In Situ Stabilization Pre-Design Investigation Work Plan

Arkema Inc. Facility
Portland, Oregon

PREPARED FOR
Legacy Site Services LLC

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ACRONYMS AND ABBREVIATIONS

Acronym	Description
Arkema	Arkema Inc.
cm/s	centimeter per second
COC	contaminant of concern
CRBG	Columbia River Basalt Group
CSM	Conceptual Site Model
DDT	dichlorodiphenyltrichloroethane
DNAPL	dense nonaqueous-phase liquid
DOC	dissolved organic carbon
ERM	Environmental Resources Management, Inc.
FS	Feasibility Study
GWET	Groundwater Extraction and Treatment
HASP	Health and Safety Plan
IRAM	Interim Remedial Action Measure
ISCO	in situ chemical oxidation
ISS	in situ stabilization/solidification
ITRC	Interstate Technology and Research Council
LEAF	Leaching Environmental Assessment Framework
LSS	Legacy Site Services LLC
ODEQ	Oregon Department of Environmental Quality
ORP	oxidation reduction potential
PDI	Pre-Design Investigation
PDI Report	*Preliminary Design Investigation for the GWET Wellfield Enhancement*
PID	photoionization detector
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RAO	remedial action objective
RI	Remedial Investigation
RI Report	*Upland Remedial Investigation Report*

Acronym	Description
ROD	record of decision
Site	the former Arkema facility located at 6400 NW Front Avenue in Portland, Oregon
SPLP	Synthetic Precipitate Leaching Procedure
TOC	total organic carbon
UCS	unconfined compressive strength
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound
Work Plan	*In Situ Stabilization Pre-Design Investigation Work Plan*

PROFESSIONAL ENGINEER'S CERTIFICATION

I, Brendan Robinson, Licensed Professional Engineer in the State of Oregon, hereby certify to the best of my knowledge and belief that this document is true and correct and has been prepared in accordance with general industry standards and applicable federal, state, and local requirements, and hereunto set out hand and affix my seal this second day of July, in the year 2024.

Brendan Robinson, PE
Oregon Professional Engineer License No. 78496PE

1. INTRODUCTION

On behalf of Legacy Site Services LLC (LSS), agent for Arkema Inc. (Arkema), Environmental Resources Management, Inc. (ERM) has prepared this *In Situ Stabilization Pre-Design Investigation Work Plan* (Work Plan) for the former Arkema facility (the "Site") located at 6400 NW Front Avenue in Portland, Oregon. The Site location is shown on Figure 1. ERM prepared this Work Plan to describe the investigation and sampling activities at the Site to inform the pre-design of Interim Remedial Action Measure (IRAM) 1. The goal of IRAM 1 is to address the monochlorobenzene source area that originated in the former Acid Plant Area of the facility (referred to as IRAM 1 Treatment Area) using excavation, in situ stabilization/solidification (ISS), and/or in situ chemical oxidation (ISCO) technologies. The treatment area of IRAM 1 focuses on dense nonaqueous-phase liquid (DNAPL) present in soil and groundwater. Excavation is expected to be used to remove approximately the top ten feet of IRAM 1 treatment area to remove all utilities, clear debris, and to create room for swell (soil that comes out of the borings during ISS due to cement injection and chemical reactions). Additionally, it is anticipated that vadose zone DNAPL will also be addressed by excavation, to the extent that it is encountered.

Implementation of this Work Plan is in accordance with the Oregon Department of Environmental Quality (ODEQ) 19 January 2024 letter (ODEQ 2024) proposing an alternative to the September 2023 *Draft Feasibility Study* (FS; ERM 2023), and as discussed at a meeting with ODEQ, LSS, and ERM on 4 March 2024.

1.1 WORK PLAN OBJECTIVES

The specific objectives of the IRAM 1 Pre-Design Investigation (PDI) are to:

1. Confirm the horizontal and vertical extent of DNAPL present within the IRAM 1 Treatment Area;
2. Evaluate the type and amount of reagents (cement and others as defined in this document) to be added to the various soil types during ISS/ISCO within the IRAM 1 Treatment Area to achieve the preliminary target reduction in hydraulic conductivity, and to evaluate the reduction of the concentration of monochlorobenzene in leachate in samples treated with reagents, compared to control samples; and
3. Collect soil from outside the DNAPL area, but within the dissolved phase plume area, for treatability testing using ISCO reagents.

To meet these objectives, LSS proposes to complete soil borings to:

- Log soil types and elevations
- Conduct visual inspection of soil cores for the presence or absence of DNAPL
- Collect samples to analyze chlorobenzene concentration
- Collect soil samples to perform treatability studies in support of the Preliminary Design of IRAM 1
- Use DyeLIF™ to screen for the presence or absence of DNAPL in situ

- Note: DyeLIF™ can only be used at the site under certain conditions. If DyeLIF™ can't be used at the site, it will be replaced with either direct push or sonic drilling techniques as discussed in Section 2.3

The ISS/ISCO treatability study results and evaluation will be used to evaluate the feasibility of ISS and the mix design if it is implemented. These data will also be used to enhance the existing Conceptual Site Model (CSM) and will be reported in the Preliminary Design Report for IRAM 1.

1.2 WORK PLAN ORGANIZATION

The Work Plan is organized as follows:

- Section 1 – Introduction
- Section 2 – Scope of Work
- Section 3 – Reporting
- Section 4 – Schedule
- Section 5 – References

1.3 SITE LOCATION AND SETTING

The Site is described in further detail in the *Upland Remedial Investigation Report* (RI Report; ERM 2005), the *Preliminary Design Investigation for the GWET Wellfield Enhancement* (PDI Report; ERM 2021), and the FS (ERM 2023). This section summarizes the information contained in these reports.

The Site is located at 6400 NW Front Avenue in the northwest industrial area of Portland, Oregon. The Site is located at approximately river-mile 7.5 of the river in the Guild's Lake Industrial Sanctuary (formerly the Northwest Portland Industrial Sanctuary), zoned and designated "IH" for heavy industrial use. The Site is bordered on the east by the Willamette River, on the south by CertainTeed Roofing Products Company, and on the north and west by Front Avenue. The Site is divided into Lots 1 through 4 and Tract A along the river. For reference, a Layout Map is included as Figure 2.

The Site is generally flat with surface elevations ranging from approximately 25 to 38 feet North American Vertical Datum of 1988. Most of the Site is surrounded by security fencing. The northern portion of the Site includes Lots 1 and 2 and is relatively undeveloped. No manufacturing has occurred on Lots 1 and 2 (ERM 2005). The southern portion of the Site includes Lots 3 and 4, which comprise approximately two-thirds of the Site (39 acres). The Site has historically conducted manufacturing in the southern portion of the Site, and has developed Lots 3 and 4 with buildings, paved roads, rail spurs, and associated tanks and piping to support manufacturing processes. Tract A is a narrow strip of property between the top of the bank and the mean high-water line along the entire riverbank of the Site.

1.3.1 GEOLOGY AND STRATIGRAPHY

The surficial geology in the Site area is characterized by fill and alluvial deposits of the Willamette River. Alluvial deposits are underlain by bedrock of the Columbia River Basalt Group (CRBG). The stratigraphic units of the Site are described in further detail in the RI Report (ERM 2005), the PDI

Report (ERM 2021), and the FS (ERM 2023). Stratigraphic units underlying the IRAM 1 Treatment Area are described below.

The subsurface of the IRAM 1 Treatment Area is characterized by six informal stratigraphic units based on historical subsurface investigations (ERM 2005 and ERM 2021), listed below in stratigraphic order:

- Artificial fill material
- Sandy silt
- Fine-to-medium sand with silt and clay
- Interbedded sand and silt
- Fine sand with clay
- Silt with clay
- CRBG

Each of the alluvial units are generally poorly sorted with the exception of the fine sand with clay unit which exhibits a higher degree of grain size sorting than the other units. Each of the alluvial units are present throughout the IRAM 1 Treatment Area with the exception of the sandy silt. The sandy silt has been historically delineated in the southwestern end of the IRAM 1 Treatment Area, under the Manufacturing Process Residue pond. The surface of the CRBG has been delineated in the northeastern portion of the IRAM 1 Treatment Area, near the riverbank of the Willamette River, at a depth between 53 and 54 feet below ground surface. The depth is expected to be greater in the western portion of the IRAM 1 Treatment Area. These stratigraphic units generally correspond with distinct hydrostratigraphic units (with the exception of the Vadose Zone) at the Site and are described in detail below.

1.3.2 HYDROSTRATIGRAPHY

As previously detailed in the RI Report, PDI Report, and FS, the hydrogeological zones beneath the Site have been designated as the Vadose Zone, Shallow Zone, Shallow-Intermediate Silt Zone, Intermediate Zone, Deep Zone, and Gravel/Basalt Zone (ERM 2005, ERM 2021, and ERM 2023). Each of these hydrogeological zones occur in the IRAM 1 Treatment Area. The hydrogeological zones and their correlation with stratigraphy are described in further detail below.

1.3.2.1 VADOSE ZONE

The Vadose Zone is the unsaturated soil above the uppermost groundwater-bearing zone (i.e., the Shallow Zone). It extends from the ground surface to the top of the Shallow Zone. In the IRAM 1 Treatment Area, the Vadose Zone consists of the artificial fill material, sandy silt, and fine-to-medium sand with silt and clay. The Vadose Zone can produce confining conditions in the southwestern end of the IRAM 1 Treatment Area where the sandy silt has been delineated.

1.3.2.2 SHALLOW ZONE

The Shallow Zone is the uppermost water-bearing zone at the Site. In the IRAM 1 Treatment Area, the Shallow Zone consists of the artificial fill material and fine-to-medium sand with silt and clay.

The Shallow Zone may be confined in the southwestern end of the IRAM 1 Treatment Area where overlain by the sandy silt.

While the regional groundwater flow in the Shallow Zone is from southwest to northeast to the Willamette River, groundwater flow at the Site is more complex where impacted locally by the historical river channel, the groundwater barrier wall, and extraction trench system. The vertical gradient in the Shallow Zone is generally downward, although occasionally upward near the river depending on the river stage.

1.3.2.3 SHALLOW-INTERMEDIATE SILT ZONE

The Shallow-Intermediate Silt Zone is an aquitard consisting of interbedded silt and sand. It is generally continuous and ranges in thickness beneath the IRAM 1 Treatment Area. Where present, the Shallow-Intermediate Silt Zone generally acts as an aquitard between the overlying Shallow Zone and underlying Intermediate Zone.

