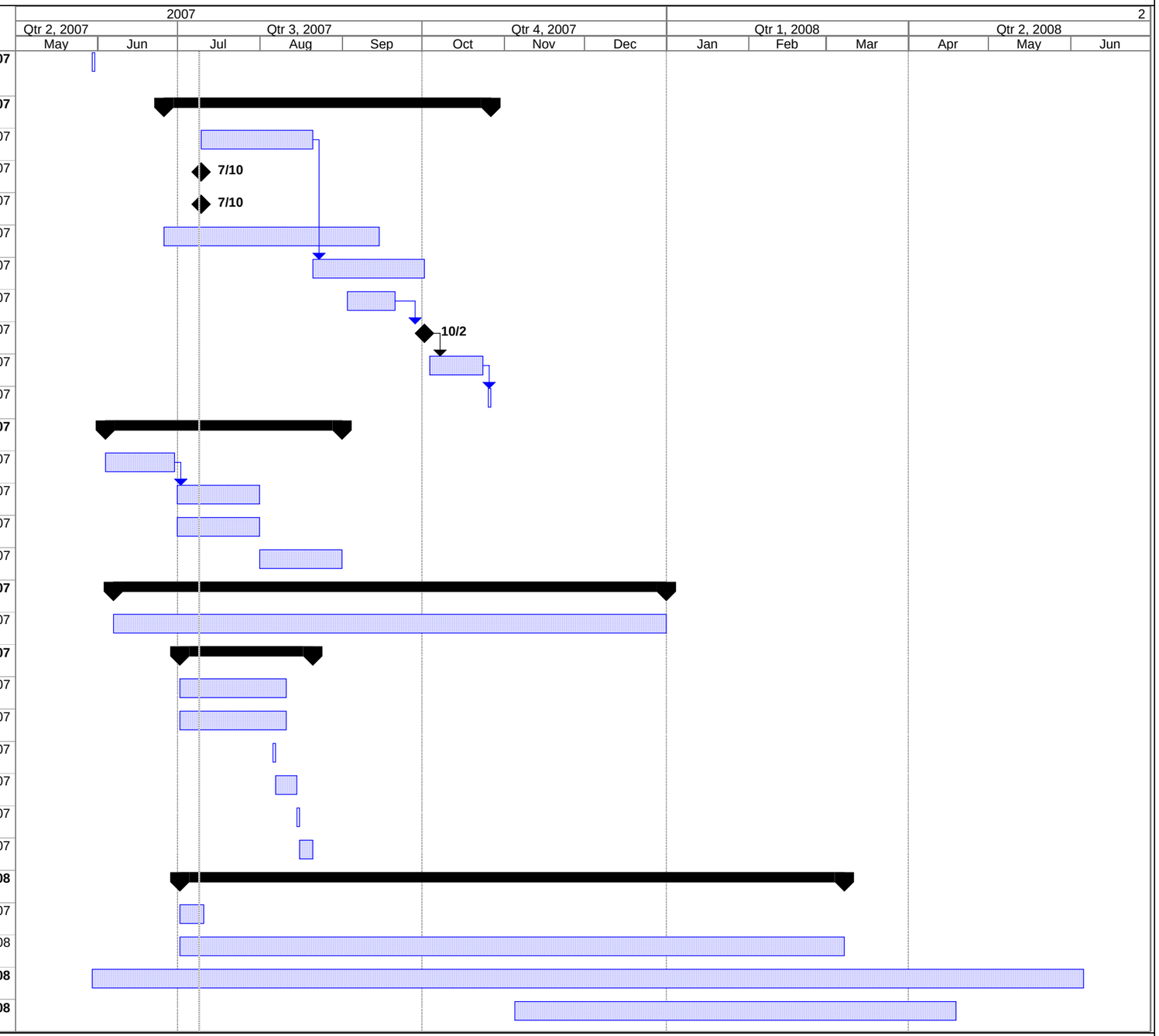
Draft

Figure 16
Preliminary North Front Avenue Interim Source Control Measure Schedule
RP - Portland Site

ID	Task Name	Start	Finish
1	**North Front Avenue (NFA) Interim Source Control Measure (ISCM) In-Situ Chemical Oxidation (ISCO)**	**Wed 5/30/07**	**Wed 5/30/07**
2	**NFA ISCM Work Plan (WP)**	**Tue 6/26/07**	**Fri 10/26/07**
3	DEQ review	Tue 7/10/07	Mon 8/20/07
4	COP and BNSF submission	Tue 7/10/07	Tue 7/10/07
5	Meeting with DEQ	Tue 7/10/07	Tue 7/10/07
6	Negotiate property access from COP	Tue 6/26/07	Fri 9/14/07
7	Negotiate property access from BNSF	Tue 8/21/07	Mon 10/1/07
8	Specification preparation	Mon 9/3/07	Thu 9/20/07
9	Request for Bid submission	Tue 10/2/07	Wed 10/3/07
10	Bid period	Thu 10/4/07	Tue 10/23/07
11	Award of Contract	Fri 10/26/07	Fri 10/26/07
12	**Lake Area (LA) Bioremediation Pilot Study Data Collection**	**Mon 6/4/07**	**Fri 8/31/07**
13	Install weathered basalt well in LA Pilot Study Area	Mon 6/4/07	Fri 6/29/07
14	Bench test for persulfate injection	Sun 7/1/07	Tue 7/31/07
15	Pump test for LA Pilot Study Area	Sun 7/1/07	Tue 7/31/07
16	In-situ persulfate injection test	Wed 8/1/07	Fri 8/31/07
17	**Facilitated Transport Evaluation (FTE)**	**Thu 6/7/07**	**Mon 12/31/07**
18	FTE work and report write-up	Thu 6/7/07	Mon 12/31/07
19	**NFA Hydrogeologic Investigation**	**Mon 7/2/07**	**Mon 8/20/07**
20	Submit NFA ISCM Hydrologic Investigation WP to DEQ	Mon 7/2/07	Fri 8/10/07
21	Negotiate access with BNSF	Mon 7/2/07	Fri 8/10/07
22	Bid documents/submit specifications to contractors	Mon 8/6/07	Mon 8/6/07
23	Contractor review of specifications	Tue 8/7/07	Tue 8/14/07
24	Award Contract	Wed 8/15/07	Wed 8/15/07
25	Conduct NFA ISCM Hydrologic Investigation	Thu 8/16/07	Mon 8/20/07
26	**NFA Transducer Study**	**Mon 7/2/07**	**Fri 3/7/08**
27	Tidal study	Mon 7/2/07	Tue 7/10/07
28	Seasonal variability study	Mon 7/2/07	Fri 3/7/08
29	**Groundwater Modeling**	**Wed 5/30/07**	**Thu 6/5/08**
30	**NFA ISCM Implementation**	**Mon 11/5/07**	**Fri 4/18/08**



Project: RP
Date: Mon 7/9/07

Task | Progress | Milestone | Summary | Rolled Up Progress

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APPENDIX A

North Front Avenue Interim Source Control Measure
System Design and Installation Plan

APPENDIX A

DRAFT SYSTEM DESIGN AND INSTALLATION PLAN
NORTH FRONT AVENUE INTERIM SOURCE CONTROL MEASURE
RP - PORTLAND SITE

July 10, 2007

Submitted to:

Oregon Department of Environmental Quality
Northwest Region
2020 S.W. 4th Avenue, Suite 400
Portland, Oregon 97201

Submitted for:

SLLI
One Copely Parkway, Suite 309
Morrisville, North Carolina 27560

Submitted by:

AMEC Earth & Environmental, Inc.
7376 S.W. Durham Road
Portland, Oregon 97224

0-61M-107030/Phase 80/T2

Table of Contents

Page

1.0 INTRODUCTION 1
1.1 Project Organization and Responsibilities 1

2.0 *IN-SITU* CHEMICAL OXIDATION SYSTEM DESIGN 2
2.1 Target Constituents 3
2.2 Injection Well Design 3
2.3 Performance Monitoring Well Design 4
2.4 System Equipment Compounds 4
2.5 System Piping and Components 4
2.5.1 Aboveground Piping 4

3.0 SYSTEM INSTALLATION 5
3.1 Project Schedule 5
3.2 Well Installation 5
3.3 Well Development 6
3.4 Baseline Groundwater Sampling 6

4.0 SYSTEM STARTUP 6

5.0 SYSTEM OPERATIONS AND MAINTENANCE 6

6.0 WASTE DISPOSAL AND HANDLING PROCEDURES 7

LIMITATIONS 8

List of Figures

Figure C-1 Cover Sheet

Figure C-2 North Front Avenue ISCM Conceptual Site Plan

Figure C-3 North Front Avenue ISCM Utility Map

Figure C-4 Lithologic Cross Section From J-J'

Figure C-5 Design Schematic (to be completed for 90%)

Figure C-6 Injection Well Design/Details

Figure C-7 Typical Well Vault Details/Sections (to be completed for 90%)

Figure C-8 Compound Layout (to be completed for 90%)

Figure C-9 System Layout and Typical Trench Section (to be completed for 90%)

List of Appendices

Appendix A-1 Injection Well and Groundwater Monitoring Well Installation Guidelines

Appendix A-2 Standard Operating Procedures and Forms

- SOP - 2 Groundwater Sampling
- SOP - 13 Waste Management Procedures
- SOP - 14 Methodology for Monitoring Well Development
- SOP - 32 Transport of Hazardous Materials by Road to RP Property

1.0 INTRODUCTION

On behalf of SLLI, AMEC Earth & Environmental, Inc. (AMEC) has prepared this 60% *In-Situ* Chemical Oxidation (ISCO) System Design and Installation Plan as part of the North Front Avenue Interim Source Control Measure (ISCM) Work Plan (Work Plan) to describe the design, installation, and operation and maintenance (O&M) of the proposed North Front Avenue ISCM ISCO system.

The North Front Avenue ISCM is a part of site-wide implementation of source control measures at the Rhône-Poulenc (RP) property, located at 6200 NW St. Helens Road, Portland, Oregon. Implementation of the North Front Avenue ISCM would limit downgradient migration of 1,2-dichlorobenzene (1,2-DCB), 1,4-dichlorobenzene (1,4-DCB), chlorobenzene (CB), and vinyl chloride (VC) within the deep gravel zone.

The proposed North Front Avenue ISCM is comprised of two “legs,” as shown on Drawing C-2. The northern leg, approximately 450 feet in length, will be located on BNSF property, on the west side of the railroad embankment, north of North Doane Lake. The southern leg of the ISCM will be located along Front Avenue, extending approximately 600 feet.

1.1 Project Organization and Responsibilities

The field team will consist of a Field Manager, a Technician Manager, and other necessary field personnel to implement portions of this System Design and Installation Plan. The Field Manager will maintain or delegate responsibility for the logistical requirements during site preparation and installation of the injection wells and performance monitoring wells including, but not limited to:

- Event scheduling, and coordination between AMEC staff and AMEC subcontractors;
- Providing oversight for work performed by the drilling subcontractor during the installation of the injection and performance monitoring wells, including completion of soil boring logs and well completion logs;
- Delivery and shipping of sample containers and coolers, and quality assurance/quality control (QA/QC);
- Overall compliance with the Site-Specific Health and Safety Plan (HASP);
- Ensuring that daily health and safety meetings for field staff take place and are documented; and
- Proper waste handling and management.

The Technician Manager will maintain responsibility for the logistical requirements of the system installation, startup, and routine system O&M, including, but not limited to:

- Event scheduling and coordination between AMEC staff and subcontractors;
- Providing oversight for work performed by subcontractors;
- Delivery and shipping of specified system components, equipment, and materials;
- Piping installation between the wellhead and the system compound and system equipment installation;
- Distribution and proper use of PPE as required by the Site-Specific Health and Safety Plan;
- Ensuring that daily health and safety meetings for field staff take place; and
- Waste handling and management.