1.3.2.4 INTERMEDIATE ZONE

The Intermediate Zone is a semi-confined water-bearing zone comprised of fine sand with clay. It is generally overlain by the Shallow-Intermediate Silt Zone aquitard, where present, and underlain by the Deep Zone. The Intermediate Zone can be confined depending on the thickness of the overlying Shallow-Intermediate Silt Zone. The Intermediate Zone is continuous and extends laterally through the IRAM 1 Treatment Area.

While the regional groundwater flow in the Intermediate Zone is toward the northeast where it discharges to the river, groundwater flow at the Site is more complex where impacted locally by the historical river channel, the groundwater barrier wall, and extraction trench system. The vertical gradient in the Shallow Zone is generally downward, although occasionally upward near the river when the river stage is high.

1.3.2.5 DEEP ZONE

The Deep Zone is an aquitard consisting of silt with clay, and it lies below the Intermediate Zone and above the Gravel/Basalt Zone. The Deep Zone generally thins to the northeast, toward the river where the underlying CRBG rises. In the IRAM Treatment 1 Area, groundwater flow in the Deep Zone is generally northeast toward the river, but the groundwater source control operations influence gradients and flow locally. The vertical gradient in the Deep Zone is generally downward; however, it is occasionally upward near the river depending on the river stage.

1.3.2.6 GRAVEL/BASALT ZONE

The Gravel/Basalt Zone in the IRAM 1 Treatment Area consists of the CRBG. It slopes upwards to the northeast from the upland towards the river.

1.4 SITE HISTORY AND DESCRIPTION

Starting in 1941, various chemicals were produced at the facility including: sodium chlorate, potassium chlorate, chlorine, sodium hydroxide, dichlorodiphenyltrichloroethane (DDT), sodium orthosilicate, magnesium chloride hexahydrate, ammonia, ammonium perchlorate, sodium perchlorate, and hydrochloric acid. Most recently, the facility was a chlor-alkali plant until the plant shut down in 2001 and the plant was decommissioned and dismantled in 2004. The RI Report (ERM 2005) described historical Site operation and manufacturing processes.

Currently, most of the Site is paved, gravel-covered/capped, or covered with building foundations. The only structures currently present are the building constructed to house the Groundwater Extraction and Treatment (GWET) system, three small motor-control buildings, a temporary trailer used as the Site office, and the original plant administration building. The only current activities at the Site are general maintenance and those associated with remediation.

1.5 NATURE AND EXTENT OF IRAM 1 TREATMENT AREA

The IRAM 1 Treatment Area includes the former Manufacturing Process Residue pond and overflow trench (i.e., DDT Trench) where disposal of spent chlorobenzene (i.e., DNAPL) occurred historically, as well as areas where soil and groundwater are impacted by DNAPL from the former Manufacturing Process Residue pond. This area also contains soils impacted by metals and pesticides at concentrations that exceed criteria for both direct exposure and leaching to groundwater pathways as well as volatile organic compounds (VOCs; e.g., monochlorobenzene) in soil that exceed leaching to groundwater criteria. This area also contains metals, chloride, VOCs, and pesticides in the groundwater in the Shallow, Intermediate, and Deep Zones; and furans and DNAPL in the Shallow Zone. The historical Site layout showing the IRAM 1 Treatment Area is included on Figure 2. Historical operation areas are depicted on Figures 3 and 4.

1.6 INTERIM REMEDIAL ACTION MEASURE – REGULATORY BASIS

The ODEQ-approved *Final Modification Revised Upland Feasibility Study Work Plan* (ERM 2022) lists the Site-specific remedial action objectives (RAO), as follows.

- RAO 1 – Reduce upland human health risks to acceptable risk-based levels from incidental ingestion, inhalation, and direct contact with soil under trespasser, outdoor worker, outdoor worker after redevelopment, and construction worker scenarios.
- RAO 2 – Reduce riverbank terrestrial ecological risks to acceptable risk-based levels from ingestion and direct contact with soil.
- RAO 3 – Prevent or reduce the potential for migration of contaminants of concern (COC) in surface soil and riverbank soil to accumulate in river sediment above acceptable risk-based levels.
- RAO 4 – Treat or remove soil hot spots to the extent feasible based on remedy selection factors.
- RAO 5 – Prevent or reduce the migration of groundwater COCs to the river above acceptable risk-based levels for surface water receptors.
- RAO 6 – Treat or remove groundwater hot spots to the extent feasible based on remedy selection balancing factors.
- RAO 7 – Reduce the potential for DNAPL to act as a continuing source of COCs in groundwater.
- RAO 8 – Treat or remove DNAPL hot spots to the extent feasible based on remedy selection balancing factors.

- RAO 9 – Reduce the migration of COCs in stormwater to the river that are at or above acceptable risk-based concentrations for surface water receptors.
- RAO 10 – Reduce the migration of COCs in stormwater to the river to prevent accumulation of COCs in river sediment above risk-based levels.

The ODEQ prepared a memorandum (ODEQ 2024) that summarizes its findings on the FS (ERM 2023) for LSS. In the memorandum, ODEQ proposed an alternative path forward focused on IRAMs to achieve the following objectives:

1. Expedite the necessary remediation to address high-risk and/or well-defined contamination.
2. Decrease potential uncertainty in the FS by resolving data gaps and conducting additional performance monitoring.

ODEQ proposed the implementation of IRAM 1 (detailed in Section 1) as an alternative path forward for the following advantages:

- To accelerate cleanup of highest risks (i.e., DNAPL)
- Reduce pesticide co-solvency with chlorobenzene and potentially improve GWET influent characteristics
- Improve near-term source control status in the stranded wedge outside of the groundwater barrier wall
- Reduce the likelihood of a post-record of decision (ROD) administrative change (i.e., Explanation of Significant Differences or ROD Amendment)
- Reduce the scope/magnitude of post-ROD cleanup actions
- Provide a clearer path to Site closure

1.7 CONCEPTUAL SITE MODEL

In 2006, ERM conducted a DNAPL investigation on behalf of LSS (ERM 2006). This study drilled throughout the Acid Plant Area of the Site between the suspected source of DNAPL contamination (i.e., the DDT Trench) and the top of bank. The extent of the DNAPL contamination identified during this investigation is shown on Figures 2 and 3. This investigation was conducted using a direct push drilling rig and did not drill beyond the Shallow Intermediate Silt Zone. This unit acts as an aquitard, and it was assumed that DNAPL that entered at the surface would largely be present on top of this aquitard. Additionally, penetration of the aquitard increased the risk of DNAPL migrating into the underlying stratigraphy. The CSM for this investigation is shown on Figure 5 and identifies the presumed source area of DNAPL, where DNAPL was identified in the 2006 study, and how the borings planned in this investigation relate to the potential distribution of DNAPL at the Site.

2. SCOPE OF WORK

This Work Plan describes the field and analytical procedures to be conducted during the PDI to gather sufficient and usable data to evaluate the feasibility of ISS/ISCO for IRAM 1, and the associated design criteria. This study also seeks to confirm the lateral extent of DNAPL in the

Shallow Zone and Shallow Intermediate Silt Zone identified in 2006, and to characterize the vertical and horizontal extent of DNAPL in the Intermediate and Deep Zones. The planned boring locations for each phase of investigation are shown on Figure 6.

2.1 IDENTIFYING BORING LOCATIONS AND SUBSURFACE CLEARANCE

Prior to any subsurface investigative activities, ERM will implement subsurface clearance procedures. ERM will review subsurface utility records, as-built drawings, and historical information to select boring locations that are sufficiently far from known existing surface and subsurface utilities. A public utility mark-out will be performed to identify subsurface utilities and then a private utility locating firm will be subcontracted to clear areas where subsurface work will be performed. Boring locations will be cleared if known active utilities are present within approximately 10 feet of the drilling location (e.g., active pumping infrastructure) using an air-knife and vacuum truck, per ERM subsurface clearance procedures, before powered drilling equipment is used. Boring outside areas of known utilities may be completed without physical preclearance per instructions from LSS. Where used, air-knife and vac truck will be employed to a depth of 8 feet below ground surface, refusal, or to a depth of 2 feet greater than the depth of known utilities within 10 feet of the proposed drilling location.

Ground surface elevation and geospatial location of the boring locations will be surveyed following drilling completion. The planned boring locations are shown on Figure 6.

2.2 SOIL SAMPLING

ERM proposes to conduct two mobilizations to characterize and delineate the DNAPL plume within the IRAM 1 Treatment Area. During Mobilization #1, the goal is to define the vertical extent of DNAPL contamination and to collect soil samples for the treatability study. The goal of Mobilization #2 (described further below) is to confirm the lateral extent of DNAPL contamination. ERM plans to perform soil borings with soil sample recovery during Mobilization #1. The soil sampling procedures are as follows:

- ERM proposes to advance approximately 20 to 30 borings within the DNAPL zone and outside of the DNAPL zone during Mobilization #1, as illustrated on Figure 6, using sonic drilling technology. Additional borings may be added while in the field based on field screening results. Specifically, if a boring is located at the previously defined lateral extent of the known DNAPL zone and is found to have DNAPL in the soil, additional borings will be added to refine the limit of the DNAPL zone (i.e., until DNAPL is not encountered).
    - Each boring will be drilled until refusal or until the CRBG is encountered. In the case where refusal is encountered unrelated to the CRBG, an adjacent boring location in the vicinity will be investigated. Borings that go through the interfaces of the Shallow Intermediate Silt Zone and Intermediate Zone, and the Intermediate Zone and the Deep Zone, will be cased off to reduce the potential for contaminant migration. The borings will start with a 10-inch core barrel, reducing to an 8-inch barrel, and finally a 6-inch barrel as each section is cased off. The following procedure will be used to seal each zone to prevent potential DNAPL migration:

1. Drill and case with 10-inch core barrel to the depth where the bentonite seal will be placed and clean out boring (e.g., at the top of the Shallow Intermediate Silt Zone).
2. Pour approximately 4 feet of bentonite chips into the casing.
3. Pull the 10-inch casing back 2 feet to allow the dry bentonite chips to take up the annulus created by the casing.
4. Put hydrant water into the casing and hydrate the bentonite chips for 1 hour.
5. Drill with a 6-inch core barrel past the bottom of the bentonite seal (typically 5 to 10 feet).
6. Advance the 8-inch casing to the depth the core barrel drilled until the next confining unit is reached, then repeat the process using smaller tooling each time an aquitard is penetrated.