The Phase Leaders will be responsible for implementation of internal QA/QC checks on field procedures. The QA/QC checks will include a comparison of field procedures to design plans and SOPs, and health and safety reviews, and will be performed by appropriate and qualified AMEC personnel not directly involved in field activities. The QA/QC checks will include unscheduled field visits and observation of procedures during field events.

The current key AMEC personnel are:

Project Manager:	Roger Gresh
Phase Leaders:	Jim Feild, and Tim Johnson
Project Engineer:	Christopher Poulsen, P.E.
Field Manager:	Joe Fassio, R.G.
Technician Manager:	Paul Stull, III, P.E.

2.0 *IN-SITU* CHEMICAL OXIDATION SYSTEM DESIGN

The location of the North Front Avenue ISCM is presented on Figure C-2, an overview of the ISCM with nearby utilities is presented in Figure C-3, and the conceptual ISCM design cross-section is presented on Figure C-4. The ISCM design includes installation of 74 chemical oxidant injection wells, 24 performance monitoring wells, four process buildings, and associated piping and appurtenances.

In general, the design process includes the following: 1) define the current contaminant distribution (based on previous groundwater sampling events from nearby wells); 2) determine injection well design radius of influence; 3) identify injection and

performance monitoring well locations and screen intervals; 4) select and size piping and components; 5) specify materials and equipment; and 6) finalize the system detail figures. Additional information regarding the design process is described below.

2.1 Target Constituents

The target constituents for the North Front Avenue ISCM are 1,2-DCB, 1,4-DCB, CB, and VC.

2.2 Injection Well Design

Using the hydraulic conductivity values derived at the RP Site, as well as literature values for similar geological and hydrogeological conditions, a conservative injection design radius of influence (ROI) of 15 feet was estimated for the North Front Avenue ISCM, and an initial well spacing for each leg of the ISCM was set to 15 feet, allowing for inefficiencies and overlap. However, actual subsurface conditions will be evaluated at the time of drilling to optimize final well spacing. Optimization will be facilitated by performing pumping and/or slug tests on select borings during the initial system installation.

The anticipated materials used for each well are as follows; however, subsurface conditions encountered at the time of drilling will be evaluated and material choices optimized for the conditions:

- Casing: 2-inch Schedule 80 polyvinyl chloride (PVC) pipe;
- Screen: 0.010-inch slotted 2-inch Schedule PVC (see Figure C-4 for anticipated screen interval depths for each of the wells;
- Filter pack: 10/20 silica sand (across entire screened interval to 1-foot above the screen) followed by a 1-foot section of 20/40 silica sand as a transition layer; and
- Seal: bentonite grout (from 3-feet below ground surface [bgs] to the top of the filter pack).

All well locations will, at a minimum, be completed with a 10-foot screened interval, set 5 feet into the weathered basalt. At well locations where the deep alluvial gravel (DAG) zone is greater than 10 feet thick, a second casing and 5 foot screen will be installed in the upper 5 feet of the DAG. Anticipated screen intervals are shown on Figure C-4, but actual completion depths will be determined at the time of drilling.

2.3 Performance Monitoring Well Design

The 24 performance monitoring wells will be installed using sonic drilling methodology. The locations of the first 10 wells are identified on Figure 15 of the Work Plan. The remaining 14 locations will be determined in the field based on initial system performance and subsurface data obtained at the time of the initial system installation. Each of the performance monitoring wells will contain a screened interval installed in the deep alluvial gravel. Each well will be installed according to the injection well and groundwater monitoring well installation guidelines included in Appendix A-1.

Performance monitoring well construction materials will be as follows:

- Casing: 2-inch Schedule 40 PVC pipe;
- Screen: 0.010-inch slotted 2-inch Schedule 40 PVC pipe;
- Filter pack: 10/20 silica sand, a minimum of 5 feet above the screened interval; and
- Seal: bentonite grout from filter pack to 3 feet bgs and a concrete surface seal for the uppermost 3 feet.

Each performance monitoring well will be completed with either a surface-grade monument or an aboveground riser steel monument and protective bollards, as necessary for off-site properties. Following installation, each performance monitoring well will be developed as described in Section 3.3.

2.4 System Equipment Compounds

It is anticipated that four equipment compounds, two per ISCM leg, will be constructed to house the controls, chemical storage tanks, equipment, and O&M materials.

2.5 System Piping and Components

The piping and related components of the remediation system will consist of well vaults with liquid oxidant injection ports at the top of the wells, underground conduits for the oxidant delivery system, and the aboveground piping and equipment.

2.5.1 Aboveground Piping

The aboveground piping in the system compound shall include all of the necessary fittings, valves, piping, and hoses for delivering oxidant to the wells.

The delivery lines will be constructed of Duraplus hose or other chemically compatible material. All of the aboveground piping, hose, and fittings shall be supported along the interior walls of the system compounds with steel c-channel struts and appropriate pipe clamps. Individual supply lines for each well will be bundled in an appropriately sized Schedule 40 PVC casing pipe.

3.0 SYSTEM INSTALLATION

3.1 Project Schedule

Installation of the ISCM system will commence upon receiving Oregon Department of Environmental Quality (DEQ) notice to proceed, according to the following schedule:

1. Select drilling and/or general contractor and provide oversight for the installation of 74 injection wells, well vaults, 24 performance monitoring wells, and aboveground monuments. Additional system installation specifications, including contractor bid specifications, will be developed as part of the 90% ISCM design.
2. Order system equipment including pumps, valves and gages, metering pumps and tanks, regulators, cylinders, piping supports, and control panels (approximately 4 weeks for delivery);
3. Install compounds and fencing (approximately 1 month of field time);
4. Install piping and appurtenances for wells and the control panel (approximately 1 month of field time); and
5. Process controls and make electrical connections (approximately 1 week of field time and an electrical contractor's time).

The Technician Manager will be responsible for performing or selecting contractors to perform the installation work. A local general contractor will be used for site grubbing and grading, as necessary. The injection and performance monitoring wells will be installed by a local drilling company familiar with the desired type of installation described in this document. A local electrical contractor would likely supply and install the control panels and electrical components.

3.2 Well Installation

Performance monitoring and injection wells will be installed according to the well design as described in Sections 2.4 and 2.5. Well completion will be conducted in accordance with state and local regulations. Proposed performance monitoring and injection well locations are shown on Figure C-2.

3.3 Well Development

The injection and performance monitoring wells will be constructed in a manner to minimize infiltration of silt or other particles and to minimize the creation of subsurface conduits for groundwater. The performance monitoring and injection wells will be developed at least 24-hours following installation to flush out particles that may remain after installation and to ensure that the well is in communication with the surrounding formation. Each well will be developed according to AMEC's standard operating procedure (SOP) - 14, Methodology for Monitoring Well Development (Appendix A-2).

3.4 Baseline Groundwater Sampling

Baseline groundwater sampling will be conducted at each of the 74 injection wells and 24 performance monitoring wells to determine baseline constituent concentrations, redox state, and bioactivity indicator concentrations prior to system start-up. Sampling methodology and analyses are described in the Work Plan, and the groundwater monitoring well sampling SOP (SOP - 2) is included in Appendix A-2.

4.0 SYSTEM STARTUP

Prior to startup of the remediation system, the following tasks will be performed:

1. Conduct baseline groundwater sampling event from the injection wells and the performance monitoring wells;
2. Measure and record pre-remediation depth to water, dissolved oxygen, and background pressure at all of the wells;
3. Measure background indigenous microorganism population through heterotrophic plate counts at the wells;
4. Measure concentrations of the target constituents and geochemical parameters at the wells; and
5. Monitor ambient conditions at each injection wellhead and within the system compound in accordance with confined space entry procedures.

A detailed start-up plan will be formulated using manufacturer's recommendations as the design process reaches 90% completion.

5.0 SYSTEM OPERATIONS AND MAINTENANCE

Utilizing manufacturer's recommendations and 90% design documents, a detailed O&M manual will be assembled.

6.0 WASTE DISPOSAL AND HANDLING PROCEDURES

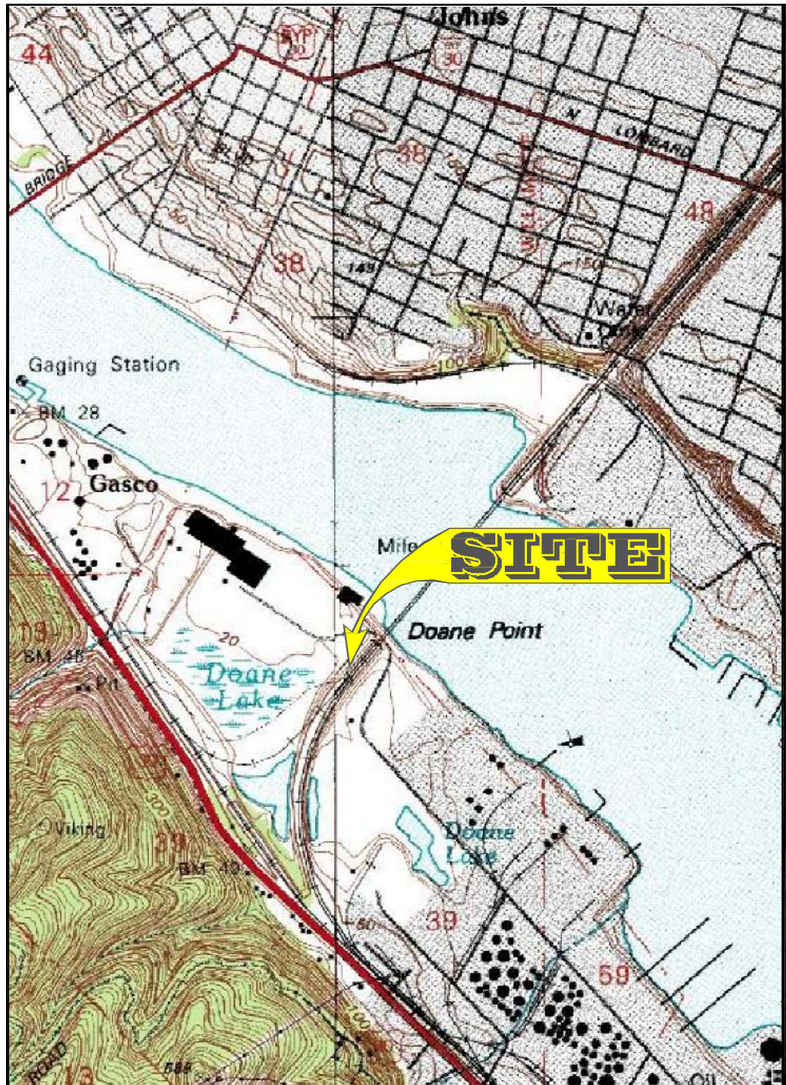
All remediation waste (RW) generated during the investigation will be handled in such a way as to prevent or minimize the potential for the spread of contamination, the creation of a sanitary hazard, or visual degradation of the site through the spread of litter. The RW will remain under the control of SLLI and its contractors at all times during its generation, containerization, and transport to the RP facility for consolidation and shipment as per SOP - 32 (Appendix A-2).

Wastes generated during the system installation covered by this System Design and Installation Plan will include soil cuttings, purge water, decontamination fluids, PPE, disposable sampling equipment, and miscellaneous solid waste. Waste will be handled according to procedures specified in SOP - 13 (Appendix A-2).

LIMITATIONS

This report was prepared exclusively for SLLI by AMEC Earth & Environmental, Inc. (AMEC). The quality of information, conclusions, and estimates contained herein is consistent with the level of effort involved in AMEC services and based on: i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions, and qualifications set forth in this report. This Draft North Front Avenue Interim Source Control Measure System Design and Installation Plan is intended to be used by SLLI for the RP - Portland Site, 6200 N.W. St. Helens Road, Portland, Oregon only, subject to the terms and conditions of its contract with AMEC. Any other use of, or reliance on, this report by any third party is at that party's sole risk.

FIGURES



ROAD CLASSIFICATION

Heavy-duty

Medium-duty

Light-duty

Unimproved dirt

U.S. Route

State Route

Interstate Route

MAP SOURCE: TERRASERVER USA

RP PORTLAND SITE

NORTH FRONT AVENUE ISCM 60% DESIGN

INDEX OF DRAWINGS

SHEET NUMBER	DESCRIPTION
C-1	COVER SHEET
C-2	CONCEPTUAL SITE PLAN
C-3	UTILITY MAP
C-4	LITHOLOGIC CROSS SECTION FROM J-J'
C-5	SYSTEM SCHEMATIC
C-6	INJECTION WELL DESIGN / DETAILS
C-7	TYPICAL WELL VAULT DETAILS / SECTIONS
C-8	COMPOUND LAYOUT
C-9	SYSTEM LAYOUT AND TYPICAL TRENCH SECTION

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REV	DATE	REMARKS	SHEETS REVISED
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X
X	X	X	X

REVISIONS

NOTE: THIS DRAWING IS A 60 % COMPLETE DESIGN OF THE NORTH FRONT AVENUE ISCM REMEDY MODEL.

DRAFT

CLIENT: SLLI

AMEC Earth & Environmental
7376 S.W. Durham Road
Portland, OR. U.S.A. 97224

amec

DWN BY: DD
CHK'D BY: CP
DATUM: -
PROJECTION: -
SCALE: NOT TO SCALE

PROJECT: RP - PORTLAND SITE

TITLE: COVER SHEET

DATE: JULY 2007
PROJECT NO: 061M107030 P80 T2
REV. NO.: -
FIGURE No. C-1

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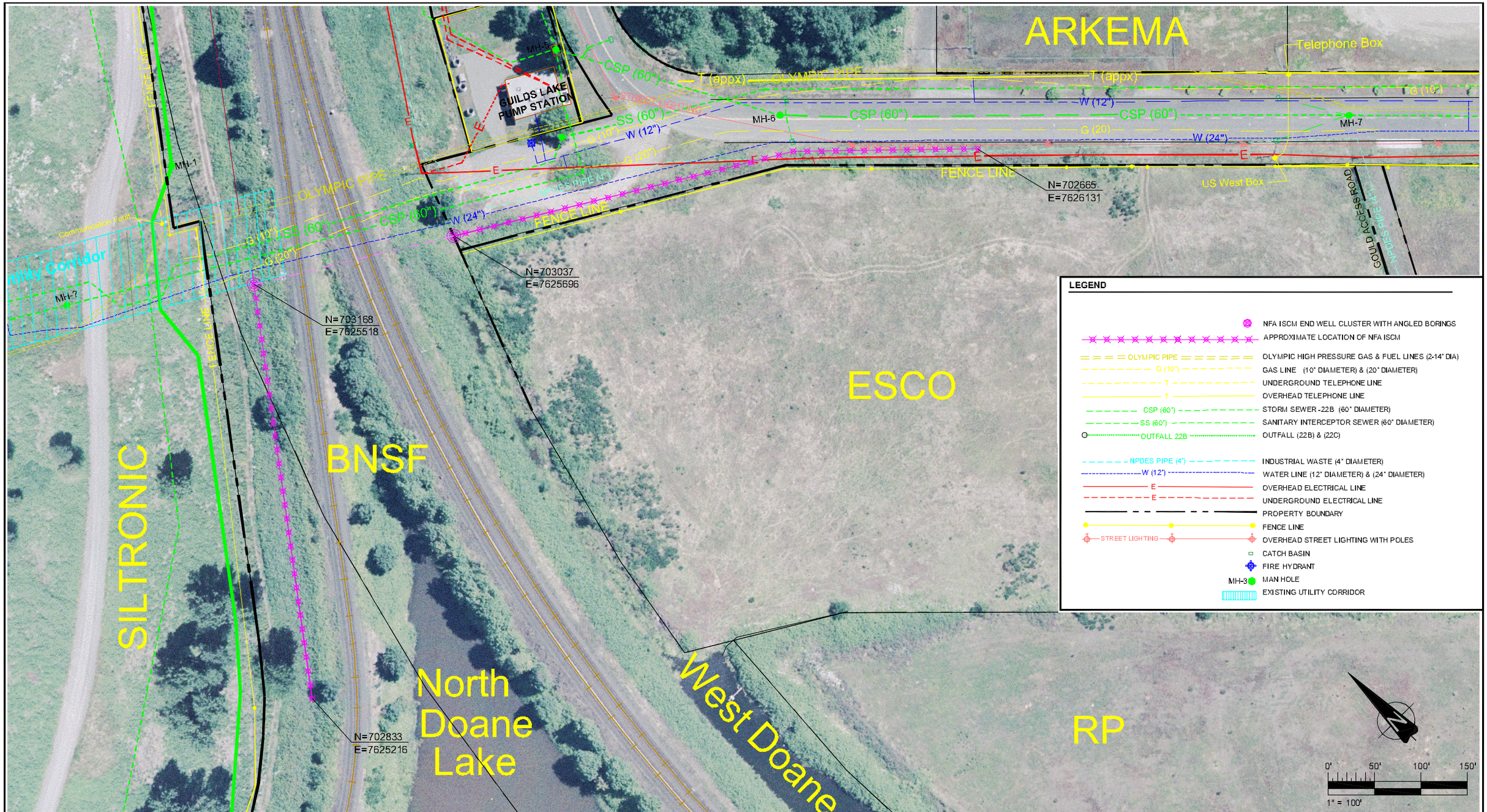

LEGEND

- NFA ISCM END WELL CLUSTER WITH ANGLED BORINGS
- APPROXIMATE LOCATION OF NFA ISCM
- OLYMPIC PIPE — OLYMPIC HIGH PRESSURE GAS & FUEL LINES (2-14" DIA)
- G (10") — GAS LINE (10" DIAMETER) & (20" DIAMETER)
- T — UNDERGROUND TELEPHONE LINE
- T — OVERHEAD TELEPHONE LINE
- CSP (60") — STORM SEWER -22B (60" DIAMETER)
- SS (60") — SANITARY INTERCEPTOR SEWER (60" DIAMETER)
- OUTFALL 22B — OUTFALL (22B) & (22C)
- NPDES PIPE (4") — INDUSTRIAL WASTE (4" DIAMETER)
- W (12") — WATER LINE (12" DIAMETER) & (24" DIAMETER)
- E — OVERHEAD ELECTRICAL LINE
- E — UNDERGROUND ELECTRICAL LINE
- PROPERTY BOUNDARY
- FENCE LINE
- STREET LIGHTING — OVERHEAD STREET LIGHTING WITH POLES
- CATCH BASIN
- FIRE HYDRANT
- MH-3 — MAN HOLE
- EXISTING UTILITY CORRIDOR

NOTE: THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL REPORT No. ___ DATED ___.

DRAFT

CLIENT LOGO

CLIENT: SLLI

AMEC Earth & Environmental
7376 S.W. Durham Road
Portland, OR. U.S.A. 97224

amec

DWN BY:	DD
CHK'D BY:	CP
DATUM:	-
PROJECTION:	-
SCALE:	1" = 100'

PROJECT: RP - PORTLAND SITE

TITLE: 60% DESIGN
NORTH FRONT AVENUE ISCM
CONCEPTUAL SITE PLAN

DATE:	JULY 2007
PROJECT NO:	061M107030 P80 T2
REV. NO.:	-
FIGURE No.	C-2

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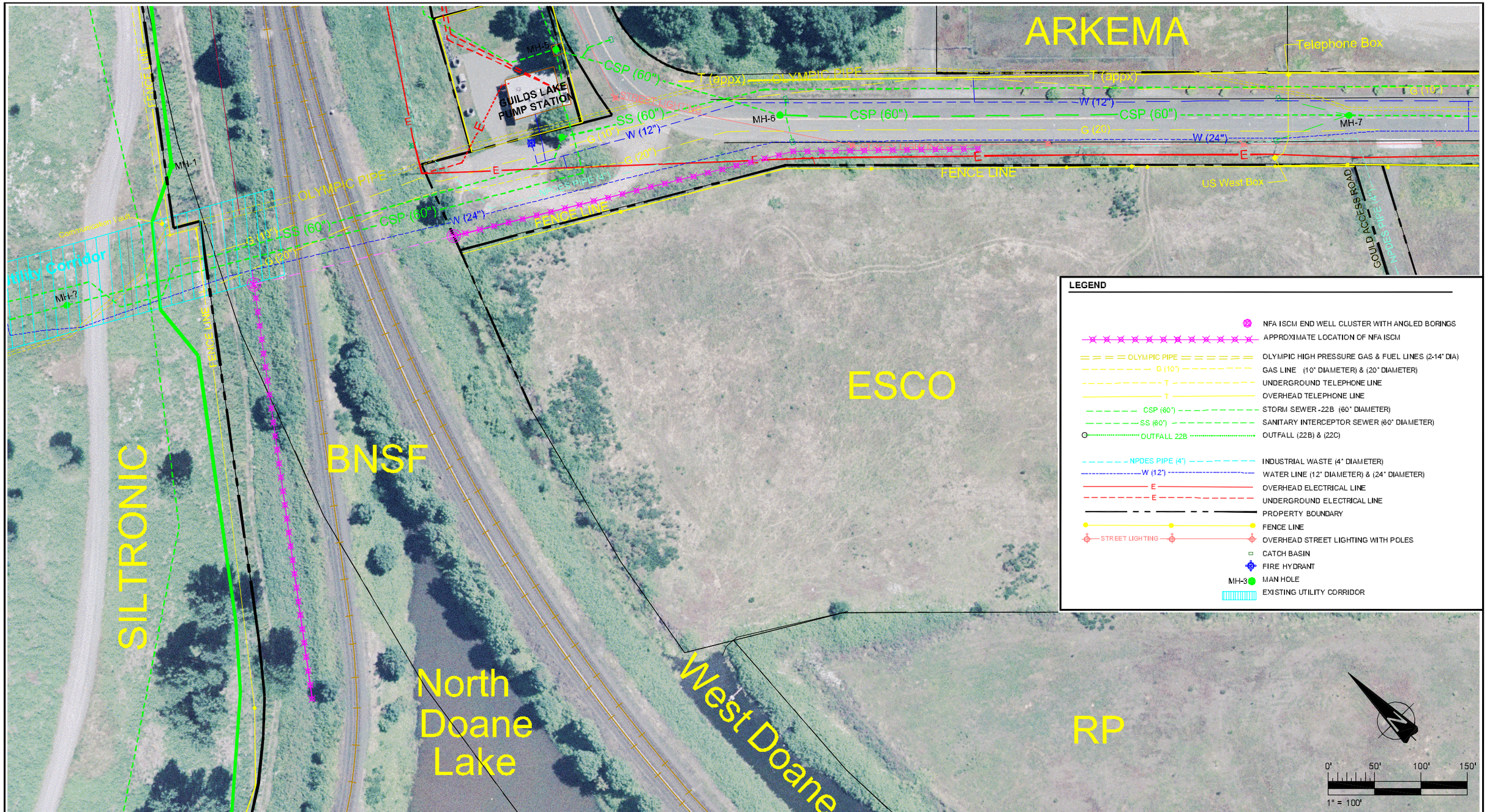