- Cores will be sampled as described below from ground surface to boring termination.
- Each core will be visually inspected for indications of DNAPL with the assistance of an oil-soluble dye, as necessary. Soil cores will be screened for evidence of VOCs using a photoionization detector (PID).
  - Oil-soluble dye testing will be completed using a non-hazardous Oil-in-Soil™ test kit or similar, commonly referred to as a shake test. This kit provides a graduated jar, oil-soluble indicator dye, water-soluble contrast dye, and styrene indicator ball. Unconsolidated soil is added to the jar to the first line, then warm tap water is added to the second line. The jar is capped and shaken for 30 seconds or until the dye cube is completely dissolved, then allowed to settle for 1 minute. Red staining of the styrene indicator ball is a positive indication of DNAPL with a detection limit of 500 parts per million. Warm tap water will be kept in an insulated carafe at the sampling location.
- If sonic drilling soil cores appear too disturbed for adequate soil logging, Lexan liners may be used during drilling to improve sample integrity.
- Soil will be logged and photo-documented by a qualified ERM geologist and reviewed by an Oregon-Registered Geologist. Soil lithology will be logged and classified according to the Unified Soil Classification System. Boring lithology will be incorporated into the CSM and reviewed to focus the drilling locations for Mobilization #2.
- Soil will be preliminarily categorized as contaminated, some contamination, or no evidence of contamination based on the following criteria:
  - Soil with visible DNAPL will be categorized as "Contaminated."
  - Soil with no visual indications of DNAPL, but a positive oil soluble dye test or staining, will be categorized as "Some DNAPL Contamination."
  - Soil with no visual indications of DNAPL, a negative oil soluble dye test, and no staining will be categorized as "No Evidence of DNAPL Contamination."
- Soil samples will be collected from depth intervals determined in the field based on visual indications of DNAPL presence, field measurements from the PID, and oil-soluble dye test results. Up to three samples will be collected from each boring corresponding to soil that is categorized as "Contaminated," "Some DNAPL Contamination," and "No Evidence of DNAPL

Contamination." Soil samples will be collected to determine VOC concentrations and correlate concentrations with field observations. Soil samples will be submitted for laboratory analysis by United States Environmental Protection Agency (USEPA) Method 5035/8260D. Depending on field and laboratory observation, a modified version of the USEPA 5035 prep method may be used, in which a slightly lower than recommended soil-to-methanol weight ratio would be collected to prevent methanol saturation with monochlorobenzene.

- Additional soil from the "Contaminated," "Some DNAPL Contamination," and "No Evidence of DNAPL Contamination" will be collected for treatability study testing and stored onsite in cold storage (preserved at0 degrees Celsius or less, with a target of -10 degrees Celsius). These samples will be segregated by contamination category and by stratigraphic category, if material differences in stratigraphy are encountered in the "Contaminated" samples per ODEQ's request. To represent the vertical mixing of the ISS implementation, samples in the "Contaminated" category will include up to 2.5 linear feet of soil above and 2.5 feet below the contamination boundary, and will be biased approximately 1:1 between "Contaminated" and adjacent not contaminated soil, by volume. The field team will attempt to collect 25 gallons of soil from the "Contaminated" or "Some Evidence of DNAPL Contamination" groupings.
  - Samples will be stored in 2-1/2 gallon UN-rated buckets lined with solvent-resistant polypropylene bags, labeled with the location, depth interval, visual contamination category, and stratigraphic zone. The headspace of the bag will be eliminated to the greatest practical extent then the bag will be heat sealed. The buckets will be sealed with a gasketed lid when not in use. All samples will be moved to cold storage for preservation following the sealing procedure.
- Treatability testing samples will be prepared from the soil stored onsite and sent to Loureiro Engineering Associates, Inc. or Evonik Industries for treatability testing using the Synthetic Precipitate Leaching Procedure (SPLP), tank method, and Leaching Environmental Assessment Framework (LEAF) methods along with additional analyses. Treatability testing is discussed further below in Section 2.4. The follow apply to the treatability testing samples:
  - Soil will be homogenized by the laboratories prior to conducting the treatability study.
  - Soil for treatability testing will be shipped under chain of custody and preserved with ice in transit to the treatability lab.
  - Any soil that remains after samples are shipped for treatability testing will be retained in onsite freezers until it is determined that the treatability labs have adequate volume for all testing.
- Dakota Technologies, Inc., requests that ERM send samples intended to be representative of the range of potential field conditions, including naturally occurring organic material, "Contaminated," "Some DNAPL Contamination," and "No Evidence of DNAPL Contamination" categories, as encountered in the field. These samples will be utilized to evaluate compatibility with the DyeLIF™ system and establish a response curve with respect to concentration.

2.3 DYE-ENHANCED LASER INDUCED FLUORESCENCE LOGGING

The DyeLIF™ method combines a direct-push probe with hydrophobic dye injection. The hydrophobic dye is solvated by the DNAPL and then has a different fluorescent signature than the un-solvated dye. The DyeLIF™ probe detects the fluorescent response of the solvated dye, and this is correlated to a concentration of DNAPL. In turn, this allows the instrument to detect or not detect DNAPL in situ. Because this method uses direct push technology with no outer casing, it is not possible to use step down casing with this tool. As a result, DyeLIF can only be used to delineate the DNAPL area if DNAPL contamination does not extend beneath the Shallow Intermediate Silt Zone. If DNAPL is found beneath the Shallow Intermediate Silt Zone, those areas will be investigated using step down casing as described in this report using sonic or direct push drilling technology as described in this work plan.

If DyeLIF™ can be used at the site, Dakota Technologies will be contracted (along with their drilling subcontractor) during Mobilization #2 to perform the DyeLIF™ method within the IRAM 1 Treatment Area to confirm the lateral extent of DNAPL contamination. The logging procedures are as follows:

- DyeLIF™ technology will be used between the margins of known DNAPL contamination and areas without DNAPL contamination to refine the boundary of DNAPL contamination, and thus the treatment area for IRAM #1, as shown in Figure 7.
- The direct-push probe will be advanced to the Shallow Intermediate Silt Zone to measure for the presence or absence of DNAPL. The step-out decision tree is summarized on Figure 7. In the case that refusal is encountered, the drilling location will be stepped out perpendicularly from the DyeLIF™ transect to a distance equivalent to the length of DyeLIF™ spacing.
- A Dakota Technologies DyeLIF™ expert will provide ERM with a detailed analysis of the data and a written report to ERM.

The CSM will be updated using DyeLIF™ results, geologic logging, and screening information, along with the analytical results. The CSM will be reviewed to identify residual impacts for targeted remediation. The logs, analytical results, and CSM will be included in the forthcoming Preliminary Design Report. The DyeLIF™ technology is not conducive to using with case-down drilling techniques. Therefore, it can only be used to drill to refusal if a given boring is non-detect for DNAPL. If DNAPL is encountered, the boring will not be advanced through any aquitards that exist below the DNAPL.

2.4 IRAM 1 ISS/ISCO BENCH-SCALE TREATABILITY STUDY

The intent of an ISS remedy is to bind COCs and encapsulate COCs in a low permeability monolith that will reduce the mobility of COCs in soil (DNAPL) and groundwater (dissolved fraction). This is accomplished by mixing the soil in situ, and adding water and Portland cement. In addition, ISS creates a lowered permeability zone that reduces groundwater flux through the monolith and promotes groundwater flow around the monolith. Additional amendments like ISCO or activated carbon can further destroy or sorb COCs to enhance the effectiveness of the Portland cement.

This treatability study will evaluate the effect of various concentrations of Portland cement (5 percent to 15 percent by weight) on the strength and permeability of treated soil, as well as the effects of various concentrations of cement-activated sodium persulfate (i.e., ISCO) and activated carbon.

Soil recovered from the borings during DNAPL plume delineation will be used to perform two parallel treatability studies:

- Saturated Soil will be collected from outside the DNAPL plume area, but inside the dissolved plume area (i.e., adjacent to the DNAPL plume). These samples will be tested to evaluate the total oxygen demand and soil oxygen demand present in saturated soil from the dissolved plume area. These data will be used to evaluate the type of remedial agent and quantity that may be required by a future IRAM to address COCs in groundwater if IRAM #1 does not fully achieve its objectives.
- The primary treatability study that is the focus of this Work Plan is an ISS/ISCO bench-scale treatability study. The treatability study will evaluate the effectiveness of various mix designs at binding COCs to soil, and reducing soil permeability, thus reducing the concentration of COCs in leachate (i.e., water surrounding the monolith).

The goals of the treatability study testing are to:

- Evaluate the reduction in leachability of the COCs from the treated soils for the conditions tested to identify the most effective and economical amendment blends.
- Determine the effects of treatment on soil strength and permeability, with the preliminary goal of achieving a hydraulic conductivity of 10^{-6} centimeters per second (cm/s), and a minimum soil unconfined compressive strength (UCS) of 50 pounds-force per square inch.
- Determine the degree of swell (i.e., expansion in soil volume) due to the addition of ISS amendments based on bulk density measurements of soil pre- and post-treatment and for cost considerations.
- Determine the effect of exothermic grout curing on the release of VOCs.

These performance goals are general field measures for ISS/ISCO and are consistent with the July 2011 Interstate Technology and Research Council (ITRC) guidance document *Development of Performance Specifications for Solidification/Stabilization* (ITRC 2011). The subsequent design may consider alternative targets based on the treatability testing results.

The ISS/ISCO amendments that will be evaluated during the treatability study are:

- Cement
- Activated carbon
- Cement-activated sodium persulfate

Additionally, trials will be conducted with the ISS/ISCO amendments at various concentrations to evaluate the effect of various amendment rates (or combinations thereof) on the relative reduction of COCs in leachate and thereby as a surrogate for post-mix groundwater conditions.