LEGEND

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- FIRE HYDRANT
- MH-3 — MAN HOLE
- EXISTING UTILITY CORRIDOR

THIS DRAWING IS A 60 % COMPLETE DESIGN OF THE NORTH FRONT AVENUE CONCEPTUAL REMEDY MODEL

DRAFT

CLIENT LOGO

CLIENT: SLLI

AMEC Earth & Environmental
7376 S.W. Durham Road
Portland, OR. U.S.A. 97224

amec

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PROJECTION:	-
SCALE:	1" = 100'

PROJECT: RP - PORTLAND SITE

TITLE: 60% DESIGN NORTH FRONT AVENUE ISCM UTILITY MAP

DATE:	JULY 2007
PROJECT NO:	061M107030 P80 T2
REV. NO.:	-
FIGURE No.	C-3

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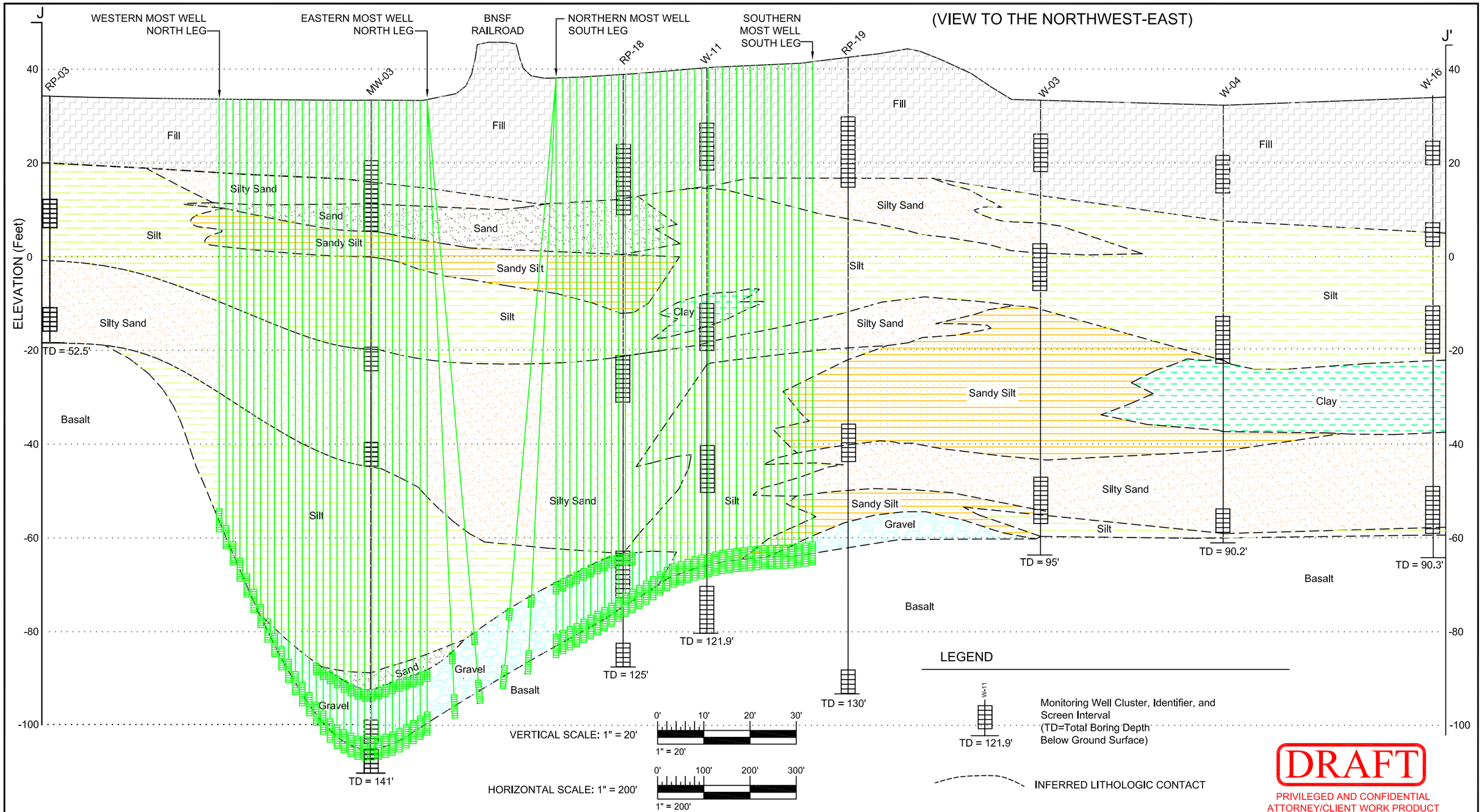


NOTE:
THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL DATED _____.

NOTE: STRATIGRAPHY BETWEEN DEPICTED BORINGS INTERPRETED FROM ADDITIONAL BORINGS NOT SHOWN ON THIS CROSS SECTION.

CLIENT:	SLLI
DWN BY:	DD
CHK'D BY:	CJ
DATUM:	City of Portland
PROJECTION:	-
SCALE:	AS NOTED
PROJECT:	RP - PORTLAND SITE
TITLE:	60% DESIGN LITHOLOGIC CROSS SECTION FROM J-J'
DATE:	JULY 2007
PROJECT NO:	061M-107030-P80
REV. NO.:	1
FIGURE No.	C-4

AMEC Earth & Environmental
7376 S.W. Durham Road
Portland, OR. U.S.A. 97224

K:\10000\10700\10703\Phase 80 North Front Ave ISCM\DWG\NEW NFA UTILITY-CONCEPT\C-4.dwg – 11x17 – Jul. 03, 2007 11:40am – doug.davis

TO BE COMPLETED @ 90% DESIGN STAGE

THIS DRAWING IS A 60% COMPLETE DESIGN OF THE SYSTEM SCHEMATIC.

DRAFT

CLIENT: SLLI

AMEC Earth & Environmental
7376 S.W. Durham Road
Portland, OR. U.S.A. 97224

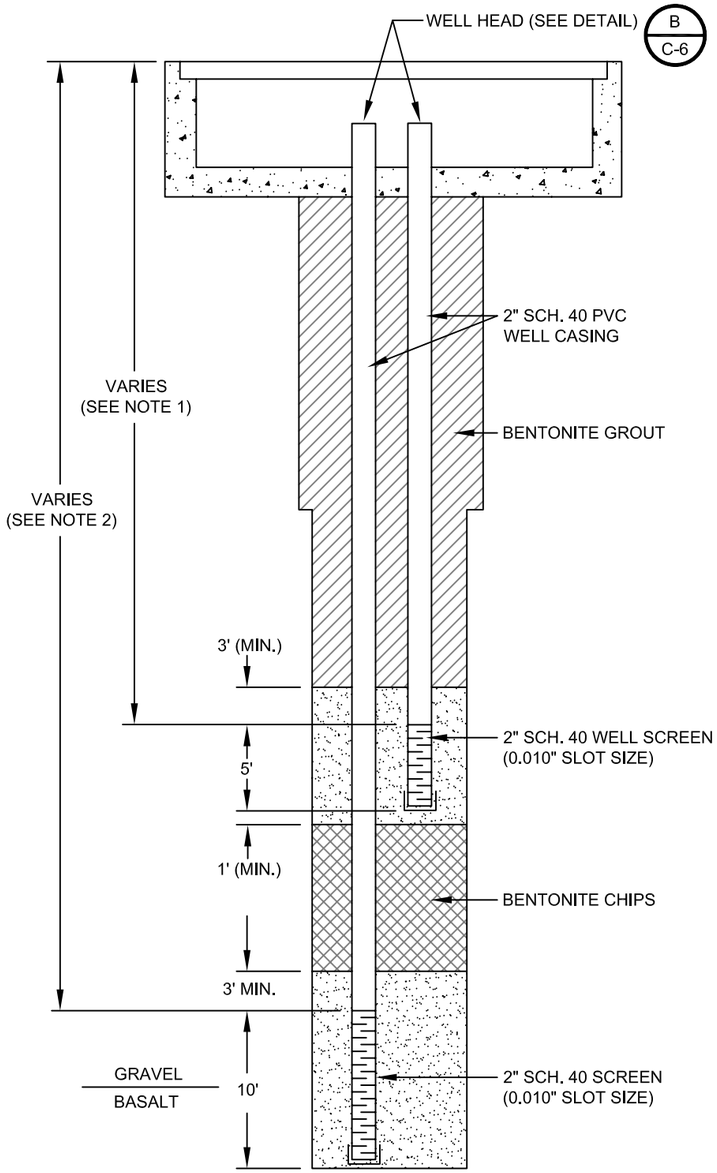
DWN BY:	DD
CHK'D BY:	PS
DATUM:	-
PROJECTION:	-
SCALE:	NOT TO SCALE

PROJECT: RP - PORTLAND SITE

TITLE: 60% DESIGN SYSTEM SCHEMATIC

DATE:	JULY 2007
PROJECT NO:	061M107030 P80 T2
REV. NO.:	-
FIGURE No.	C-5

K:\10000\10700\10703\Phase 80 North Front Ave ISCM\DWG\NEW NFA UTILITY-CONCEPT\C-5.dwg - Layout1 - Jul. 09, 2007 4:14pm - patrick.mccarthy



TYPICAL INJECTION WELL DESIGN (A / C-6)
NTS

WELL HEAD DETAIL (to be completed @ 90%) (B / C-6)
NTS

NOTE: THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE AMEC EARTH & ENVIRONMENTAL REPORT No. ___ DATED ___.

DRAFT

CLIENT: SLLI	DWN BY: DD	PROJECT: RP-PORTLAND SITE	DATE: JULY 2007
	CHK'D BY: CP		PROJECT NO: 061M107030P-80T-2
AMEC Earth & Environmental, 7376 S.W. Durham Road, Portland, OR. U.S.A. 97224	DATUM: -	TITLE: INJECTION WELL DESIGN / DETAILS	REV. NO.: -
	PROJECTION: -		FIGURE No. C-6
	SCALE: NOT TO SCALE		

K:\10000\10700\10703\Phase 80 North Front Ave ISCM\DWG\NEW NFA UTILITY-CONCEPT\C-6.dwg – Layout1 – Jul. 03, 2007 2:09pm – doug.davis

TO BE COMPLETED @ 90% DESIGN STAGE

THIS DRAWING IS A 60% COMPLETE DESIGN OF THE TYPICAL AIB WELL VAULT PLAN / SECTIONS.

DRAFT

CLIENT: SLLI

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Portland, OR. U.S.A. 97224

amec

DWN BY:	DD
CHK'D BY:	PS
DATUM:	-
PROJECTION:	-
SCALE:	NOT TO SCALE

PROJECT: RP - PORTLAND SITE

TITLE: 60% DESIGN
TYPICAL WELL VAULT DETAILS / SECTIONS

DATE:	JULY 2007
PROJECT NO:	061M107030 P80 T2
REV. NO.:	-
FIGURE No.	C-7

K:\10000\10700\10703\Phase 80 North Front Ave ISCM\DWG\NEW NFA UTILITY-CONCEPT\C-7.dwg - Layout1 - Jul. 09, 2007 4:16pm - patrick.mccarthy

TO BE COMPLETED @ 90% DESIGN STAGE

THIS DRAWING IS A 60% COMPLETE DESIGN OF THE SYSTEM CROSS-SECTION.

DRAFT

CLIENT:	SLLI
AMEC Earth & Environmental 7376 S.W. Durham Road Portland, OR. U.S.A. 97224	amec
DWN BY:	DD
CHK'D BY:	PS
DATUM:	-
PROJECTION:	-
SCALE:	NOT TO SCALE
PROJECT	RP - PORTLAND SITE
TITLE	60% DESIGN COMPOUND LAYOUT
DATE:	JULY 2007
PROJECT NO:	061M107030 P80 T2
REV. NO.:	-
FIGURE No.	C-8

K:\10000\10700\10703\Phase 80 North Front Ave ISCM\DWG\NEW NFA UTILITY-CONCEPT\C-8.dwg - Layout1 - Jul. 09, 2007 4:17pm - patrick.mccarthy

TO BE COMPLETED @ 90% DESIGN STAGE

THIS DRAWING IS A 60% COMPLETE DESIGN OF THE ALPHA SYSTEM LAYOUT AND TRENCH SECTION.