2.4.1 PHASE 1 TREATABILITY STUDY

Soil collected in the field will be homogenized by the treatability study laboratory, and will be formed into standard sized monoliths. The standard SPLP method requires monolithic samples to be broken into pieces of 3/8 inch or less in diameter prior to conducting the leaching procedure. This step would break up the monolith created by the addition of Portland cement, which is not representative of ISS in the field, and creates an unrealistically conservative test case. Therefore, the treatability study will follow the modified SPLP method that will use the same test conditions, solution, duration, and other factors, but does not crush or breakup the sample, keeping the monolith as whole as possible during the test.

The tank method is an internal leaching method developed by each lab to provide a rapid determination of which reagents to advance to LEAF testing. The tank method is based on ANSI method 16.1 and is similar to the LEAF method with four to five time intervals over 28 days rather than nine time intervals over 63 days.

For each test condition, the soil will be mixed with the amendments. After the amendments, water and soil are thoroughly combined, the mixtures for each test condition will be transferred to several replicate molds to supply the laboratories with enough sacrificial samples per analysis per time point. The molds will consist of high-density polyethylene, 2- x 4-inch cylinders, and will be allowed to cure at room temperature until sacrificed for analysis. The number of samples and analyses proposed in Phase 1 are shown in Table 1.

Prior to sacrificing the treated soil cylinders as described below, the laboratory will inspect the demolded soil cylinder for evidence of free liquid, sheen, supernatants, gels, DNAPL, cracking, or other evidence of physical degradation, and will record and report their observations.

Each amendment mix will be molded and cured for 28 days, then the UCS will be measured according to ASTM method D1633, Standard Test Methods for Compressive Strength of Molded Soil-Cement Cylinders. The acceptable range of UCS is 50 to 60 pounds-force per square inch.

The permeability of each amendment mix will be measured according to ASTM method D5084, Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter, following a 28-day cure time. The permeability of the baseline consolidated soil will be measured using ASTM method D2434, Standard Test Method for Permeability of Granular Soils (Constant Head). The permeability of the cured sample will be compared to the baseline permeability. The preliminary target permeability of the amended mix is no greater than 10^{-6} cm/s. However, the permeability will be considered together with the key performance criteria of leachability reduction when selecting the mixes to retain for Phase 2 testing. If the native soil is very permeable and a permeability of 10^{-6} cm/s is not achievable, a goal of a 2-3 order of magnitude reduction in permeability may be used.

The pH and oxidation reduction potential (ORP) of the baseline soils will be measured in the field using a direct reading probe designed for soil (ExTech PH220-C or similar) and recorded in field logbooks. ORP is a time-sensitive measurement due to the anaerobic soil absorbing oxygen upon contact with air, which contraindicates laboratory measurement of baseline samples.

The pH and ORP of the aqueous phase of the ISCO-only amended soils will be measured in the lab using a direct reading probe. The ORP of ISCO-amended soils is not readily affected by exposure to air due to the strongly oxidizing chemical mixed with the soil.

The total organic carbon (TOC) of the baseline soil and of the ISCO-only amended soils will be measured using USEPA method 9060A. The baseline soil and the aqueous phase of the ISCO-only amended soil will also be analyzed for dissolved organic carbon (DOC). The DOC of the baseline soil will be leached into deionized water using United State Geological Survey method 31.

Off-gassing of the treated soil induced by exothermic grout curing will be assessed by placing a molded cylinder or other representative aliquot of baseline or amended soil into an impermeable plastic bag and measuring the VOC concentration of the headspace using a 10.6-electronvolt PID. Measurements will be collected immediately after placing the mold in the bag, after 24 hours, and after 72 hours.

The reagents that show the best performance from modified SPLP testing will be advanced to tank testing. The concentration of COCs in leachate, compressive strength, and hydraulic conductivity will be considered in selecting the mix designs that achieve the greatest reductions in COC concentrations and hydraulic conductivity for testing in Phase 2.

2.4.2 PHASE 2 TREATABILITY STUDY

The reagent(s) that show the best performance from Phase 1 testing will be advanced to leachability testing using the USEPA 1315 LEAF method. The LEAF method provides the release rates of COCs from a monolithic sample in which the predominant water flow is around, not through, the sample. The LEAF method is generally a more accurate representation of the potential for leaching that may occur from a solidified monolithic mass over time compared to the modified SPLP method or tank method. The same procedures as the modified SPLP, for creating the monoliths, will be followed during the setup of the LEAF mixtures.

The LEAF method determines the mass-transfer release rate over a series of nine time points for each test condition as the monolith cures over time. At each of the time points, VOCs and pesticides will be measured for each test condition. Semivolatile organic compounds, metals, pH and ORP, TOC, and DOC will be measured for each test condition at the beginning, middle, and end of the study. At the completion of the 63-day study, each of the treatment options will be evaluated for performance compared to the control. The number of samples and analyses proposed in Phase 2 depend on the results from Phase 1, but are estimated in Table 2.

The UCS and permeability of each Phase 2 amendment mix will be measured as described above after a 28-day cure time and again after a 56-day cure time. If a mix shows results are within the required range after 28 days, the 56-day test may be omitted.

2.5 EQUIPMENT DECONTAMINATION AND WASTE MANAGEMENT

Sampling, drilling, and other field equipment will be decontaminated prior to use and between sample locations. Sampling equipment will be scrubbed with an aqueous solution of laboratory grade detergent, followed by a rinse with tap water, followed by an isopropyl alcohol rinse, followed by a rinse with deionized water.

Soil cuttings and other solids derived from the soil borings will be placed in a double-lined and covered roll-off box suitable for asbestos-containing material (if encountered). Representative composite soil samples will be collected for waste characterization. Soil will be segregated into different containers depending on the anticipated disposal pathway (e.g., asbestos-containing material, state only hazardous waste, etc.). Composite samples will be analyzed in accordance with requirements specified by the waste disposal facility based on generator knowledge. Each boring will be abandoned immediately upon completion using bentonite grout applied with a tremie pipe. All downhole equipment will be decontaminated on a temporary decontamination pad prior to and after each boring, whereas sampling equipment will be hand washed during sampling activities.

Investigation-derived waste generated during soil sampling activities will be placed in a roll-off container and sampled prior to disposal. Decontamination fluids and purge water will be contained in 300-gallon intermediate bulk containers (totes) and then processed in the GWET system. Disposable sampling equipment and used personal protective equipment will be disposed of as non-hazardous solid waste.

2.6 QUALITY ASSURANCE PROJECT PLAN AND HEALTH AND SAFETY PLAN DEVELOPMENT

This Work Plan incorporates previously approved work plans to utilize approved sampling and analysis methods, standard operating procedures, and quality assurance/quality control (QA/QC) procedures. As shown in Tables 1 and 2, ERM plans to include a duplicate, matrix spike, and matrix spike duplicates of samples to confirm the validity of the data obtained during the treatability study. To the extent that there are any inconsistencies to references, the previously approved work plans control in the following order:

1. 2011 Addendum Update to the Quality Assurance Project Plan (QAPP) provided within the *Elf Atochem Acid Plant Area Remedial Investigation and Feasibility Study Work Plan* (Exponent 1998)
2. *Draft – Data Gaps Assessment Work Plan* (ERM 2009), and the addendum to the QAPP to the *Elf Atochem Acid Plant Area Remedial Investigation and Feasibility Study Work Plan* submitted as part of groundwater sampling
3. *Elf Atochem Acid Plant Area Remedial Investigation and Feasibility Study Work Plan* (Exponent 1998)

ERM will develop a Health and Safety Plan (HASP) prior to performing any field activities. The HASP will be prepared to document the procedures required to ensure the safety of the Site workers and surrounding community during the completion of field activities, and to also address the actions required in the event of an emergency situation. The HASP will include information on personnel training, personal protective equipment, anticipated COCs, potential health risks, emergency contact numbers, hospital routes, action levels, and other health and safety-related concerns.

2.7 QUALITY ASSURANCE AND QUALITY CONTROL

2.7.1 FIELD SAMPLES

Field QA/QC samples will be collected in accordance with the QAPP and associated addenda as described in Section 2.6. Trip blanks will be included in each cooler that contains VOC samples.

For every 20 samples collected and submitted for analysis, the following QA/QC samples will be collected:

- One field duplicate sample
- One equipment rinsate sample to verify efficacy of decontamination of equipment, collected for every 20 samples
- One matrix spike/matrix spike duplicate

Field notes taken during sampling activities will be recorded in the field logbook. Samples will be immediately labeled following collection, with the required data. Sample data will be entered into the Chain-of-Custody record to ensure proper tracking and control. Analytical samples will be shipped or delivered to the laboratory in sealed containers and accompanied by the Chain-of-Custody record. QA/QC samples will be collected, controlled, and shipped in the same manner as normal field samples.

2.7.2 LABORATORY SAMPLES

Treatability lab QA/QC samples will be collected in accordance with the QAPP and associated addenda as described in Section 2.6. For every 20 samples collected and submitted for analysis, the following QA/QC samples will be collected:

- One treatability lab duplicate sample
- One matrix spike/matrix spike duplicate

A minimum of one lab duplicate and a minimum of one matrix spike / matrix spike duplicate will be collected if the total number of samples is less than 20. Lab notes will be recorded in the lab's logbook. Samples will be immediately labeled following collection, with the required data. Sample data will be entered into the Chain-of-Custody record to ensure proper tracking and control. Analytical samples will be shipped or delivered to the laboratory in sealed containers and accompanied by the Chain-of-Custody record. QA/QC samples will be collected, controlled, and shipped in the same manner as normal lab samples.

A duplicate of LEAF test condition #1 will be assessed for a single random time point between 2 and 28 days. The eluate will be changed as normal until the set time. Following sample collection including matrix spike / matrix spike duplicate, the duplicate sample will be discarded.

3. REPORTING

ERM anticipates that the ISS/ISCO bench-scale treatability study results will be available from the laboratory within 16 to 25 weeks of receipt of soil by the laboratory. Results from the DNAPL investigation and treatability testing will be included in a Preliminary Design Report, which will include the analytical data and field observations made during the PDI, as well as the treatability study results. This information will be used to identify the volume of soil proposed for treatment, as well as the mix design consisting of what reagents will be used, and their quantities.

4. SCHEDULE

The estimated schedule is presented below:

- The sampling activities described in Sections 2.3 and 2.4, above, are anticipated to be completed in 20 to 30 onsite working days for the soil sampling program activities and 14 onsite working days for the DyeLIF™. The soil sampling program will be overseen by two ERM field technicians/geologists, while the DyeLIF™ will be overseen by one ERM field technician.
- The Bench-Scale Treatability Study schedule is expected to be completed by year-end 2024, with mobilization for IRAM 1 fieldwork starting in 2025. The schedule for specific tasks within the planned scope of services is anticipated as follows:
  - Test setup following receipt of samples: 1 to 2 weeks
  - Typical time for sample curing: 2 to 4 weeks for UCS/permeability
  - Time to receive sample results: 2 to 3 weeks after submitting samples
  - Review results, plan Phase 2 LEAF, and set up samples: 1 to 2 weeks
  - Typical time for sample curing: 4 weeks for UCS/permeability
  - LEAF testing: 9 weeks
  - Receipt of results: 2 to 3 weeks
  - Final report: 1 to 2 weeks

The proposed project schedule may be affected by outside conditions including, but not limited to:

- Weather
- Surface and subsurface Site conditions
- Contractor availability
- Regulatory approvals
- Utility clearance and location

5. REFERENCES

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TABLES

Table 1
Phase 1 In Situ Stabilization Test Conditions and Analyses
Portland, Oregon

PHASE 1 ISS, ISS/ISCO and ISCO Test Conditions

Treatability Sample			Mix Ratios (% weight of dry soil)			UCS	Permeability	Modified SPLP 1312[1] Whole Monolith[4][5]			Total COCs in Soil			Total COCs in Water	Modified Tank Method (28 day) [4][5]			Other					
			PC	C	SP	28 Day	28 Day	VOCs	DDx	pH	VOCs	DDx	pH	VOCs	VOCs	DDx	pH	TOD	ORP	TOC	DOC[7]	Curing VOCs[6]	Volumetric Expansion
Contaminated[3] (e.g. DNAPL from different lithology if encountered)	Baseline [2]						2	2	2	2	6	6	6					1		1		1	1
	Control														1	1	1						
	5% PC	5% PC	5%			2	2	2	2	2					1	1	1					1	1
		5% PC, 1% C	5%	1%		2		2	2	2												1	1
		5% PC, 4% C	5%	4%		2		2	2	2												1	1
		5% PC, 1% SP	5%		1.0%	2		2	2	2												1	1
		5% PC, 2.5% SP	5%		2.5%	2	2	2	2	2					1	1	1					1	1
	10% PC	10% PC	10%			2	2	2	2	2												1	1
		10% PC, 5% SP	10%		5.0%	2	2	2	2	2												1	1
	15% PC	15% PC	15%			2	2	2	2	2					1	1	1					1	1
		15% PC, 1% C	15%	1%		2		2	2	2												1	1
		15% PC, 4% C	15%	4%		2		2	2	2												1	1
		15% PC, 1% SP	15%		1.0%	2		2	2	2					1	1	1					1	1
		15% PC, 5% SP QC DUP/MS/MSD	15%		5.0%	1	1	3	3	3					3	3	1					1	1
		15% PC, 5% SP	15%		5.0%	2	2	2	2	2					1	1	1					1	1
	ISCO	Control									1	1	1	1					1	1	1		
		Alk-SP 1%									1	1	1	1					1	1	1		
		Alk-SP 2%									1	1	1	1					1	1	1		
Some DNAPL Contamination	Baseline [2]						1	1	1	1	3	3	3					1		1		1	1
	Control														1	1	1						
	5% PC	5% PC	5%			1	1	1	1	1					1	1	1					1	1
		5% PC, 1% C	5%	1%		1																1	1
		5% PC, 4% C	5%	4%		1																1	1
		5% PC, 1% SP	5%		1.0%	1		1	1	1												1	1
		5% PC, 2.5% SP	5%		2.5%	1	1	1	1	1					1	1	1					1	1
	7.5% PC	7.5% PC	7.5%			1	1	1	1	1												1	1
		7.5% PC, 5% SP	7.5%		5.0%	1	1	1	1	1												1	1
	10% PC	10% PC	10%			1	1	1	1	1					1	1	1					1	1
		10% PC, 1% C	10%	1%		1																1	1
		10 PC, 4% C	10%	4%		1																1	1
		10% PC, 1% SP	10%		1.0%	1		1	1	1												1	1
		10% PC, 2.5% SP	10%		2.5%	1																1	1
		10% PC, 5% SP	10%		5.0%	1	1	1	1	1					1	1	1					1	1
	ISCO	Control			0.0%						1	1	1	1					1	1	1		
		Alk-SP 1%			1.0%						1	1	1	1					1	1	1		
		Alk-SP 2%			2.0%						1	1	1	1					1	1	1		
No Evidence of DNAPL Contamination (i.e., outside of DNAPL area, within dissolved plume)	ISCO	Baseline									1	1	1	1				1		1			
		Control			0.0%						1	1	1	1					1	1	1		
		Alk-SP 1%			1.0%						1	1	1	1					1	1	1		
		Alk-SP 2%			2.0%						1	1	1	1					1	1	1		
Total Number of Tests Phase 1:						38	22	38	38	38	19	19	19	10	56	56	48	3	9	12	9	28	28

Notes:
[1] Synthetic Precipitation Leaching Procedure, modified to keep the monolith whole instead of crushing
[2] Baseline sample submitted prior to test setup to confirm soil is impacted with typical levels of COCs detected at the site. The six samples indicated for COCs in soil represent homogonization QC
[3] The number of test conditions increased to two, reflecting strategy of sampling most impacted soil from areas of different lithology
[4] If analytes are not observed in testing of baseline sample, leachability testing for these analytes likely to be eliminated
[5] Only the worst-case result of the different lithologies will be carried forward beyond SPLP and into Tank testing
[6] A molded cylinder or other representative aliquot of baseline or cement-amended soil is placed in an impermeable plastic bag. A PID is used to measure the headspace VOC concentration immediately after preparation, after 24 hours, and after 72 hours.
[7] DOC of aqueous phase
Alk-SP = alkaline-activated sodium persulfate, activate with sodium hydroxide according to supplier recommendations
C = carbon
COC = contaminant of concern
DDx = 4,4'-DDT, -DDE, -DDD
Metals = total recoverable metals: RCRA 8
PC = Portland cement
ORP = Oxidation/Reduction Potential of the saturated soil or pore water
SP = sodium persulfate
SVOCs = semi-volatile organic compounds
TOD = Total Oxidant Demand, assumes impacted soil
UCS = unconfined compressive strength
VOCs = volatile organic compounds
x% = weight of reagent to weight of soil

Test Name	Method Reference
Unconfined Compressive Strer	ASTM D1633
Permeability Testing	ASTM D5084 (monolith) or D2434 (baseline soil)
Modified SPLP	EPA Method 1312, modified to keep the monolith whole
Volumetric Expansion	ASTM D7263, bulk density

Table 2
Phase 2 In Situ Stabilization Test Conditions and Analyses
Portland, Oregon

PHASE 2 Test Conditions																
Treatability (Monolith leachability) testing		Mix Ratios (% weight of dry soil) To Be Determined by Phase 1			UCS		Permeability		LEAF 1315 [1][2]							
		PC	C	SP	28 Day	56 Day[5]	28 Day	56 Day[5]	VOCs	SVOCs	DDx	Metals[3]	pH	ORP	TOC	DOC
Contaminated	Control								9	3	9	3	3	3	3	3
	Condition #1				1	1	1	1	9	3	9	3	3	3	3	3
	Condition #1 QC DUP/MS/MSD[4]				1	1	1	1	3[4]	3[4]	3[4]	3[4]	1[4]	1[4]	3[4]	3[4]
	Condition #2				1	1	1	1	9	3	9	3	3	3	3	3
	Condition #3				1	1	1	1	9	3	9	3	3	3	3	3
Some DNAPL Contamination	Control								9	3	9	3	3	3	3	3
	Condition #1				1	1	1	1	9	3	9	3	3	3	3	3
	Condition #2				1	1	1	1	9	3	9	3	3	3	3	3
	Condition #3				1	1	1	1	9	3	9	3	3	3	3	3
Total Phase 2:					7	7	7	7	75	27	75	27	25	25	27	27

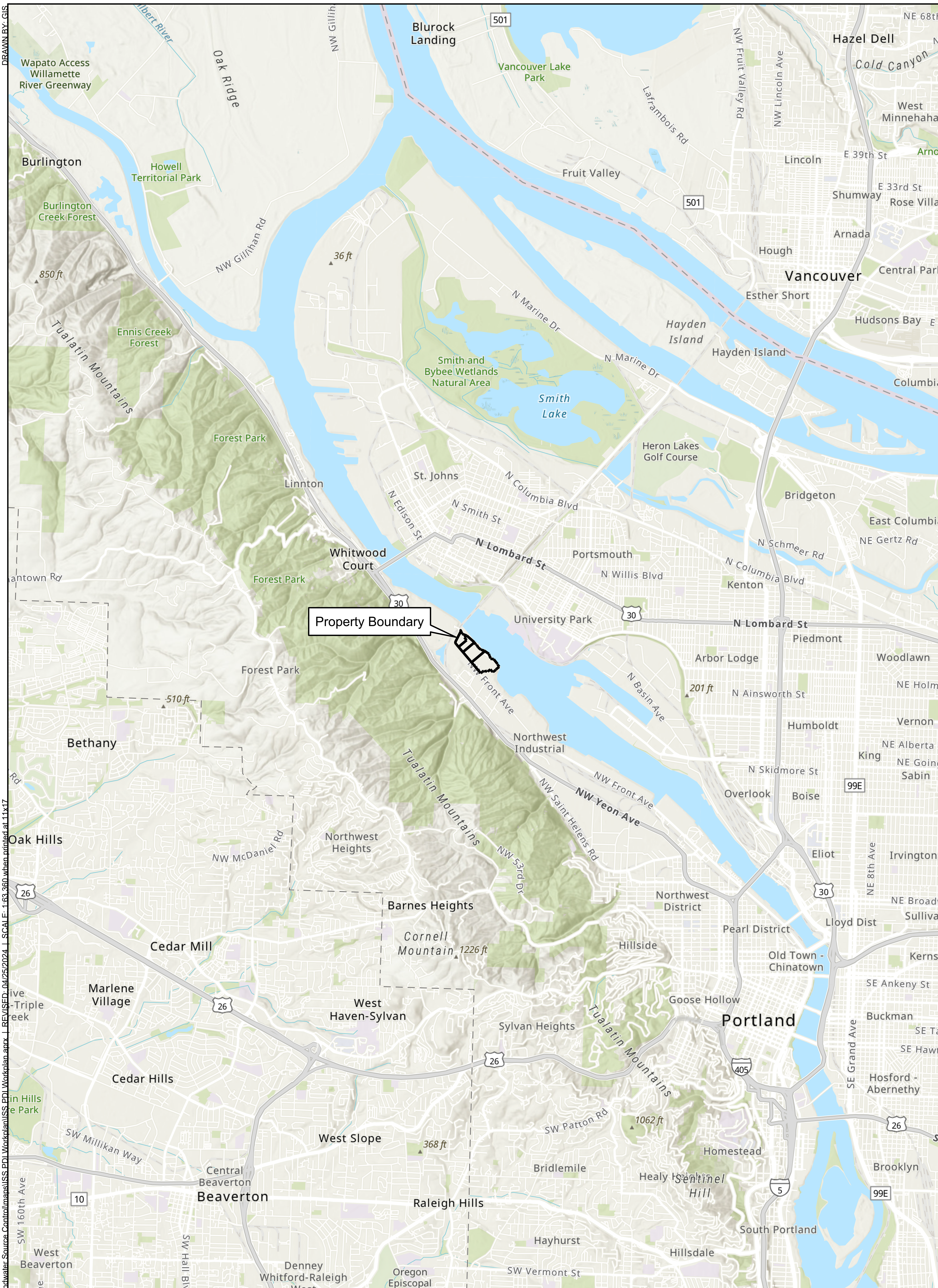
Notes:
[1] The LEAF 1315 testing consists of 9 discrete eluate changes at 9 time points of 0.08, 1, 2, 7, 14, 28, 42, 49, and 63 days.
[2] If analytes are not observed in testing of control sample, leachability testing for these analytes likely to be eliminated
[3] Analytes with three time points of analysis would be sampled at start, middle, and end of LEAF test, i.e., at 1, 28, and 63 days
[4] Lab to select one timepoint between 2 and 28 days to sample. Eluate to be changed as normal for other timepoints not tested.
[5] If the 28-day test results are within required range, the 56-day test may be omitted at ERM's discretion