DRAFT

CLIENT: SLLI

AMEC Earth & Environmental
7376 S.W. Durham Road
Portland, OR. U.S.A. 97224

DWN BY:	DD
CHK'D BY:	PS
DATUM:	-
PROJECTION:	-
SCALE:	NOT TO SCALE

PROJECT: RP - PORTLAND SITE

TITLE: 60% DESIGN SYSTEM LAYOUT AND TYPICAL TRENCH SECTION

DATE:	JUNL 2007
PROJECT NO:	061M107030 P80 T2
REV. NO.:	-
FIGURE No.	C-9

K:\10000\10700\10703\Phase 80 North Front Ave ISCM\DWG\NEW NFA UTILITY-CONCEPT\C-9.dwg - Layout1 - Jul. 09, 2007 4:18pm - patrick.mccarthy

APPENDIX A-1

Injection Well and Groundwater Monitoring
Well Installation Guidelines

INJECTION WELL AND GROUNDWATER MONITORING WELL INSTALLATION GUIDELINES

PURPOSE

Monitoring wells are installed to allow collection of groundwater samples multiple times at a constant location and depth. Monitoring wells are constructed in a manner to minimize infiltration of silt or other particles from entering the well, and to minimize the creation of subsurface conduits to groundwater. Monitoring well construction must comply with State regulations for monitoring well design. Monitoring wells are developed following installation to flush out particles that may remain after installation and to ensure that the well is in communication with the surrounding formation.

EQUIPMENT LIST

1) Photo-ionization detector (PID)
2) Blank Boring Log Form and field logbook with indelible pens (Field Documentation)
3) Electronic water level probe (Water Level Measurement)
4) Proposed well design details
5) Surge block
6) Submersible pump, controller, and power source (e.g., generator)
7) Portable turbidity meter and power source (e.g., charged batteries)
8) Buckets for containing purged well development water
9) Decontamination equipment
10) Site map and Site health and safety plan (HASP)
11) PPE appropriate for Site (see HASP if applicable)

PROCEDURE

This guideline includes procedures for monitoring well installation, as described in the sections below. All newly installed monitoring wells will be developed prior to use in accordance with SOP-14. Monitoring wells are completed using the same general procedures.

Monitoring Well Installation

Monitoring well installation should begin after specified soil sampling has been completed and the total depth of the boring has been reached. State regulations will determine the diameter of the borehole relative to the diameter of the well. For instance, in Oregon, the diameter of the borehole should be four inches larger than the diameter of the well. A 2-inch-diameter well requires a 6-inch-diameter borehole. No auger or casing should be removed from the boring prior to the commencement of well installation.

Monitoring well construction materials are as follows (unless otherwise specified in well design):

- Casing: Schedule 40 PVC for monitoring and injection wells;
- Filter pack: 10/20 silica sand or 8/12 silica sand, depending on native materials in the screened interval;
- Seal: bentonite and/or bentonite/cement grout, and/or bentonite chips, depending on native material and well depth;
- Screen: 0.010-inch slot PVC.

The steps necessary to install a monitoring well are described below.

1) Prior to the placement of well screen or prepackaged well screen and filter pack, confirm that a bottom plug is in place at the end of the well screen/casing string. If the depth of the well is 15 feet or less, the well screen and casing can be assembled prior to placement. The well screen/casing string should be slowly lowered into the boring through the center of the hollow-stem auger, air rotary or sonic casing. The bottom plug should contact the base of the boring. The well screen/casing should be centered inside the boring.

2) After placement of the well screen/casing, installation of annulus materials will commence. Filter pack sand should be poured into the well annulus from the surface. A temporary cap should be placed on the top of the well screen/casing to prevent sand from entering the well interior. As filter pack material is poured into the annulus, auger or casing will be extracted from the boring, simultaneously. In situations where there are heaving sands, clean potable water may be added to the boring to keep the sands out of the casing during well installation. Monitoring wells with a prepack screen will also require additional sand to be poured into the boring, although the size might be coarser than 10/20, depending on the size of sand in the prepack screen assembly. The level of sand in the boring should remain 1 to 2 feet above the bottom of the lead auger or casing. Well construction materials (e.g., filter

pack sand or grout) should always be up inside the lead auger or casing during well installation and auger/casing removal. Auger or casing should continuously be pulled while filter pack material is added, until the top of the filter pack reaches an elevation of approximately 3 to 5 feet above the top of the casing.

3) After filter pack installation is complete, and prior to placement of an annular seal, the filter pack should be surged with a surge block. Surging should be continued until the filter pack ceases to settle. If necessary, additional filter pack material may be added and the well surged until the design elevation for the filter pack is reached.

4) Following filter pack development, the annular seal should be installed. Follow State requirements for a minimum annular seal length of 2 feet. The annular seal should be installed by pouring bentonite chips directly into the annulus, or using a pipe to tremie bentonite grout seal materials onto the top of the filter pack materials. Conditions of the formation and depth of the well will determine the method and materials used in seal placement. The elevation of the annular seal should be brought to within 6 inches below ground surface.

5) After the annular seal has been installed and hydrated, the remaining auger flights or casing should be removed from the boring.

6) Depending on the location of the well, either a flush or above-ground monument should be installed to secure, protect, and allow access to the well. An above-ground well monument may be installed in areas where surface runoff may occasionally pool or where the monument can be protected and it does not interfere with Site operations. A flush surface monument should be installed in areas where surface runoff is not anticipated to pool and where an above-ground monument would affect pedestrian or vehicular traffic. The well casing is cut off just below grade for a flush surface monument, or extended above grade for an above-ground completion.

7) The flush monument should be rated for vehicular traffic and set using concrete pre-mix, with the top of the monument a minimum of 1 inch above the surrounding surface to prevent small amounts of surface water from ponding on top of the monument. The flush monument includes a flush lid secured by bolts.

8) The above-ground monument includes a steel outer casing set in concrete with a lid that can be secured with a padlock. Three steel posts (bollards) are also set in concrete around the above-ground monument to protect it from damage.

9) Before the field crew leaves the Site and following the completion of monitoring well installation, the temporary well cap should be removed from the top of the well and replaced with a locking cap and padlock.

10) Well installation details should be accurately recorded on the Boring Log Documentation.

LOCATION

WEATHER _____

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TEST BORING LOG

HOLE NO. _____
SHEET _____ OF _____
TOTAL DEPTH _____
DATE BEGUN _____
DATE COMPLETED _____

SAMPLING

SAMPLING METHOD	SAMPLE NUMBER	BLOW COUNT	DEPTH SAMPLED	RECOVERY	DEPTH IN FEET	SOIL DESCRIPTION
					0	
					1	
					2	
					3	
					4	
					5	
					6	
					7	
					8	
					9	
					0	
					1	
					2	
					3	
					4	
					5	
					6	
					7	
					8	
					9	
					0	

GROUNDWATER TABLE

ATD=AT TIME OF DRILLING AB=AFTER BORING

DEPTH IN FEET _____
TIME _____
DATE _____

PROJECT NAME _____
PROJECT NUMBER _____
GEOLOGIST/ENGINEER _____
DRILLING CONTACTOR/ CREW _____
METHOD USED _____

SAMPLING METHOD: SPT=STANDARD PENETRATION TEST T=TUBE R=RING

BORING LOG SUMMARY

–	
–	
–	
–	
–	

amec
Earth & Environmental

MONITORING WELL AS-BUILT REPORT

PROJECT No. _____

LOCATION _____

PROJECT NAME _____

OBSERVED BY _____

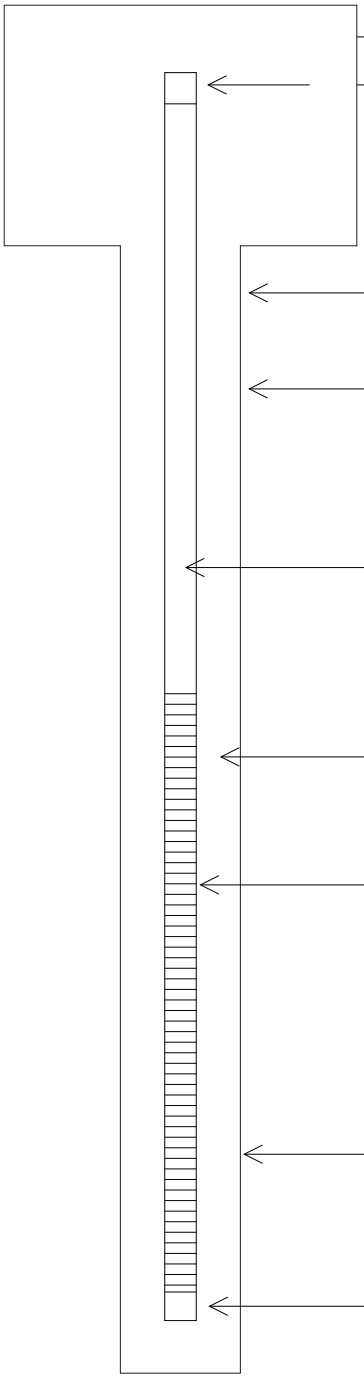
BORING/WELL I.D. _____

DRILLER/INSTALLER _____

DATE _____

START CARD#/ WELL TAG I.D.# _____

SOIL TYPE DEPTH



ABOVE GROUND RISER HEIGHT (IF APPLICABLE) _____

MONUMENT TYPE (IF APPLICABLE) _____

WELL CAP TYPE _____

GROUT TYPE/#SACKS _____

BENTONITE SEAL /#SACKS _____

WELL CASING I.D. _____

TYPE OF CASING _____

TYPE OF CONNECTION _____

FILTER PACK / SIZE/ #SACKS _____

WELL SCREEN I.D. _____

TYPE OF SCREEN _____

SLOT SIZE _____

DIAMETER OF BOREHOLE _____

ENDCAP TYPE _____

REMARKS _____

APPENDIX A-2

Standard Operating Procedures and Forms

SOP - 2 Groundwater Sampling

SOP - 13 Waste Management Procedures

SOP - 14 Methodology for Monitoring Well Development

SOP - 32 Transport of Hazardous Materials by Road to RP Property

RP - PORTLAND SITE
SOP - 2
METHODOLOGY FOR GROUNDWATER SAMPLING

1.0 PURPOSE

Groundwater samples are collected from monitoring wells for analysis of physical and chemical parameters, either using field observations and portable equipment or using off-Site laboratory analytical methods. Monitoring wells are purged using low flow purge techniques to ensure that water sampled is representative of the formation. The procedures in this standard operating procedure (SOP) are specific to standard monitoring wells with a single slotted interval. This method can be used when using dedicated pumps or portable pumps. Only in extreme circumstances and when no other choices are available will bailers be used for groundwater sampling.