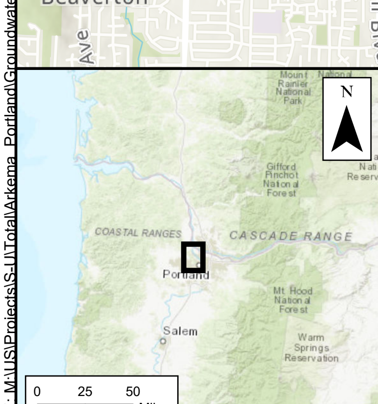
µg/L = micrograms per liter
COC = contaminants of concern
C = carbon
PC = Portland cement
SP = sodium persulfate
UCS = unconfined compressive strength
VOCs = volatile organic compounds, target analyte list
SVOCs = semi-volatile organic compounds, target analyte list
DDx = 4,4'-DDT, -DDE, -DDD
Metals = dissolved metal, target analyte list
Condition = results of Phase 1 will inform the type and quantity of amendments tried in Phase 2

Test Name	Method Reference
Unconfined Compressive Strength	ASTM D1633
Permeability Testing	ASTM D5084
LEAF	EPA Method 1315

ERM

FIGURES





Legend

— Parcel and Property Boundaries

N

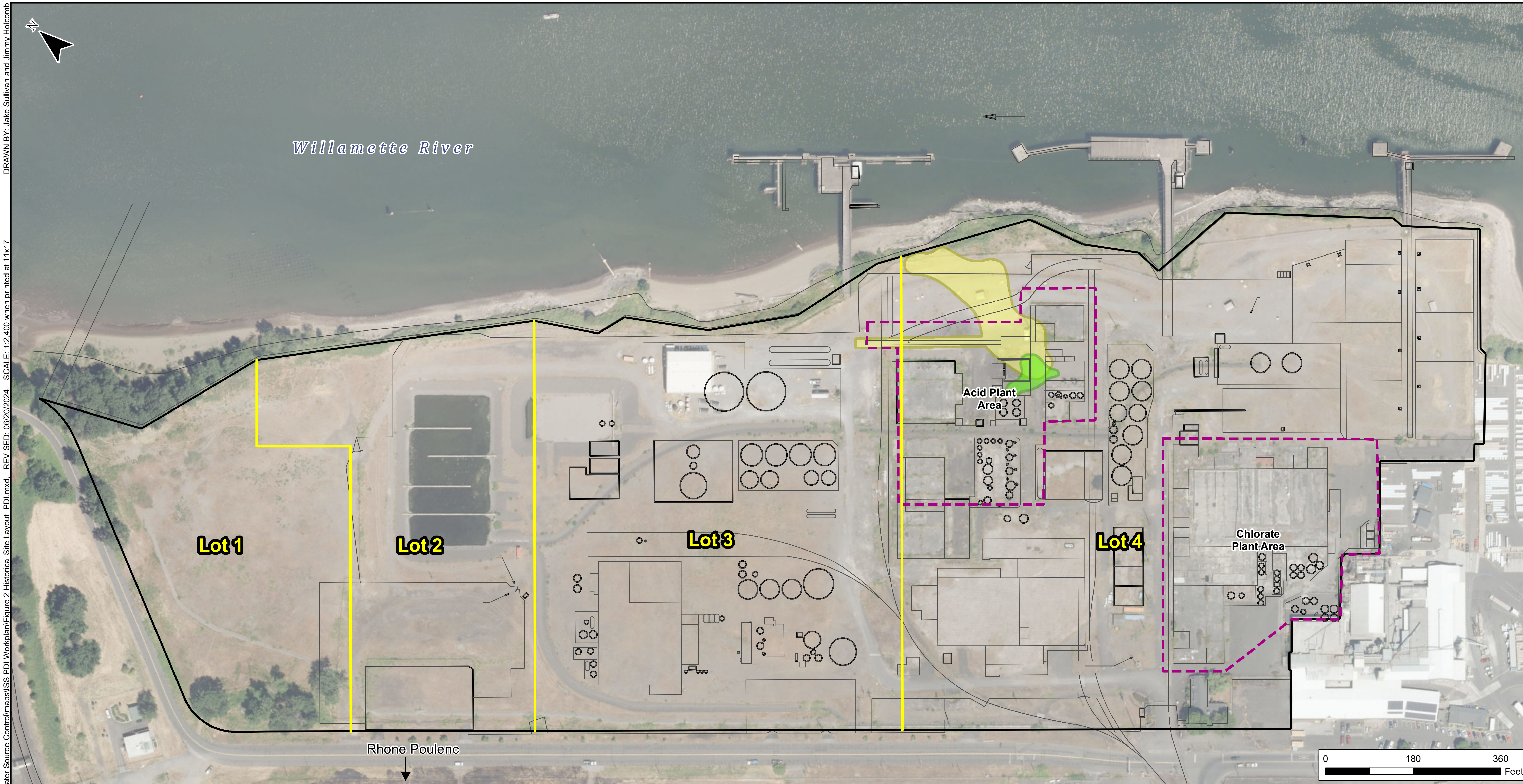
0 1 2

Miles

Figure 1
Site Location
Arkema Inc.
Portland, Oregon

ERM

Source: Esri - World Topoographic Map; NAD 1983 StatePlane Oregon North FIPS 3601 Feet Intl



Legend

- Parcel and Property Boundaries
- Lot Boundaries
- Acid Plant Area and Chlorate Plant Area Boundaries
- Vadose Soil Zone DNAPL (5-10 ft bgs), proposed ISS boundary
- Shallow Aquifer Zone DNAPL, proposed ISS boundary

Note:
A number of the buildings and structures noted
on this diagram have been demolished and/or removed.

Figure 2
Historical Site Layout
Arkema Inc.
Portland, Oregon

ERM

M:\US\Projects\S-U\Total\Arkema_Portland\Groundwater Source Control\maps\ISS PDI Workplan\Figure 2 Historical Site Layout_PDI.mxd, REVISED: 06/20/2024, SCALE: 1:2,400 when printed at 11x17 DRAWN BY: Jake Sullivan and Jimmy Holcomb

Source: City of Portland Aerial Imagery, Flow 7/2018 at 6in per pixel; NAD 1983 HARN StatePlane Oregon North FIPS 3601 Feet Intl