2.0 EQUIPMENT LIST

1) Well lock keys
2) Groundwater Sampling Field Form, other appropriate Site-specific form(s), and field logbook with indelible pens
3) Electronic water level probe or interface probe (DNAPL)
4) Check-valve Teflon® bailer with new cord to measure DNAPL if present
5) Knife or scissors
6) Decontamination equipment (see RP SOP - 3 Decontamination Procedure, and sampling plan for additional Site-specific requirements)
7) Site map and Site health and safety plan (HASP), if applicable
8) PPE appropriate for Site (see HASP if applicable)
9) Submersible pump (for monitoring wells without dedicated pumps), and associated pump equipment (controller, connectors, power cord, etc.)
10) Compressed nitrogen gas source (if dual-valve pump is used)
11) Disposable discharge tubing, if necessary
12) Field water quality monitoring equipment (see RP SOP - 4 Field Measurement of Groundwater Parameters) and flow-through cell
13) Buckets or other containers for purged water
14) Sample containers, labels, packaging material

3.0 PROCEDURE

Groundwater samples can be collected using low-flow purging and sampling or standard purging and sampling methods. Low-flow purging and sampling is the preferred sampling method, however both are presented here. Standard purging and sampling methods may be used at wells that are not amenable to low-flow purging, such as wells with short water columns and slow recharge. Every effort should be made to use low-flow purging and sampling methods if at all possible.

Low-Flow Purging and Sampling

This SOP emphasizes the need to minimize stress by inducing low pumping rates in order to collect samples with minimal alterations to water chemistry. While purging and sampling, accurate measurement of physical groundwater quality parameters in the field requires a closed system in which groundwater does not come in contact with air. Dissolved oxygen (DO), oxidation-reduction potential (ORP), and pH measurements in groundwater are sensitive to reactions with the atmosphere. The flow-through cell (flow cell) is used to measure field parameters when collecting groundwater water samples from a submersible or peristaltic pump. Stabilization of indicator field parameters is used to indicate that conditions are suitable for sampling to begin.

In addition, drawdown needs to be measured and recorded while performing low flow purging. Although a drawdown of less than 0.3 foot is desirable, it is not necessary for successful low flow sampling. Even more important is the stabilization of the drawdown as well as water quality parameters. If after all efforts are made to reduce drawdown the well appears to be drying up (i.e., the water level in the well continues to descend while pumping at or below 0.1 liters per minute [L/min]), start collecting groundwater samples as soon as water parameters indicate stabilization. Stop prior to total dry up of the well and allow recharge. If necessary, return the next day to finish collecting the groundwater sample. Priority for sample collection is given in the attached table.

The following sequential steps are to be completed during groundwater sampling from monitoring wells:

1) Check well for security damage or evidence of tampering and record pertinent observations. Note any maintenance tasks that should be completed, such as well cap or padlock replacement.
2) Lay out a sheet of clean plastic sheeting (visqueen) around the well monument for monitoring and sampling equipment.

3) After removing the well cap, immediately measure the air space in the well bore for the presence of volatile organic compound (VOC) vapors using a photoionization detector.

4) Measure the depth to water using an electronic water level indicator. All measurements should be referenced to a marked point on the well casing.

5) For wells without dedicated pumps, to minimize disturbance in the water column, slowly lower the pump (or intake of the disposable tubing if using a peristaltic pump) into the well to the midpoint of the zone to be sampled using a safety cable attached to the top of the pump. Keep the pump or intake at least 2 feet from the bottom of the well to minimize the mobilization of silt that may be present in the sump at the bottom of the well.

6) Start the pump at a low setting to minimize agitation of the water column. Measure the discharge rate. Monitor the depth to water and select a pumping rate of 0.5 L/min or less that will allow the depth to water to stabilize. Ideally there should be drawdown of 0.3 feet or less, but in some wells, drawdown will be greater. Continually monitor drawdown and look for it to stabilize.

7) During well purging, monitor the field parameters every three to five minutes. Purging is considered complete and sampling may begin when the field parameters have stabilized for three consecutive readings (taken at three to five minute intervals) and the drawdown has stabilized. These readings should be within the following limits:

Temperature:	3%
Conductance:	3%
pH:	+/- 0.1 pH units
DO	+/- 0.3 mg/L
ORP	+/- 10 millivolts
Drawdown	+/- 0.1 feet

Turbidity of the sample water will be measured using field instruments prior to sample collection and upon obvious visual changes in turbidity during sample collection.

NOTE: If conditions do not allow for low-flow purging methods, such as drawdown continuing and/or the well drying up, use the following procedures (Items 8 and 9) for purging a well:

8) For wells at which the water level is above the screen interval prior to purging or sampling, and drawdown continues even at a very low pumping rate: Make note of this on the Groundwater Sampling Field Form. Be aware of the screen depths and do not draw water levels below the top of the screen, if possible. Stop pumping when the water level reaches the top of the screen and allow the well to recharge. Check the water level after 15 minutes and restart the pump (see #9 if there is

insufficient water recovery). Continue to monitor the water level and stop any time it reaches the top of the screen. After clearing out two tubing volumes, start sampling, keeping the water level above the screen at all times. Use the attached table for the hierarchy of analytes for sample collection. Document well and groundwater (e.g., turbidity) conditions thoroughly.

9) For wells at which the water level is within the screen interval at the beginning of sampling and drawdown approaches the top of the pump even at a very low pumping rate, or the water level does not recover above the top of the screen after 15 minutes (following #8 above): Make note of this on the Groundwater Sampling Field Form. Pump the well dry, being careful not to disturb sediment that may have collected at the bottom of the well, and let it sit a minimum of 24 hours. After 24 hours or so, if there is sufficient water within the well, collect at least one round of water quality parameters. If the water level remains at the top of the pump or below the well screen (depending on the initial conditions), collect groundwater samples without additional purging to ensure enough volume for sample collection. Stop pumping and allow recovery while sampling, if necessary. If enough sample volume cannot be collected after following this procedure for up to 2 days (48 hours), call Project Manager/Phase Coordinator to make a decision about whether or not to continue sampling. Use the attached table for the hierarchy of analytes for sample collection. Document well and groundwater (e.g., turbidity) conditions thoroughly.

10) The water sample must be collected before the water passes through the flow cell. Disconnect the influent tubing from the flow cell and directly fill the sample containers. Turbidity of the sample water will be measured using field instruments prior to sample collection and upon obvious visual changes in turbidity during sample collection. Groundwater samples for dissolved metals analysis will be field-filtered with a 0.45-micron filter by placing the filter in-line to the sample tubing from the pump. Water should be directed down the inside walls of the bottles to minimize aeration.

11) All the sample bottles will be properly labeled, protected from breakage, placed in storage bags, and placed in a cooler on ice and packed for transport to the laboratory. Samples will be shipped to the laboratory within 48 hours of collection.

12) Discard the dedicated tubing as Investigation-Derived Waste (IDW) after sampling.

13) Before securing the well, measure and record the water level.

14) Decontamination of sampling equipment is addressed in SOP - 3 Decontamination Procedure.

15) All field observations made, and data generated in conjunction with the sample collection, will be entered on a well-specific Groundwater Sampling Field Form, dated, and signed by the field personnel.

16) Complete the chain-of-custody documentation after samples are collected, and before moving to the next well.

Well purge water will be stored in an appropriately labeled poly tank and transported from the generation point to the RP wastewater treatment system for discharge in accordance with the NPDES permit dated September 15, 2003. This will occur on the day of generation. The quantity of water discharged to the RP wastewater treatment system will be recorded on the 90-Day Investigation Derived Waste Log (SOP-13).

RP - PORTLAND SITE
SOP - 13
WASTE MANAGEMENT PROCEDURES

1.0 PURPOSE

To promote proper and consistent handling, storage, and disposal of waste generated during field investigations, and to prevent or minimize the potential for the spread of contamination, creation of sanitary hazards, or visual degradation of the RP site through the spread of litter.

2.0 EQUIPMENT LIST

1) Site-specific Health and Safety Plan (HASP), including site map
2) Personal Protective Equipment (PPE) appropriate for the tasks to be performed, and material to which contact will occur (see HASP)
3) Waste Log form (attached)
4) Daily Water Disposal Log form (attached)
5) Field notebook
6) Waste labels
7) Indelible ink pens
8) Heavy duty plastic sacks
9) Plastic film bags
10) Portable water storage tank
11) Department of Transportation (DOT)-approved, removable head, 55-gallon steel drums
12) Drum liners
13) On-site, chemical-resistant container with secondary containment (e.g., 30-gallon, Teflon®-bonded, hard-top steel drum with volumetric gauge contained with secondary containment and cover, and large dedicated funnel), capable of storing non-aqueous phase liquid (NAPL)
14) A portable, chemical-resistant container with secondary containment (e.g., 3-gallon Teflon®-bonded steel container within a 5-gallon bucket), capable of storing NAPL
15) Manifest forms appropriate for oversight of waste transport

3.0 PROCEDURES

Wastes generated during field activities may include decontamination fluid, purged groundwater, PPE, soil, disposable sampling equipment, NAPL, and/or other hazardous and non-hazardous wastes. Generated waste, other than decontamination fluid and purge water, will be sorted by media type, boring or excavation location, investigation area, and/or investigation event, or field activity, then packaged in drums and stored in the RP waste storage facility (WSF). A temporary label will be affixed to each container of waste (see Section 3.7). If any field tests are run and/or free water is removed, a description of the tasks performed will be recorded in a field logbook to aid in the safe packaging, handling, and storage of wastes.

3.1 Decontamination Fluid and Purge Water

Decontamination fluid and purge water generated during decontamination or sampling activities will be contained in 5-gallon buckets that are placed on a plastic liner and transferred to an appropriately labeled portable tank located in the back of a field truck for transport to the RP wastewater treatment plant (WTP). Decontamination fluids and purge water, hazardous and non-hazardous, will be transported from the generation point to the RP WTP for discharge in accordance with the NPDES permit renewal granted to RP on September 15, 2003. This will occur on the day of generation. The quantity of water discharged to the WTP will be recorded on the Daily Water Disposal Log.

3.2 Removal Action and Remedial Action Waste

Generated waste, other than decontamination fluid and purge water (addressed in Section 4.2.1 below), will be drummed by media type, boring or excavation location, investigation area, and/or investigation event and stored in the WSF. A temporary label (Appendix B) will be affixed to each container of waste generated during the event (see Section 4.2).

Where appropriate, hazardous waste will be managed in DOT approved UN 1A2, removable head steel drums lined with a plastic film bag. Overpack drums may consist of either salvage drum size (85-gallon) or smaller (30- or 55-gallon) sizes as appropriate. Hazardous debris will also be managed in accordance with 40 CFR 268.45 prior to disposal. Following waste characterization the waste and/or debris will be disposed of according to applicable state and federal laws.

During removal or remedial actions, circumstances may warrant the use of soil bins and/or water tanks with larger storage capacity than drums. Use of these types of containers will be evaluated on a case-by-case basis and managed as for drums, as

described herein, except in cases where the containers cannot be safely put into the WSF. In those cases, the containers will be securely covered and stored on the site blacktop during characterization activities. In addition, field tests may be used during removal or remedial actions to aid in appropriate waste handling. If such field tests are run, results will be taken into consideration as part of the waste characterization.

Containers storing non-liquid wastes will periodically be examined for the presence of free liquid. If free liquid is observed, the free liquid will be decanted and absorbent added to the container, and such actions will be noted in the Waste Log

3.3 Personal Protective Equipment

All disposable health and safety PPE (Tyvek® suits, Nitrile gloves, etc.) will be collected and stored in heavy-duty, plastic sacks and transported to the WSF on the same day it was generated. The sacks with discarded PPE will be placed in DOT-approved UN-1A2 removable head steel drums, lined with plastic film bags, for storage. The quantity and origin of PPE placed in the WSF will be recorded daily on the Waste Log. Following waste characterization, the PPE will be transported to an off-site treatment, storage, and disposal facility (TSDF) for treatment, as necessary, and for final disposition of the waste according to applicable state and federal laws.