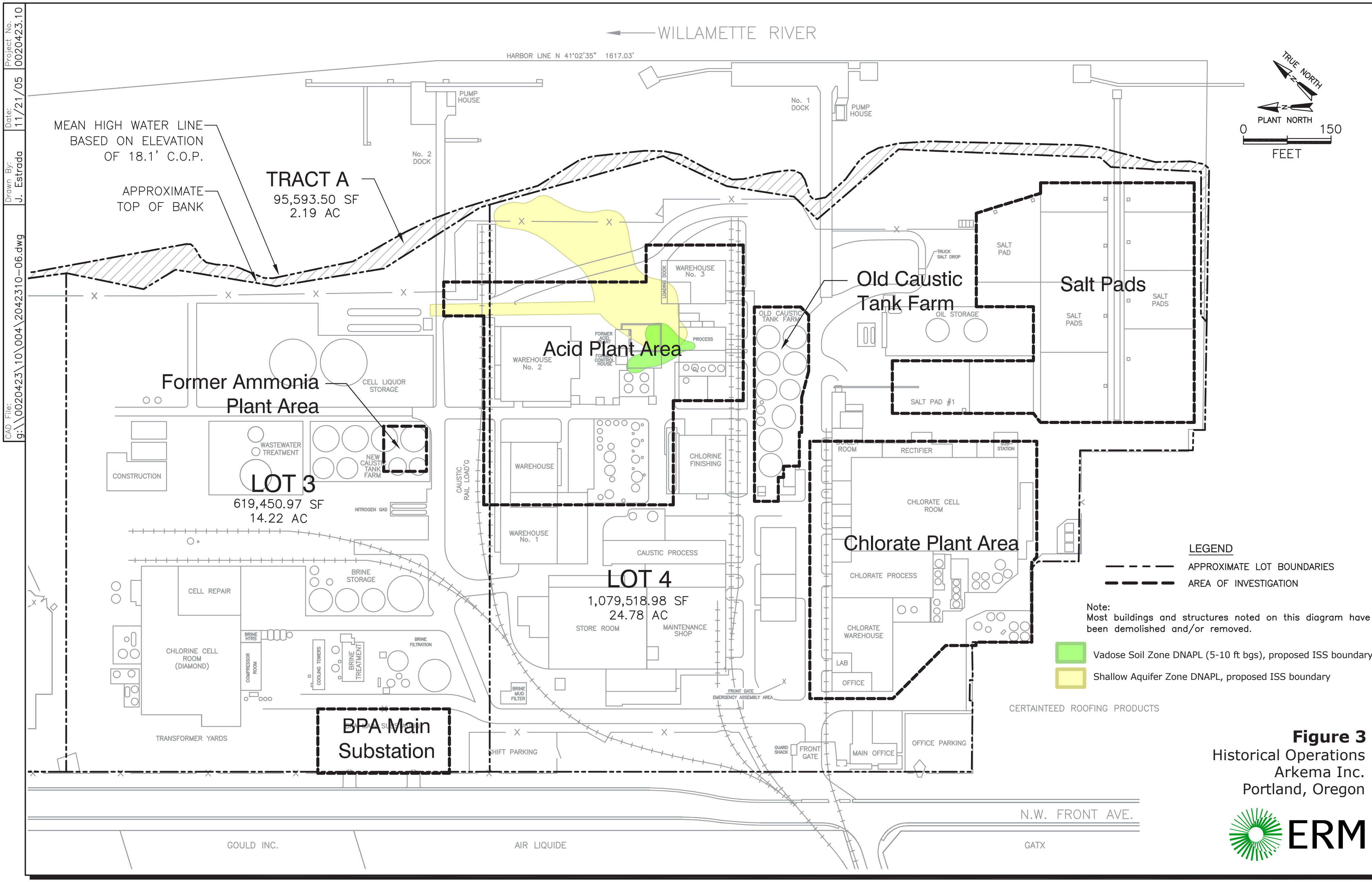


Figure 3
Historical Operations
Arkema Inc.
Portland, Oregon

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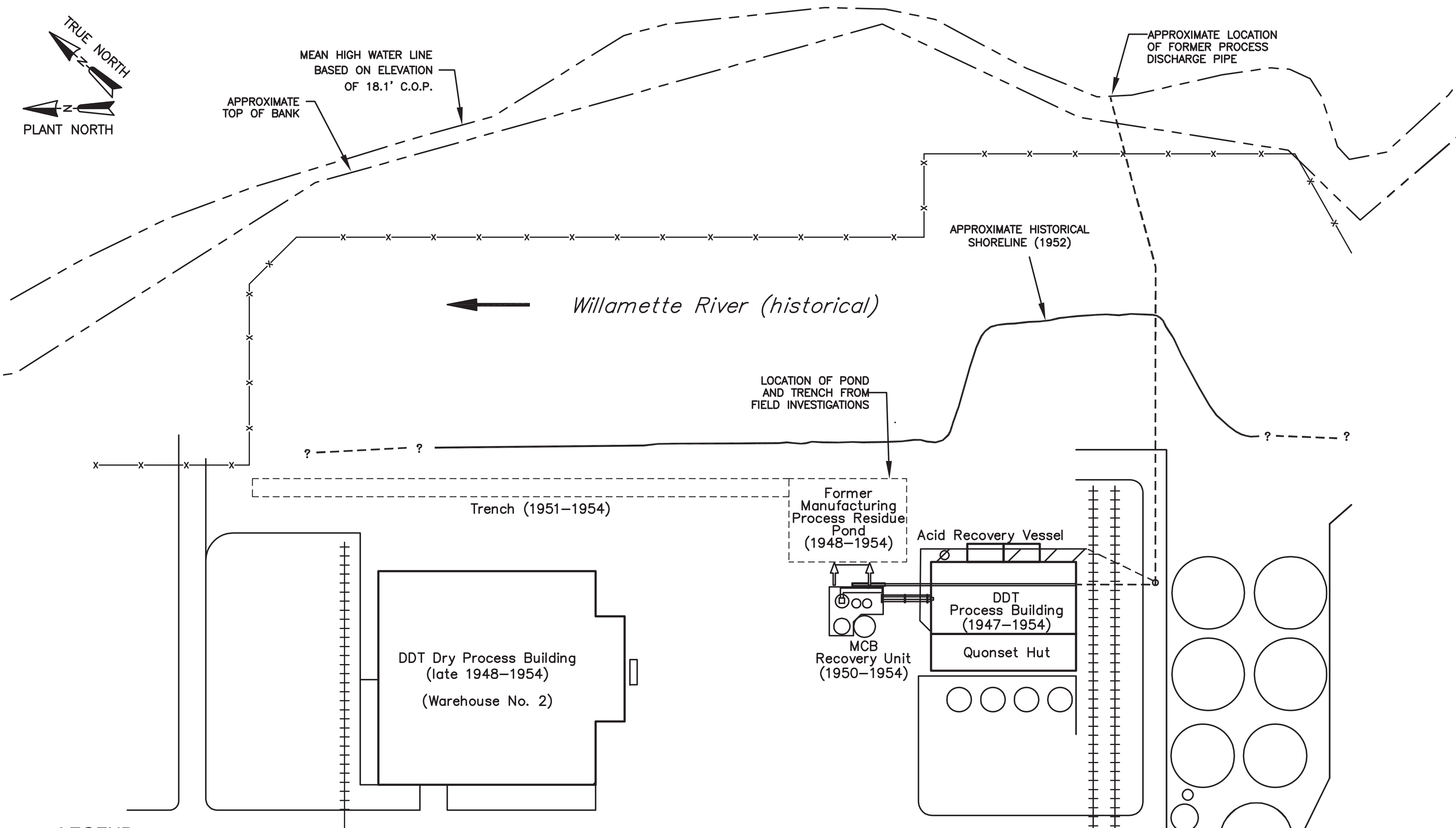


LEGEND

--- Sewer Pipelines (approximate)

⇦ Discharge to Pond

Notes:
1. All dates are approximate.
2. Most buildings and structures noted on this diagram have been demolished and/or removed.

0 40 80

Approx. Scale (feet)

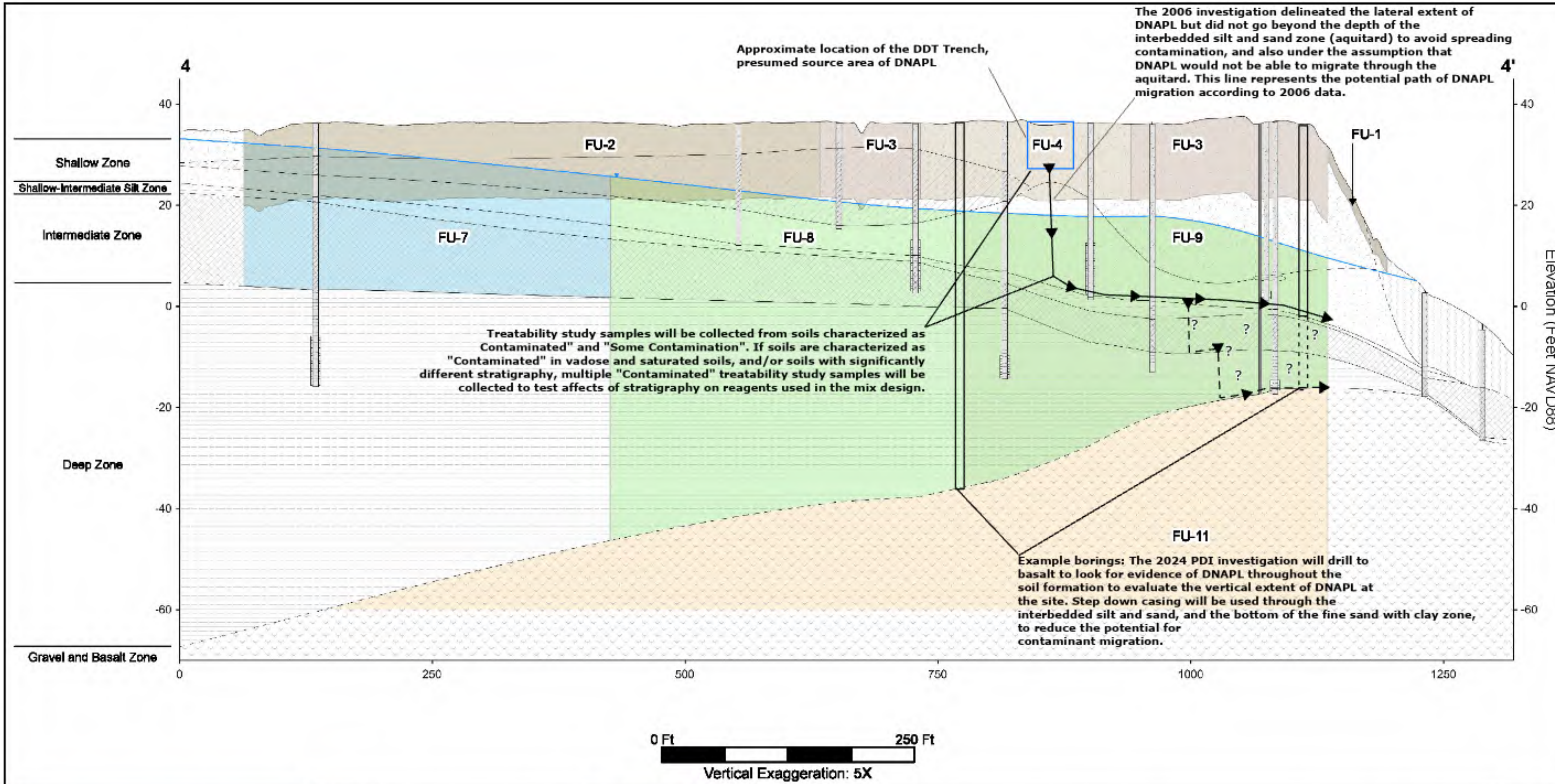
Figure 4

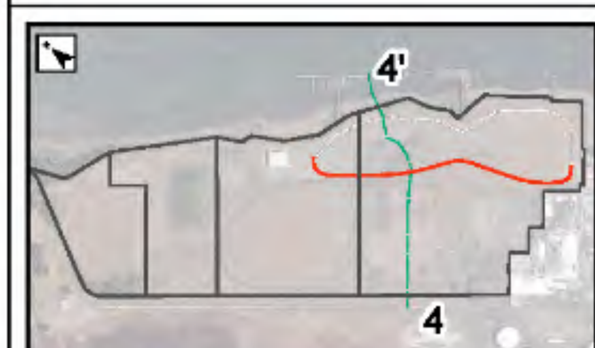
Historical DDT Manufacturing Operations (1947-1954)

Arkema Inc.

Portland, Oregon

ERM





Legend

- Shallow Zone potentiometric surface (ft NAVD88)
- Inferred soil contact (dashed where uncertain)
- Screened Interval

Functional Units

Soil	Groundwater	
1	5	9
2	6	10
3	7	11
4	8	12

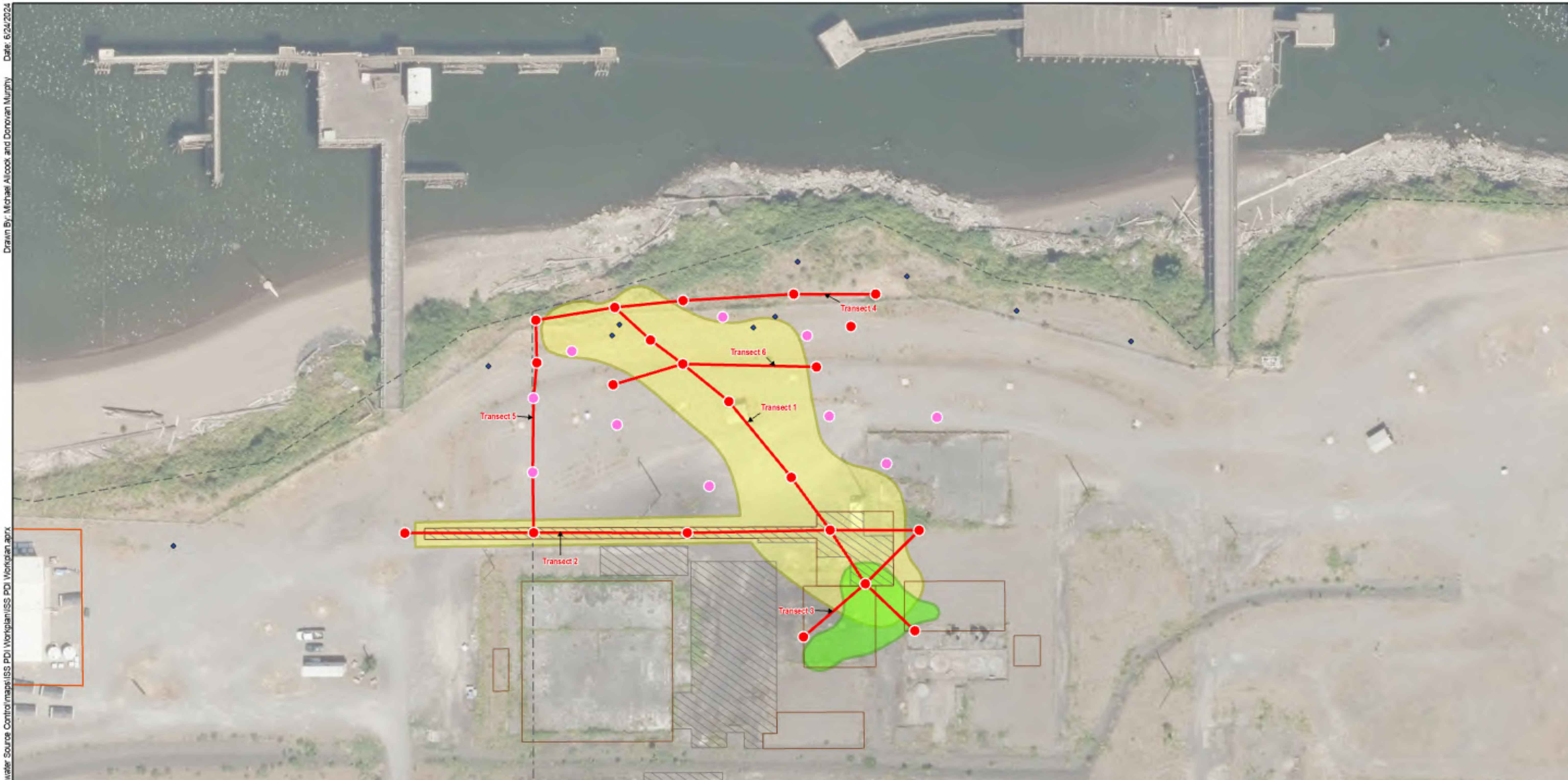
Lithology

- Groundwater Barrier Wall
- Fill
- Clay with Silt
- Sandy Silt
- Fine to medium sand with silt and clay
- Interbedded silt and sand
- Fine sand with clay
- Silt with clay
- Gravel
- Basalt

Notes:
Shallow Zone potentiometric surface is representative of averaged groundwater elevations during 2022.
Cross section geology generated from 3D geologic model.

Figure 5
DNAPL Conceptual Site Model for Pre-Design Investigation
Pre-Design Investigation Work Plan
Arkema Inc.
Portland, Oregon
ERM

Drawn By: Michael Allcock and Donovan Murphy Date: 6/24/2024
File: M:\US\Projects\S-U\Total\Arkema_Portland\Groundwater Source Control\maps\ISS PDI Workplan\ISS PDI Workplan.aprx



Legend

- Geoprobe
- Proposed Primary Boring Location
- Proposed Secondary Boring Location
- Proposed DyeLIF Transect Location
- Proposed Transect
- Shallow Zone Monitoring Well
- Shallow Zone Piezometer
- Intermediate Zone Monitoring Well
- Intermediate Zone Piezometer
- Deep Zone Monitoring Well
- Deep Zone Piezometer
- Barrier Wall Alignment
- Parcel and Property Boundaries
- Shallow Aquifer Zone DNAPL
- Vadose Soil Zone DNAPL (5-10 ft bgs)
- Excavated Area

Note:
Most recent chlorobenzene results are displayed at each well location in micrograms per liter (µg/L).

N

0 25 50 100
Feet

Figure 6
Proposed Boring and Transect Locations
ISS PDI Workplan
Arkema Inc.
Portland, Oregon

ERM

Date: 6/24/2024
Drawn By: Michael Allcock and Donovan Murphy
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Imagery Source: City of Portland, 2018; NAD 1983 HARN StatePlane Oregon North FIPS 3601 Feet Intl

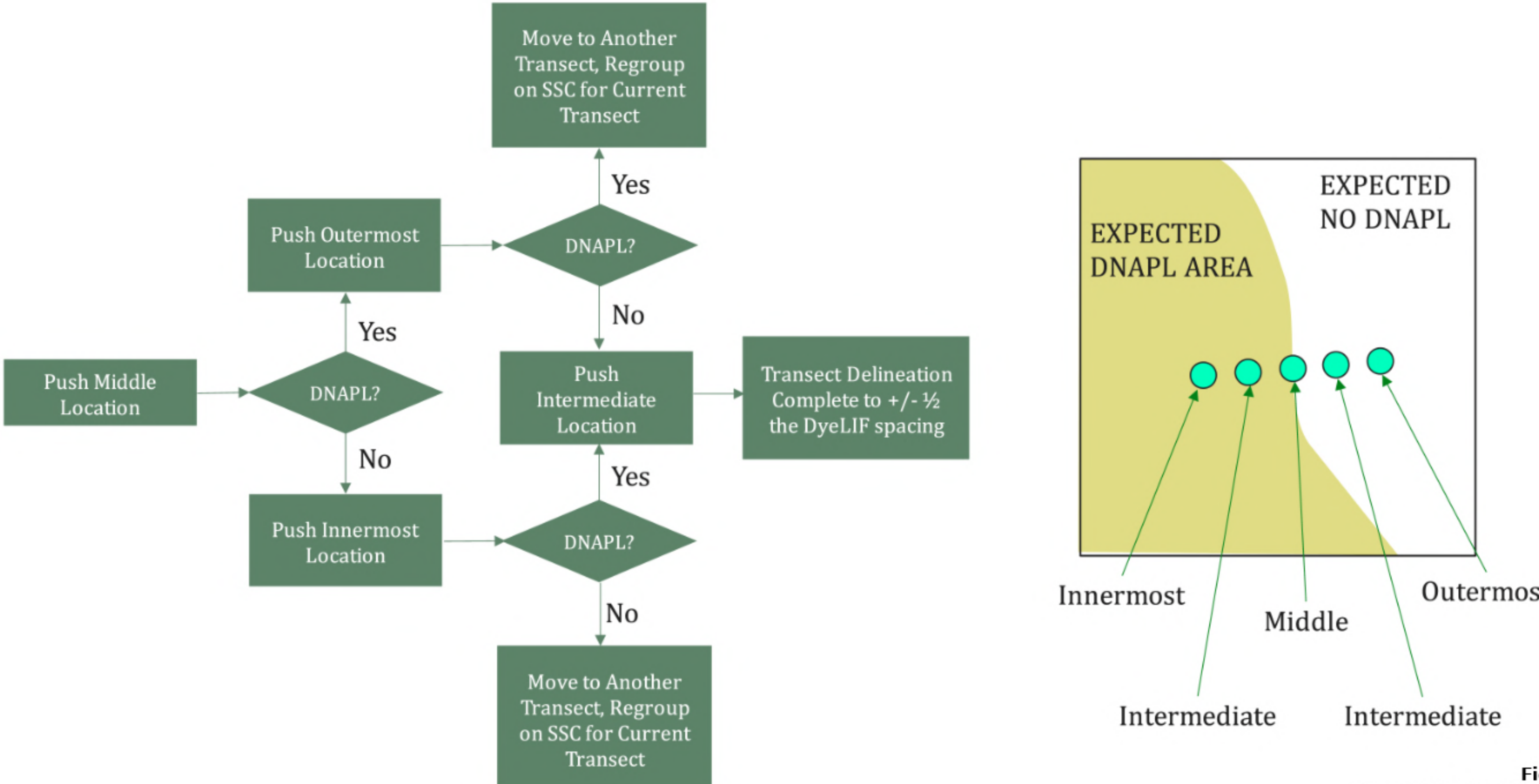

Figure 7
Proposed DyeLIF Decision Tree
ISS PDI Workplan
Arkema Inc.
Portland, Oregon

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