3.4 Soil Cuttings and Core Liners

Soil cuttings and associated disposable sampling equipment (e.g., core liners) generated during sampling activities will be packaged in DOT-approved UN-1A2 removable head steel drums, lined with plastic film bags. Soil generated from boring operations typically contains free water at the time of generation. Immediately following initial placement of the soil cuttings and/or core liners in drums, free water often ponds on top of the waste material. The free water will be removed and disposed of, at the WTP. Drums containing soil cuttings and core liners will be transported from the generation point to the WSF during the day of generation. The approximate percentages of soil versus debris, and types of debris material in each drum receiving waste, will be recorded, on a daily basis, as field notes for each container. The quantity (estimated weight and percent of drum capacity remaining) of soil cuttings and core liners placed in the WSF will be recorded daily on the Waste Log.

Free water may separate from the soil cuttings upon standing in drum during storage. Prior to shipping the investigation-derived waste off-site for treatment and/or disposal, free water will be removed and transferred to the WTP, and /or an appropriate absorbent material (e.g., vermiculite) will be added. Following waste characterization, the soil cuttings and core liners will be transported to an off-site TSDF for treatment, as

necessary, and for final disposition of the waste according to applicable state and federal laws.

3.5 NAPL and NAPL/Fluid Mixtures

NAPL and NAPL/fluid mixtures generated during field activities will be placed in a portable, chemical-resistant container within secondary containment for transport from the area of generation to the WSF. Inside the WSF, the contents of the portable container will be transferred to a stationary 55-gallon chemical-resistant container with secondary containment using a dedicated, industrial-sized funnel with a flip-top reclosable lid. Transport of NAPL and/or NAPL/fluid mixture to the WSF will occur on the day of generation. The quantity of NAPL and NAPL/fluid mixture placed in the WSF will be recorded daily on the Waste Log.

3.6 Disposable Sampling Equipment

Disposable sampling equipment (disposable bailers, plastic tubing, etc.) to which little or no soil is adhered, will be collected and placed in plastic film bags and transported to the WSF on the day of generation. The bags will be placed in DOT approved UN 1A2 removable head steel drums. The quantity of disposable sampling equipment placed in the WSF will be recorded daily on the Waste Log. Following waste characterization, the disposable sampling equipment will be transported to an off-site TSDF for treatment, as necessary, and for final disposition of the waste according to applicable state and federal laws.

3.7 Miscellaneous Solid Wastes

Non-hazardous wastes that may be generated during field activities include paper, food containers and wrapping, aluminum cans, bottles, plastic bags, and other miscellaneous debris. This material will be contained in heavy duty plastic sacks for daily disposal in approved sanitary waste receptacles.

3.8 Wastes from Facility Maintenance

Waste generated as part of general facility maintenance may include used motor oil, fluorescent light bulbs, old machinery or equipment, and unused or out-of-date paints and cleaners. Used motor oil is stored on-site in a DOT approved UN 1A2, removable head steel drum pending removal to an authorized oil recycler. Used fluorescent light bulbs are stored in boxes as a Universal Waste and forwarded to a Universal Waste handler for recycling.

Old machinery and equipment that is not designated as hazardous waste is disposed as solid waste. Unused, out-of-date paints and cleaners are stored in DOT approved UN 1A2, removable head steel drums pending characterization and disposal. The wastes are handled and disposed in accordance with applicable state and federal laws

3.9 Temporary Container Labeling

Immediately upon placement of waste in a drum, a temporary label with the language, "This container on hold pending analysis. Do not tamper with container. Authorized personnel only," will be applied. Information that will be added to the temporary label will include:

1) The accumulation start date;

2) The event name;

3) Waste origin (i.e., boring or excavation location, investigation area, etc.);

4) Media type (e.g., PPE and debris, soil, etc.); and

5) A unique identification (ID) number. **NOTE*** the unique ID number should be obtained from the Task Leader, who is responsible for maintaining the waste management records, including an inventory of the hazardous wastes stored in the WSF.

3.10 Waste Characterization

Wastes are characterized in accordance with the RP Waste Analysis Plan. Collection of additional samples for use in waste characterization depends on the availability of analytical results. If samples appropriate to characterize the waste stream were collected during investigation activities, then additional samples of the waste will not be collected. If no samples, or insufficient samples, were collected during investigation activities, then a representative sample will be collected from the drum(s) of the affected waste stream. Efforts should be made to schedule sample collection activities to occur at the time the waste is placed in the WSF, before field investigation activities are completed.

3.11 Record-Keeping and Labeling

Upon transfer of waste to the hazardous waste storage area within the WSF, a Waste Log will be initiated. At the end of each day, for each drum receiving waste that day, a record that includes the area/location of waste, type of waste, amount of waste added, and the remaining capacity in each drum will be entered into the log. An adhesive,

temporary label completed using an indelible marker, as described in Section 3.7, will be affixed to the upper 1/3 side of the container, such that the label can be read without moving the container.

If, using analytical results and process knowledge, a waste is characterized as hazardous, then a hazardous waste label will be applied to the packaging in which the waste is contained. The temporary label will be removed or covered. If it is not possible to remove the temporary label, it will be rendered illegible with spray paint. SOP - 21 provides further instruction for hazardous waste drum shipment.

WASTE LOG
RP - Portland Site

Container Number	Accum. Start Date	Area/location(s)		Types of Waste[1]	Field Event	Samples Collected from Waste? (Yes or No)	% Volume by Waste Type	Remaining Capacity of Container (%)[2]
Example: 204	*4/22/2002*	*NRA*	*RP-07-S*	*drill cuttings*	*Spring 2005 GW*	*N*	*20% soil, 80% PPE and/or debris*	*50%*

Notes:
LA = Lake Area
IA = Insecticide Area
HA = Herbicide Area
NRA = Non-RP – Portland Site Area
[1] Waste types fall into the following three categories: soil (silt, sand, gravel, etc), PPE (gloves, tyvek suits, respirator filters), and debris (wood, paper, plastic, broken sample bottles)
2

DAILY WATER DISPOSAL/STORAGE LOG

DATE:_____

SITE: RP - Portland, Oregon

JOB #: 0-61M-10703-0 Phase _____

Activity/Task Name:_____

Field Representative:_____

Instructions: Please completely fill out form on a daily basis.

One sheet per task/activity at RP.
Make sure a copy of this sheet is returned daily to the AMEC Portland office.

Generation Date (office use only)	Gallons of Water	Storage, Transfer, or Disposal to WTP	Container Number	Container Size (5-, 10-, 30-, 55-, 2,500-gal, etc.)	Type of Container (metal w/ poly liner, poly bucket, poly drum, poly tank)	Container Location	Labeled (pending analysis or DOT hazwaste)	Area/Location(s)[1]		Type of Waste Water (Purge, decon, development, other)
EXAMPLES	*150 gals*	*Storage*	*400*	*55-gal*	*poly drum*	*WSF*	*PA*	*NRA-Siltronic*	*SIL-04*	*Purge Water*
	150 gals	*Storage*	*401*	*55-gal*	*poly drum*	*WSF*	*PA*	*NRA-Siltronic*	*SIL-03*	*Purge Water*
	2,500 gals	*Disposal to WTP*	*350*	*2,500-gal*	*poly tank*	*Near WTP*	*PA*	*NRA-Siltronic*	*All*	*Purge and decon water*

Notes: (1) Area abbreviations: LA = Lake Area, HA = Herbicide Area, IA = Insecticide Area, NRA = Non - RP Area - specify

RP - PORTLAND SITE
SOP - 14
METHODOLOGY FOR MONITORING WELL DEVELOPMENT

1.0 PURPOSE

Monitoring wells are constructed in a manner to minimize infiltration of silt or other particles from entering the well, and to minimize the creation of subsurface conduits to groundwater. Monitoring wells are developed following installation to flush out particles that may remain after installation and to ensure that the well is in communication with the surrounding formation.

2.0 EQUIPMENT LIST

1) Photo-ionization detector (PID)
2) Blank Well Development Log form, other site-specific form (as appropriate), and field logbook with indelible pens
3) Electronic water level probe
4) Well construction details
5) Surge block
6) Submersible pump, pump controller, and power source (e.g., generator)
7) Portable turbidity meter and power source (e.g., charged batteries)
8) Containers for containing purged well development water
9) Site map and site health and safety plan (HASP), if applicable
10) PPE appropriate for site (see HASP if applicable)

3.0 PROCEDURE

Well development should accomplish the following objectives: 1) removal of fine materials from the well (both the filter pack and the casing); 2) removal of smeared formation mud on the sides of the bore hole from drilling augers; 3) removal of drilling fluids or surface contamination that may have been introduced during drilling; and 4) removal of water introduced into the boring to aid in drilling, cuttings removal, or monitoring well installation.

1) Surge the well vigorously with a surge block over the entire length of the well screen. The purpose of the surging is to: 1) break up accumulations of fine

materials in the bottom of well casing, and 2) force water back and forth to settle the sand pack.

2) Place a submersible pump or other appropriate pump in the well, near the bottom of the well. The well should be pumped aggressively until well is pumped dry or until discharge is clear. The drawdown of the groundwater and an approximate average pumping rate are noted during and at the completion of the development. Repeat steps 1 and 2 about 3 times or until no further improvement in water clarity is visible.

   A well volume is calculated by adding the volume of water in the casing to the volume of water in the filter pack. Filter pack volume is calculated by multiplying the volume of the annulus between the casing and the borehole by (0.3). This value (0.3) allows for the space occupied by the sand (8-12 and 10-20 grain sizes) in the annulus. A minimum of five well volumes of water should be removed from the well. If water was added to the well during installation, that amount of water should be removed from the well in addition to the five well volumes.

3) The most obvious indication of well development is the clarity of the discharge water. Ideally, the groundwater turbidity should be reduced to 5 nephelometric turbidity units (NTUs) upon completion of development.

4) Monitoring well development activities should be recorded on the Well Development Log and the field logbook. Information recorded should include methods used, volume of water removed, and turbidity readings.

5) Purge water will be stored in an appropriately labeled tank and transported from the generation point to the RP wastewater treatment system for discharge in accordance with the NPDES permit modification granted to RP on September 15, 2003. This will occur on the day of generation. All purge water will be discharged to the RP wastewater treatment system because both hazardous and non-hazardous waste can be disposed of in the RP wastewater treatment system. The quantity of water discharged to the RP wastewater treatment system will be recorded on the 90-Day Investigation Derived Waste Log.

RP - PORTLAND SITE
SOP - 32
TRANSPORT OF HAZARDOUS MATERIALS BY PUBLIC ROAD TO RP PROPERTY

1.0 PURPOSE

To promote proper and consistent packaging, labeling, completion of proper shipping papers, and transport by public road to RP property of waste generated during field investigations.

2.0 EQUIPMENT LIST

1) Site-specific Health and Safety Plan (HASP), including site map;
2) Personal Protective Equipment (PPE) appropriate for the tasks to be performed, and material with which contact will occur (see HASP);
3) Photoionization detector (PID);
4) Department of Transportation (DOT) Class 9 Labels;
5) Bill of Lading/Shipping Papers appropriate for waste transport;
6) Decontamination equipment (see SOP - 3 Decontamination Procedure and event-specific sampling plan for additional site-specific requirements);
7) Daily Waste Generation Log form (attached);
8) Daily Water Disposal/Storage Log form (attached);
9) Field notebook;
10) Indelible ink pens;
11) Heavy duty plastic sacks;
12) Duct tape;
13) UN-certified, removable head, 55-gallon steel drums;
14) Drum inserts;
15) Optional: DOT-approved poly drum (see Task Leader/Project Waste Coordinator for determination of appropriateness); and
16) USDOT Registration Certifications for AMEC and SLLI.

3.0 PROCEDURES

1. Bill of Lading/Shipping Papers

a. A Bill of Lading, less signatures, will be completed prior to commencement of field activities. A Bill of Lading will be prepared satisfying all DOT requirements for shipping papers, including:

   - Contents, with hazardous material listed first;
   - Name of shipper;
   - Emergency response telephone number;
   - Hazardous materials description, in accordance with 49 CFR 172.202;

   For liquid solutions:

   - Environmentally hazardous substances solution, liquid, n.o.s., 9, UN 3082, III, RQ (contains….), total quantity by weight;

   For solid mixtures:

   - Environmentally hazardous substances mixture, solid, n.o.s., 9, UN 3077, III, RQ (contains…), total quantity by weight;

b. A list of likely constituents contained within the shipped containers should be attached to the Bill of Lading;

c. The Bill of Lading will be considered complete upon signing by both the shipper and the carrier/transporter;

d. Provide completed Bill of Lading to the Project Waste Coordinator; and

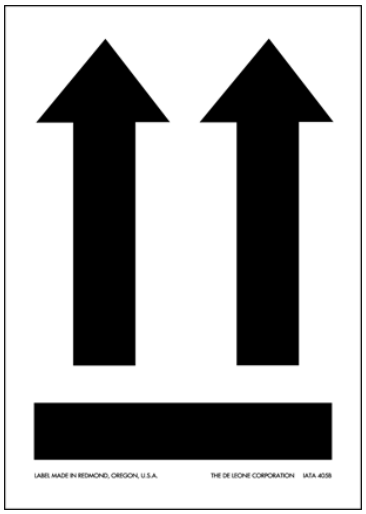
e. The original Bill of Lading will be retained at the site, and a copy of the completed Bill of Lading will be retained at the consultant's office for 2 years following transport.

2. Packaging of hazardous substances

   a. Liquids generated during groundwater sampling

      - Decontamination fluid and purge water generated during decontamination or sampling activities will be contained in an appropriate drum. Please consult with the Project Waste Coordinator for definition of "appropriate" prior to field event.
      - Steel drums require the use of an internal plastic drum liner.
      - Ensure that the locking ring is over the cover and the top lip of the drum, the bolting section extends below the ring (instead of over the lid), and the bolt is tightened securely.
      - Clean external surface of drums
      - Drums containing liquid will be marked with an upright arrow sticker to indicate upright orientation of drum.

Figure 1 Example of Sticker Indicating Upright Position for Drums Containing Liquids



b. Personal Protective Equipment and Debris

- All disposable health and safety PPE (Tyvek® suits, Nitrile gloves, etc.) and debris (used paper towels, disposable tools, etc.) will be collected and stored in heavy-duty, plastic sacks. The sacks with discarded PPE will be placed in UN-certified UN-1A2 removable head steel drums.
- The drums will be lined with a plastic drum insert.
- Ensure that the locking ring is over the cover and the top lip of the drum, the bolting section extends below the ring (instead of over the lid), and the bolt is tightened securely.
- Clean external surface of drums.

3. Labeling

a. The appropriate DOT label will be placed directly onto the upper 1/3 of the side of the container, before the container is loaded for transport.

- Drums containing liquids will be marked with a label identifying contents as “Environmentally hazardous substances solution, liquid, n.o.s., 9, UN 3082, III, RQ.”
- Drums containing solids will be marked with a label identifying contents as “Environmentally hazardous substances mixture, solid, n.o.s., 9, UN 3077, III, RQ.”

Figure 2 Example of Class 9 DOT Label

c. Affix shipping label that includes the appropriate information:

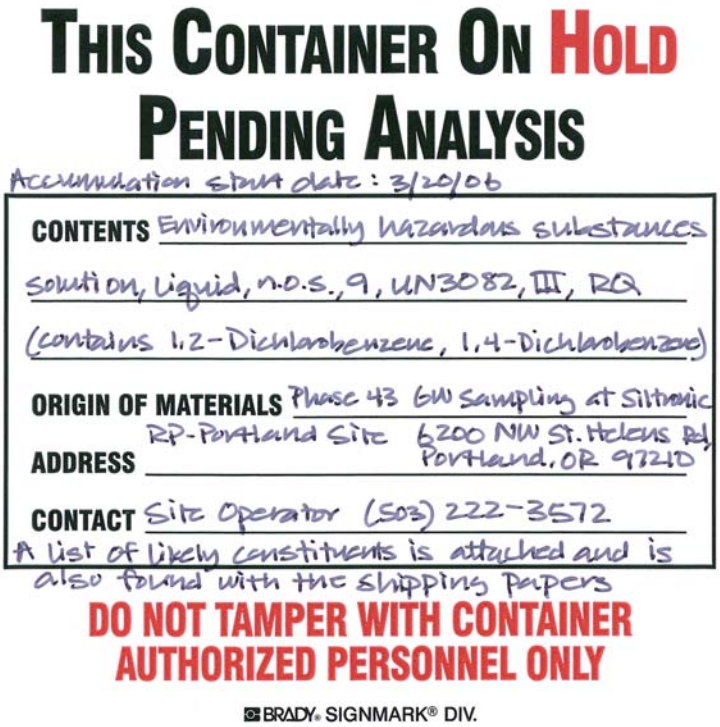
For liquids, use following:

Contents: Environmentally hazardous substances solution, liquid, n.o.s., 9, UN3082, III, RQ (contains LIST TWO OF THE MOST LIKELY CONSTITUENTS)
Accumulation Start Date:
A list of likely constituents is attached and is also found with the shipping papers
Origin of Materials: Phase 43 Groundwater Sampling at NAME SITE
Address: RP-Portland Site, 6200 NW St. Helens Rd., Portland, OR 97210
Contact: Site Operator – 503-222-3572

For PPE/Debris, use following:

Contents: Environmentally hazardous substances mixture, solid, n.o.s., 9, UN3077, III, RQ (contains LIST TWO OF THE MOST LIKELY CONSTITUENTS)
Accumulation Start Date:
A list of likely constituents is attached and is also found with the shipping papers
Origin of Materials: Phase 43 Groundwater Sampling at NAME SITE
Address: RP-Portland Site, 6200 NW St. Helens Rd., Portland, OR 97210
Contact: Site Operator – 503-222-3572

Figure 3 Example of Shipping Label for Drum Containing Liquid



d. A list of likely constituents should be placed in a plastic bag taped to the drum next to the shipping label;

4. Transport

   a. Ensure drums listed for transport match Bill of Lading and are labeled and marked in accordance with DOT regulations

   b. Bill of Lading and will be kept in driver's cab during transport. If AMEC personnel are transporting the material, then the AMEC and SLLI USDOT Registration Certificates shall be kept in the driver's cab during transport.

   c. Arrange for drums arriving at WSF at RP property to be placed on pallets in the "Awaiting Characterization" area.

5. Log Forms

   a. Following receipt at the RP property of the transported materials, a Daily Waste Generation Log and a Daily Water Disposal/Storage Log will be completed with the following information (see SOP - 13):

      - The date;
      - The Phase number;
      - The name of the activity/task (i.e., event) name;
      - The name of the field representative completing the form;

- Waste-specific information (see log forms). All storage and disposal information related to waste waters will be recorded on a Daily Water Disposal/Storage Log. Storage information related to <u>any</u> non-water wastes will be recorded on a Daily Waste Generation Log.
- If a waste is stored in a container, a unique container number should accompany each log entry. NOTE* the unique ID number should be obtained from the Project Waste Coordinator, who is responsible for maintaining the waste management records, including an inventory of the hazardous wastes stored in the WSF.

APPENDIX B

Groundwater Monitoring Field Sheet

amec	**AMEC Earth & Environmental, Inc.** **GROUNDWATER** **SAMPLING FIELD FORM**	Project Name: RP Project #: 0-61M-107030 Monitoring/Sampling Date:

Monitoring Well ID:	Field Personnel:
Start Time:	Weather Conditions: Approx. Air Temp (F):

INITIAL WELL DATA & WELL PURGING INFORMATION

PID (ppm) Background: In well Casing:	PID Calibration Standard:
%LEL Background: In well Casing:	PID Calibration Date:
Date/Time of Measurement: /	Depth to Water Measuring Technique:
Depth Well Bottom (TD) (TOC - ft.):	Detection Method of Free Product:
Depth to Water Level (DTW) (TOC - ft.):	Conversions Factors (casing dia. = gallons/linear ft.) Circle One
Depth to Free Product (TOC - ft.):	0.75" = 0.02 1" = 0.04 2" = 0.17 3" = 0.37
Calculated Column Height (ft.):	4" = 0.66 6" = 1.47 8" = 2.61 12" = 5.88
Casing Diameter (in.):	Three Well Purge Volumes (gallons) = 3 x (TD-DTW) x ___ =____
Quantity of Free Product Collected (gal.):	Method of Collecting Free Product:
Observation of sheen or LNAPL:	Observation of DNAPL:

Casing Volumes (#)	Volume Purged (liters)	Water Temperature (degree C)	Water pH (S.U.)	Specific Conductivity (ms)	Turbidity (NTUs)	Dissolved Oxygen (mg/L)	ORP (mV)	Time (0:00 - 23:59)

Total Purged =	Purge Pumping Rate (approx. L/m):	Well Yield: High / Moderate / Low
Purge Method (circle one): PVC Bailer / Poly Bailer / SS Bailer / Peristalic Pump / Grunfos Pump / Other =		
Ferrous Iron (ppm):	Decontamination Method:	
Instrument Type & Number:	Water Disposal:	
Instrument Calibration Date & Time:	Approx. Pump/Intake Depth:	

WELL CONDITION

Casing (circle one): Stainless Steel Carbon Steel PVC Other:	
Casing Condition: OK / NA / Needs Repairs / Repaired	Lock Condition: OK / NA / Needs Repairs / Replaced
Cap Condition: OK / NA / Needs Repairs / Repaired	Inner Casing Condition: OK / NA / Needs Repairs / Repaired
Paint Condition: OK / NA / Needs Repairs / Repaired	Monument Condition: OK / NA / Needs Repairs / Repaired
Recommended Well Repairs:	

SAMPLING INFORMATION / DATA

Date Sampled: See Reversed	QA/QC Sample (circle one): YES / NO	Water Chemistry Sample: YES / NO
Time Sampled: See Reversed	Sampling Method (circle one): SS Bailer Poly Bailer Grunfos Pump	
Chain-of-Custody #s: See Reverse	Teflon Bailer Peristaltic Pump Other:	

Sample ID	Bottles (total)	Bottles (size)	Preservative	Destination Laboratory	Sample Transporter	Analytical Parameters
See Reverse						

All samples were immediately placed into a cooler and packed with ice or "Blue Ice", unless otherwise noted. _____

Field Observations/Notes of Sampling Event: _____

CERTIFICATION STATEMENT

By signing below, the listed AMEC sampler states that the information provided on this page is accurate.

Sampler (Print): Sampler Signature: Date Signed:

amec	**AMEC Earth & Environmental, Inc.** **GROUNDWATER** **SAMPLING FIELD FORM**	Project Name: RP Project #: 0-61M-107030 Monitoring/Sampling Date:

Monitoring Well ID: | Field Personnel:

INITIAL WELL DATA & WELL PURGING INFORMATION

Casing Volumes (#)	Volume Purged (liters)	Water Temperature (degree C)	Water pH (S.U.)	Specific Conductivity (ms)	Turbidity (NTUs)	Dissolved Oxygen (mg/L)	ORP (mV)	Time (0:00 - 23:59)

WELL CONDITION

Recommended Well Repairs/Additional Notes:

SAMPLING INFORMATION / DATA

Date Sampled: | Chain-of-Custody #s: NCA -

Time Sampled: | Triangle -

Sample ID	Bottles (total)	Bottles (type)	Preservative	Destination Laboratory	Sample Transporter	Analytical Parameters

Field Observations/Notes of Sampling Event:

CERTIFICATION STATEMENT

By signing below, the listed AMEC sampler states that the information provided on this page is accurate.

Sampler (Print): Sampler Signature: Date Signed: