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Feasibility Study
Operable Unit E
Former Georgia-Pacific Wood Products Facility Fort Bragg, California

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Prepared for

Georgia-Pacific LLC
133 Peachtree Street NE
Atlanta, Georgia 30303

K/J Project No. 1665018*16

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List of Acronyms & Abbreviations

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
AOC	Area of Concern
AOI	area of interest
AME	Acton•Mickelson•Environmental, Inc.
ARARs	applicable or relevant and appropriate requirements
Arcadis	Arcadis U.S., Inc.
AST	aboveground storage tank
B(a)P	benzo(a)pyrene
BBL	Blasland, Bouck & Lee, Inc.
BERA	baseline ecological risk assessment
BHHERA	Baseline Human Health and Ecological Risk Assessment
bgs	below ground surface
bss	below sediment surface
btoc	below top of casing

CalEPA	California Environmental Protection Agency
CCC	California Coastal Commission
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980
CFR	Code of Federal Regulations
CHHSL	California Human Health Screening Level
City	City of Fort Bragg, Mendocino County, California
CMP Update No. 6	Comprehensive Monitoring Program Update Number 6 (Arcadis, 2013c)
COI	chemical of interest
Construction Completion Report	Construction Completion Report for Foundation and Ash Pile Removal Projects (Arcadis BBL, 2007a)
COPC	chemical of potential concern
CRAM	California Rapid Assessment Method
CSM	conceptual site model
cy	cubic yards
dioxin	polychlorinated dibenzo-*p*-dioxin
DTSC	California Environmental Protection Agency, Department of Toxic Substances Control
ELCRs	excess lifetime cancer risk
ERA	ecological risk assessment
ESA	environmental site assessment
ESHA	environmentally sensitive habitat areas
°F	degrees Fahrenheit
FS	Feasibility Study
ft/ft	foot per foot or feet per foot
furan	polychlorinated dibenzofuran
GAC	granular activated carbon
Georgia-Pacific	Georgia-Pacific LLC
GRA	general response action
GWET	groundwater extraction and treatment
HDPE	high-density polyethylene
HI	hazard index
Hygienetics	Hygienetics Environmental Services, Inc.

IARAP	Interim Action Remedial Action Plan (Arcadis, 2008b)
IRM	interim remedial measure
ISCO	in-situ chemical oxidation
ISS	in-situ stabilization/solidification
LBP	lead-based paint
LGW	leaching to groundwater
MCL	Maximum Contaminant Level
MES	Mobile Equipment Shop
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
MNA	monitored natural attenuation
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
O&M	operation and maintenance
Order	Site Investigation and Remediation Order (Docket No. HAS-RAO 06-07-150)
ORM	oxygen-releasing material
OU	Operable Unit
OU-C and D RI Report	Remedial Investigation, Operable Units C and D (Arcadis, 2011a)
OU-E RI Report	Final Remedial Investigation Report Operable Unit E (Arcadis, 2013a)
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
pg/kg	pictogram(s) per kilogram
ppm	parts per million
ppt	parts per trillion
PRA	presumptive remedy area
PRB	permeable reactive barrier
PSL	primary screening level
RAA	removal action area
RAO	remedial action objective
RAP	remedial action plan
RBTL	risk-based target levels

RI	remedial investigation
RWQCB	Regional Water Quality Control Board
sf	square foot or square feet
site	Former Georgia-Pacific Wood Products Facility, Fort Bragg, California
SMP	soil management plan
SVE	soil vapor extraction
SVOC	semi-volatile organic compound
TBC	to-be-considered
TCDD	tetrachlorodibenzo-p-dioxin
TEQ	toxic equivalent
TPH	total petroleum hydrocarbon
TPHd	total petroleum hydrocarbons in the diesel range
TPHg	total petroleum hydrocarbons in the gasoline range
TPHmo	total petroleum hydrocarbons in the motor oil range
TRC	TRC Companies, Inc.
µg/L	microgram per liter
UCL	upper confidence limit
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compound
WRA	WRA Environmental Consultants
WQO	Water Quality Objective

Executive Summary

This Feasibility Study (FS) was prepared by Kennedy/Jenks Consultants (Kennedy/Jenks) on behalf of Georgia-Pacific LLC (Georgia-Pacific) for Operable Unit E (OU-E) at the former Georgia-Pacific Wood Products Facility located at 90 West Redwood Avenue in Fort Bragg, Mendocino County, California (site), as shown on Figure 1-1. The purpose of this FS is to identify cost effective remedial methods for OU-E that will meet cleanup objectives and comply with applicable laws and requirements.

This FS includes an updated conceptual site model (CSM) that summarizes the site setting, investigations and interim remedial actions, and the nature and extent of chemicals of concern. This FS describes the remedial action objectives (RAOs) and applicable or relevant and appropriate requirements (ARARs) for the site, as well as an evaluation of general response actions (GRAs) and a preliminary screening of potentially feasible process options. The process options that were carried through the preliminary screening are then further developed into remedial alternatives and evaluated against comprehensive screening criteria. The preferred alternatives were selected on a comparative basis, as summarized in Section 8 and presented on Table 8-1.

Background

OU-E is one of five operable units on the site (Figure 1-2), and consists of approximately 12 acres of man-made ponds and seasonal wetland areas and 45 terrestrial acres divided into eight areas of interest (AOIs) Aquatic areas include Ponds 1 through 9 and the North Pond. Terrestrial areas include the Water Treatment and Truck Dump AOI, Sawmill #1 AOI, Compressor House and Lath Building AOI, Powerhouse and Fuel Barn AOI, and Pond 8 Fill Area AOI as well as the Riparian AOI, Interim Remedial Measure (IRM) AOI and West of IRM AOI (Figure 1-3), which were transferred from operable units C and D. This FS addresses soil and groundwater in the terrestrial AOIs and aquatic sediment in the aquatic AOIs. Industrial features in OU-E were related to power production, milling of timber, water treatment, management of fly ash, and fuel storage. The ponds were constructed for operational purposes, including management of wastewater from site operations, providing a source of water for firefighting, and use as a log pond. Pond 8 also receives stormwater runoff from the City of Fort Bragg, California (City) via the City's stormwater collection system. The majority of industrial features within OU-E have been removed. Soil was placed in portions of the terrestrial area to cover foundations in the lowland following building demolition and interim cleanup activities in those areas. Currently, OU-E is vacant, there are no active structures or uses in the terrestrial area and the primary use of the aquatic areas, specifically Pond 8, is to provide stormwater management for the City prior to discharge to the ocean. The foreseeable future use of OU-E is as continued stormwater management facilities, parkland, and recreational trail development.

For development of remedial alternatives, AOIs were grouped into areas of concern (AOCs) due to similarities in nature and extent of chemicals of interest (COIs) and affected media. The four lowland terrestrial soil AOIs that are to be further evaluated in this FS (Water Treatment and Truck Dump AOI, Sawmill #1 AOI, Compressor House and Lath Building AOI, and the Powerhouse and Fuel Barn AOI) were grouped into the 'Lowland Terrestrial Soil AOC'. The Pond 8 Fill Area AOI is not being considered due to the absence of chemicals of potential concern (COPCs) above relevant screening levels. Additionally, the IRM and West of IRM groundwater AOIs were combined into the 'IRM and West of IRM AOC'. Aquatic sediment AOIs (i.e., pond and riparian AOIs) will be evaluated individually. The Pond 5 and 9 AOIs are not considered in this FS as no further action is necessary per the approved BHHERA (Arcadis, 2015b). Further, in 2016, GP submitted a Remedial Action Work Plan (RAW) for OU-E that describes soil and sediment removal activities to be completed prior to the construction of the next phase of the City of Fort Bragg Coastal Trail project. The RAW was approved on October 13, 2016. AOCs that were included in the RAW are separated from other AOCs to simplify this OU-E FS.

The AOCs evaluated and COIs relevant in each include:

AOCs included in the RAW:

- Lowland Terrestrial Soil – petroleum constituents (TPHd), benzo(a)pyrene (B(a)P) toxic equivalent (TEQ), polychlorinated dibenzo-p-dioxin (dioxin) TEQ (2,3,7,8-tetrachlorodibenzo-p-dioxin [2,3,7,8-TCDD]), and lead
- Ponds 1 through 4 (Southern Ponds) Aquatic Sediment – arsenic and dioxin TEQ
- Pond 7 Aquatic Sediment – arsenic, barium, and dioxin TEQ
- Riparian Aquatic Sediment – arsenic, zinc, polycyclic aromatic hydrocarbons (PAHs), and dioxin TEQ
- AOCs not included in the RAW: North Pond and Pond 6 Aquatic Sediment – arsenic and dioxin TEQ
- Pond 8 Aquatic Sediment – dioxin TEQ
- OU-E Groundwater.

Remedial Action Objectives and Preliminary Evaluation

The Remedial Action Objectives (RAOs) presented below have been developed based on the current environmental conditions and anticipated future use of the site.

1. Protect human health and the environment through mitigation of exposure pathways of groundwater, surface water, soil, and/or sediment that contain COIs at concentrations greater than the proposed site cleanup goals under the reasonably foreseeable future land use scenarios.
2. For the AOC(s) with COI-impacted groundwater, provide a remediation alternative that will promote mitigation of COI-impacted groundwater to ultimately achieve North Coast Regional Water Quality Control Board water quality objectives (WQOs).
3. Provide an economically reasonable and technically feasible remedy.
4. Achieve the remedy in a reasonable time-frame.

In conjunction with the RAOs, ARARs were established to ensure that the initial development of remedial alternatives consider compliance requirements. GRAs were developed for initial comparison of categories of process options against RAOs and ARARs. GRAs evaluated include no action, institutional controls, containment, in-situ treatment, and ex-situ treatment. All categories were carried on for further development and evaluation as process options.

Specific process options that fit into each of the GRA categories listed above have been preliminarily screened for effectiveness, implementability, and overall cost. Process options that were carried through this preliminary screening process were either evaluated as a stand-alone alternative or combined with other process options into a remedial alternative.

Evaluation of Soil, Sediment, and Groundwater Remediation Alternatives

Remedial alternatives developed from the feasible process options have been screened according to U.S. Environmental Protection Agency (USEPA)-specified evaluation criteria and compared to identify a recommended alternative per AOC. The criteria used to screen the remedial alternatives are summarized below, followed by the recommended alternatives for each AOI.

Approved OU-E Removal Action Work Plan

The OU-E Removal Action Work Plan (RAW) was prepared to expedite remediation in select AOCs to facilitate construction of the City of Fort Bragg's coastal trail (Arcadis, 2016a). Excavation and disposal was approved as the remedial action for the Lowland Terrestrial Soil AOC, the Pond 7 Aquatic Sediment AOC, the Ponds 1 through 4 (Southern Ponds) Aquatic Sediment AOC, and the Riparian Aquatic Sediment AOCs. Implementation is planned for 2017. Clean imported soil will be utilized for backfill in each of the AOCs. Land use controls may still be necessary following excavation, and this will be evaluated after implementation of the remedial action is complete. Estimates for the volume of excavation, vertical extent, and surface area for each AOC are below.

Lowland Terrestrial Soil AOC – excavation and disposal**.** Approximately 1,410 cubic yards (cy) of soil to a maximum depth of 9-feet below ground surface (bgs) over an area of approximately 7,900 square feet (sf), will be excavated and disposed of offsite.

Pond 7 Aquatic Sediment AOC – excavation and disposal**.** Approximately 1,500 cy of sediment to a depth up to approximately 7.5 feet bgs over the entire footprint of Pond 7 (approximately 5,500 sf) will be excavated and disposed of offsite.

Ponds 1 through 4 (Southern Ponds) Aquatic Sediment AOC – excavation and disposal. Approximately 45 cy of sediment to a depth up to approximately 2 feet bgs over an area of approximately 800 sf will be excavated and disposed of offsite.

Riparian Aquatic Sediment AOC – excavation and disposal. An approximate total of 7 cy of sediment at a depth up to approximately 0.5 feet bgs over an area of approximately 375 sf will be excavated from four separate excavation areas and disposed of offsite.

Results of Remedial Alternatives Evaluation and Comparison

Pond 8, North Pond and Pond 6 Aquatic Sediment AOCs – institutional controls. Due to the nature and extent of constituents and evaluation of the nine criteria, institutional controls is the recommended alternative for the Pond 8, North Pond and Pond 6 Aquatic Sediment AOCs. Institutional controls would include a deed restriction and comprehensive SMP to further reduce the potential pathways for future site receptors. Site use and sediment disturbing activities would be controlled by the SMP until agency approval for unrestricted use is received based on COI degradation or future remediation.

OU-E Groundwater AOC – monitored natural attenuation (MNA). Based on historical groundwater monitoring data and the nine evaluation criteria, MNA with use restrictions is the recommended alternative. MNA uses long-term monitoring and analysis to demonstrate established stable or decreasing COI trends and a low risk to human health and the environment. A deed restriction would prohibit the use of groundwater to eliminate exposure to COIs. Groundwater use would be restricted until Water Quality Objectives are achieved or agency approval for unrestricted use is received.

Table 7-1 presents a comparison of the retained alternatives for each AOC and Table 8-1 presents a summary of the recommended alternatives for each AOC. Cost estimates associated with these remedies are included in Appendix A.

Section 1: Introduction

This Feasibility Study (FS) was prepared by Kennedy/Jenks Consultants Inc. (Kennedy/Jenks) on behalf of Georgia-Pacific LLC (Georgia-Pacific) for Operable Unit E (OU-E) at the former Georgia-Pacific Wood Products Facility (site) located at 90 West Redwood Avenue in Fort Bragg, Mendocino County, California, as shown on Figure 1-1.

This FS was prepared as required by the California Department of Toxic Substances Control (DTSC) under Site Investigation and Remediation Order Docket No. HAS-RAO 06-07-150 (Order) in accordance with the federal National Oil and Hazardous Substances Pollution Contingency Plan (NCP; U.S. Environmental Protection Agency [USEPA], 1990) and the Guidance for Conducting Remedial Investigations and Feasibility Studies (RI/FS) Under the Federal Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA; USEPA, 1988).

The 415-acre site is located west of Highway 1 along the Pacific Ocean coastline and is bounded by Noyo Bay to the south, the City of Fort Bragg (City) to the east and north, and the Pacific Ocean to the west. Union Lumber Company began sawmill operations at the site in 1885. Georgia-Pacific acquired the site in 1973. Sawmill operations at the site included lumber production and power generation by burning residual bark and wood. Georgia-Pacific ceased operations on August 8, 2002. Much of the equipment and structures associated with the sawmill operations have been removed. A northern public coastal trail extending 4.5 miles north of Fort Bragg Landing on 82 acres was opened in 2014. An additional public coastal trail extending from the southern end of the property 0.8 miles to the north side of the City of Fort Bragg Waste Water Treatment Plant on 5 acres was opened in 2016. With the exception of the public coastal trails, the site is fenced, security patrolled and locked to restrict trespassers.

OU-E is one of five operable units on the site (Figure 1-2), and consists of approximately 12 acres of man-made ponds and seasonal wetland areas and 45 terrestrial acres divided into eight areas of interest (AOIs) Aquatic areas include Ponds 1 through 9 and the North Pond. Terrestrial areas include the Water Treatment and Truck Dump AOI, Sawmill #1 AOI, Compressor House and Lath Building AOI, Powerhouse and Fuel Barn AOI, and Pond 8 Fill Area AOI as well as the Riparian AOI, Interim Remedial Measure (IRM) AOI and West of IRM AOI (Figure 1-3), which were transferred from operable units C and D. Predominant industrial features in OU-E were related to power production, milling of timber, water treatment, management of fly ash, and fuel storage. The ponds were constructed for operational purposes, including management of wastewater from site operations, providing a source of water for firefighting, and use as a log pond. Pond 8 also receives stormwater runoff from the City via the City's stormwater collection system. The majority of industrial features within OU-E have been removed. Soil was placed in portions of the terrestrial area to cover foundations in the lowland following building demolition and interim cleanup activities in those areas. Currently, OU-E is vacant, there are no structures or uses in the terrestrial area and the primary use of the aquatic areas, specifically Pond 8, is to provide stormwater management for the City prior to discharge to the ocean. The foreseeable future use of OU-E is as continued stormwater management facilities, parkland, and recreational trail development.

1.1 Objectives

The purpose of this FS is to develop and evaluate appropriate remedial alternatives such that relevant information concerning the remedial action options can be presented and an appropriate remedy selected. Alternatives shall be developed that protect human health and the environment by recycling waste or by eliminating, reducing, and/or controlling risks posed through each pathway by the site. The FS is based on data presented in the *Final Remedial Investigation Report Operable Unit E* (OU-E RI Report; Arcadis, 2013a) and the *Baseline Human Health and Ecological Risk Assessment (BHHERA) – Operable Unit E* (Arcadis, 2015b) and data collected from subsequent investigations (see Section 2.2). The FS also includes summaries of remedial actions approved for the OU-E Lowlands, Ponds 1, 2, 3, and 4 (the Southern Ponds), Pond 7, and Riparian AOIs, which are presented in the OU-E Removal Action Work Plan (OU-E RAW; Arcadis, 2016a).

The scope of this FS includes all OU-E areas recommended for inclusion based on the OU-E RI Report and BHHERA (Arcadis, 2013a and 2015b), with addition of the following areas:

- IRM AOI
- West of IRM AOI
- Riparian AOI

These areas are located within and adjacent to the Mill Pond, originally within OU-C and OU-D; however, they were moved to be included in this FS as these AOIs are closely associated with the AOIs from OU-E (Arcadis, 2012a).

1.2 Operational History

The following documents provide information about the operational history at the site, OU-E, and AOIs formerly associated with OU-C and OU-D:

- Phase I Environmental Site Assessment (ESA; TRC Companies, Inc. [TRC], 2004a)
- Phase II ESA (TRC, 2004b)
- Additional Site Assessment Report (TRC, 2004c)
- Work Plan for Additional Site Assessment (Acton•Mickelson•Environmental, Inc. [AME], 2005a)
- Current Conditions Report (Blasland, Bouck & Lee, Inc. [BBL], 2006)
- Dioxin Sampling and Analysis Report (AME, 2006a)
- Construction Completion Report for Foundation and Ash Pile Removal Projects (Construction Completion Report; (Arcadis BBL, 2007a)
- Fuel Oil Line Removal Report (Arcadis, 2008a)

- Final Interim Action Remedial Action Plan and Feasibility Study (Arcadis, 2008b)
- Remedial Investigation, Operable Units C and D (Arcadis, 2011a)
- Feasibility Study, Operable Units C and D (Arcadis, 2012a)
- Final Remedial Investigation Report Operable Unit E (Arcadis, 2013a)
- Baseline Human Health and Ecological Risk Assessment - Operable Unit E (Arcadis, 2015)
- Removal Action Work Plan Operable Unit E (Arcadis, 2016a).

A general summary of the operational history of the terrestrial area and ponds associated with OU-E is provided below, followed by a description of the historical use of each AOI, focusing on those areas where activities could have resulted in a release of hazardous substances. The AOIs have been grouped into three Areas of Concern (AOCs); lowland terrestrial, aquatic, and groundwater) depending on nature and extent of constituents. The AOI locations and site features are shown on Figure 1-3.

1.2.1 Lowland Terrestrial Areas of Interest

1.2.1.1 Water Treatment and Truck Dump AOI

The Water Treatment and Truck Dump AOI is located in the northwest section of OU-E (Figure 1-4). Former features in the area include the Alum Tank, Water Treatment Plant, Sewage Pump Station, Water Supply Switch Building, Water Valve Shed, Water Tower, Powerhouse Fuel Storage Shed, Chipper Building, Truck Dump, Truck Dump Hydraulic Unit Building, and the Bunker Fuel Aboveground Storage Tank (AST) Area.

Built in the 1970s, the Alum Tank, Water Treatment Plant, Sewage Pump Station, Water Supply Switch Building, and Water Valve Shed supported water treatment processes. The Water Treatment Plant treated water to prevent corrosion and scaling of the cooling towers. Inside the plant were two treatment tanks and two air compressors. Each treatment tank had a mixing tank, clarifier, and additional settling tank. The following chemicals were identified inside the plant during the Phase I ESA (TRC, 2004a): liquid chlorine (mostly empty 350-gallon tank), alum (250-gallon tank in secondary containment), caustic soda (350-gallon tank in secondary containment and two 55-gallon drums), and ammonium chloride. Site documents also suggested that sodium hypochlorite (approximately 500 gallons) and sodium hydroxide (350 gallons) were present.

Outside the plant, a concrete AST may have held a treated water supply for the Powerhouse. About 300 feet northwest of the plant was a 4,000-gallon AST containing alum[1]. The Alum Tank foundation and the Water Treatment Plant foundation were broken up, and the concrete was

[1] Alum is a combination of an alkali metal (such as sodium, potassium, or ammonium) and a trivalent metal (such as aluminum, iron, or chromium). In water treatment, alum is used as a coagulant, which binds together very fine suspended particles into larger particles that can be removed by settling and filtration.

moved to the concrete storage area in August 2006. After demolition of the foundations, a dry cap[2] was placed in the removal area.

The Chipper Building consisted of a wood structure with a concrete floor. The Truck Dump was located next to the Chipper Building. The Truck Dump included a hydraulic system formerly used to empty trucks of their wood fuel loads (it was assumed to have been built in the mid-1970s); inside the building was a transformer. A concrete slab was used for structural support at this location. The walls of the Chipper Building were left in place, as they support a slope north of the building. After the demolition of the foundations in June and July 2006, a dry cap was placed in the area. The majority of the dry cap was later excavated with the removal of the Fuel Oil Line in 2007 (Arcadis, 2008a), which is further discussed in Section 2.2.3.2.

The Sewage Pumping Station consists of a concrete slab and an underground concrete tank.

The Water Supply Switch Building was constructed of corrugated metal with a concrete foundation. The foundation was removed and a dry cap installed in July 2006.

The Powerhouse Fuel Storage Shed was built in 1995 with corrugated metal, had a concrete floor and berm (secondary containment), and was open to the north and east. The shed contained three horizontal ASTs, each with a capacity of 10,000 gallons. In May 1999, 4,000 gallons of fuel spilled within secondary containment and was cleaned up. Soil and groundwater sampling conducted as part of the Phase II ESA (TRC, 2004b) showed concentrations of total petroleum hydrocarbons (TPH) below screening levels. To the west of the building, there was a 30,000-gallon Water Tower, built from wood with a concrete base. The Water Tower pad and the Fuel Storage Area were removed and a dry cap installed in July 2006.

Backup fuel was stored in two ASTs in the Former Bunker Fuel AST area north of the Powerhouse. Both ASTs had concrete secondary containment and were removed in 1996. Underground piping associated with the ASTs was excavated in 2007 (see Section 2.2.3.2 and the *Fuel Oil Line Removal Report* [Arcadis, 2008a]).

1.2.1.2 Sawmill #1 AOI

The Sawmill #1 AOI is an "L" shaped area located north of the eastern half of Pond 8. Former features in the area include the Sawmill #1 Building, Press Building, Green Chain (and Elevated Roadway), Lath and Shake Mill, Refuse Wood for Fuel Area, Engine House Area, Number 5 Shingle Mill Area, and AST (Figure 1-4).

Historical photos, Sanborn maps, and interviews with site personnel suggest that the former Sawmill #1 Building was constructed in the late 1880s. It was equipped with saws, edgers, trimmers, wood chippers, cyclones, and target boxes. It generally handled larger diameter logs, which were first debarked by either hydraulic or mechanical means, cut to remove tattered edges, and trimmed. Finished logs were sent to re-saw areas for size reduction or to the Green Chain for manual sorting and stacking in preparation for transfer to storage areas, planer mill, shipping areas, or drying areas. The Sawmill #1 ceased operations in 1998; later that year,

[2] Dry caps were placed where groundwater was not considered likely to extend to the bottom of excavations. They consisted of a geosynthetic clay liner covered with clean fill material.

some of the aboveground structures of the Sawmill #1 Building and the Green Chain were demolished. The remainder of the Sawmill #1 Building was demolished in 1999 and 2000. The concrete foundations of the Sawmill #1 Building, as well as the concrete structural supports for the Green Chain, were demolished in June and July of 2006. After the demolition, a wet cap[3] was placed over the area, which was completed in September 2006.

The Press Building was constructed of wood with a concrete floor and was located south of the former Sawmill #1 Building. The building contained a sugar cane press until the early 1990s when it was removed. Press Building pad and footings removal occurred in July 2006, followed by placement of a dry cap in the removal area.

The former Lath and Shake Mill, Refuse Wood for Fuel Area, Engine House Area, AST, and Number 5 Shingle Mill Area were also present in the Sawmill #1 AOI. These areas are illustrated on Figure 1-4.

1.2.1.3 Compressor House and Lath Building AOI

The Compressor House and Lath Building AOI included two small buildings (Compressor House 1 and Compressor House 2), Electrical Shop, Compressor House Shed, Lath Building, and a secondary containment structure (Figure 1-4).

Compressor House 1, an enclosed structure composed of corrugated metal with concrete floors, housed two compressors and related maintenance equipment and materials (e.g., 55-gallon oil drums, used oil filter drums). A compressed air AST and backup air compressor were located outside the building.

Compressor House 2, a smaller corrugated metal structure with concrete floors, stored 55-gallon oil drums and various other materials. Three overhead transformers were observed south of Compressor House 2 during the Phase I ESA (TRC, 2004a).

The Compressor House Shed, constructed of corrugated metal without a concrete foundation/floor, housed a large metal tank with an air pressure gauge.

Compressor Houses 1 and 2 were removed in July 2006 (Arcadis BBL, 2007a) and covered with a dry cap, the majority of which was later excavated as part of the interim action to remove TPH and metal-impacted soil from under the former Electrical Shop, Compressor House 1, and Compressor House 2 buildings (Arcadis, 2010a).

The Lath Building was located northwest of the former Compressor House buildings, near the former Sawmill #1 Building. It housed a small process area that made products from scrap/waste wood. The building structure was removed prior to 2006. Because of the presence of a seep wetland feature, the concrete foundation for this structure was not removed during the summer of 2006.

[3] Wet caps were placed where groundwater was considered likely to extend to the bottom of excavations. They consisted of a geosynthetic clay liner covered with one to four inches of crushed concrete, covered with clean fill, and then covered by a geosynthetic clay liner.

An interim action involving the excavation of impacted soils from this area (Arcadis, 2008b) was completed in 2008. Impacted soils were removed, and clean, treated soils were backfilled into this area (Arcadis, 2010a). The interim action is discussed in further detail in Section 2.2.3.3.

1.2.1.4 Powerhouse and Fuel Barn AOI

The Powerhouse and Fuel Barn AOI is located directly north of Pond 8 (Figure 1-4). Former features in the area include the Dewatering Slabs, Equipment Fueling Area, Steam Dry Kilns, Former South Pond, Fuel Barn, Powerhouse Building, Transformer Pad, Oil Storage Shed, Chemical Storage Tank, Poly Tanks/Small Transformer Pad to the south, Paint Storage Shed, Fly Ash Reinjection System, Open Refuse Fire Area, and Cooling Towers (including the Poly Tank/Transformer Pad and the Cooling Towers Storage Shed). Features still present include the Concrete Lined Tank and Process Water Pumping Station.

During operation, the Powerhouse used residual wood chips from plant operations to generate power. The Powerhouse had a concrete foundation and contained brick ovens, boilers, turbines, water pumps, and other associated equipment to generate power for site operations. Chemicals used and stored in the Powerhouse included: grease, solvent, filter oil, turbine oil, automatic transmission fluid, motor oil, trisodium nitrilotriacetate (a boiler feed water additive), and mercury (contained within switches). Review of site records indicates the presence of two hydraulic units (total containment: 100 gallons), one each on the north and south sides of the boilers on the fire deck area. Site documentation also indicated the presence of three turbine oil tanks (total containment: 2,100 gallons) beneath the floor grating between the east and west ends of the turbines. Several 1- and 5-gallon buckets of paint and a large pump were stored in a small wood shed with concrete flooring on the south side of the Powerhouse. Also on the south side of the Powerhouse were two 330-gallon ASTs containing water and sodium hydroxide. A transformer was observed next to the ASTs (Figure 1-4).

The foundations of the Powerhouse and associated structures were demolished in August 2006. After the demolition, the area was covered with a wet cap in September 2006.

The Poly Tanks/Transformer Pad, Chemical Storage Shed, and Paint Storage Shed were located south of the Powerhouse Building. The Paint Storage Shed was constructed of wood with a concrete floor. The foundations of these structures were not removed during the foundation removal effort in 2006 (Arcadis BBL, 2007a).

Two transformer pads were located north of the Powerhouse. The larger pad was constructed of concrete and enclosed with a chain-link fence, while the smaller pad consisted of an open-sided shed southeast of the larger Transformer Pad. An Oil Storage Shed was located directly east of the larger Transformer Pad. The Oil Storage Shed had dimensions of approximately 15 by 20 feet, was constructed of wood and had a concrete secondary containment base with expanded metal grating. Plant personnel indicated that the shed was constructed in the late 1980s. The large and small transformer pads and the Oil Storage Shed north of the Powerhouse were broken up in July 2006.

The Cooling Towers were located south of the Powerhouse on the berm that separated the Powerhouse area from Pond 8 (Figure 1-4). The area consisted of the Cooling Towers, a small shed, and two concrete pads for poly tank storage. The Cooling Towers building (visible in the 1983 aerial photograph) was constructed and operational in the mid-1970s (according to plant personnel) and contained four cooling elements. The building had a concrete foundation and corrugated metal walls on the east and west sides. The north and south sides of the building were screened with metal slats. The small storage shed was located east of the Cooling Towers. According to site personnel, the shed was built in the mid-1970s and was constructed of corrugated metal on a concrete foundation. During the Phase I ESA (TRC, 2004a), ammonium chloride, sodium hypochlorite, and soda ash were noted as being stored in the shed. South of the shed were three poly tanks on a concrete pad. Chemicals stored in the tanks included sodium hypochlorite, isopropanol, and formula 222 (sodium molybdenum). All foundations in the Cooling Towers area were removed in August 2006, and a dry cap was placed in the removal area.

The Fuel Barn was located west of the Powerhouse. Historical photos, Sanborn maps, and interviews with site personnel suggest that the Fuel Barn was built prior to the early 1950s. The walls were constructed of corrugated metal, and the floor was composed of soil and mulch. There was a concrete “trench” in the center of the Fuel Barn, which was used to support a conveyor system. During plant operations, the “fuel” (wood chips) for the Powerhouse was stored in the Fuel Barn. A fuel digger, located in the Fuel Barn, moved the wood chips onto a conveyor belt and into the Powerhouse. The concrete stem wall foundation and center concrete structure at the Fuel Barn were removed in June 2006.

The Dewatering Slabs were located in the northwestern corner of the AOI near the North Pond. The slabs were constructed of concrete and were used until 1996 to dewater wet fly ash from the Powerhouse. Scrubber; water from the boilers contained fly ash and was piped to the two dewatering slabs; after drying, the residual fly ash was placed in a dump hopper for removal and placement at an offsite location. Use of the slabs was discontinued in 1996, when the Fly Ash Reinjection System was installed east of the Powerhouse. Following this installation, process water was conveyed to Pond 7 and from there via an underground pipe to Ponds 1 through 4. The Dewatering Slab foundation and the northern portion of the Fly Ash Reinjection System building pad were removed in June 2006, and a dry cap was placed in the removal area. The Fly Ash Reinjection System pad foundation, located within approximately 15 feet of the retaining wall, was not removed.

1.2.1.5 Pond 8 (also known as the Log Pond or Mill Pond) Fill Area AOI

The Pond 8 Fill Area AOI comprises the land along the eastern, southern, and western perimeters of Pond 8 (Figure 1-4). Pond 8 originally extended further west. The western portion of Pond 8 appears to have been filled prior to 1973 (TRC, 2004a).

Prior to the construction of the Cooling Towers in the Powerhouse AOI (Section 1.2.1.4) such towers were located near the southwestern corner of Pond 8. According to plant personnel, the Cooling Towers at this location ceased operation and were subsequently demolished in the early 1970s. The former Cooling Towers location is currently undeveloped and consists of a concrete pad in a gravel area with some vegetation.

1.2.2 Aquatic Areas of Interest

Ponds 1 through 9 and the North Pond range in size from 0.1 acre to 7.29 acres. The ponds were constructed for operational purposes, including management of wastewater from site operations, providing a source of water for firefighting, and use as a log pond. Pond 8 also provides stormwater management for runoff from the City. The historical use of the ponds was described in the *Preliminary Site Investigation Work Plan Operable Unit E – Onsite Ponds* (Arcadis BBL, 2007b). A schematic illustrating the flow between the ponds is provided in Figure 1-5.

1.2.2.1 Ponds 1 through 4 (Southern Ponds)

Ponds 1 through 4 (a total of 2.8 acres), collectively known as the Southern Ponds, were a series of treatment ponds related to the operation of the former Powerhouse (Figure 1-5). Ponds 1 through 4 were settling ponds that treated water received from Pond 7 (see Section 1.2.2.3). The Southern Ponds discharge to the southwest end of Pond 8 through a culvert system.

1.2.2.2 Ponds 5 and 9

Pond 5 (0.6 acres) was man-made for facility purposes. Pond 5 received water from Pudding Creek as well as runoff from the main office area (OU-B) and offsite runoff from Highway 1 (Figure 1-5).

Pond 9 (0.71 acres) is a man-made reservoir supplied by surface water pumped from Pudding Creek. Water from this pond was pumped to hydrants for firefighting. Water is not currently pumped to Pond 9 from Pudding Creek (Figure 1-5).

1.2.2.3 Pond 7

Pond 7 (0.13 acres) received effluent from the wet scrubbers operating in the former Powerhouse power plant (Figure 1-5). From approximately the mid-1970s up until 1996, fly ash emissions from the boilers were controlled by multi-cyclone collectors, followed by wet scrubbers. Scrubber water from the boilers contained fly ash and was piped to two dewatering slabs where, after drying the residual, fly ash was placed in a dump hopper for removal and placement at an offsite location. Water on the dewatering slabs that did not evaporate was conveyed to Pond 7, and then pumped to Ponds 1 through 4 for further treatment. Pond 7 also received water from the dewatering slabs and wash water from the Powerhouse as well as groundwater and surface water runoff from the Powerhouse area.

1.2.2.4 Pond 6 and North Pond

Pond 6 (0.17 acres) collects stormwater runoff during winter storm events and also receives discharge from the North Pond and drainage water from Parcel 2. When the plant was operational, water from Pond 6 (when full) would be pumped to Pond 7 and subsequently to Ponds 1 through 4 when full. There is also an overflow culvert in Pond 6 that allows discharge of stormwater to Fort Bragg Landing (Figure 1-5).

The North Pond (0.06 acres) was formerly used as a settling basin for water used during the operation of the hydraulic debarker. Water from surface runoff from the surrounding uplands to the north currently enters the North Pond via a culvert on its east side and discharges to Pond 6 via a culvert (Figure 1-5).

1.2.2.5 Pond 8

Pond 8 (7.3 acres), also known as the Log Pond, was created in the late 1800s by the damming of Alder and Maple Creeks (Figure 1-5). Pond 8 receives storm-water runoff as well as overflow from Pond 5. Water from Pond 8 discharges over the dam spillway to the beach adjacent to Fort Bragg Landing. The total contributing watershed to Pond 8 is approximately 417 acres, consisting of 190 acres (including Pond 8 itself) within the Mill Site property and 227 acres outside the Mill Site property (related to stormwater management for the City). Total direct rainfall to the surface of the pond is less than two percent of the total inflow to the pond.

1.2.2.6 Riparian AOI (formerly associated with OU-D)

The Riparian AOI was moved from OU-D to be further assessed in the OU-E FS. This AOI consists of undeveloped, wooded land along the eastern boundary of Parcel 7 (Figure 1-3). A riparian wetland and perennial surface drainage are present in the northern end of the AOI, and a seasonal wetland ditch runs along the western perimeter of the AOI. Shallow, unpaved drainage ditches run from the Former Log Storage and Sediment Stockpile AOI into the ditch in the Riparian AOI. Three existing groundwater wells (FB-1 through FB-3) were identified in the wooded area along the east side of Parcel 7 during previous investigations. The locations of these wells are not known, and they are, therefore, not presented on figures in this FS. Remnants of a corrugated metal drainage pipe have been observed in the stream bed approximately midway in the north-south section of the drainage. A water supply well on the western edge of this AOI contained a pump connected to an aboveground plastic pipeline used to transmit water to the nursery in Parcel 9 (TRC, 2004a). Sanitary sewer lines run through the north end of this AOI. No other historical uses of this AOI have been identified.

1.2.3 Groundwater Areas of Interest

1.2.3.1 IRM AOI (formerly associated with OU-C)

The IRM AOI is located directly south of Pond 5 (Figure 1-3). The AOI was dominated by the Former Parcel 5 Mobile Equipment Shop (MES) and adjacent buildings, such as the Former Tire Shop, the Former Washdown Building, and the Former Fuel Storage and Dispenser Building. A truck wash pit was formerly located southwest of the Former Fuel Storage and Dispenser Building.

The Former Parcel 5 MES historically housed tanks containing petroleum solvent, acetylene, and oxygen. In addition, the Former Parcel 5 MES contained an old diesel dispenser, a former paint storage room at the northwestern corner of the building interior, a former oil change waste pit in the northern portion of the building interior, and a room that formerly housed an air compressor north of the fuel dispenser at the building exterior. Within the building were two sheds that were used for chemical storage, including lube oil, waste oil, used oil filters, transmission fluid, hydraulic fluid, grease, and antifreeze. At the time of AME's (2005a) additional investigation work, the west shed contained 1,100 gallons of tractor hydraulic fluid and 330 gallons of lube oil in the form of six 55-gallon drums. Prior to this, the shed contained four 27-gallon ASTs (three containing hydraulic fluid and one containing transmission fluid); five plastic and metal 55-gallon drums containing gear lube oil, used oil, waste-paint-related material, used oil filters, and lube oil; and two open 55-gallon drums, cut in half, that contained used oil, oil-stained cardboard, oil-stained spill pads, and booms. A concrete-lined pit covered by a perforated steel plate was also located in the shed. Water and sludge collected in the pit and were periodically removed. An AST was also formerly located just outside the southwest corner of the building. The Former Parcel 5 MES was demolished during the summer of 2007.

The Former Tire Shop was a 40-foot by 50-foot building located west of the southern end of the Former Parcel 5 MES. It was constructed between the late 1980s and early 1990s. Maps and photographic evidence from 1963 to 1982 show a different building in this location, but there are no records pertaining to its use (AME, 2005a). The Former Tire Shop was demolished during the summer of 2007.

The Former Washdown Building was located immediately southeast of the Former Parcel 5 MES and contained three sumps. One was located in the northwestern corner of the building, one near the center of the building, and another in the southern portion of the building next to the fuel island. A recycled AST was also located in this area. North of the building was an area with surface staining and a drainage area. The Former Washdown Building was demolished during the summer of 2007.

The Former Fuel Storage and Dispenser Building was the southernmost building in Parcel 5. It housed four ASTs that were used to store lube oil, unleaded gas, diesel, and waste oil. Piping from the northwestern corner of the Former Fuel Storage and Dispenser Building ran underground from the waste oil and lube oil ASTs northward along the west side and to the northwestern corner of the Former Parcel 5 MES. An additional covered trench for compressed air piping ran from the Former Fuel Storage and Dispenser Building to the Former Washdown Building. The piping entered the Former Parcel 5 MES and was formerly connected to an interior oil fuel dispenser adjacent to the former paint storage room. The Former Fuel Storage and Dispenser Building was demolished during the summer of 2007.

Southwest of the Former Fuel Storage and Dispenser Building was the location of the Former Truck Wash Pit. The 1981 plant drain map (Georgia-Pacific, 1981) shows an oil trap, sump, and wash rack in this area. The pit was open, but is now backfilled. The Phase I ESA (TRC, 2004a) identified an oil trap in this area and there may have been a separator associated with the pit.

An interim action involving the excavation of impacted soils from this area (Arcadis, 2008b) was completed in 2009. Impacted soils were removed, and clean, treated soils were backfilled into this area (Arcadis, 2010a). The interim action is discussed in further detail in Section 2.2.3.4.

1.2.3.2 West of IRM AOI (formerly associated with OU-C)

The West of IRM AOI is bounded by the IRM delineation on the east, the OU-D delineation on the south, and the OU-E delineation on the west (Figure 1-3). It extends no further north than the IRM. An interim action (Arcadis, 2008b) completed in 2009 extended into this AOI. Impacted soils were removed, and clean, treated soils were backfilled into this area (Arcadis, 2010a). The interim action is discussed in further detail in Section 2.2.3.4.

1.3 Report Organization

The remainder of this FS is organized as follows:

Section 2: Conceptual Site Model summarizes the site setting, investigations and interim remedial actions, and the nature and extent of chemicals of interest (COIs). Based on the nature and extent of COIs, terrestrial AOIs were grouped as “Lowland Terrestrial Soil” and groundwater AOIs were grouped as “IRM and West of IRM Groundwater” and “Lowland Groundwater”. Aquatic sediment AOIs were left as individual areas for further evaluation.

Section 3: Objectives and Requirements of Remediation presents the applicable or relevant and appropriate requirements (ARARs), remedial action objectives (RAOs), and cleanup goals established for the site.

Section 4: Areas and Volumes for Remedial Alternative Development provides an overview of general response actions (GRAs) that could potentially be used to meet the RAOs.

Section 5: Identification and Screening of Remedial Technologies and Process Options evaluates the effectiveness, implementability, and cost-effectiveness of potential technologies and screens for further analysis.

Section 6: Identification of Screening Criteria discusses the screening criteria utilized to evaluation remedial alternatives.

Section 7: Development and Evaluation of Remedial Alternatives summarizes approved remedial actions for the lowland terrestrial soil area and the aquatic sediment areas (Ponds 1 through 4 [Southern Ponds] and Pond 7), as presented in the OU-E RAW (Arcadis, 2016a); and develops remedial alternatives for the remaining aquatic sediment areas (North Pond and Pond 6 and Pond 8) and evaluates against the screening criteria. Remedial alternatives are compared and a preferred alternative is selected per area.

Section 8: Summary of Recommended Remedial Alternatives summarizes the preferred alternative per AOI.

Section 9: References presents the references cited throughout the report.

Section 2: Conceptual Site Model

This section presents the conceptual site model (CSM) that describes the site setting, summarizes previous investigations and interim remedial measures, and provides an overview of the nature and extent of COIs. The CSM is primarily based on data reported in the OU-E RI Report (Arcadis, 2013a), BHHERA (Arcadis, 2015b), *Remedial Investigation, Operable Units C and D* (OU-C and D RI Report; Arcadis, 2011a), and *Feasibility Study, Operable Units C and D* (Arcadis, 2012a). This updated CSM forms the basis for assessing soil and groundwater conditions at the site. As such, it summarizes the fundamental information required to assess the feasibility of potential remedial actions.

2.1 Site Setting

This section presents the site setting in terms of land use, ecology, climate, geology, hydrogeology, occurrence of groundwater, surface water hydrology, and cultural resources.

2.1.1 Land Use

Most industrial features within OU-E have been removed, with the exception of a few smaller features shown on Figure 1-4. With the exception of these remaining industrial features, OU-E is generally vacant. There are no active structures or uses in the terrestrial area and the primary use of the aquatic areas, specifically Pond 8, is to provide stormwater management prior to discharge to the ocean. While foundations of former buildings remain in certain portions of this area, there has been extensive investigation of these areas. A public coastal trail extending both north and south of Fort Bragg Landing were opened in 2014 and 2016 respectively. The foreseeable future use of OU-E is as continued stormwater management facilities, open space, and recreational trail development. The site is fenced and locked to restrict trespassers.

Environmentally sensitive habitat areas (ESHAs[4]) comprise approximately one-fifth of the OU-E lowland (Section 2.1.2) and approximately one-third of the remaining area.

2.1.2 Ecology

The majority of OU-E, along with the IRM AOI and West of IRM AOI, was previously developed industrial land characterized by large areas covered with structures/foundations, asphalt, crushed rock, or a mixture of both. Weedy ruderal vegetation is occasionally observed in these areas (WRA Environmental Consultants [WRA], 2005).

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[4] ESHAs are referred to as "environmentally sensitive habitat area[s]" in Section 30107.5 of the California Coastal Act, and are defined as "any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments". ESHAs in OU-E include wetland and open water habitats. Regulatory protection of ESHAs in the California Coastal Zone ultimately falls under the jurisdiction of the California Coastal Commission (CCC). The City administers CCC Coastal Act jurisdiction for the site under their Local Coastal Program.

Within OU-E, identified wetlands and waters include ponds and ditches used in former sawmill operations and seasonal wetlands[5], and wetland seeps[6] (Figures 2-2, 2-3, and 2-4). Most of the ponds at the site are dominated by species typical of freshwater marshes, although a few consist of open water with less than five percent cover by vegetation.

Two ESHA delineation efforts occurred to identify “any area in which plant or animal life or their habitats are either rare or especially valuable because of their special nature or role in an ecosystem and which could be easily disturbed or degraded by human activities and developments” (California Coastal Commission [CCC] definition; CCC, 2000). In 2009, WRA delineated 20 waters, including wetlands, totaling 13.31 acres, including Ponds 1 through 9 and the North Pond (classified as industrial ponds) and three wetland seeps on the vegetated slope of the northern portion of OU-E (Wetlands B, C, and D, shown on Figure 2-3; WRA, 2009).

In 2010, Arcadis identified three wetland seeps (the eastern portion of Wetland E-1, Wetland E-3, and Wetland E-8) and four seasonal wetlands in OU-E (the western portion of Wetland E-1, Wetland E-2, Wetland Complex E-5 and E-6, and Wetland E-7; Figure 2-3). One additional wetland classified as an industrial pond (Wetland E-4) was identified in a concrete-lined pit that was a remnant of a demolished building. Additional discussion of these areas is included in the *Environmentally Sensitive Habitat Areas Delineation Report* (Arcadis, 2011b).

2.1.2.1 OU-E Flora and Fauna

In 2005, WRA conducted a biological assessment (WRA, 2005) to identify potentially sensitive biological resources at the site. Non-sensitive plant communities identified at the site included developed industrial, non-native grassland, northern coastal bluff scrub, coastal strand, and planted coniferous woodland. Sensitive plant communities observed at the site included coastal terrace prairie, north coast riparian scrub, coastal and valley freshwater marsh, freshwater seep, riparian wetland, seasonal wetland, and seasonal wetland ditch.

The majority of the terrestrial portion of OU-E consists of industrial land characterized by large areas previously covered with structures/foundations, asphalt, crushed rock, or a mixture of both. Vegetation in these areas includes non-native annual grasses and weeds, including sow thistle *(Sonchus asper)*, wild radish *(Raphanus sativa)*, and Italian ryegrass *(Lolium multiflorum)*. Pampas grass (*Cortaderia selloana*), a common invasive species, grows in the terrestrial areas of OU-E.

Waters and wetlands identified in OU-E support a mix of native and invasive hydrophytes. Ponds at the site are dominated by species typical of freshwater marshes, which typically support perennial emergent monocots from 4 to 5 meters tall, often forming completely closed canopies (Holland, 1986). Ponds dominated by emergent vegetation at the site contained species such as water parsley *(Oenanthe sarmentosa)*, parrot’s feather *(Myriophyllum aquaticum)*, slough sedge *(Carex obnupta)*, and cattail *(Typha latifolia)*. Plant species observed in seasonal wetlands present at the site include all flatsedge *(Cyperus eragrostis)*, purple velvet

[5] Seasonal wetland plant communities occur in depressions that are inundated during the rainy season for sufficient duration to support vegetation adapted to wetland conditions.

[6] Freshwater seep plant communities are wetlands containing perennial and annual herbs, including sedges and grasses, which occur in areas that receive perennial or semi-perennial hydrological input as a result of subsurface flow of water.

grass *(Holcus lanatus)*, common horsetail (*Equisetum arvense*), and California blackberry *(Rubus ursinus)*. Plant species associated with the freshwater seeps at the site include panicled bulrush *(Scirpus microcarpus)*, seep monkey flower *(Mimulus guttatus),* soft rush *(Juncus effusus)*, and common horsetail *(Equisetum arvense)*.

A variety of birds and mammals may occur within the boundaries of OU-E, including rabbits, deer, geese, raccoon, muskrat, mallard, egret, and heron. Killdeer (*Charadrius vociferous*) and marsh wren (*Cistothorus palustris*) may use the terrestrial area for nesting.

The ponds provide habitat for amphibians and aquatic plants, and provide a food source for wildlife. The isolated nature of the ponds and some aspects of the physical configuration (e.g., pond banks are generally very steep, there is little open water, and/or water levels are low and turn anoxic in late summer/fall) limit the utility of the ponds by fish.

During the 2005 Biological Assessment, WRA (2005) recorded 54 special status species of wildlife in the site vicinity, indicating that appropriate habitat may exist on or near the site for each species listed, but that the species may not be present onsite, or that the species may spend little time onsite and not feed onsite. Only three species – the double-crested cormorant (*Phalacrocorax auritus*), the California brown pelican (*Pelecanus occidentalis californicus*), and the osprey *(Pandion haliaetus)* – have a high potential for occurrence in the site vicinity. The pelagic cormorant (*Phalacrocorax pelagicus*, not a special status species) has been observed nesting along the bluffs, but the double-crested cormorant has not. The pelican has been observed foraging offsite but has not been observed to visit the site itself. Osprey roost in trees on the bluffs and hunt offshore. These species do not nest onsite, and are not expected to obtain a significant portion of their diet from the site.

WRA (2005) and Sholars (2005a and b) recorded 47 special status plant species in the site vicinity. Of the 47 special status plant species, 18 have a moderate potential to occur at the site, and only three sensitive plant species were found during the Sholars (2005a and b) botanical surveys: Blasdale's bent grass *(Agrostis blasdalei)*, Mendocino Coast Indian paintbrush *(Castilleja mendocinensis)*, and short-leaved evax *(Hesperevax sparsifolia* var. *brevifolia)*. None of these special status plant species are likely to occur within OU-E. Monthly surveys conducted in OU-E from February to May 2010 did not identify special status plant species in OU-E (Arcadis, 2011b).

2.1.2.2 OU-C Flora and Fauna (IRM AOI and West of IRM AOI)

The IRM AOI and West of IRM AOI, formerly associated with OU-C, are developed industrial land similar to the terrestrial portion of OU-E (WRA, 2009). The IRM AOI and West of IRM AOI are largely covered by asphalt, with occasional weedy ruderal vegetation such as sow thistle *(Sonchus asper)*, wild radish *(Raphanus sativus)*, and Italian ryegrass *(Lolium multiflorum)*. Where no concrete is present, soils are highly compacted and sometimes mixed with wood chips, with some areas dominated by subterranean clover *(Trifolium subterraneum)*, Italian ryegrass, and white clover *(Trifolium repens).*

Birds and mammals likely do not use the upland areas of OU-C, including the IRM AOI and West of IRM AOI, for foraging, nesting, or meeting other critical needs, as OU-C provides little to no habitat for these potential receptors.

2.1.2.3 OU-D Flora and Fauna (Riparian AOI)

Plant communities that occur within the Riparian AOI include planted coniferous woodland, north coast riparian scrub, riparian wetland, seasonal wetland and wetland ditch, and drainages. Although the wetland area in the Riparian AOI may provide some limited areas of suitable habitat for some aquatic-feeding species, such as the great blue heron, the Riparian AOI is not known to support populations or significant numbers of fish or macroinvertebrates to serve as a significant prey base for larger wildlife.

2.1.3 Climate

Western Mendocino County has a relatively mild climate with abundant rainfall. Temperatures remain cool throughout the year, with averages ranging from 53 to 57 degrees Fahrenheit (°F). At Fort Bragg, the difference in the average monthly temperature of the coolest month (January) and the warmest month (September) is only 8°F. Marine air minimizes the difference between daytime and nighttime temperatures; at Fort Bragg, the variation between the average high and low daily temperatures for August is 15°F (Natural Resources Conservation Service, 2002).

Precipitation levels vary from 35 to 80 inches per year, and precipitation occurs mostly from October through April. The lesser amounts occur along the immediate coast near Fort Bragg and Point Arena. Marine fog commonly occurs in coastal areas, especially during the nearly rainless summer months.

Mean annual wind speed in the area is 7.3 miles per hour, and the prevailing wind direction is generally from the north to northwest in the summer and from the south in the winter (City, 2004).

2.1.4 Site Geology

2.1.4.1 Regional

Fort Bragg is located along the northern California coastline within the Coast Range geomorphic province. The regional geology consists of complexly folded, faulted, sheared, and altered bedrock. The bedrock of the region is the Franciscan Complex of Cretaceous to Tertiary (late Eocene) age (40 to 70 million years old). The Franciscan Complex comprises a variety of rock types. In the north coast region, the Franciscan Complex is divided into two units: the Coastal Belt and the Melange. In Mendocino County, the Melange lies inland and is an older portion of the Franciscan Complex, ranging in age from the Upper Jurassic to the late Cretaceous. The Coastal Belt consists predominantly of greywacke sandstone and shale.

Besides the Coastal Belt, other geologic units present in Fort Bragg and in the vicinity include surficial deposits of beach and dune sands, alluvium, and marine sediments. As discussed below, the most important of these at the site are the marine sediments, which cut bedrock surfaces along the coast and form much of the coastal bluff material overlying bedrock. Artificial fill (reworked native soil or imported material) is also prevalent at the site.

The surficial geology of the site and environs is depicted on Figure 2-5. The site is underlain by Quaternary (less than 1.5 million years old) marine sediments deposited in thicknesses up to 30 feet on wave-cut surfaces parallel to the coast (Blackburn Consulting, Inc., 2006). These surfaces were created during the Pleistocene Epoch, when sea level fluctuations caused by glaciation created a series of terraces cut into the Franciscan bedrock by wave action (BACE Geotechnical, 2004). The marine sediments comprise poorly to moderately consolidated silts, sands, and gravels, and in some locations, are overlain by a 3- to 4-feet-thick mantle of topsoil or up to a 20-feet-thick layer of artificial fill (BACE Geotechnical, 2004). Both the topsoil and fill are generally relatively coarse in texture, ranging primarily from sandy silts to gravel. The marine sediments are also generally coarse, but appreciable thicknesses of finer materials are also found onsite. Beneath these Pleistocene materials are the Tertiary-Cretaceous rocks (approximately 65 million years old) of the Coastal Belt, composed of well-consolidated sandstone, shale, and conglomerate.

2.1.4.2 OU-E Specific

The shallow subsurface of the terrestrial portions of OU-E contains up to three lithologic units: artificial fill, marine sediments, and bedrock.

2.1.4.2.1 Artificial Fill

Soil borings, test pits, and potholes completed in the terrestrial portions of OU-E identified artificial fill in most areas. In general, the fill consists of reworked marine sediments with foreign materials. It can be generally characterized as coarse-textured material (silty sands to silty gravels), often containing wood chips, bark, ash, sawdust, brick, scrap metal, charcoal, and plastic. Fill thicknesses greater than 30 feet below ground surface (bgs) have been observed along the eastern edges of Ponds 6 and 8, but thicknesses on the order of 5 to 10 feet bgs are more common in the terrestrial areas and around the ponds in Parcel 7.

2.1.4.2.2 Marine Sediments and Bedrock

Marine sediments and bedrock underlie the artificial fill (where present) in OU-E. As with other portions of the site, Franciscan bedrock is present beneath the upland portions of OU-E, but based on lithological information available from borings advanced at the site, its surface undulates and depths to bedrock can vary widely over short lateral distances. For example, within a 350-feet distance along the eastern edge of Pond 8, depths to bedrock vary from less than 10 feet bgs to greater than 40 feet bgs. Bedrock depths are generally shallow (approximately 10 feet bgs) near the ponds in Parcel 7, but in the formerly developed areas of Sawmill #1 and the Powerhouse, bedrock depths are generally no less than 30 feet bgs. In some locations around the margins of Pond 8, marine sediments are completely absent and artificial fill is in direct contact with bedrock.

2.1.4.3 OU-C and OU-D Specific (Riparian AOI, IRM AOI, and West of IRM AOI)

Similar to OU-E, the shallow subsurface of OU-C and OU-D contains up to three lithologic units: artificial fill, marine sediments, and bedrock. The artificial fill thickness has been measured up to 18 feet bgs within Parcel 5, which includes the IRM AOI and the West of IRM AOI. The Riparian AOI lies on the eastern edge of Parcel 7, where fill thicknesses are typically 10 feet bgs. Similar to OU-E, marine sediments and bedrock underline the artificial fill in OU-C and OU-D. The bedrock surface has been observed to range between approximately 10 and 30 feet bgs.

2.1.5 Site Hydrogeology

2.1.5.1 Regional

The regional hydrogeologic setting of the Mendocino County coast has been presented in the Mendocino County Coastal Ground Water Study (California Department of Water Resources, 1982). The site is located in the western coastal area of the county, which was divided into five subunits in the study: Westport, Fort Bragg, Albion, Elk, and Point Arena, separated by the major rivers that discharge to the Pacific Ocean. The study included all areas where coastal terrace deposits had been mapped. The site is located within the Fort Bragg subunit, which extends from Big River to the south to Ten Mile River to the north.

Fresh groundwater is primarily obtained from shallow wells in the semi-consolidated marine terrace deposits or through municipal or privately owned water systems. These water systems divert surface flow and springs or tap shallow alluvial aquifers. A combination of wells and surface water diversions is commonly necessary to provide adequate supply year-round.

2.1.5.2 Site Groundwater Occurrence and Hydraulic Properties

Based on quarterly monitoring from 2004 to 2012 and semi-annual monitoring from 2013 to 2016, groundwater generally flows radially at the site toward Fort Bragg Landing and the Pacific Ocean (Figure 2-6) under average horizontal hydraulic gradients ranging from approximately 0.018 to 0.035 foot per foot (ft/ft; Arcadis, 2015a). Gradients are generally steeper in the central portion of the site and flatter in the northern and southern portions of the site. Depths to first-encountered groundwater have historically ranged from less than 1 foot to approximately 29 feet below top of casing (btoc). In terms of elevation, groundwater levels have ranged from approximately 7 to 104 feet relative to North American Vertical Datum of 1988 (NAVD88). Depending on the location, groundwater levels have been observed to fluctuate seasonally up to 12 feet with the seasons; elevations are higher in the winter and spring and lower in the summer and fall. During the September 2016 monitoring event, groundwater was encountered at depths that ranged from 4.70 to 12.60 feet btoc. Groundwater elevations ranged from 7.37 to 83.73 feet relative to NAVD88, which is consistent with historical trends (Arcadis, 2016b). Figure 2-6 provides the groundwater contour map based on water elevations measured in September 2016.

2.1.5.3 Groundwater Use

Groundwater is not currently used at the site. Groundwater in OU-E is generally relatively shallow. Unlike some upland areas of OU-C and OU-D where future use may be possible, most areas of OU-E, particularly all of the OU-E lowland, are close to the ocean and groundwater use would be limited by salinity and the potential to cause saltwater intrusion. Further, groundwater use in the OU-E lowland would dewater the existing groundwater-fed wetlands and wetland destruction in these areas would not be acceptable to applicable permitting agencies. Therefore, groundwater use for municipal or industrial purposes in OU-E is not expected, particularly in the shallow zones in the current monitoring program.

2.1.5.4 OU-E Lowland

Much of OU-E lies at the lowest elevations at the site and groundwater flow paths tend to converge in the areas around Fort Bragg Landing, with eventual discharge to the Pacific Ocean (Figure 2-6). Along an east-to-west cross-section through the terrestrial area of OU-E, average horizontal hydraulic gradients were on the order of 0.033 ft/ft during the September 2016 monitoring event (Arcadis, 2016b). Average horizontal gradients along the north-to-south direction of the radial flow paths were about double (on the order of 0.056 ft/ft). In September 2016, groundwater was encountered across OU-E at depths that ranged from 4.70 to 12.23 btoc. Groundwater elevations across OU-E ranged from 7.37 to 17.76 feet relative to NAVD88. Depths to groundwater of approximately less than 1 foot btoc have been recorded in the center of the area north of Pond 8 (monitoring wells MW-4.4 and MW-5.16), with depths along the eastern (monitoring well MW-5.18) and western perimeters (monitoring well MW-4.6) increasing to more than 12 feet btoc.

2.1.5.5 IRM AOI and West of IRM AOI

Across the IRM AOI and the West of IRM AOI, groundwater flows northwesterly toward OU-E under an average hydraulic gradient of 0.011 ft/ft (Figure 2-6). In September 2016, groundwater was encountered at depths that ranged from 7.32 to 13.51 btoc. Groundwater elevations across the IRM AOI and the West of IRM AOI ranged from 41.63 to 49.85 feet relative to NAVD88 (Arcadis, 2015a).

2.1.5.6 Riparian AOI

In general, groundwater flows northwesterly in the vicinity of the Riparian Area under average horizontal hydraulic gradients of 0.017 ft/ft (Figure 2-6). In September 2016, groundwater encountered at depths that ranged from 4.71 to 17.49 btoc. Groundwater elevations in the vicinity of the Riparian AOI (formerly associated with OU-D) ranged from approximately 39.86 to 83.73 feet relative to NAVD88 (Arcadis, 2016b).

2.1.6 Surface Water Hydrology

Figure 1-3 identifies the locations of 10 man-made ponds (Ponds 1 through 9 and the North Pond) ranging in size from 0.1 acre to 7.29 acres. The ponds served operational purposes, and Pond 8 also provides stormwater management for the City. Water transfer into and among the ponds was an integral part of the operational history of the site. Figure 1-5 provides a schematic illustration of surface water flow at the site. More information on use of the ponds during historical site operations appears in Section 1.2.2.

Most waters and wetland features (Section 1.2.2) rely on direct precipitation and surface water runoff. Some wetland seep features receive groundwater discharge as well. Waters and wetlands in this area lack a direct hydrologic surface connection to Fort Bragg Landing. One exception, Pond 6, has a surface flow connection to Fort Bragg Landing via a corrugated high-density polyethylene (HDPE) culvert that discharges through the beach berm separating the OU-E lowland from Fort Bragg Landing. Runoff into the OU-E lowland also occurs from impervious surfaces (i.e., asphalt and concrete) in the higher elevation areas located to the north and east

Pond 8, also known as the Log Pond, was created in the late 1800s by the damming of Maple and Alder Creeks. Pond 8 receives stormwater runoff from the City as well as overflow from Pond 5. It is estimated that approximately 50 to 60 percent of the stormwater runoff entering the ponds comes from the City, depending on storm conditions and magnitude (Arcadis, 2012b). Water from Pond 8 discharges over the dam spillway to the beach adjacent to Fort Bragg Landing.

In the past, the Southern Ponds (Ponds 1 through 4) received water from site operations. Currently, the Southern Ponds capture rainfall, stormwater runoff and some groundwater seeps. The bottom elevation of Pond 1 lies above the groundwater table, making Pond 1 seasonal and dry for a portion of the year. Ponds 2 and 4 are also seasonal, but have some groundwater input as the water table can rise above the pond bottom during the rainy season. The southeast and northwest portions of Pond 3 generally have groundwater infiltration year-round.

Pond 5 currently receives runoff from the main office area located to the north of the Pond, as well as from Pudding Creek. Pond 9 received surface water pumped from Pudding Creek to supply water to hydrants for firefighting.

2.1.7 Cultural Resources

TRC (2003, Undated #1, and Undated #2) conducted archival research and archeological surveys of the site and found that portions of the site are considered likely to contain intact prehistoric deposits, as well as historic sites. Areas that are likely to contain historic deposits are important in understanding the early settlement and development of the local community, as well as the lumber operations onsite.

Within OU-E, TRC identified moderate to high potential for prehistoric resources in the lowland terrestrial area. The area nearest Fort Bragg Landing was identified as having a high potential for prehistoric cultural resources. Although subsequent industrial activities may have destroyed prehistoric deposits near Fort Bragg Landing, the road and sea wall may have preserved possibly significant prehistoric cultural resources. OU-E was also identified as having high potential for historic resources. Historic buildings and infrastructure associated with past milling operations are found throughout the lowland terrestrial area (TRC, 2003).

No prehistoric sites were identified in the IRM AOI and the West of IRM AOI. TRC identified moderate potential for subsurface historic resources within the IRM AOI and the West of IRM AOI.

Within OU-D, the area identified by TRC that is considered to have a high potential to contain prehistoric cultural remains is the wooded area (Riparian AOI) on the eastern side of the site adjacent to the nursery. This AOI has been largely untouched by the industrial development that occurred on the other portions of the site. Most of the Riparian AOI was categorized as having moderate potential for historic resources, with the exception of a small area on the southwestern boundary of the Riparian AOI. This area may contain debris that may relate to earlier phases of lumber operations (TRC, 2003).

2.2 Investigations and Interim Remedial Actions

This section describes previous environmental investigations, biological assessment, interim remedial measures, remedial investigations, and risk assessments. The utilized dataset includes analytical results from the previous investigations described in the subsections below.

Investigation data collected prior to January 1998 were excluded as they have not been formally validated and have limited quality assurance/quality control information. Additionally, their age is a concern for characterizing current site conditions. Data from the investigations presented below were found usable, with the exception that additional data validation was required and completed for the data collected from January 1998 to March 2005, which did result in the qualification of a few analytical data points (Arcadis, 2010b). These data were used in the OU-E work plans (Arcadis BBL, 2007b and 2007c; Arcadis, 2010b, 2013b, 2014), OU-E RI Report, and BHHERA in order to adequately characterize the nature and extent of contamination in OU-E and associated AOIs (IRM, West of IRM, and Riparian AOIs formerly associated with OU-C and OU-D).

2.2.1 Environmental Investigations

This section summarizes environmental investigations conducted at the site relevant to OU-E, including lead-based paint (LBP) investigations, Phase I and Phase II environmental assessments, 2004 and 2005 additional site assessments, and groundwater monitoring.

2.2.1.1 Lead-Based Paint Investigation

In January 1998, TRC conducted a preliminary investigation of surface and shallow subsurface soil to evaluate paint on select buildings for elevated lead levels and to evaluate if chemicals associated with site operations were present in subsurface soil in the areas scheduled for demolition in Parcels 3, 4, and 5 (TRC, 1998).

2.2.1.2 Phase I Environmental Site Assessment

TRC performed a Phase I ESA of the site between 2002 and 2004 (TRC, 2004a). The Phase I ESA included visual inspections of each parcel; a site history survey, including historical Sanborn® maps, historical U.S. Geological Survey maps, and aerial photograph review; personal, telephone, and written communication with local and county regulatory agencies; interviews with current and past Georgia-Pacific employees with historical operational knowledge of the site; and a computer database search of sites with known environmental concerns within a 1-mile radius of the site.

As part of the Phase I ESA, Hygienetics Environmental Services, Inc. (Hygienetics) conducted an additional asbestos and LBP investigation in late 2002. Samples from the upland portion of OU-E were found to contain LBP in the Water Treatment Plant Building, the Chipper Building, Sawmill #1 Building, Compressor House 1, and the Powerhouse Building at concentrations up to 17,000 parts per million (ppm) lead (Hygienetics, 2003).

2.2.1.3 Phase II Environmental Site Assessment

TRC conducted a Phase II ESA to characterize site soils and groundwater in the AOIs identified in the Phase I ESA, and to refine the understanding of the nature and extent of affected media. Preliminary Phase II activities were conducted in March and April 2003. Supplemental Phase II activities were conducted in December 2003 and January 2004. Activities included the installation of seven monitoring wells within OU-E. The results were presented in the Phase II ESA report (TRC, 2004b).

2.2.1.4 2004 Additional Site Assessment

TRC conducted additional assessment activities pursuant to recommendations for follow-up assessment presented in TRC's Phase I and Phase II ESAs. The additional site investigation included the completion of pothole investigations, geophysical investigation, and soil borings for the purpose of collecting additional soil samples, and to investigate surface anomalies and potential waste deposit areas. The results of the additional site assessment were presented in the *Additional Site Assessment Report* (TRC, 2004c).

2.2.1.5 2005 Additional Site Assessment

In 2005 and 2006, AME conducted additional site assessment work, including additional soil and groundwater sampling, geophysical surveys, and the installation of additional groundwater monitoring wells. Activities were conducted in general accordance with the *Work Plan for Additional Site Assessment* (AME, 2005a*).* Analytical data were reported in the *Dioxin Sampling and Analysis Report* (AME, 2006a) and the *Data Transmittal Report* (AME, 2006b).

2.2.1.6 Pond Sediment Investigations

2.2.1.6.1 2008 Pond Sediment Investigations

Arcadis conducted pond sediment sampling activities in March 2008, as described in the *Data Summary Report, Operable Unit E Pond Sediment* (Arcadis, 2009). These activities were performed in general accordance with the *Preliminary Site Investigation Work Plan Operable Unit E – Onsite Ponds* (Arcadis BBL, 2007b). Sediment samples were collected from 26 locations in Ponds 1 through 9 and the North Pond. Sediment samples were collected from the intervals of 0 to 0.5 foot below sediment surface (bss) and 0.5 to 1.5 feet bss and analyzed for COIs for which a data gap had been identified: metals, TPH as diesel (TPHd), TPH as motor oil (TPHmo), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and polychlorinated dibenzo-p-dioxin (dioxins) and polychlorinated dibenzofuran (furans). In some locations, samples were also collected at depths up to 9.5 feet bss. Sample locations were selected to characterize areas not previously addressed during historical investigations and/or to fill data gaps related to the spatial and vertical distribution of specific COIs. Pond sediment sampling locations are shown on Figures 2-7 through 2-9.

2.2.1.6.2 2009 Mill Pond (Pond 8) Additional Sediment Investigation

An additional sediment sampling event was conducted in June 2009 to understand the magnitude and spatial extent of the COIs in Pond 8, to provide samples for sediment bioassay and bioaccumulation studies, and to provide paired data for estimation of site-specific bioaccumulation factors. Sample methods and results are described in full in the *Data Summary Report – Additional Investigation Pond 8 Sediment* (Arcadis, 2011c).

Because surface sediment (0 to 0.5 foot bss) was identified as the primary exposure media for Pond 8 (Arcadis BBL, 2007b and Arcadis, 2009), the investigation focused on surface sediment only. For this investigation, nine sediment samples were collected from Pond 8 and one sample was collected from Pond 9 to provide a basis for comparison for the Pond 8 sediment results, as Pond 9 has no known associated sources of site-related contaminants. Samples were analyzed for metals, TPHd, TPHmo, and dioxins and furans, as well as bioassay and bioaccumulation testing (Arcadis, 2011c). Pond sediment sampling locations are shown on Figures 2-7 through 2-9.

2.2.1.6.3 2012 Mill Pond (Pond 8) Geotechnical and Chemical Investigation

In February and March 2012, Arcadis conducted a sediment volume survey, and geotechnical and chemical investigation of Pond 8 sediments to further evaluate cleanup and restoration options. To further characterize sediment volume, the surface area of the pond was manually probed at recorded coordinates, and later integrated over the surface area of the pond to estimate a total of 106,000 cy of sediment in the pond (Arcadis, 2012b). Sediment samples were collected and analyzed for metals and dioxins and furans. Pond sediment sampling locations are shown on Figure 2-7.

Samples were also collected for geotechnical characterization. Results indicated that Pond 8 sediment is generally classified as silty sand with an organic content between 20 and 50 percent, and a hydraulic conductivity ranging from $1x10^{-7}$ to $4x10^{-7}$ centimeters per second, which is lower than what is typically observed for silty sand. Additionally, the total porosity is higher than what is typically observed for silty sands, suggesting that the sediment also has many clayey characteristics (Arcadis, 2012b).

2.2.1.7 Groundwater Monitoring

Quarterly groundwater monitoring at the site was initiated by TRC in 2004. The monitoring network has varied over the years and is currently consistent with Comprehensive Monitoring Program Update Number 6 (CMP Update No. 6; Arcadis, 2013c) as approved by DTSC in November 2013 (DTSC, 2013). CMP Update No. 6 includes the gauging of 18 groundwater monitoring wells (six of which are located in OU-E) and sampling of 17 groundwater monitoring wells (five of which are located in OU-E). The comprehensive groundwater monitoring dataset for the site, including all data collected through the first quarter of 2015 from active groundwater monitoring wells, is presented in the *First Semi-Annual 2015 Groundwater Monitoring Report* (Arcadis, 2015a).

2.2.2 Biological Assessment

In 2005, WRA conducted a biological assessment at the site to identify biological resources at the site. A total of 54 special status species of wildlife were recorded in the site vicinity, but only three species (the double-crested cormorant, the California brown pelican, and the osprey) have a potential for occurrence in the site vicinity. Although these species may be observed and/or occur at times onsite, these species do not nest onsite, and are not expected to obtain a significant portion of their diet from the site. A total of 47 special status plant species were identified in the site vicinity, 18 of which have a moderate potential to occur at the site. Three sensitive plant species were found onsite during the botanical surveys: Blasdale's bent grass, Mendocino Coast Indian paintbrush, and short-leaved evax; however, none of these special status plant species are likely to occur within OU-E and monthly surveys conducted in OU-E from February to May 2010 did not identify any special status plant species (WRA, 2005, updated 2007).

ESHA delineation activities were conducted by WRA in 2009 and Arcadis in 2010 to identify potential ESHAs (including potential federal and state jurisdictional waters, including wetlands [waters/wetlands]) located onsite. WRA (2009) delineated 20 waters/wetlands totaling 13.31 acres in OU-C, OU-D and OU-E. Of these delineated areas, 8.89 acres were classified as U.S. Army Corps of Engineers (USACE) jurisdictional waters/wetlands. Approximately 308 acres of the 317 acres that Georgia-Pacific owns were considered non-jurisdictional for USACE purposes. In 2010, Arcadis identified and delineated the following additional features as potential ESHAs: 17 waters/wetlands totaling approximately 3.64 acres, approximately 2.21 acres of riparian area, and approximately 375 linear feet of bedrock groundwater seep complexes. Arcadis also delineated coastal waters associated with Fort Bragg Landing. In total, there are 48 potential ESHA areas totaling approximately 19.16 acres of the approximately 317-acres comprising OU-C, OU-D and OU-E (Arcadis, 2011a). Delineated ESHAs within OU-E are shown on Figures 2-2, 2-3, and 2-4.

In 2010, Arcadis conducted a functional assessment of the delineated potential waters/wetlands to evaluate their ecological function. Arcadis followed guidance provided in *California Rapid Assessment Method (CRAM) for Wetlands* (Collins et al., 2008). Overall CRAM scores indicate that waters/wetlands evaluated on the site possess between 33 and 58 percent of the total functional capacity that a reference wetland system could attain. These CRAM scores indicate the generally degraded character of the site waters/wetlands. Ponds on the site scored lowest in the CRAM evaluation (i.e., between 32 and 45 percent of total functional capacity). Seasonal and seep wetlands that have developed in the OU-E lowland since demolition of the building foundations in this area scored the highest in the CRAM evaluation (i.e., 58 percent of total functional capacity). The complete results of the CRAM evaluation are presented in the *Mill Pond Complex Restoration Draft Conceptual Design* (Arcadis, 2011d).

2.2.3 Interim Remedial Measures

IRM activities as described in the *Interim Action Remedial Action Plan* (IARAP; Arcadis, 2008b) and *Interim Action Completion Report* (Arcadis, 2010a) were initiated in 2008 and completed in 2009. IRM activities include:

- Foundation removal and cap placement
- Excavation of former fuel pipe that extended from the former Fuel Storage Shed to the Powerhouse
- Excavation and disposal of soil impacted with metals near the former Compressor Houses
- Excavation and onsite treatment of TPH-affected soil near the former Compressor Houses

- In-situ groundwater treatment for TPH (biosparging and addition of oxygen-releasing material [ORM] before backfilling) near the former Compressor Houses
- Excavation and onsite treatment of TPH-affected soil within the IRM AOI and the West of IRM AOI
- In-situ groundwater treatment for TPH (biosparging and addition of oxygen releasing materials [ORM] before backfilling) within the IRM AOI and the West of IRM AOI.

2.2.3.1 Foundation Removal

Concrete slab and foundation demolition activities were conducted in 2006. Following foundation removal, confirmation soil samples were collected in accordance with approved work plans (AME, 2005a,b,c). Caps consisting of geotextile membranes and crushed concrete, rock, and/or soil fill were placed in areas where foundations had been removed, as illustrated on Figure 2-10. Details regarding the demolition, investigation, and removal activities performed and the analytical results from the sampling are presented in the *Construction Completion Report* (Arcadis BBL, 2007a). Additional details regarding the caps and their design and construction are provided in the Final Cap Design Memorandum, included as Appendix G of the *Construction Completion Report* (Arcadis BBL, 2007a).

2.2.3.2 Pipeline Removal

In 2007, Arcadis removed a 4-inch-diameter, double-walled fiberglass fuel oil pipeline that extended south of the Powerhouse Fuel Storage Shed in a general southward direction across Parcel 4 to the Powerhouse (Arcadis, 2008a). The fuel oil line historically transported Bunker C fuel oil (also referred to as No. 6 fuel oil), a highly viscous long-chain or heavy oil used in boiler/combustion operations produced by blending long-chain residual oils with light oil, typically No. 2 fuel oil. The fuel oil was delivered by rail car, unloaded, and pumped to two steel ASTs. These tanks, located on the south side of the Powerhouse Fuel Storage Shed, were in operation from the 1950s to 1995, when they were decommissioned and demolished.

The pipeline excavation was completed in the north and south directions, well short of the Powerhouse to the south and the Fuel Storage Shed to the north, because the pipes had extended aboveground at these points to previously demolished overhead pipe racks. Overall, approximately 200 linear feet of the pipeline and 3,000 cy of soil were removed within the excavation boundary shown on Figure 2-10. The excavation of the fuel oil pipeline was completed on June 21, 2007.

2.2.3.3 Interim Action Compressor House Area

Metals and TPH-impacted soils were excavated from the Compressor House area in the summer of 2008. Approximately 60 cy of metals-impacted soil was excavated and transported offsite. Excavation of TPH-impacted soil at the Compressor House area was initiated following completion of the metals-impacted soil excavation. The total excavation area measured approximately 7,000 sf and 2,600 cy of soil were removed and transported to the land treatment unit for bioremediation (Arcadis, 2010a). Excavation proceeded to the south until a retaining wall was reached. Excavation boundaries are shown on Figure 2-11.

The excavation was advanced to at least 2 to 3 feet below the water table; groundwater that infiltrated into the excavation was treated by biosparging. Oxygen-releasing material was added to the backfill soil to address residual TPH contamination in soil and downgradient groundwater that may not have been affected by biosparging. Confirmation soil samples were collected from the walls and floor of the excavation, and samples were collected from the groundwater in the excavation prior to and following the biosparging. These results are presented in the *Interim Action Completion Report, Operable Units C and E* (Arcadis, 2010a).

2.2.3.4 Interim Action IRM AOI and West of IRM AOI

Between 2008 and 2009, four separate excavations were conducted within the IRM AOI and the West of IRM AOI to remove TPH-impacted soil. Excavation activities are presented in the *Interim Action Completion Report, Operable Units C and E* (Arcadis, 2010a). The excavation boundaries are presented on Figure 2-11 and the locations are described below:

- MES Upgradient Area – a subsection of the Former MES Area within the IRM AOI, which included the Former MES Building. This area was separated from the MES Road Area by a shallow soil berm, due in large part to logistical reasons (e.g., timing of the excavation completion, availability of equipment and personnel, etc.). The northern half of this area was excavated in 2008, and excavation of the southern half was completed in 2009. At the end of field work in 2008, the total excavation area measured approximately 18,250 sf, and another 17,550 sf were excavated in 2009 (Figure 2-11). Approximately 5,050 cy of soil were removed in 2008 and 5,700 cy of soil were removed in 2009. All excavated soil was transported to the land treatment units for bioremediation. The final excavation depths ranged from 4 to 14 feet bgs (Arcadis, 2010a).

- MES Road Area – a subsection of the Former MES Area expanding across the IRM AOI, West of IRM AOI and the Miscellaneous AOI, including the section of road running through Parcel 5 from Pond 5 to the southern end of the Former MES Building. The excavation, which was completed in 2008, was separated from the MES Upgradient Area by a shallow soil berm. The final excavation area was approximately 18,000 sf, with approximately 7,400 cy of soil removed (Figure 2-11). Excavation depths ranged from 5 to 13 feet bgs. The excavated soil was transported to the land treatment unit for bioremediation. Due to safety concerns related to maintaining an open excavation in high traffic areas, the entire MES Road Area excavated in 2008 was backfilled with bioremediated soils from the landfarm following completion of groundwater treatment. Prior to backfilling, sidewalls were covered with plastic sheeting to separate the clean backfill material from contaminated areas that were to be excavated in 2009 (Arcadis, 2010a).

- MES R53 Area – a shallow polygon located south of the Former MES Building. This small excavation was started and completed in 2009. Excavation of TPH-impacted soil at the MES R53 Area comprised an area of 65 feet by 75 feet (about 4,875 sf), and reached depths of 2 to 2.5 feet bgs (Figure 2-11). The total volume of excavated soil was approximately 400 cy, which was transferred to the land treatment units for bioremediation (Arcadis, 2010a).

- West of MES Area – excavation including the northern half of the West of IRM AOI, as well as a small portion of the IRM AOI and the Miscellaneous AOI. This area was addressed in 2009. The excavation area was directly adjacent to the western side of the 2008 MES

Road Area excavation, and residual TPH-impacted soil left in place at the end of the 2008 season was removed. Pond 8 limited the western wall of the West of MES excavation; an approximately 20-foot barrier was left to avoid impacting the stability of the pond wall. The remaining TPH-d along the barrier ranges between 160 to 3,700 mg/kg at 9 to 9.5 feet bgs. Excavation progressed north to remove impacted soil. The West of MES excavation measured approximately 58,000 sf, with approximately 21,000 cy of soil removed and transported to the land treatment units for bioremediation treatment (Figure 2-11). The final excavation depths ranged from 8 to 10 feet bgs (Arcadis, 2010a).

The planned excavation depth at all locations except for the MES R53 Area was extended at least 2 feet below groundwater so that groundwater would infiltrate the excavations and could be treated with biosparging and application of ORM. The ORM was added to the backfill soil to address residual TPH contamination in soil and downgradient groundwater that may not have been affected by biosparging (Arcadis, 2010a).

2.2.4 Remedial Investigations

In June 2010, additional sampling was conducted at OU-E in accordance with the *Site Investigation Work Plan, Operable Unit E – Upland* (Arcadis, 2010b) in preparation of the OU-E RI Report. In October 2010, Arcadis evaluated the existing historical site data and the June 2010 sampling data, and identified data gaps that required step-out sampling to fully delineate chemical impact (Arcadis, 2010c). Additional step-out sampling was conducted in November and December 2010 (Arcadis, 2011e). Comprehensive analytical results were discussed in the RI Report to characterize the nature and extent of impacts (Arcadis, 2013a).

A screening level analysis for unrestricted use, including potential residential receptors, was conducted in the DTSC approved RI Report and exceedances of the unrestricted residential screening levels were identified (Arcadis, 2013a). Figures 2-12, 2-13, and 2-14 present comparison of lead, benzo(a)pyrene (B(a)P) TEQ, and dioxin TEQ in soil with human health preliminary screening levels (PSLs), respectively. Figures 2-15 and 2-16 present a comparison of arsenic and dioxin TEQ in Ponds 6, 7, 8, and North Pond with human health PSLs, and Figures 2-17 and 2-18 present a comparison of arsenic and dioxin TEQ in the southern ponds with human health PSLs, respectively.

Conclusions from the RI Report are summarized below, as discussed per AOI in Section 2.3 (alongside the refined conclusions from the BHHERA). These include constituents detected at concentrations greater than human health and/or ecological PSLs appropriate for unrestricted land use.

- OU-E Lowland Terrestrial Soil: metals (antimony, arsenic, barium, chromium, copper, lead, mercury, molybdenum, and zinc), TPHd, polychlorinated dibenzo-*p*-dioxin/polychlorinated dibenzofurans (dioxins/furans), and PAHs were detected at concentrations greater than PSLs.

- OU-E Aquatic Area Sediment: metals (arsenic, barium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, and zinc), PAHs, volatile organic compounds (VOCs), dioxins/furans, PCBs, pesticides, and TPH were found at concentrations greater than PSLs.

- OU-E Groundwater: Metals (arsenic, barium, cobalt, copper, lead, molybdenum, nickel, thallium, and vanadium), PAHs, VOCs, dioxins/furans, PCBs, and TPH were found at concentrations greater than PSLs.

The RI Report recommended four of the five lowland terrestrial AOIs (Water Treatment and Truck Dump AOI, Sawmill #1 AOI, Compressor House and Lath Building AOI, and Powerhouse and Fuel Barn AOI) for further evaluation in the BHHERA. The RI Report recommended no further action for the Pond 8 Fill Area AOI, due to only a single zinc exceedance of the ecological PSL and no exceedances of human health PSLs. All ten OU-E aquatic AOIs (Ponds 1 through 9, and the North Pond) were recommended for further evaluation in the BHHERA. The additional site investigation and risk assessment activities conducted for the BHHERA are further discussed in Section 2.2.6.

The OU-C and OU-D RI evaluated the nature and extent of constituents in the IRM and West of IRM AOC and assessed the risk associated with soil and groundwater conditions, as detailed in Section 2.2.5. The Riparian AOI was further delineated in during the investigation that accompanied the BHHERA. The purpose of the investigation was to provide a baseline human health and ecological risk assessment for OU-E and associated AOIs, which included the Riparian AOI. The COIs in the Riparian AOI that were investigated were metals (arsenic, barium, selenium, vanadium, and zinc) and PAHs (Arcadis, 2015b). The nature and extent of constituents considered in the BHHERA are presented in Section 2.2.6. No additional investigation of dioxin in soil or sediment was conducted as part of the BHHERA investigation for the Riparian AOI (DTSC, 2016).

2.2.5 OU-C and OU-D IRM and West of IRM Soil and Groundwater Investigations and Risk Assessment

In accordance with the IARAP (Arcadis, 2008b), soil excavation and in-situ groundwater treatment (biosparging and application of ORM) were conducted between 2008 and 2009 in the IRM and West of IRM AOIs. COI concentrations in non-excavated soil are generally below the screening levels. Slightly elevated TPHd concentrations remain in soil beneath the excavation area northwest of the MES and the excavation boundary in the vicinity of the Former Diesel AST (Arcadis, 2011a).

The BHHERA evaluation provided in the DTSC approved OU-C and OU-D RI concluded that COI concentrations in soil at the IRM and West of IRM AOIs do not pose a risk to human health or the environment. The IRM and West of IRM AOIs were recommended for evaluation in this FS for fuel-related constituents, VOCs, and arsenic in groundwater (Arcadis, 2011a).

2.2.6 OU-E Baseline Human Health and Ecological Risk Assessment

The RI Report and BHHERA were completed for the IRM and West of IRM AOIs as part of the OU-C and OU-D RI (Arcadis, 2011a) and are not further discussed in this section. This section presents the nature and extent of constituents for the Riparian AOI based on additional sediment and porewater samples collected from the Riparian AOI as part of the OU-E BHHERA investigation.

In April 2013, additional sediment and porewater samples were collected from Ponds 1 through 9, the North Pond, and the Riparian AOI (Figures 2-19, 2-20, 2-21, and 2-22). Data collected in the additional BHHERA investigation were used in conjunction with RI data to provide an evaluation of potential risk in OU-E for reasonably anticipated future receptors, based on current land and assumed future land use presented in the *Mill Site Specific Plan* (Mill Site Coordinating Committee, 2012; Figure 2-1). Human receptors evaluated in the terrestrial exposure area of OU-E included construction workers, maintenance/utility workers, passive (occasional) child and adult recreational visitors, frequent adult recreational visitors, and commercial/industrial workers (Figure 2-23). Human receptors in the combined aquatic exposure areas of OU-E included passive child and adult recreational visitors (Figure 2-24).

The OU-E ecological risk assessment (ERA) estimated exposure and characterized potential ecological risk in accordance with the CSM presented in this OU-E BHHERA and methods described in the *Site-Wide Risk Assessment Work Plan* (Site-Wide RAWP; Arcadis, 2008c) and the OU-E BHHERA Work Plan (Arcadis, 2013b).

Results of the OU-E BHHERA and hot-spot/residual risk and hazard analyses for the Lowland Terrestrial AOC, the Aquatic AOC, and the Riparian AOI are summarized in the following sections.

2.2.6.1 Lowland Terrestrial AOC Risk Assessment

The BHHERA for the Lowland Terrestrial AOC included four of the five terrestrial AOIs (Water Treatment and Truck Dump AOI, Sawmill #1 AOI, Compressor House and Lath Building AOI, and Powerhouse and Fuel Barn AOI). In response to DTSC comments on the BHHERA work plan, and due to the absence of COPCs above relevant screening levels, the Pond 8 Fill Area AOI was not included as part of the BHHERA dataset.

The soil target concentrations used to identify presumptive remedy areas (PRAs) in the Lowland Terrestrial Area of Concern (AOC) were calculated, and presented in the HERO memorandum, dated June 25, 2014. In that memorandum, site-specific risk-based soil concentrations targets for specific chemicals were developed, and they represent acceptable exposure point concentrations as 95% upper confidence levels (UCLs) on the arithmetic mean (identified as risk-based target levels [RBTLs] in this FS). These risk-based soil concentrations targets were multiplied by three to estimate not-to-exceed soil values, which are:

- 0.90 mg/kg for benzo(a)pyrene (B(a)P) equivalents (TEQ)
- 160 pica grams per kilogram (pg/kg) or parts per trillion (ppt) for dioxin TEQ
- 320 mg/kg for lead.

All data points in the terrestrial AOC were compared to those ceiling concentrations. Data points at or above those ceiling concentrations were identified, and those locations were designated as hot spots or PRAs. After the removal of those identified data points, the residual exposure point concentrations were calculated from the remaining data points and compared to acceptable exposure point concentrations, i.e., RBTLs. After the presumptive remedy is completed, confirmation sampling will confirm that remaining sample data points do not exceed these ceiling concentrations. Within the Lowland Terrestrial AOC, the following hot spots were identified for the following constituents in the vicinity of the indicated locations:

- B(a)P Equivalents (Figure 2-25):
  - Powerhouse and Fuel Barn AOI: one sample location (HSA-4.3 from 2 to 2.5 feet bgs)
  - Sawmill #1 AOI: four sample locations (OUE-DP-073 from 2 to 3 feet bgs, OUE-DP-074 at 2 to 3 feet bgs, OUE-DP-075 from 2 to 3 feet bgs, and OUE-DP-026 from 2 to 3.5 feet bgs)
  - Waste Treatment and Truck Dump AOI: two sample locations (OUE-DP-099 from 0.5 to 1.0 foot bgs and OUE-DP-100 from 2.5 to 3.5 feet bgs)
- Dioxin TEQ (Figure 2-26):
  - Powerhouse and Fuel Barn AOI: one sample location (DP-052 from 0 to 0.5 foot bgs and 0.5 to 1.5 feet bgs)
- Lead (Figure 2-27):
  - Sawmill #1 AOI: two sample locations (OUE-DP-070 from 3 to 4 feet bgs and DP-05.57 from 0.5 to 1 foot bgs)
  - Powerhouse and Fuel Barn AOI: two sample locations (OUE-DP-094 from 5.5 to 6 feet bgs and OUE-DP-090 from 5.5 to 6 feet bgs)

These hot spots were identified for removal in the OU-E Remedial Action Work Plan (RAW) (Arcadis 2016a). No hot spots were identified in the Compressor House and Lath Building AOI. Hot spots were identified in the remaining three terrestrial AOIs (Powerhouse and Fuel Barn AOI, Sawmill #1 AOI, and the Waste Treatment and Truck Dump AOI).

Residual B(a)P equivalents, dioxin TEQ, and lead exposure point concentrations (i.e., the 95% UCL on the arithmetic mean) were calculated excluding the identified hot spot concentrations to assess residual risks and hazards assuming hot spot removal. The BHHERA demonstrated that residual human and ecological risks assuming hot spot removal in Lowland Terrestrial AOCs were below the risk-based target levels identified by DTSC (2014) for the current and reasonable likely future land uses.

Petroleum related constituents (TPHd) were detected above human health screening levels in one location. The overall human health risk for petroleum related constituents based on exposure point concentrations is acceptable. One location (OUE-DP-025, 12,634 mg/kg) slightly exceeds the human health screening level of 10,772 mg/kg and was not identified as a human health hot spot based on the limited risk relative to the human health PSL. This location was identified for removal in the OU-E Remedial Action Work Plan (RAW) (Arcadis 2016a).

BHHERA results indicated that baseline terrestrial excess lifetime cancer risks (ELCRs) range from less than one in a million (1×10^{-6}) to 4×10^{-5}, depending on the exposure scenario evaluated, with the highest risk for the commercial worker. Baseline terrestrial Hazard Indices (HIs) ranged from less than one to five, depending on the exposure scenario evaluated, with the highest HI for the construction worker. Dioxin TEQ concentrations in soil in the terrestrial OU-E lowland AOC represented the largest contributor to potential cancer risk and non-cancer hazard (Arcadis, 2015b).

Results of the ERA for the terrestrial exposure area indicated that potential unacceptable risk for populations of plants, soil invertebrates, birds, and mammals is unlikely. HQs were generally less than one, or COPC EPCs were below site-specific background concentrations. Barium HQs for plants, invertebrates, and invertivorous mammals were greater than one, but were driven by a few samples located in a small area of the site, indicating potential population-level exposure is limited. Furthermore, the ERA concluded that exposure of individual receptors in the small area would not result in unacceptable effects to local populations.

2.2.6.2 Aquatic AOC Risk Assessment

For the Aquatic AOCs, the BHHERA evaluated all 10 aquatic AOIs. Ponds 1, 2, 3, and 4 were combined into a single Southern Ponds AOC, resulting in a total of seven aquatic AOCs as separate exposure areas in the BHHERA (Ponds 1 through 4, Pond 5, Pond 6, Pond 7, the North Pond, Pond 8, and Pond 9). Additionally, all ponds were evaluated as one exposure area (the Combined Aquatic AOC) under two exposure scenarios: assuming 50 days exposure per year and 12 days of exposure per year. DTSC has indicated that they are primarily interested in the results of the risk assessment for the individual aquatic AOIs under the 50-day exposure frequency (DTSC, 2016).

For the Combined Aquatic AOC (i.e., all 10 aquatic AOIs combined), ELCRs and HIs for the occasional (passive) recreator were below 1×10^{-6} and 1, respectively, when a 12 day per year exposure frequency was considered. Under the 50-day exposure frequency, the HIs for the occasional (passive) recreator remained below 1 for potential noncancer effects, while the ELCRs were 5×10^{-6} (0 to 0.5 foot bgs interval) and 6×10^{-6} (0 to 2 feet bgs interval). For both sediment intervals, arsenic and dioxin TEQ were the primary risk drivers via incidental sediment ingestion.

The separate aquatic AOIs were evaluated using the conservative exposure frequency of 50 days per year. Since a lower exposure frequency would be expected in Ponds 1 through 4 due proposed “industrial” and “urban reserve” land uses (Section 2.1.1), the BHHERA also evaluated the Southern Ponds AOI assuming potential exposures of 12 days per year.

The separate aquatic AOI evaluations indicated HIs for all ponds were 1 or less, assuming an exposure frequency of 50 days per year. ELCRs for Ponds 5 and 9 were below 1×10^{-6}. Aquatic ELCRs for the passive recreational visitor, as analyzed on an individual pond basis, ranged from less than 1×10^{-6} (Ponds 5 and 9) to 2×10^{-5} (Pond 7).

The ERA for the aquatic AOIs concluded that unacceptable risks are not expected for populations of plants, benthic organisms, amphibians, birds, or mammals exposed to COPC in sediment. However, there is potential for localized risk to benthic organisms from barium exposure in Pond 7 sediment, based on comparison of porewater barium concentrations to the selected surface water screening level (Regional Water Quality Control Board [RWQCB], 2013).

The BHHERA results for the seven aquatic AOIs are summarized below:

- Ponds 1 through 4 (Southern Ponds) AOI – HIs were below one. ELCRs for the 50 days per year scenario in the 0 to 0.5 foot bgs and 0 to 2 feet bgs exposure intervals were 8 x 10^{-6} and 7 x 10^{-6}, respectively. ELCRs for the 12 days per year scenario in the 0 to 0.5 foot bgs and 0 to 2 feet bgs exposure intervals were both 2 x $10^{-6.}$ For both exposure scenarios, the potential exposure to arsenic and dioxin TEQ from sediment ingestion was the primary contributor to the ELCRs. For the 12-day exposure scenario, the cumulative ELCR in Ponds 1 through 4 for the adult/child occasional recreator would be equal to 1 x 10^{-6} if the minimal contribution of soil and dust to human body burden for dioxin TEQ were taken into account in calculating baseline risks.

- Pond 5 AOI – The occasional recreator HI and ELCR for Pond 5 were below 1 and 1 x 10^{-6} respectively, under the 50-days-per-year exposure frequency. Because the ELCR for Pond 5 was below the risk management threshold of 1 x 10^{-6}, Pond 5 will be recommended for no further action in the OU-E Remedial Action Plan (RAP) and is therefore not discussed further herein.

- Pond 6 AOI – Pond 6 ELCRs were 4 x 10^{-6} and 3 x 10^{-6}, for the 0 to 0.5 foot bgs exposure interval and the 0 to 2 feet bgs interval under the 50-days-per-year exposure frequency, respectively. For both sediment intervals, arsenic and dioxin TEQ were the primary risk drivers via incidental sediment ingestion.

- Pond 7 AOI – Pond 7 ELCRs were 2 x 10^{-5} in both the 0 to 0.5 foot bgs and 0 to 2 feet bgs depth intervals under the 50 days-per-year exposure frequency. For both sediment intervals, arsenic and dioxin TEQ were the primary risk drivers via incidental sediment ingestion. Pond 7 AOI contained the highest sediment concentrations of dioxin TEQ of all the ponds on site (1,227 pg/g at 0 to 0.5 feet bgs and 1,668 pg/g at 0 to 2 feet bgs). Pond 7 AOI contained arsenic greater than local background concentrations (11 to 103 mg/kg at 0 to 0.5 feet bgs, and 11 to 115 mg/kg at 0 to 2 feet bgs).

- Pond 8 AOI – Pond 8 ELCRs were 2 x 10^{-6} in both the 0 to 0.5 foot bgs and 0 to 2 feet bgs depth intervals under the 50-days-per-year exposure frequency. For both sediment intervals, arsenic and dioxin TEQ were the primary risk drivers via incidental sediment ingestion, but this result is conservative. The results presented in the BHHRA for Pond 8 are mitigated by the following factors:

    - From a practical standpoint, exposure to the sediments in Pond 8 for any duration is remote due to site-specific factors that discourage access such as dense vegetation, steep banks, and cold surface water and air temperatures for much of the year.

    - From a risk analysis standpoint, arsenic concentrations in Pond 8 are comparable to background, so arsenic ELCRs are not associated with site conditions for the Pond 8 AOI. When the Pond 8 occasional recreator is evaluated without considering background arsenic exposures, the resulting cumulative ELCR in Pond 8 is 1 x 10^{-6}.

    - If the minimal contribution of soil and dust to human body burden for dioxin TEQ were taken into account in calculating baseline risks in Pond 8, the cumulative ELCR would decrease by an order of magnitude to below 1 x 10^{-6}. The use of the body burden adjustment in the derivation of dioxin TEQ remedial goals is documented in HHRA Note 2 (DTSC/HERD, 2009) entitled "Remedial Goals for Dioxins and Dioxin-like Compounds for Consideration at California Hazardous Waste Sites".

- Pond 9 AOI – The occasional recreator HI and ELCR for Pond 9 were below 1 and 1 x 10^{-6} respectively, under the 50-days-per-year exposure frequency. Because the ELCR for Pond 9 was below the risk management threshold of 1 x 10^{-6}, Pond 9 will be recommended for no further action in the OU-E RAP and is therefore not discussed further herein.

- North Pond AOI – ELCRs were 2 x 10^{-6} in both the 0 to 0.5 foot bgs and 0 to 2 feet bgs depth intervals under the 50-days-per-year exposure frequency. Arsenic was the primary risk contributor in North Pond.

Cancer and noncancer risks were evaluated for occasional recreators in the combined aquatic exposure area. As noted above, actual recreational exposures to pond sediments and surface water are unlikely. ELCRs and HIs for the occasional recreator in aquatic areas were below target thresholds for potential cancer and noncancer effects when a 12-day exposure frequency was considered. When a conservative alternative exposure frequency (50 days per year) was assumed, the HIs were below one, and the ELCRs in the 0 to 0.5 foot bgs and 0 to 2 feet bgs exposure intervals remained low (5 x 10^{-6} and 6 x 10^{-6}, respectively. Dioxin sediment ingestion exposures made up the greatest proportion of the ELCR for this alternative recreator scenario (54 percent for the 0 to 0.5 foot bgs interval and 63 percent for the 0 to 2 feet bgs interval). Within the combined aquatic exposure area, the highest concentrations of dioxin TEQ were detected in sediments collected from Pond 7 (samples Pond 7-01 and Pond 7-02). Expected exposures to sediments and the exposure frequency of 50 days per year are unlikely.

Results of the ERA for combined aquatic exposure areas indicated that unacceptable risk is not likely for populations of plants, benthic organisms, birds, mammals and amphibians exposed to site sediment and surface water. ERA results for ponds evaluated individually indicated potential risk is not likely, with the exception of barium partitioning to porewater in Pond 7 sediment, which may pose a potential risk to benthic organisms based on comparison of porewater concentrations at locations Pond 7-01 (1570 micrograms per liter [μg/L]), Pond 7-01 (1935 μg/L), and DP-4.13 (1780 μg/L) to the selected screening level of 1,000 μg/L.

2.2.6.3 Riparian AOI Risk Assessment

Riparian Area AOI soil and groundwater were evaluated for human health risks in the BHHRA section of the DTSC approved OU-C and OU-D RI as part of the Open Space exposure unit. The Open Space EU includes the Log Storage and Sediment Stockpile AOI, the Riparian AOI, and the "Open Space" designated areas of the West of IRM AOI and IRM AOIs. ELCRs and HIs for all receptors (resident, commercial/industrial, construction, and utility/trench workers, and both recreational visitors) evaluated in the Open Space EU were below DTSC's thresholds.

The DTSC approved OU-C and OU-D RI additionally states, "Sediment data are available for the riparian subarea of the Open Space EU. This area will be designated as open space, and access to this sensitive resource area will be limited. As a result, exposure by a hypothetical human receptor (recreator) to constituents in sediment is assumed to be insignificant, and sediment data were not evaluated as part of the Open Space EU BHHRA."

The Riparian AOI was evaluated for ecological risks in the DTSC approved OU-C and OU-D RI as part of the open space exposure unit. The OU-C and OU-D baseline ecological risk assessment (BERA) for the open space exposure unit included upper and lower trophic level receptors. In the riparian area, BERA hazard quotients were less than one for all avian and mammalian receptors. The OU-C and OU-D RI (Arcadis, 2011a) identified metals, PAHs and dioxins/furans exceeding conservative sediment screening levels for protection of benthic organisms in the Riparian AOI. In order to further evaluate the risks posed by metal and PAH concentrations, porewater and sediment data were collected under the OU-E BHHERA investigation.

Based on the outcomes of the metals and PAH evaluations, the BHHERA concluded that ecological risk in the OU-D Riparian AOI is negligible. No further evaluation for dioxin/furan risk was performed in the BHHERA because invertebrates lack specific biochemical receptors essential to produce dioxin related toxicity (Céspedes et al., 2010; Hahn, 2002; West et al., 1997). Dioxin toxicity is expressed via the aryl hydrocarbon receptor in vertebrates. However, invertebrates lack the aryl hydrocarbon receptor, and aryl hydrocarbon receptor homologues identified in invertebrates have been shown to not bind dioxin compounds (Céspedes et al., 2010; Hahn, 2002; West et al., 1997). Furthermore, toxicity testing conducted on various invertebrate species has shown no toxicity associated with tissue concentrations up to 9.5 mg/kg lipid (West et al., 1997).

2.2.7 OU-E Removal Action Work Plan

The OU-E Removal Action Work Plan (RAW) was developed to expedite remediation of certain AOCs to facilitate construction of the City of Fort Bragg’s coastal trail and expedite remediation of the site. The AOCs included in the OU-E RAW are the Lowland Terrestrial AOC, the Ponds 1, 2, 3, and 4 (Southern Ponds) AOC, the Riparian AOC, and the Pond 7 AOC. The OU-E RAW included an evaluation of remedial alternatives and proposed excavation and disposal as the selected remedial action. The OU-E RAW, and therefore the excavation and disposal remedial alternative, was approved by DTSC on October 13, 2016 (DTSC, 2016b). AOCs included in the OU-E RAW are summarized herein.

2.3 Nature and Extent of Chemicals of Interest

A detailed analysis of soil, sediment, and groundwater conditions for AOIs within, and associated with, OU-E were provided in the OU-E RI Report (Arcadis, 2013a), the OU-C and OU-D RI Report (Arcadis, 2011a), and the BHHERA (Arcadis, 2015a). Only conditions identified in the OU-E RI Report and the OU-C and OU-D RI Report as needing further evaluation are addressed in this section. As discussed previously, the AOIs have been grouped into three AOCs depending on nature and extent of constituents. AOCs included for further consideration in this FS are as follows:

- Lowland Terrestrial AOC (includes the Water Treatment and Truck Dump AOI, Sawmill #1 AOI, Compressor House and Lath Building AOI, and Powerhouse and Fuel Barn AOI)

- Aquatic AOCs
  - Ponds 1, 2, 3, and 4 (Southern Ponds) AOC
  - Pond 6 and North Pond AOC
  - Pond 7 AOC
  - Pond 8 AOC
  - Riparian AOC

- Groundwater AOC (includes IRM AOI and West of IRM AOI)

As discussed in Section 2.2.4, the Pond 8 Fill Area AOI was recommended for no further action in the OU-E RI Report due to no sample exceedances of human health PSLs. In accordance with the OU-E RI Report, the Pond 8 Fill Area AOI was not included within the Lowland Terrestrial AOC dataset used for the BHHERA. The Pond 8 Fill Area AOI is therefore not considered in this FS.

Based upon the OU-E RI Report recommendations, the BHHERA evaluation, discussed in Section 2.2.6, considered all ten OU-E aquatic AOIs. When evaluated as individual aquatic AOIs, human health risks for Southern Ponds, Pond 6, Pond 7, Pond 8, and North Pond were within the risk management range of 10^{-4} to 10^{-6} established in the NCP (40 CFR 300.430; 2014) and by CalEPA (1996). Human health risks calculated in the BHHERA for Ponds 5 and 9 were below the risk management threshold (less than 1 x 10^{-6}), and therefore Ponds 5 and 9 are not included in this FS evaluation.

2.3.1 Soil Conditions in Lowland Terrestrial Area of Concern

2.3.1.1 Water Treatment and Truck Dump AOI

Localized concentrations of metals above PSLs (antimony, arsenic, barium, chromium, copper, lead, mercury, molybdenum, and zinc) and PAHs were identified in the OU-E RI Report. B(a)P TEQ concentrations in two samples collected from this area (OUE-DP-099 at 0.5 to 1.0 foot bgs, and OUE-DP-100 at 2.5 to 3.5 feet bgs) (Figure 2-25) were identified as hot spots in the OU-E BHHERA and are within PRAs. The PRAs were proposed for removal in the OU-E RAW.

Further remedial action to address soil at the Water Treatment and Truck Dump AOI is discussed in Section 7.1.

2.3.1.2 Sawmill #1 AOI

Localized concentrations of metals (antimony, arsenic, barium, copper, chromium, lead, mercury, molybdenum, nickel, vanadium, and zinc) and TPHd were detected above PSLs in the Sawmill #1 AOI. The BHHERA identified hot spots for lead in soil in the vicinity of two sample locations (OUE-DP-070 from 3 to 4 feet bgs; and DP-05.57 from 0.5 to 1 foot bgs). These locations (Figure 2-27) were identified as PRAs for inclusion in this FS. The PRAs were proposed for removal in the OU-E RAW.

The OU-E RI Report identified a localized area under the east end of the former Sawmill #1 Building where TPHd and PAH were detected above PSLs (Figure 2-13). PAHs were also detected along the drain line south of the Former Sawmill #1 Building. The BHHERA identified four sample locations as hot spots within the Sawmill #1 AOI. The four sample locations (OUE-DP-073, OUE-DP-074, OUE-DP-075, and OUE-DP-026) range in depths from approximately 2 to 3.5 feet bgs and form a single PRA for evaluation in this FS (Figure 2-25). One location (OUE-DP-025, 12,634 mg/kg) slightly exceeds the human health screening level of 10,772 mg/kg and was not identified as a human health hot spot based on the limited risk relative to the human health PSL. The PRAs and the area around OUE-DP-025 were proposed for removal in the OU-E RAW.

Further remedial action to address soil at the Sawmill #1 AOI is discussed in Section 7.1.

2.3.1.3 Compressor House and Lath Building AOI

Historical and RI sampling data from the Compressor House and Lath Building AOI indicate no detections of metals, total petroleum hydrocarbons in the gasoline range (TPHg), TPHmo, TPHd, PCBs, and VOCs above human health screening levels. Localized PAHs were detected above PSLs within the extent of the former Compressor House excavation (Figure 2-13).

2.3.1.4 Powerhouse and Fuel Barn AOI

Historical and RI sampling data from the Powerhouse and Fuel Barn AOI indicate detections of metals (antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, vanadium, and zinc), dioxin, and PAHs above PSLs. The BHHERA identified hot spots for lead in the vicinity of two sample locations (OUE-DP-094 from 5.5 to 6 feet bgs; and OUE-DP-090 from 5.5 to 6 feet bgs). These two locations (Figure 2-27) were identified as PRAs for inclusion in this FS. The PRAs were proposed for removal in the OU-E RAW.

The maximum dioxin TEQ (2.729 pg/kg) was detected at OUE-DP-052 from 0.5 to 1.5 feet bgs within the extent of the former Open Refuse Fire Area (Figure 2-14). This location was identified as a dioxin TEQ hot spot in the BHHERA and is included as a PRA within this FS (Figure 2-26). This PRA was proposed for removal in the OU-E RAW.

The maximum B(a)P TEQ concentration detected in the Powerhouse and Fuel Barn AOI was 27 mg/kg at sample location HSA-4.3 from 2 to 2.5 feet bgs, at the northwest corner of the former fuel barn (Figure 2-13). This location was identified as a B(a)P TEQ hot spot in the BHHERA and is included as a PRA in this FS (Figure 2-25). This PRA was proposed for removal in the OU-E RAW.

Further remedial action to address soil at the Powerhouse and Fuel Barn AOI is discussed in Section 7.1.

2.3.1.5 Grouping for Further Analysis

For the remainder of this FS, the Water Treatment and Truck Dump AOI, Sawmill #1 AOI, and the Powerhouse and Fuel Barn AOI are grouped as a single AOC unit known collectively as the Lowland Terrestrial Soil AOC.

2.3.2 Sediment Conditions in Aquatic Areas of Concern

2.3.2.1 Ponds 1 through 4 (Southern Ponds)

Dioxin and metals (arsenic, barium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, and zinc) were detected at concentrations above PSLs in Ponds 1, 2, and 3 during historic and RI sampling activities (Figure 2-18). Historical and RI sediment sample results for Ponds 1, 2 and 3 indicated no detections of TPHg, TPHmo, and PCBs above PSLs.

As discussed in Section 2.2.6.2, the Southern Ponds were evaluated as a combined aquatic AOC in the BHHERA, under both a 12-days-per-year and 50-days-per-year exposure scenario. The ELCRs for both exposure frequencies were within the risk management range of 1 x 10^{-4} to 1 x 10^{-6} established in the NCP. Potential exposure to arsenic and dioxin TEQ via sediment ingestion was the primary contributor to human health risk. Planned remediation in the Southern Ponds, as presented in the OU-E RAW, is expected to result in site conditions suitable for planned future uses, including an ecological restoration project.

2.3.2.2 North Pond and Pond 6

Historical and RI soil sample results from the North Pond and Pond 6 indicated concentrations of TPHg, TPHmo, PCBs in sediment were below PSLs. Sediment samples from Pond 6 contained concentrations of metals (arsenic and lead), PAHs, and dioxins/furans above PSLs. PAHs detected above PSLs in Pond 6 were limited to shallow sediments. PAHs and arsenic were detected at concentrations above PSLs in the North Pond. PAHs were present in the North Pond in deeper soil from 19.0 to 19.5 feet bss. (Figures 2-15 and 2-16).

As discussed in Section 2.2.6.2, Pond 6 and the North were evaluated as two individual aquatic AOIs in the BHHERA, assuming an exposure of 50 days per year. The ELCRs for both ponds were within the risk management range of 1 x 10^{-4} to 1 x 10^{-6} established in the NCP. Arsenic and dioxin TEQ were the primary risk drivers within Pond 6 sediment, while arsenic was the primary risk contributor in the North Pond.

2.3.2.3 Pond 7

Historical and RI sediment samples from Pond 7 contained concentrations of metals (arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, and zinc), PAHs and dioxins/furans above PSLs (Figures 2-15 and 2-16).

As discussed in Section 2.2.6.2, Pond 7 was evaluated as an individual aquatic AOI in the BHHERA, assuming an exposure of 50 days per year. The ELCR for Pond 7 was within the risk management range of 1 x 10^{-4} to 1 x 10^{-6} and had the highest ELCR (2 x 10^{-5}) of the separate aquatic AOIs evaluated in the BHHERA. Potential exposure to arsenic and dioxin TEQ via sediment ingestion was the primary contributor to human health risk. Arsenic and dioxin TEQ were the primary risk drivers within Pond 7 sediment. The ERA identified barium in Pond 7 sediment and porewater as a potential risk to benthic organisms based on comparison to the surface water screening level. Planned remediation in Pond 7, as presented in the OU-E RAW, is expected to result in site conditions suitable for planned future uses.

2.3.2.4 Pond 8

Metals (arsenic, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, and zinc), PAHs, VOCs, dioxins/furans, PCBs, TPH and pesticides were detected in Pond 8 sediment at concentrations greater than PSLs (Figures 2-15 and 2-16).

As discussed in Section 2.2.6.2, Pond 8 was evaluated as an individual aquatic AOI in the BHHERA, assuming an exposure of 50 days per year. The ELCR for Pond 8 was within the risk management range of 1 x 10^{-4} to 1 x 10^{-6}. Potential exposure to arsenic and dioxin TEQ via sediment ingestion was the primary contributor to human health risk. The arsenic concentrations within Pond 8, however, were comparable to background and the BHHERA concluded that arsenic concentrations were not related to site activities at Pond 8. When the ELCR was evaluated without the background arsenic exposure, the resulting cumulative ELCR in Pond 8 was below 1 x 10^{-6}.

2.3.2.5 Riparian AOI

The OU-C and OU-D RI (Arcadis, 2011a) identified metals, PAHs and dioxins/furans at concentrations above PSLs in the Riparian AOI. Based on the results of the human health and ecological risk assessment presented in the OU-C and OU-D RI, including the conclusion that potential human exposure to sediment in the Riparian AOI is expected to be limited, the OU-C and OU-D RI recommended that Riparian AOI drainage area sediments should be carried forward into the FS due to potential ecological risk to benthic invertebrates (Arcadis, 2011a).

As discussed in Section 2.2.6.3, additional porewater and sediment data were collected in the Riparian AOI under the OU-E BHHERA investigation to further evaluate the risks posed by metal and PAH concentrations. Based on the BHHERA evaluation, the risks posed by metals and PAHs in Riparian AOI sediment were determined to be negligible. No further evaluation for dioxin/furan risk was performed in the BHHERA due to an incomplete exposure pathway for invertebrates (see Section 2.2.6.3). Planned remediation in the Riparian Area, as presented in the OU-E RAW, is expected to result in site conditions suitable for planned future uses.

2.3.3 Groundwater Areas of Concern

Human health and ecological risks in the IRM and West of IRM AOIs were evaluated in the OU-C and OU-D RI (Arcadis, 2011a) and further assessment was therefore not conducted for the OU-E BHHERA (see Section 2.2.5). Historical and RI investigations at both the IRM and West of IRM indicated impacts to soil and groundwater, although IRMs discussed in Section 2.2.3.4 resulted in soil conditions that do not pose a risk to human health or the environment. The OU-C and OU-D RI recommended that IRM AOI and West of IRM AOI groundwater should be carried forward into the FS for fuel-related constituents (Arcadis, 2011a). No risks from groundwater were identified in the OU-E BHHERA; however, the concentration of barium at MW-4.1 exceeds the MCL. OU-E Lowlands AOC groundwater is also included in the FS due to barium detected in MW-4.1.

2.3.3.1 IRM AOI

TPH-impacted soil was largely removed during the interim action excavation work. Slightly elevated TPHd concentrations remain in soil beneath the excavation area northwest of the

MES, as shown in excavation confirmation samples. TPHd was analyzed and reported according to carbon chain fractions in this area. The maximum remaining concentrations are 420 mg/kg as C10 - C12, 3,200 mg/kg as C12 - C16, and 3,200 mg/kg as C16 - C24. These are below the human health screening value for direct contact and are not resulting in concentrations of TPHd in groundwater significantly above the WQO of 0.1 mg/L. These represent areas that could not be accessed during the interim action. Due to the excavation and remediation (biosparging and ORM application) work that was conducted in this AOI, at the time of the OU-C and D RI Report the existing groundwater data were considered not representative of current conditions downgradient of the Former Parcel 5 MES. Historical data indicated groundwater in the area upgradient (east) and south of the MES area was not impacted by site activities. Groundwater quality improvements for this AOI associated with the interim action was recommended for further assessment using data from groundwater monitoring wells MW-5.19 and MW-5.20. Concentrations of TPHd have declined at these two wells since monitoring began and as of the second semi-annual monitoring event 2016 are near the WQO with concentrations below the WQO during one or more events in the last two years. The maximum concentrations of TPHd at MW-5.19 and MW-5.20 in the last four events are 0.110 mg/L and 0.180 mg/L respectively. The OU-C and D RI Report recommended the inclusion of the IRM AOI in the FS for fuel-related constituents in groundwater.

2.3.3.2 West of IRM AOI

Historical and RI sampling activities indicated TPHd concentrations in soil above screening levels in the area directly south of the excavation boundary and in the vicinity of the Former Diesel AST and along the western edge of the excavation boundary as shown in excavation confirmation samples. TPHd was analyzed and reported according to carbon chain fractions in this area. The maximum remaining concentrations are 2,000 mg/kg as C10 - C12, 7,900 mg/kg as C12 - C16, and 6,500 mg/kg as C16 - C24, all at location DP-5.43 at a depth of 8.5 – 9 feet bgs. Concentrations in the same boring in the sampling intervals above and below this depth were less than 47 mg/kg for all fractions. These concentrations are below the human health direct contact screening level of 10,772 mg/kg and are not resulting in concentrations of TPHd in groundwater above the WQO of 0.1 mg/L. These are within areas that could not be accessed during the interim action. Due to the excavation and remediation (biosparging and ORM application) work that was conducted in this AOI, at the time of the OU-C and D RI Report the existing groundwater data were considered not representative of current conditions downgradient of the Former Parcel 5 MES. Groundwater quality improvements for this AOI associated with the interim action were to be further assessed using data from groundwater monitoring wells (W-5.17, MW-5.18 and MW-5.21). Concentrations of TPHd have declined at these three wells since monitoring began and as of the second semi-annual monitoring event 2016, have been below the WQO for four or more consecutive events in the last two years. The maximum concentrations of TPHd at MW-5.17, MW-5.18, and MW-5.21 during the last four events are 0.094 mg/L, 0.054 mg/L, and not detected above a reporting limit of 0.054 respectively. The OU-C and D RI Report recommended the inclusion of the West of IRM AOI in the FS for fuel-related constituents in groundwater.

2.3.3.3 Grouping for Further Analysis

Based on post-IRM TPH groundwater concentrations, the OU-C and OU-D RI identified groundwater in the IRM and West of IRM AOIs for further evaluation in the FS. Additionally, barium is detected in MW-4.1 in the OU-E Lowlands at concentrations exceeding the MCL, and therefore groundwater in the OU-E Lowland AOC is also included in the FS. For the remainder of this FS, the IRM AOI, West of IRM AOI, and OU-E Lowlands AOC groundwater are grouped as a single AOC unit known collectively as the OU-E Groundwater AOC.

Section 3: Objectives and Requirements of Remediation

This section identifies and evaluates the objectives and requirements of remediation which will drive the development and screening of remedial alternatives.

3.1 Applicable or Relevant and Appropriate Requirements

CERCLA and its regulations (40 CFR 300 et seq., referred to as the NCP) provide an established, and generally accepted, framework for evaluating and remediating industrial sites. Under the NCP, remedial actions must attain (or justify the waiver of) any federal or more stringent state environmental standards and facility citing laws that are “applicable or relevant and appropriate.” These regulatory requirements are known as ARARs. The ARARs are used to develop quantitative RAOs, determine the extent of site cleanup, and govern the implementation and operation of the selected alternatives.

Identification of ARARs must be completed on a site-specific basis and involves a two-part analysis: first, a determination of whether a given requirement is applicable and then, if it is not applicable, a determination of whether it is nevertheless both relevant and appropriate. Federal, state, and local ARARs can be divided into the following categories:

- Chemical-specific ARARs: Chemical-specific or ambient requirements include those laws and regulations that govern the release to the environment of materials possessing certain chemical or generally set health- or risk-based concentration limits, or discharge limitations for specific hazardous substances that may be found in, or discharged to, the ambient environment. If, in a specific situation, a chemical is subject to more than one discharge or exposure limit, the more stringent of the requirements should generally be applied.

- Performance, design, or action-specific ARARs: Action-specific ARARs consist of requirements that define acceptable handling, treatment, and disposal procedures for hazardous substances. These ARARs generally set performance, design, or other similar action-specific controls or restrictions on particular kinds of activities related to management of hazardous substances or pollutants. These requirements are triggered by the particular remedial activities that are selected to accomplish the cleanup remedy.

- Location-specific ARARs: Location-specific ARARs are those requirements that relate to the geographical or physical position of the site, rather than the nature of the contaminants or the proposed site remedial actions. These requirements may limit the type of remedial action that can be implemented, and may impose additional constraints on the cleanup action.

A requirement may not meet the definition of an ARAR, but may still be useful in determining whether to take action at a site or to what degree action is necessary. Some requirements are called to-be-considered (TBC) criteria. The TBC requirements are non-promulgated advisories or guidance issued by federal, state, or local government that are not legally binding, but may provide useful information or recommend procedures for remedial action.

ARARs and TBCs have been compiled for the soil, sediment, and groundwater in the AOCs addressed in this FS using federal, state, and local statues, regulations, and guidance listed in Table 3-1.

3.2 Remedial Action Objectives

RAOs are medium-specific goals for protecting human health and the environment that, in consideration with the estimated remedial scope and cost for screening alternatives and existing data, will be used to define the scope of remediation work to be proposed in the forthcoming Remedial Action Plan (RAP). RBTLs will be calculated and presented in the RAP and will be used to evaluate site conditions. The RBTLs will be compared to post-remedy exposure estimates (i.e., 95% UCLs) to confirm that site conditions are protective of human and ecological receptors. GRAs are presented in Section 5.

RAOs are guidelines used in the development of potential remedial action alternatives and selection of a proposed remedial action. The RAOs presented herein have been developed based on the current environmental conditions and anticipated future use of the site.

- Protect human health and the environment through mitigation of exposure pathways of groundwater, surface water, soil, and/or sediment that contain COIs at concentrations greater than the proposed site cleanup goals under the reasonably foreseeable future land use scenarios.
- For the AOC(s) with COI-impacted groundwater, provide a remediation alternative that will promote mitigation of COI-impacted groundwater to ultimately achieve North Coast Regional Water Quality Control Board WQOs.
- Provide an economically reasonable and technically feasible remedy.
- Achieve the remedy in a reasonable time-frame.
- The relevant human exposure pathways for human receptors in the terrestrial exposure area include: incidental soil ingestion, dermal contact with soil, inhalation of particulates, and contact with groundwater (construction and utility workers only). Exposure pathways for the passive recreator receptor in the aquatic area included: incidental sediment ingestion, dermal contact with sediment, and contact with surface water.

3.3 Chemical-Specific Remedial Goals

Chemical-specific remedial goals were presented in the OU-E RAW (termed “removal action goals”). The numeric goals are based on the DTSC memorandum *Identification of Presumptive Remedy Areas on Operable Unit E* (DTSC 2014) and an email dated July 18, 2014 and are site-specific. The following factors were considered in developing remedial alternatives:

- California Human Health Screening Levels (CHHSLs; CalEPA, 2010)
- USEPA 2015 risk-based Regional Screening Levels (USEPA, 2015)

- Remedial Goals for Dioxins and Dioxin-like Compounds for Consideration at California Hazardous Waste Sites (DTSC, 2009)
- California Hazardous Waste threshold limiting concentrations (California Code of Regulations, Title 22. Social Security, Division 4.5. Health Standards for the Management of Hazardous Waste, Chapter 11. Identification and Listing of Hazardous Waste)
- Action levels for PCBs (under the performance-based approach) from the Toxic Substances Control Act of 1976 (40 CFR 761.3)
- North Coast Regional Water Quality Control Board WQOs (North Coast Regional Water Quality Control Board, 2011)
- Levels protective of human health, as presented in the DTSC Human and Ecological Risk Office (HERO) Human Health Risk Assessment Note Number 3 (DTSC/HERO 2015)
- Levels protective of ecological receptors, calculated using the literature-based ecological soil screening level bioaccumulation factor (USEPA 2007)
- Results presented in the Baseline Human Health and Ecological Risk Assessment (BHHERA; Arcadis, 2015a)
- Site-specific Remedial Goals developed for TPH, as presented in Appendix C of the OU-C/D RAP (Arcadis, 2015)
- Site-specific risk-based levels to be developed and proposed in the forthcoming RAP.

These factors are applied to site data to evaluate remedial strategies and focus activities to achieve remedial objectives. Active remediation to achieve these goals is not always technically feasible or economical. Recommended remedial alternatives may include natural attenuation, land use controls, and restricted use approaches to achieve conditions that meet remedial objectives. Additional data collection and risk assessment may also be used to demonstrate that remedial action or attenuation will achieve an acceptable level of risk.

Section 4: Areas and Volumes for Remedial Alternative Development

The area and vertical extent of soil and groundwater within OU-E to be incorporated into remedial alternative development is presented in this section. The delineation of remedial areas and volumes is based on the RAOs, the BEHHRA, available site analytical data, and site history. The areas exceeding remedial goals and estimates of contaminant mass are used as the basis for developing remedial alternatives and evaluating their ability to achieve the RAOs. Area and volume estimates are provided below by AOC.

4.1 Areas Addressed in OU-E RAW

The OU-E RAW evaluated risk, presented estimated areas and volumes for excavation, and evaluated the selected remedial action for select AOCs. These discussions are re-presented in the following sections.

4.1.1 Lowland Terrestrial Soil

4.1.1.1 Risk Summary

The RAW RAAs, as presented in the following sections, were developed considering the results of the hot spot analysis included in the BHHERA (Arcadis 2015a), to accelerate remediation within the identified AOCs by removing areas where elevated concentrations of COPCs have been identified, to reduce the risk to human health and the environment, and to support the construction and public use of the central portion of the Fort Bragg Coastal Trail. Once the proposed activities are complete, the risks to public health and the environment will be reduced and the areas addressed by the OU-E RAW are anticipated to be acceptable for planned future use.

4.1.1.2 Area Exceeding Remedial Goals

4.1.1.2.1 Water Treatment and Truck Dump Area of Interest

Based on the RI results, the BHHERA (Arcadis 2015a) identified two hot spots within this AOI based on B(a)P TEQ concentrations (OUE-DP-099 at 0.5 to 1.0 foot bgs and OUE-DP-100 at 2.5 to 3.5 feet bgs).

4.1.1.2.2 Sawmill #1 Area of Interest

Based on the RI results, the BHHERA (Arcadis 2015a) identified hot spots for lead in soil near two sample locations (OUE-DP-070 from 3 to 4 feet bgs and DP-05.57 from 0.5 to 1 foot bgs). The BHHERA identified four hot spots based on B(a)P TEQ concentrations in soil within the Sawmill #1 AOI. The four sample locations (OUE-DP-073, OUE-DP-074, OUE-DP-075, and OUE-DP-026) range in depths from approximately 2 to 3.5 feet bgs. Based on communication with DTSC (DTSC 2016a) and the results of the RI Report (Arcadis 2013a), OUE-DP-025 was also identified as a RAA for TPHd.

4.1.1.2.3 Powerhouse and Fuel Barn Area of Interest

The BHHERA (Arcadis 2015a) identified hot spots for lead near two sample locations (OUE-DP-094 from 5.5 to 6 feet bgs and OUE-DP-090 from 5.5 to 6 feet bgs). The BHHERA also identified a hot spot for dioxin TEQ (2.729 picograms per kilogram) at OUE-DP-052 from 0.5 to 1.5 feet bgs within the former Open Refuse Fire Area. The maximum B(a)P TEQ concentration detected in the Powerhouse and Fuel Barn AOI was 27 mg/kg at sample location HSA-4.3 from 2 to 2.5 feet bgs, at the northwestern corner of the former fuel barn. This location was identified as a B(a)P TEQ hot spot in the BHHERA.

4.1.1.3 Area for Remedial Alternative Development

Each of the 12 hot spots identified in the OU-E Lowland AOC in the BHERRA (Arcadis 2015a) are RAAs. Four sample locations (OU-E-HA-023B, OU-E-DP-088, OUE-DP-076, and P4-40) were identified with lead concentrations exceeding the not to exceed (NTE) value established in the BHHERA (320 mg/kg). These locations were not previously identified as hot spots, as they are outside the depth interval evaluated in the BHHERA (0 to 6 feet bgs). However, these locations are co-located in the area and were selected for removal based on their exceedance of NTE criteria. The area surrounding boring location OUE-DP-025 is additionally identified for removal based on TPHd concentrations exceeding the soil remedial goal established in the Remedial Action Plan Operable Units C and D (OU-C/D RAP; Arcadis 2015b) for the protection of human health (10,772 mg/kg). Based on proximity, these locations were grouped into 12 distinct RAAs.

The RAAs are listed below, by constituent:

- B(a)P TEQ
  - RAA-B1 (Powerhouse and Fuel Barn AOI): includes one sample location (HSA-4.3 from 2 to 2.5 feet bgs)
  - RAA-B2 (Sawmill #1 AOI): includes four sample locations (OUE-DP-073 from 2 to 3 feet bgs, OUE-DP-074 at 2 to 3 feet bgs, OUE-DP-075 from 2 to 3 feet bgs, and OUE-DP-026 from 2 to 3.5 feet bgs)
  - RAA-B3 (Waste Treatment and Truck Dump AOI): includes two sample locations (OUE-DP-099 from 0.5 to 1.0 foot bgs and OUE-DP-100 from 2.5 to 3.5 feet bgs)
- Lead
  - RAA-L1 (Sawmill #1 AOI): includes one sample location (OUE-DP-070 from 3 to 4 feet bgs)
  - RAA-L2 (Sawmill #1 AOI): includes one sample location (DP-05.57 from 0.5 to 1 foot bgs)
  - RAA-L3 (Powerhouse and Fuel Barn AOI): includes one sample location (OUE-DP-094 from 5.5 to 6 feet bgs)

  - RAA-L4 (Powerhouse and Fuel Barn AOI): includes one sample location (OUE-DP-090 from 5.5 to 6 feet bgs)
  - RAA-L5 (Powerhouse and Fuel Barn AOI): includes one sample location (OUE-DP-088 from 6 to 7 feet bgs)
  - RAA-L6 (Powerhouse and Fuel Barn AOI): includes two sample locations (OUE-HA-023B from 6.5 to 8 feet bgs and OUE-DP-076 from 6 to 7 feet bgs and 8 to 9 feet bgs)
  - RAA-L7 (Powerhouse and Fuel Barn AOI): includes one sample location: (P4-40 from 6.5 to 7 feet bgs)

- TPHd
  - RAA-T1 (Sawmill #1 AOI): includes one sample location (OUE-DP-025 from 1.5 to 5 feet bgs)

- Dioxin TEQ
  - RAA-D1 (Powerhouse and Fuel Barn AOI): includes one sample location (DP-052 from 0 to 0.5 foot bgs and 0.5 to 1.5 feet bgs)

Based on similarities in site conditions, evaluation and implementation of removal action alternatives for the 12 terrestrial RAAs were addressed in the OU-E RAW collectively as the OU-E Lowland RAA. As summarized in the BHHERA (Arcadis 2015a), removal activities in these RAAs will reduce terrestrial EPCs of the B(a)P TEQ, lead, and dioxin TEQ to levels below the site-specific soil risk-based target levels (RBTLs) developed by DTSC (DTSC 2014).

4.1.2 Ponds 1 through 4 (Southern Ponds) Aquatic Sediment

4.1.2.1 Risk Summary

Dioxins, arsenic, lead, and PAHs were detected in the Southern Ponds sediment at concentrations exceeding human health PSLs. Additional metals (barium, cadmium, chromium, cobalt, copper, mercury, molybdenum, nickel, and zinc) were detected above ecological PSLs. Risks were further evaluated in the BHHERA, and the BHHERA indicated ELCRs for the Southern Ponds were within the risk management range of 1×10^{-4} to 1×10^{-6} established in the NCP, with arsenic and dioxin TEQ as the primary risk drivers. The ERA indicated that unacceptable ecological risk is not likely for populations of plants, benthic organisms, birds, mammals and amphibians exposed to site sediment and surface water. The Southern Ponds were further evaluated in the OU-E RAW (Arcadis 2016a).

4.1.2.2 Area Exceeding Remedial Goals

Potential ecological and human health aquatic risks were further evaluated in the BHHERA (Arcadis 2015a). For the human health evaluation of the Southern Ponds AOC, the BHHERA concluded that noncancer hazards are below 1, while cumulative excess lifetime cancer risks (ELCRs) for an occasional recreator (assuming 50 days per year of exposure) are greater than

$1x10^{-6}$. Potential exposure to arsenic and dioxin TEQ from sediment ingestion are primary contributors to the ELCRs, with the COPC-specific ELCRs for arsenic and dioxin TEQ greater than $1x10^{-6}$. The ELCRs for the aquatic recreator receptors in the Southern Ponds AOC were within the risk management range of $1x10^{-4}$ to $1x10^{-6}$ established in the National Contingency Plan (NCP; 40 Code of Federal Regulation [CFR] 300.430; 2014). The ERA concluded that unacceptable ecological risk is not likely for populations of plants, benthic organisms, birds, mammals, and amphibians exposed to sediment and surface water in the Southern Ponds AOC.

4.1.2.3 Area for Remedial Alternative Development

For aquatic AOCs, RAAs were developed based on risk drivers identified in the BHHERA (Arcadis 2015a). As indicated above, arsenic and dioxin TEQ are the primary risk drivers in the Southern Ponds AOC; therefore, the RAAs were defined to target locations with elevated concentrations of dioxins and arsenic. Removal activities in these portions of the Southern Ponds AOC will result in the reduction of arsenic and dioxin TEQ EPCs, thereby reducing potential risk. The RAAs within the Southern Ponds AOC were evaluated in the OU-E RAW collectively for removal alternative development as the Southern Ponds RAA.

4.1.3 Pond 7 Aquatic Sediment

4.1.3.1 Risk Summary

Dioxins, arsenic, lead, and PAHs were detected in Pond 7 sediment at concentrations exceeding human health PSLs. Additional metals (cadmium, chromium, copper, mercury, molybdenum, nickel, and zinc concentrations) were detected above ecological PSLs. Risks were further evaluated in the BHHERA, and the BHHERA indicated the ELCR for Pond 7 was within the risk management range of 1×10^{-4} to 1×10^{-6} but had the highest ELCR of the aquatic AOIs evaluated in the BHHERA. Arsenic and dioxin TEQ were the primary risk drivers in sediment. The ERA identified barium in Pond 7 sediment and porewater as a potential risk to benthic organisms based on comparison to the surface water screening level. Pond 7 was further evaluated in the OU-E RAW (Arcadis 2016a).

4.1.3.2 Area Exceeding Remedial Goals

Pond 7 was evaluated as an individual aquatic AOI in the BHHERA (Arcadis 2015a), assuming an exposure of 50 days per year. For the human health evaluation of the Pond 7 AOC, the BHHERA concluded that non-cancer hazards are below 1, while cumulative ELCRs for an occasional recreator (assuming 50 days per year of exposure) are 2×10^{-5}. Potential exposure to arsenic and dioxin TEQ from the sediment are primary contributors to the ELCRs. The ERA identified barium in Pond 7 sediment and porewater as a potential risk to benthic organisms based on comparison to the surface water screening level.

4.1.3.3 Area for Remedial Alternative Development

For aquatic AOCs, RAAs were developed based on risk drivers identified in the BHHERA (Arcadis 2015a). As indicated above, arsenic, dioxin TEQ, and barium are the primary risk drivers in the Pond 7 AOC; therefore, the RAA was defined to target locations with historically elevated concentrations of dioxins and arsenic. Removal activities in this RAA will result in the reduction of arsenic, dioxin TEQ, and barium exposures and thereby a reduction/elimination of potential risk.

It is assumed that the entire footprint of Pond 7 will be excavated. The RAA within the Pond 7 AOC is referred to as the Pond 7 RAA for removal alternative development.

4.1.4 Riparian Aquatic Sediment

4.1.4.1 Risk Summary

Dioxins, arsenic, zinc, PAHs, and TPH were detected in Riparian AOI sediment at concentrations exceeding human health screening levels. Additional metals were detected above conservative ecological screening levels. Arsenic concentrations were above the human screening level but generally comparable to background. TPH and PAHs concentrations were detected either below or just slightly exceeding the human health screening level. Riparian Area AOI soil and groundwater were evaluated for human health risks in the BHHRA section of the DTSC approved OU-C and OU-D RI as part of the Open Space exposure unit. The Open Space EU includes the Log Storage and Sediment Stockpile AOI, the Riparian AOI, and the "Open Space" designated areas of the West of IRM AOI and IRM AOIs. Exposure by a hypothetical human receptor (recreator) to constituents in sediment was accepted as insignificant, ELCRs and HIs for all receptors (resident, commercial/industrial, construction, and utility/trench workers, and both recreational visitors) evaluated in the Open Space EU were below DTSC's thresholds. The OU-C and OU-D RI recommended that Riparian AOI drainage area sediments (dioxins/furans, metals, and PAHs) should be carried forward into the FS (Arcadis, 2011a) based on potential ecological risk to benthic organisms. Risks were further evaluated in the BHHERA, and the BHHERA indicated that the risks posed by metals and PAHs in Riparian AOI sediment were negligible. No further evaluation for dioxin/furan risk was performed in the BHHERA due to an incomplete exposure pathway for invertebrates (see Section 2.2.6.3). The Riparian Area was further evaluated in the OU-E RAW (Arcadis 2016a).

4.1.4.2 Area Exceeding Remedial Goals

Based on the results of the human health and ERA presented in the OU-C/D RI, the OU-C/D RI recommended that Riparian AOI drainage area sediments should be carried forward into the FS due to potential ecological risk to benthic invertebrates (Arcadis 2011a). The Riparian AOI was evaluated further in the OU-E RAW.

Risks were further evaluated in the BHHERA (Arcadis 2015a), which indicated that the risks posed by metals, dioxin/furans, and PAHs in Riparian AOI sediment were negligible. However, subsequent to the BHHERA, DTSC requested further evaluation for dioxin in the Riparian AOI (DTSC 2016a). Based on the relatively limited extent of concentrations above unrestricted use criteria in the Riparian AOI, RAAs within the Riparian AOI were evaluated in the OU-E RAW given the potential to meet unrestricted use and achieve No Further Action status in this area.

4.1.4.3 Area for Remedial Alternative Development

For the Riparian AOI, the RAAs were delineated based on samples OUD-HA-042, OUD-HA-044, OUD-HA-046, and OUD-SED-HA-049, which have dioxin TEQ concentrations that are higher than other sediment samples collected in the Riparian AOI. Removal activities in the Riparian AOI will result in the reduction of dioxin TEQ EPCs and thereby a reduction in potential risk.

The RAAs within the Riparian AOI were evaluated in the OU-E RAW collectively for removal alternative development as the Riparian RAA.

4.2 Areas Not Addressed in OU-E RAW

4.2.1 North Pond and Pond 6 Aquatic Sediment

4.2.1.1 Risk Summary

Dioxins, arsenic, and PAHs were detected in Pond 6 and North Pond sediment at concentrations exceeding human health PSLs. Lead was also detected above the human health PSL in Pond 6. Risks were further evaluated in the BHHERA, and the BHHERA indicated ELCRs for the North Pond and Pond 6 were within the risk management range of 1×10^{-4} to 1×10^{-6} established in the NCP. Arsenic and dioxin TEQ were the primary risk drivers in Pond 6 sediment, while arsenic was the primary risk contributor in North Pond sediment. The ERA indicated that unacceptable ecological risk is not likely for populations of plants, benthic organisms, birds, mammals and amphibians exposed to site sediment and surface water.

4.2.1.2 Area Exceeding Remedial Goals

The North Pond and Pond 6 were evaluated as individual aquatic AOCs in the BHHERA (Arcadis 2015a), assuming an exposure of 50 days per year. For the human health evaluation of the North Pond and Pond 6 AOCs, the BHHERA concluded that non-cancer hazards are below 1, while cumulative ELCRs for an occasional recreator (assuming 50 days per year of exposure) are greater than 1×10^{-6}. Potential exposure to arsenic and dioxin TEQ from the sediment are primary contributors to the ELCRs. The majority of the risk in the North Pond and Pond 6 is attributed to arsenic. Dioxin-specific ELCRs for the two ponds do not exceed 1×10^{-6} and the maximum concentration of dioxin in the ponds is 175 pg/g. Maximum concentrations of arsenic in the North Pond and Pond 6 are 32.7 mg/kg and 30.2 mg/kg respectively. COPC-specific risk values without considering the contribution of background arsenic would be lower for arsenic than calculated when using the EPCs for each pond, which are maximum concentrations due to the relatively limited data set. Based on the concentrations of arsenic and dioxin, the North Pond and Pond 6 exceed unrestricted use goals but do not contain significant hot spots where concentrations are isolated. While concentrations of arsenic in the ponds vary by location, generally arsenic is highest in sample depths less than 5 feet. The area exceeding remedial goals is assumed to be over the footprint of the ponds to depths between 2 and 5 feet.

4.2.1.3 Area for Remedial Alternative Development

Based on the areas affected by arsenic and dioxin, the area for remedial alternative development in the North Pond and Pond 6 is approximately 3,000 and 7,000 square feet respectively. To a depth of approximately 5 feet this represents 1,800 cubic yards.

4.2.2 Pond 8 Aquatic Sediment

4.2.2.1 Risk Summary

Dioxins, arsenic, lead, and PAHs were detected in Pond 8 sediment at concentrations exceeding human health PSLs. Risks were further evaluated in the BHHERA, and the BHHERA indicated ELCRs for Pond 8 were within the risk management range of 1×10^{-4} to 1×10^{-6}. Arsenic and dioxin TEQ were the primary contributors to human health risk. The arsenic concentrations within Pond 8, however, were comparable to background and the BHHERA concluded that arsenic concentrations were not related to site activities at Pond 8. When the ELCR was evaluated without the background arsenic exposure, the resulting cumulative ELCR in Pond 8 was below 1×10^{-6}. The ERA indicated that unacceptable ecological risk is not likely for populations of plants, benthic organisms, birds, mammals and amphibians exposed to site sediment and surface water.

4.2.2.2 Area Exceeding Remedial Goals

Pond 8 was evaluated as an individual aquatic AOC in the BHHERA (Arcadis 2015a), assuming an exposure of 50 days per year. For the human health evaluation of the Pond 8 AOC, the BHHERA concluded that the non-cancer hazards are below 1, while cumulative ELCRs for an occasional recreator (assuming 50 days per year of exposure) are greater than 1×10^{-6}. Potential exposure to dioxin TEQ from the sediment is the primary contributor to the ELCR. The COPC-specific ELCR for dioxin TEQ is equal to 1×10^{-6}. Dioxin concentrations range between 4 pg/g and 231 pg/g as 2,3,7,8-TCDD TEQ and are generally within the order of magnitude between 20 and 200 pg/g. The exposure point concentration (EPC) within the 0 to 0.5 feet and 0 to 2 feet depth intervals used in the risk assessment are 118 pg/g and 110 pg/g respectively. While the BHHERA indicated dioxin does not pose an unacceptable risk based on the expected future use for Pond 8, the pond does not meet the criteria for unrestricted use. The EPCs are above the California residential screening level of 50 pg/g and below the commercial/industrial screening level of 200 pg/g for the purpose of evaluating potential acceptable use.

While concentrations of dioxin in the pond are generally highest in the east near the storm drain outfalls and lowest in the west close to the ocean, significant variability is not observed laterally or vertically, particularly as compared to the screening levels, and no discernable patterns are observed. For example, concentrations are not the highest or lowest at the surface or in any given depth interval and may increase or decrease with depth depending on the location and may vary significantly in laterally or vertically adjacent samples. Based on this information the area exceeding the unrestricted use goal is defined as all Pond 8 sediment.

4.2.2.3 Area for Remedial Alternative Development

Based on the area exceeding remedial goals and the relative uniformity of sediment quality, the area for remedial alternative development for Pond 8 is the 280,000 sf pond area. Sediment thickness ranges up to approximately 25 feet and are typically on the order of 10 feet on average. The total volume of sediment in Pond 8 is estimated to be 106,000 cubic yards.

4.2.3 OU-E Groundwater

4.2.3.1 Risk Summary

The OU-C and OU-D RI recommended that IRM AOI and West of IRM AOI groundwater should be carried forward into the FS for fuel-related constituents (Arcadis, 2011a). Since the submittal of the OU-C/OU-D RI (Arcadis 2011a), both AOIs, as well as MW-4.1 in the OU-E Lowlands, have been assessed and continue to be monitored under the Comprehensive Monitoring Plan (CMP) and associated updates (Arcadis BBL 2007; Arcadis 2008a,b; Arcadis 2010b,c; Arcadis 2013c).

4.2.3.2 Area Exceeding Remedial Goals

Groundwater quality was most recently presented in the Second Semi-Annual 2016 Groundwater Monitoring Report (Arcadis 2016b) for wells in Parcel 5 and the First Semi-Annual 2016 Groundwater Monitoring Report (Arcadis 2016) for MW-4.1. A summary of the most recent results reported is presented below:

TPHg was detected in MW-5.20 at a concentration of 0.029 mg/L, which is less than the RWQCB taste and odor objective of 0.05 mg/L and the RBSC for aromatics and aliphatics of 0.31 mg/L (Arcadis 2016b).

TPHd was detected in MW-5.20 at a concentration of 0.18 mg/L, which exceeds the RWQCB taste and odor objective of 0.1 mg/L but less than the RBSC for aromatics (0.47 mg/L) and aliphatics (1.22 mg/L). TPHd was detected in other wells (MW-5.19 at 0.096 mg/L, and MW-5.18 at 0.090 mg/L) but at concentrations less than the RWQCB taste and odor objective and the RBSC for aromatics and aliphatics. TPHd was not detected in wells MW-5.17 and MW-5.21.

The area exceeding WQOs in the IRM and West of IRM AOIs of the OU-E groundwater AOC is limited to the vicinity immediately surrounding MW-5.20. During recent monitoring this area is periodically below WQOs. MW-5.20 is bounded on all sides by other monitoring wells. MW-5.17, MW-5.18, MW-5.19, and MW-5.21 are actively monitored and are to the north and west of MW-5.20. Concentrations of TPHd at these locations have been below WQOs during recent monitoring. MW-5.3, MW-5.4, MW-5.5, MW-5.13, and MW-5.15 were monitored in the past but monitoring was stopped at each of these locations because TPHd was not detected above WQOs during the most recent monitoring timeframes at those locations. The approximate area surrounding MW-5.20 where TPHd is periodically above WQOs is approximately 20,000 square feet for alternative development.

In March 2016, barium was detected in monitoring well MW-4.1 at a concentration of 1,100 mg/L, which is above the WQO of 1,000. MW-4.1 is surrounded to the west, north, and east by wells MW-4.6, MW-4.5, MW-4.3, MW-4.3R, and MW-4.4 and to the south by Ponds 7 and 8. Barium has not been detected above WQOs in the monitoring wells surrounding MW-4.1. The approximate area surrounding MW-4.1 where barium is above the WQO is approximately 20,000 square feet for alternative development.

4.2.3.3 Area for Remedial Alternative Development

Groundwater in the IRM AOI, West of IRM AOI, and OU-E Lowlands AOI will be evaluated collectively to develop remedial alternatives.

Section 5: Identification and Screening of Remedial Technologies and Process Options

In accordance to the FS process as described by USEPA's Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (referred as FS Guidance, USEPA 1988a), remedial alternatives are developed by assembling combinations of technologies, based on the media to which they would be applied, into alternatives that address contamination at a site. In addition to the first step which included the development of RAOs described in Section 3, the FS process consists of five additional general steps including the following, as discussed through the remainder of this FS:

- Develop GRAs for each medium of interest defining remedial actions that may be taken to satisfy RAOs (Section 5.1)
- Identify volumes or areas of media to which GRAs might be applied (Section 5)
- Identify and screen the technologies applicable to each GRA to eliminate those that cannot be technically implemented at the site (Section 5.2)
- Identify and evaluate technology process options to select a representative process for each technology type retained for consideration (Section 5.2)
- Assemble the selected representative technologies into alternatives representing a range of treatment and containment combinations, as appropriate, for evaluation and comparison (Sections 6, 7, 8 and 9).

This section details the development of GRAs and selection process of the potential remedial technologies for site soil, sediment, and groundwater. The purpose of the preliminary screening is to select remedial technologies or combinations of technologies that can be technically implemented at the site. Any treatability testing that may be required for those technologies that are probable candidates for consideration are also identified during this initial screening.

5.1 General Response Actions

GRAs are categories of actions that, when implemented, will allow meeting of RAOs established for the site, and provide a basis for identifying specific remedial technologies and process options. GRAs are developed for each medium of interest and define remedial actions that may, as standalone or in combination, be taken to satisfy the RAOs for the site. For the site, GRAs for soil, sediment, and groundwater have been considered.

The GRAs that have been considered for remediation of site soil are as follows:

- No action
- Institutional controls (ICs)
- Containment
- In-situ treatment
- Ex-situ treatment
- Removal

The GRAs that have been considered for remediation of site sediment are as follows:

- No action
- ICs
- Containment
- In-situ treatment
- Ex-situ treatment
- Removal

The GRAs that have been considered for remediation of site groundwater are as follows:

- No action
- ICs
- Monitored natural attenuation (MNA)
- Containment
- In-situ treatment
- Ex-situ treatment

Specific process options within each GRA are described and screened based on technical implementability in the following sections and in Tables 6-1 and 6-2.

5.2 Identification and Screening of Technologies and Process Options

As discussed previously, the identification and screening of technologies and process options is developed in two steps. The first step is to develop a short-list of remedial technologies and process options that are technically implementable for remediation of the target COIs within each media of interest. The second step is to further evaluate and refine technologies and process options based on effectiveness, implementability (e.g., institutional) and relative cost. Following the completion of the identification and screening process, each retained technology and associated process option will be further evaluated.

5.2.1 Preliminary Identification and Screening of Technologies and Process Options

The preliminary identification and screening criterion (or evaluation criterion) for remedial technologies and their associated process options is technical implementability. The screening for technical implementability is based on 1) the site-specific RAOs and ARARs, 2) site-specific conditions, such as the geologic setting and contaminant distribution, and 3) contaminant characteristics. During the preliminary identification and screening process, remedial technologies that cannot be technically implemented are eliminated from further evaluation.

5.2.1.1 Soil Remedial Technologies

The preliminary identification and screening process of remedial technologies and associated process options for treatment of soil at the site are discussed in this section and summarized in Table 5-1. The following remedial technologies and associated process options for soil were identified and evaluated based on technical implementability:

- No action
- ICs
- Containment: cover in place with soil, geosynthetics, asphalt, or other capping materials
- In-situ physical treatment: in-situ soil mixing (ISM), soil vapor extraction (SVE), multi-phase extraction (MPE), thermal treatment
- In-situ biological treatment: mycoremediation
- In-situ chemical treatment: in-situ chemical oxidation (ISCO)
- Ex-situ physical/biological treatment: landfarming, biopiling
- Removal: excavation and offsite disposal.

In order to provide a baseline for comparison of alternatives as required by the National Oil and Hazardous Substances Contingency Plan (NCP, USEPA 1990), the “No Action” technology has been retained for all media. ICs, such as land use restrictions, have been retained to provide protection of human health and the environment through administratively restricting land use until chemical-specific clean up goals are met.

A barrier or cover is a containment process option that prevents exposure of potential receptors to affected media. A cover would effectively restrict the potential risk to receptors in accordance with RAOs until cleanup goals are achieved; therefore, covers are retained for incorporation in remedial alternatives.

In-situ soil mixing encapsulates contaminants in solidified media by in-situ mixing of impacted soil with solidifying reagents (e.g., cement, bentonite). This process option does not destroy COIs, but incorporates them into a dense, homogeneous, low-permeability structure that reduces concentrations and mobility. In-situ mixing can be implemented in the target AOCs and is retained for further evaluation.

SVE, also known as soil venting or vacuum extraction, is an in-situ treatment process option commonly used to remove volatile and certain semivolatile organic compounds in vapor from vadose zone soils. Similarly, MPE and thermal remediation rely upon volatization and capture of COIs to achieve mass reduction. Based on contaminant characteristics in the areas identified in Section 5, SVE, MPE, and thermal remediation are retained for further evaluation of process options in soil.

A laboratory study of mycoremediation was prepared by NewFields for use of mushrooms and fungi to remediate dioxins and furans at the Site (NewFields, 2011). The primary objective of this study was to evaluate the potential for various strains of fungi to degrade dioxins/furans in site soils to determine whether mycoremediation could be an effective remedial process option at the site. A total of 30 fungal strains were evaluated for growth potential using site soils and sediments; nine of these fungal strains were collected from the site. The 10 strains that showed the greatest growth potential in site soils and sediments were selected for the dioxin/furan degradation phase of the study. Comparison of analytical results for spiked samples containing fungi to spiked control samples not containing fungi found no discernable degradation of dioxins/furans after incubation. Based on these results, mycoremediation has been determined to not be a viable remedial process option for dioxins/furans in soils at the site and will not be carried forward for further evaluation.

ISCO technology involves reduction/oxidation reactions that chemically convert hazardous contaminants to non-hazardous or less toxic compounds that are more stable or inert. One reactant is oxidized (loses electrons) and another is reduced (gains electrons). ISCO can be utilized for COIs identified in the AOCs, and is retained for further evaluation.

Land farming is an ex-situ process option that consists of spreading the excavated soils in windrows to stimulate aerobic microbial activity through aeration and/or the addition of minerals, nutrients, and moisture to expedite treatment. Biopiling is an ex-situ process option that involves heaping COI-impacted excavated soils into aboveground storage cells and stimulating aerobic microbial activity via aeration and/or addition of minerals, nutrients, and moisture. The biodegradation induced by biopiling is likely effective for VOCs and SVOCs; therefore, both options are retained for further evaluation.

Removal (i.e., excavation) provides immediate and complete removal of impacted soil from the site to achieve RAOs and was retained for further consideration.

5.2.1.2 Sediment Remedial Technologies

The preliminary identification and screening process of remedial technologies and associated process options for treatment of sediment at the site are discussed in this section and summarized in Table 5-2. The following remedial technologies and associated process options for soil were identified and evaluated based on technical implementability:

- No action
- ICs
- Containment: covers with sand, gravel, or other suitable materials
- In-situ physical treatment: ISM
- In-situ biological treatment: mycoremediation, in-situ biological oxidation (ISB)
- In-situ chemical treatment: ISCO
- Ex-situ physical/biological treatment: landfarming, biopiling
- Removal: excavation and offsite disposal.

In order to provide a baseline for comparison of alternatives as required by the National Oil and Hazardous Substances Contingency Plan (NCP, USEPA 1990), the “No Action” technology has been retained for all media. ICs, such as land use restrictions, have been retained to provide protection of human health and the environment through administratively restricting land use until chemical-specific cleanup goals are met.

A cover would be implemented as a vegetative barrier to cover sediments in the ponds to restrict exposure of potential receptors to affected media. A cover would effectively restrict the potential risk to receptors in accordance with RAOs until cleanup goals are achieved; therefore, covers are retained for incorporation in remedial alternatives.

On-site consolidation in a lined cell may not be acceptable within the Coastal Zone and has other issues with implementability. Section 30233 of the Coastal Act limits allowable use for wetland fill to seven specific uses. Consolidating contaminants within a wetland is not included within the listed allowable uses for wetland fill. Also, past experience with consolidation of contaminants at the former Mill Site demonstrated the difficulty with implementing this type of process option; therefore, on-site consolidation has not been retained for further evaluation.

Mycoremediation within the Pond AOIs with impacts to sediment is not feasible as the sediments are typically submerged. Further, Mycoremediation was not shown to be effective in previous studies.

Implementation of ISM may pose difficulties due to accessibility restrictions for construction equipment; however, various modifications of the technology exist to adapt to site conditions. In-situ mixing can be implemented in the target AOCs and is retained for further evaluation.

ISB involves injection of substrates into the target media to promote biological degradation of target COIs. ISB relies upon reactions within the aqueous phase, which would occur within the pore space of the target sediments. As discussed above, ISCO relies upon abiotic reactions between reagents and target COIs to achieve mass reduction. Technical implementability concerns exist with both technologies, as well installation or direct push injections activities to deliver reagents will be restricted for sediments located in pond areas. In addition, achieving significant distribution of reagents is likely not feasible within fine-grained matrices characteristic of the sediments at the site. ISB and ISCO are not retained for further evaluation.

Land farming and biopiling can both be readily implemented for COIs in sediment; therefore, both options are retained for further evaluation.

Removal (i.e., excavation) provides immediate and complete removal of impacted sediment from the site to achieve RAOs and was retained for further consideration.

5.2.1.3 Groundwater Remedial Technologies

The preliminary identification and screening process of remedial technologies and associated process options for treatment of groundwater at the site are discussed in this section and summarized in Table 5-3. The following remedial technologies and associated process options with regarding to each GRA for remediating groundwater were identified and evaluated based on technical implementability:

- No action
- ICs
- Monitored natural attenuation (MNA)

- Hydraulic containment: diversion barriers
- In-situ physical treatment: Air Sparge (AS) & SVE, thermal treatment
- In-situ biological treatment: enhanced aerobic bioremediation, enhanced anaerobic bioremediation, phytoremediation
- In-situ chemical treatment: ISCO, permeable reactive barrier (PRB)
- Ex-situ treatment: pump and treat and reinjection, pump and treat and disposal.

In order to provide a baseline for comparison of alternatives as required by the NCP (USEPA 1990), the "No Action" technology has been retained for all media. ICs, such as land use controls, have been retained to provide protection of human health and the environment through administrative striction of groundwater use until chemical-specific ARARs are met. MNA has been retained to be used as a standalone technology or in conjunction with other more aggressive remedial technologies as a polishing step subsequent to active treatment.

Diversion barriers are engineered controls constructed to contain groundwater within the AOC and divert ambient groundwater around the impacted zone until cleanup goals have been met. Diversion barriers are readily implemented at the site through a variety of construction techniques and are retained for further consideration.

Air sparging relies upon injection of air into the saturated interval to promote mass transfer of volatile constituents to the vapor phase and is complemented with recovery through SVE in the vadose zone. Similarly, thermal remediation relies upon heating groundwater using a variety of technologies to enhance volatization of constituents and capturing COIs with SVE. Air sparging and thermal are readily implementable for fuel constituents in groundwater in the IRM and West of IRM AOIs and are retained for further evaluation.

Enhanced aerobic and anaerobic bioremediation rely upon the injection of reagents into the subsurface through permanent wells or temporary points to enhance biological degradation of COIs. Both anaerobic and aerobic degredation pathways have been established and proven effective for fuel constituents in groundwater. Bioremediation is readily implementable across the target areas and is retained for further evaluation.

ISCO technologies, including oxidation processes using Fenton's reagent, persulfate, and permanganate as oxidants, are proven technologies for treatment of VOCs in groundwater and have been retained for further consideration. A PRB is a subsurface emplacement of reactive materials that extend below the water table to intercept and treat contaminated groundwater, typically under natural hydraulic gradient. A PRB is technically feasible at the site and is retained for further evaluation.

Groundwater recovery with treatment and reinjection and groundwater recovery with treatment and disposal are both proven and effective means for groundwater treatment and are retained for further evaluation.

5.2.2 Evaluation of Technology Types and Selection of Representative Process Options

Following completion of the preliminary screening based on technical implementability, the retained remedial technologies and associated process options are to be further evaluated in greater detail based on effectiveness, implementability (i.e., administrative), and relative cost.

In terms of effectiveness, remedial technologies and process options are evaluated by the following:

- Potential effectiveness in addressing the estimated areas and volumes of media and meeting the RAOs
- Potential health and safety concerns for the remedial action or potential impacts to the environment during construction and implementation
- How proven and reliable the process is with respect to the types of contamination and site conditions that will be encountered.

Implementability encompasses both the technical and institutional feasibility of implementing a technology process. As discussed in Section 5.2.1, technical implementability is used as an initial screening of technology types and process options to eliminate those that are clearly ineffective or infeasible for a site. Therefore, this subsequent evaluation places greater emphasis on the institutional aspects of implementability, such as the ability to obtain necessary permits for offsite actions, the availability of treatment, storage, and disposal services (including capacity), and the availability of necessary equipment and skilled workers to implement the technology (USEPA 1988a).

Cost plays a limited role in the evaluation of process options at this step. Relative capital and operations and maintenance (O&M) costs are used rather than detailed estimates. Each process option is evaluated on the basis of engineering judgment as to whether costs are high, moderate, or low relative to the other process options of the same remedial technology type.

Tables 5-1through 5-3 present the screening of technologies and process options retained in the preliminary screening step, based on effectiveness, implementability, and relative cost for soil, sediment, and groundwater.

5.2.2.1 Detailed Screening of Soil Process Options

The detailed screening of process options for treatment of soil at the site are discussed in this section and summarized in Table 5-1.

The “No Action” technology continued to be retained to provide a comparative baseline. ICs have been retained to provide protectiveness through administrative actions until chemical-specific ARARs are met. Covers are retained because they effectively limit exposure and protect current and future receptors until ARARs are met.

Of the in-situ physical process options, SVE, MPE, and thermal remediation all rely upon construction of an aboveground treatment system to treat extracted vapors. Successful implementation of SVE is limited to COIs with sufficient volatility to be removed in the vapor phase. Due to the variability of COIs triggering exceedances within each AOC indicated in Section 5, SVE, MPE, and thermal will not be effective at remediating the AOC in its entirety. The capital cost associated with treatment system installation is too expensive per level of effectiveness on a comparative basis to be considered for partial implementation. SVE, MPE, and thermal will not be carried forward for further evaluation. ISM provides effective mitigation of risks to receptors, and is applicable to all COIs within each AOC; therefore, ISM is retained for evaluation.

The only in-situ treatment option, ISCO, is only potentially effective for a small portion of COIs in soil, and the overall effectiveness must be evaluated by treatability test or bench scale study. Chemical oxidation of soil also may result in secondary water quality effects as byproducts are typically formed during activation and redox reactions, and leaching of metals may occur. Additionally, reaction of the reagents with target COIs occurs in the aqueous phase; therefore, contaminant reduction in soils is highly dependent on sufficient contact with soil moisture in the pore space. Considering implementability concerns and the potential for generation of byproducts, ISCO is not retained for further evaluation.

Excavation and land farming is readily implementable and effective for reduction of volatile COIs. Land farming may be a cost-effective alternative to offsite disposal; therefore, land farming is retained for further evaluation.

Biopiling is a similar process option that relies upon simulation of bacteria within aboveground storage cells to promote bioremediation of COIs. Biopiling would require a bench-scale study and/or a pilot test prior to the determination of site-specific effectiveness and design development. Biopiling is not retained for further development and evaluation due to the associated uncertainty and comparative moderate to high costs compared to other ex-situ treatment/disposal methods.

Excavation and disposal has been retained for treatment of soil because it is immediately effective and readily implementable. When compared to other technologies, excavation and disposal may have a higher capital cost but represents a lower risk as all COIs are removed offsite. Excavation and disposal are retained for further evaluation.

5.2.2.2 Detailed Screening of Sediment Process Options

The detailed screening of process options for treatment of sediment at the site are discussed in this section and summarized in Table 5-2.

The “No Action” technology continued to be retained to provide a comparative baseline. ICs have been retained to provide protectiveness through administrative actions until chemical-specific ARARs are met. A cover is retained as a process option to restrict access until cleanup goals are achieved.

As discussed previously, mycoremediation was not found to be effective at reducing COI concentrations in sediments during historical bench-scale tests. Based on these results, mycoremediation has been determined to not be a viable remedial process option and will not be carried forward for further evaluation.

Previous treatability tests of ISM have been conducted at the site to evaluate the technical feasibility and the effectiveness at reducing COI accessibility to receptors. Results of the treatability test indicate that due to high sediment organic and moisture content and poor post-treatment strength results, ISM requires significant volumes of binders and Portland cement to be effective.

Landfarming and biopiling both rely upon biological treatment of COIs to achieve effective mass reduction. Based on the nature of COIs driving risk within the sediment AOIs, biological treatment will not be sufficient to reduce COI concentrations to meet target cleanup goals and achieve RAOs. Landfarming and biopiling are not retained for further evaluation for sediment.

Excavation and disposal has been retained for treatment of sediment because it is immediately effective and readily implementable. When compared to other technologies, excavation and disposal may have a higher capital cost but represents a lower risk as all COIs are removed offsite. Excavation and disposal is retained for further evaluation.

5.2.2.3 Detailed Screening of Groundwater Process Options

The detailed screening of process options for treatment of groundwater at the site are discussed in this section and summarized in Table 5-3.

The “No Action” technology continues to be retained to provide a comparative baseline. ICs have been retained to provide protectiveness through administrative actions until chemical-specific ARARs are met. MNA, which is effective, readily implementable, and has low capital cost (i.e., using existing monitoring well network) and low O&M cost, has been retained to be used in conjunction with other treatment technologies.

Hydraulic containment is applied to groundwater/soil when there is a risk of dispersion to uncontaminated areas. It can be applied as a stand-alone technology when passive containment is sufficient, or can be combined with other technologies such as groundwater pump and treat systems. Diversion barriers are effective for containment of the groundwater plume if contaminant mobility is of significant concern. Since the IRM were conducted as discussed in Section 2.2.3, groundwater conditions in the vicinity of the OU-E Groundwater AOC have remained relatively stable. Given the nature and extent of COIs in the OU-E Groundwater AOC, installation of diversion barriers will not likely meet RAOs and will likely not provide a significant advantage when implemented in conjunction with another remedial technology, and will not be further evaluated in this FS.

AS/SVE and thermal remediation both present physical removal processes for removing COIs by volatilization and recovery. Both technologies can be effective for mass removal in groundwater; however, thermal remediation requires significant capital and O&M costs for implementation. Additionally, thermal remediation poses several health and safety and permitting concerns for implementation. Based on the comparison of physical process options, AS/SVE is retained for further evaluation in areas affected by petroleum-related compounds.

Enhanced aerobic and anaerobic bioremediation are effective and implementable for remediation of VOCs and other fuel-related constituents. Both process options rely upon injection of a variety of reagents to enhance the attenuation of target COIs. Based on their proven effectiveness in areas with petroleum-related impacts, enhanced aerobic and anaerobic bioremediation are retained for further evaluation.

Phytoremediation is a passive biological treatment technology that utilizes vegetation to address a wide range of contaminants. For groundwater impacted by petroleum hydrocarbons, rhizodegradation is often the primary mechanism used to enhance microbial biodegradation of contaminants. Given the average depth of groundwater near the OU-E Groundwater AOC, a tree/shrub plantation with roots extending 10 to 15 feet bgs would likely be the main application for treatment. The effectiveness of phytoremediation at the site is unknown, and would require treatability studies to establish remedial timeframes. Given the uncertainty associated with the remedial approach in achieving RAOs, phytoremediation is not retained for further evaluation.

Hydrocarbon degradation through ISCO is an established technology that can be effective utilizing several chemical reagents and delivery methods. Redox reactions can generate a variety of byproducts that can enhance natural attenuation through biological pathways, similar to anaerobic bioremediation. ISCO is retained for further evaluation.

A PRB relies upon the ambient groundwater flux to reduce concentrations of COIs within the constructed treatment zones. The majority of trench-installed PRBs use zero-valent iron as the reactive medium for converting contaminants to non-toxic mediums, however, other mediums such as limestone, granular activated carbon, zeolites, and various carbon sources (e.g., compost) have also been deployed in PRBs to treat metals and some organic compounds (Interstate Technology & Regulatory Council, 2005). PRBs utilize similar degradation pathways as other in-situ process options; however, the effectiveness is tied to groundwater flushing across the AOC. Additionally, permitting of permanent reactive barriers within the Coastal Zone may pose significant implementation challenges. Based on effectiveness and administrative considerations, PRBs are not retained for further evaluation.

Both pump and treat process options rely upon extraction of groundwater and treatment on-site followed by either reinjection or disposal. Ex-situ treatment can be conducted through a variety of technologies including air stripping and adsorption using granular organic carbon. Both technologies are proven to effectively treat hydrocarbons and both are feasible at the site. Both process options would require permitting with state and local agencies; however, on-site disposal is more readily implemented if treated water is discharged to Pond 8. Based on current and anticipated site conditions, pump and treat and disposal is retained for further evaluation.

5.2.3 Description of Selected Process Options

This section presents general descriptions of selected remedial technologies and process options for all onsite media. To avoid repetition, technologies and process options that are specific to all media are presented in Section 5.2.3.1 (Site-Wide Process Options). Technologies and process options that are specific to soil, sediment, and groundwater are presented in Sections 5.2.3.2 through 5.2.3.4.

5.2.3.1 Site-Wide Process Options

Site-wide remediation process options included in this evaluation are discussed below and provdied in Tables 5-1 through 5.3.

5.2.3.1.1 No Action

The NCP requires that a No Action alternative be evaluated in an FS to serve as a baseline for comparison purposes, as described in Section 5.2.1.1. A No Action alternative will be developed for all soil, sediment, and groundwater AOCs.

5.2.3.1.2 Institutional Controls

Institutional controls include a variety of measures designed to restrict current and future property owners from taking actions that would expose potential receptors to unacceptable risk, interfere with effectiveness of the final remedial action, and/or convert the site to an end use that is not consistent with the level of remediation. The primary objective of institutional controls is to limit potential for exposure to COIs by restricting access to impacted areas.

For soil and sediment, this technology would protect human health by assigning a “restricted” land use covenant to prevent the potential risk of receptors encountering COI-impacted soil and sediment. A soil management plan (SMP) would be developed based on COIs and associated risks to further protect potential future receptors. Implementing institutional controls is possible given current site conditions, and the overall cost is relatively low.

For groundwater this technology can be implemented by applying groundwater use restrictions within the AOC. Groundwater use restrictions are incorporated into the property deed(s) and may limit the locations and types of allowable groundwater use at the site. Groundwater use restrictions do not physically alter conditions at the site and do not, or are not intended to, reduce the mobility, toxicity, or volume of COIs at the site as part of the remedial process option. The primary objective of groundwater restrictions is to eliminate potential for exposure to COIs by restricting access to affected groundwater.

5.2.3.2 Soil Process Options

Soil remediation process options included in this evaluation are discussed below and provdied in Table 5-1.

5.2.3.2.1 Covers

A barrier or cover is a containment process option that prevents exposure of potential receptors to affected media. A cover can be constructed of pavement materials such as concrete or asphalt, clean soil protected from erosion by vegetative growth or other erosion control measures, or an engineered cover or structure that may include low permeability materials or liners. The cover layer may consist of clean material that is already in place above affected media and is restricted from being removed. The cover layer may limit potential direct contact with affected soils, migration of vapors, or infiltration of water. Given the foreseeable future use of the site and habitat status, a vegetative cover will be the type of cover considered for implementation as a vegetative cover can provide long-term enhancement of ecological habitat.

A vegetative cover system does not pose significant risk to human health or the environment during construction or operational period. Installation of a vegetative cover is a proven and effective method of providing an exposure barrier. Deed restrictions may be used to require that redevelopment design add, modify, or maintain covers appropriate for the future (and possibly different) use of specified areas at the time of future construction. Installation of a cover would be relatively simple to implement and can be completed with standard construction equipment and methods. Implementation is considered comparatively low in cost.

5.2.3.2.2 In-situ Soil Mixing

ISM technology can be used to immobilize organic and inorganic compounds in saturated and vadose zone soil, using reagents to produce an inert, geotechnically strong, and relatively less permeable material, such as Portland cement. This process option does not destroy COIs, but incorporates them into a dense, homogeneous, low-permeability structure that reduces concentrations and mobility. In-situ mixing can be performed with an excavator bucket or a large diameter crane-mounted auger depending on depth and volume. Onsite air monitoring for dust, vapor, and odor control to protect workers and the public would be typical during implementation.

Because Portland cement will be added to the soil, the volume of treated soil will be greater than the original material volume. In order to account for bulking, excess material would be tested and used for backfill elsewhere at the site, or transported offsite for disposal.

5.2.3.2.3 Land Farming

Land farming is an ex-situ treatment technology that consists of spreading the excavated soils in windrows to stimulate aerobic microbial activity through aeration and/or the addition of minerals, nutrients, and moisture to expedite treatment. The windrows are regularly tilled to enhance volatilization. Land farming is sensitive to environmental conditions and would likely require a bench-scale study and/or pilot test prior to the determination of site-specific effectiveness and design development. The biodegradation induced by land farming is likely effective for VOCs and SVOCs, but land farming may not be effective for heavier and more persistent COIs such as metals or chlorinated solvents (USEPA, 1994).

5.2.3.2.4 Excavation and Disposal

Excavation involves the physical removal of soil using standard excavation practices and equipment. Typical equipment used includes excavators, backhoes, drag lines, clamshells, vacuum trucks, and front-end loaders. Excavated soil is transported to a landfill offsite and is required to meet federal and state transportation and disposal regulations. Backfilling, grading, and revegetation are performed following excavation. Sampling and analysis of the backfill material source is typically performed to determine the acceptability of the backfill material. Given the nature and distribution of COI-impacted soil, hotspot excavation of designated PRAs is sufficient to meet RAOs and will be considered in preference to full excavation of all COI-impacted media.

Excavation and removal of affected soil is protective of human health and the environment. However, excavation carries a higher risk to the health and safety of workers. Onsite air monitoring and dust, vapor, and odor control provisions would be necessary during excavation operations to avoid the release of fugitive dusts and runoff from disturbed soil. Dust controls could include water sprays or application of chemical dust suppressants. Surface water controls may also be required.

5.2.3.3 Sediment Process Options

Sediment remediation process options included in this evaluation are discussed below and provdied in Table 5-2.

5.2.3.3.1 Covers

A barrier or cover is a containment process option that prevents exposure of potential receptors to affected media. Within the context of sediment, a barrier is primarily implemented in the form of a vegetative barrier.

A vegetative cover system does not pose significant risk to human health or the environment during construction or operational period. Installation of a vegetative cover is a proven and effective method of providing an exposure barrier. Deed restrictions may be used to require that redevelopment design add, modify, or maintain covers appropriate for the future (and possibly different) use of specified areas at the time of future construction. Installation of a cover would be relatively simple to implement and can be completed with standard construction equipment and methods. Implementation is considered comparatively low in cost.

5.2.3.3.2 In-situ Soil Mixing

ISM technology can be used to immobilize organic and inorganic compounds in saturated sediments, using reagents to produce an inert, geotechnically strong, and relatively less permeable material, such as Portland cement. This process option does not destroy COIs, but incorporates them into a dense, homogeneous, low-permeability structure that reduces concentrations and mobility. In-situ mixing can be performed with an excavator bucket or a large diameter crane-mounted auger depending on depth and volume. Onsite air monitoring for dust, vapor, and odor control to protect workers and the public would be typical during implementation.

Because Portland cement will be added to the sediment, the volume of treated material will be greater than the original material volume. In order to account for bulking, excess material would be tested and used for backfill elsewhere at the site, or transported offsite for disposal. Use of Portland cement in aquatic environments is generally not accepted without significant mitigation and the areas treated could not remain aquatic environments due to elevated pH and the loss of suitable habitat materials.

5.2.3.3.3 Excavation and Disposal

Excavation of sediment relies upon similar methods of removal as excavation of soils; however, additional consideration is required to address access restrictions and dewatering. Excavation may require the need for long-stick excavators and potential engineered controls adjacent the excavation to support equipment during removal. Dewatering is required of excavated sediment to reduce the moisture content prior to transportation and disposal. After dewatering, excavated sediment is transported to a landfill offsite and is required to meet federal and state transportation and disposal regulations. Restoration following excavation of sediments may require backfilling and revegetation to restore existing habitat.

5.2.3.4 Groundwater Process Options

Groundwater remediation process options for the OU-E Groundwater AOC included in this evaluation are discussed below and provdied in Table 5-3.

5.2.3.4.1 Monitored Natural Attenuation

MNA entails monitoring to confirm that COI concentrations are attenuating over time via natural subsurface processes such as dilution, dispersion, volatilization, biodegradation, adsorption, and abiotic chemical reactions. Intrinsic biodegradation is generally the dominant attenuation mechanism.

The primary objective of the evaluation and subsequent MNA implementation is to demonstrate that natural processes of COI degradation will reduce concentrations below regulatory standards before potential exposure pathways are completed. Data may be used to demonstrate that attenuation processes are occurring and to calculate an approximate time to reach cleanup objectives. During MNA, sampling and sample analysis is conducted periodically throughout the process to confirm that degradation is proceeding at rates consistent with fate and transport interpretations and the established cleanup objectives.

5.2.3.4.2 Air Sparging and Soil Vapor Extraction

AS is an in-situ groundwater treatment process option in which air is injected into the subsurface. Injected air moves horizontally and vertically in channels through the soil column, removing COIs by volatilization and stripping. Injected air flushes volatile COIs into the unsaturated zone, where a vapor extraction system is usually implemented to remove vapors. Physical removal of COIs through volatilization is the primary treatment mechanism accomplished via air sparging. Secondary treatment via enhanced biodegradation of COIs may also occur. Biological degradation requires the presence of microbes, nutrients, and oxygen in sufficient quantities to degrade targeted COIs.

5.2.3.4.3 Enhanced Aerobic Bioremediation

Enhanced aerobic bioremediation degrades COIs in the subsurface by enhancing the natural microbial biodegradation processes by delivering oxygen as an electron acceptor to the subsurface. In microbial degradation, microbes derive energy by transferring electrons from the carbon source to a suitable electron acceptor such as oxygen. Generally, there are sufficient quantities of carbon present but limited amounts of electron acceptors. Oxygen, the most energetically efficient electron acceptor, tends to become quickly depleted in the presence of sufficient carbon prompting the utilization of other electron acceptors by bacteria. Enhanced aerobic bioremediation would provide additional oxygen to augment microbial degradation.

Oxygen is typically added through sparging or diffusing gases, or direct-push of slurry solutions such as pure oxygen, calcium peroxide, or by injection of reagents containing dissolved oxygen or oxygen releasing compounds. For the purposes of this FS, direct-push injection of calcium peroxide reagent has been selected as an effective means of oxygen delivery for evaluation and will be further evaluated in this FS. Calcium peroxide is an oxygen-releasing compound when injected in slurry form via direct-push, serves as a slow-release source of oxygen due to its sparingly soluble nature in groundwater (less than 0.2 percent by weight). Calcium peroxide is oftentimes more cost effective than other name-brand oxygen-releasing materials in terms of cost per pound of oxygen delivered.

5.2.3.4.4 Enhanced Anaerobic Bioremediation

Enhanced anaerobic bioremediation degrades COIs in the subsurface by enhancing the natural microbial biodegradation processes by adding a non-oxygen electron acceptor in a low-oxygen or oxygen-free environment. Similar to enhanced aerobic bioremediation, enhanced anaerobic bioremediation augments microbial degradation, however, relies on redox couples other than oxygen (e.g., nitrate reduction, ferric iron reduction, sulfate reduction, and methanogenesis) to facilitate cellular respiration.

Injection of a non-oxygen electron acceptor to stimulate enhanced anaerobic bioremediation is likely to affect secondary water quality parameters in the short term. For example, sulfate has a secondary Maximum Contaminant Level (MCL) of 250 milligrams per liter (mg/L) based on aesthetic effects (i.e., taste and odor) and nitrate (as nitrogen) has a primary MCL of 10 mg/L. Due to the elevated nitrate dose required for treatment relative to the primary MCL, the preference to select an injection reagent with less potential for secondary water quality effects, and the relative similarity of these two electron acceptors in achieving treatment, sulfate is recommended as the preferred reagent.

During the enhanced anaerobic bioremediation process, sulfate is consumed and converted to sulfide. Free sulfide reacts readily with naturally-occurring ferrous iron that is also present in these systems to form iron-sulfide precipitates. While achieving an initial increase in sulfate concentrations is the intent following an injection, the concurrent delivery of sulfate materials with organic carbon will serve as the primary mechanism to limit the long-term permanence of sulfate within the treatment areas and prevent adverse effects on long-term groundwater chemistry.

Anaerobic processes generally occur at slower rates than those observed for aerobic processes; however, non-oxygen electron acceptors (i.e., sulfate) can be advantageous because they are highly soluble, can be supplied at elevated dissolved concentrations, and have minimal abiotic or non-target reactions that typically limit oxygen persistence in the subsurface. The solubility of sulfate associated with gypsum is approximately 2 grams per liter, which is more than enough to sustain enhanced anaerobic bioremediation, and approximately three orders of magnitude greater than the solubility of oxygen. Comparatively, aerobic remediation through injection of an oxygen-releasing substrate, such as calcium peroxide is fundamentally limited by low oxygen solubility in groundwater and multiple competing oxygen sequestration reactions. Additionally, aquifer pH in the immediate vicinity of the calcium peroxide application is anticipated to be elevated during the period of active treatment. Therefore, while the kinetic rates of anaerobic hydrocarbon bio-oxidation may be slower than under aerobic conditions, the ability to deliver elevated concentrations of non-oxygen electron acceptors over a relatively long time period can be more effective in treating residual contaminants in groundwater.

Enhanced anaerobic bioremediation utilizing Epsom Salt (i.e., magnesium sulfide) will be incorporated into remedial alternative development in this FS.

5.2.3.4.5 In-situ Chemical Oxidation

ISCO technology involves reduction/oxidation reactions that chemically convert hazardous contaminants to non-hazardous or less toxic compounds that are more stable or inert. One reactant is oxidized (loses electrons) and another is reduced (gains electrons).

ISCO is sensitive to environmental conditions and would likely require a bench-scale study and/or pilot test prior to the determination of site-specific effectiveness and design development. The effectiveness of ISCO strategies depends on several variables, including the bond-breaking strength of oxidant, kinetics of the oxidant-target compound reaction, non-target chemical oxidant demand, and the target compounds sequestered in non-aqueous phase materials, such as natural soil organic matter or residual oils associated with contaminant releases that are shielded from oxidant attack. These last three variables are highly site-dependent and determine the potential rates of reaction, the mass of oxidant that must be injected to achieve remedial objectives, and the potential amount of contaminant that will remain when the oxidation reactions have reached their completion.

There are four basic oxidants available for in-situ application, including hydrogen peroxide, ozone, permanganate, and persulfate. Two of these, hydrogen peroxide and ozone, are designed to synthesize hydroxyl radicals in the treatment zone. The hydroxyl radical is a highly reactive, indiscriminant oxidant. Peroxide-based systems have been developed for use in the waste water treatment industry employing a Fenton’s approach, which involves the reduction of the pH of the water to a pH less than 5 via the addition of sulfuric acid and the use of an iron catalyst. This reaction can be controlled in a waste water treatment plant, but has been shown to be difficult to control in an environmental setting.

The permanganate system is much less reactive (and, therefore, safer), as it does not employ radicals but works via direct oxidation. It has a long half-life in aqueous systems but requires large injection volumes. Persulfate offers a safer slower reaction, but employs a highly reactive sulfate radical, which can effectively oxidize a wide variety of organic compounds. Therefore, persulfate has multiple advantages for safe controlled effective oxidation of petroleum hydrocarbons and is incorporated into remedial alternative development in this FS.

5.2.3.4.6 Groundwater Extraction, Treatment, and Disposal

Groundwater extraction and treatment (GWET), also known as a pump and treat, consists of pumping COI-affected groundwater from extraction wells to an aboveground treatment system, where the groundwater is treated via granular activated carbon (GAC) and air stripping. Following treatment, water is discharged as surface water.

GWET systems are dependent on site-specific hydrogeological conditions and require a developed CSM prior to specific design. Several extraction wells would be installed in and slightly downgradient of the COI-affected shallow aquifer. Each extraction well would be equipped with a bottom-loading pump capable of removing COIs and groundwater. A pump test would be conducted on the extraction wells to optimize the pumping rate to yield the most efficient contaminant removal rate without dewatering the wells. The extraction wells are connected to the aboveground treatment system via power source and PVC piping. The groundwater would be flushed through GAC vessels. Air stripping would remove, treat, and off-gas VOCs. Ion-exchange or reverse osmosis would be required to remove metals such as

Barium. The treated groundwater would likely be discharged under permit to Pond 8 that eventually discharges to the Pacific Ocean.

GWET systems typically require heavy permitting and oversight during implementation and operation. Operations and maintenance (O&M) would be conducted regularly on the system, and monitoring and sampling would be conducted regularly on both pre- and post-dilution water.

Section 6: Identification of Screening Criteria

Remedial technologies retained through preliminary screening are now further developed and evaluated against applicable remedial alternative screening criteria. In accordance with USEPA FS and DTSC RAP guidance, the nine criteria described in the sections below must be used to evaluate remedial alternatives (USEPA, 1988; DTSC, 1995). For an alternative to be selected, it must meet the first two threshold Criteria, which are: 1) overall protection of human health and the environment; and 2) compliance with ARARs. Criteria 3 through 7 are the five primary balancing criteria that provide comparisons between the alternatives and identify tradeoffs between them; Criteria 8 and 9 are the two modifying criteria that consider acceptance by the state and local community.

6.1 Threshold Screening Criteria

Threshold screening criteria are those considered absolutely necessary for an alternative to be considered sound. These criteria reflect the overall protection of human health and the environment and compliance with ARARs. Threshold criteria are typically considered “yes or no” criteria. If a screened technology fails a threshold criterion, the technology is considered as not viable for further consideration.

6.1.1 Overall Protection of Human Health and the Environment

All remedial alternatives being evaluated must be protective of human health and the environment. No alternative should result in unacceptable levels of risk to onsite or offsite receptors during or after implementation, drawing upon the assessment of other evaluation criteria, including short- and long-term effectiveness and compliance with the RAOs. This component of the alternative evaluation assesses how potential exposure pathways are eliminated, reduced, or controlled through removal, treatment, engineering controls, or institutional controls.

6.1.2 Compliance with ARARs

The remedial alternatives must be evaluated to determine whether they comply with ARARs under federal environmental laws and state environmental or facility siting laws, or whether there are grounds for a waiver. ARARs are presented in Section 4.

6.2 Balancing Criteria

Balancing criteria represent a combination of technical measures and management controls for addressing the environmental issues at the site. These criteria have gradations in value. The balancing screening criteria emphasize short- and long-term effectiveness; implementability; cost; and reductions of toxicity, mobility, or volume through treatment. The balancing criteria also consider the preference for treatment as a principal element and the bias against offsite land disposal of untreated waste.

6.2.1 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence screening criterion evaluates the ability of an alternative to perform intended functions such as containment, diversion, removal, destruction or treatment, and the permanence of the remedy. This criterion also assesses protection of human health and the environment after the RAOs have been met (USEPA, 1988). In accordance with NCP guidance, the long-term effectiveness screening criterion includes the magnitude of residual risk from any untreated waste or treatment residuals remaining at the conclusion of remediation activities, and the adequacy and reliability of controls (such as containment systems and institutional controls) that are necessary to manage treatment residuals and untreated waste. This criterion may be evaluated by design specifications or performance evaluation.

6.2.2 Reduction of Toxicity, Mobility, or Volume through Treatment

The reduction of toxicity, mobility, and volume screening criterion evaluates the degree to which an alternative employs recycling or treatment options that reduce toxicity, mobility, or volume, including how treatment is used to address principal threats potentially posed by the site. Factors considered for this criterion include treatment process and volume of materials to be treated; ability of the treatment to reduce the toxicity, mobility, or volume of contamination; nature and quantity of residuals that would remain after treatment; relative amount of hazardous substances and/or constituents that would be destroyed, treated, or recycled; and the degree to which the treatment is irreversible (USEPA, 1988).

6.2.3 Short-Term Effectiveness

The short-term effectiveness screening criterion assesses the short-term impacts of alternatives by considering short-term risks that may be posed to the public and the potential impacts on workers during remedial action implementation. This criterion also evaluates the effectiveness and reliability of protective measures, potential impacts on the environment and the effectiveness and reliability of mitigative measures, and amount of time until protection is achieved (USEPA, 1988).

6.2.4 Implementability

The implementability screening criterion evaluates the technical and administrative feasibility of implementing the remedial alternative, including the availability of various services and materials required for implementation (USEPA, 1988). Implementability depends on factors such as constructability (e.g., physical setting, permitting, disposal options), duration of work, reliability of the technology, ease of operation, availability of services and materials, and ability to monitor effectiveness (USEPA, 1988).

6.2.5 Cost

The cost screening criterion compares the anticipated approximate costs, direct (construction and materials) and indirect (engineering and legal) capital costs, as well as O&M costs. O&M costs may include operating labor, energy, chemicals, and sampling and analysis. O&M assumptions for each alternative are noted in the text. These costs were estimated with an anticipated accuracy between -30 to +50 (USEPA, 1988), and are represented in 2017 dollars applying 30-year net present value for future costs where necessary.

6.3 Modifying Criteria

Modifying criteria, which include state (support agency) and community acceptance, will be evaluated after submission of the FS to DTSC and after submittal of a RAP and receipt of public comments. The modifying criteria are described below.

6.3.1 State Support/Agency Acceptance

This criterion indicates whether, based on current knowledge of regulations and agency mandates, the applicable regulatory agencies would agree with the preferred alternative. The rankings listed in the sections below are based on preliminary input from agency meetings and knowledge of regulatory mandates. Actual assessment of regulatory agency acceptance is dependent on comments received during the agency review and public comment periods.

6.3.2 Community Acceptance

This criterion indicates whether community concerns are addressed by the remedy. Each alternative is evaluated in terms of currently available public input and the anticipated public reaction to the alternative, but is considered preliminary. However, actual assessment of community acceptance is dependent on comments received during public comment period of the draft RAP.

6.4 Other Criteria

California Health and Safety Code Section 25356.1(d) also outlines six additional criteria, which need to be addressed for the recommended remedial alternative. As these criteria are addressed within the nine USEPA criteria, a separate analysis has not been conducted.

Section 7: Development and Evaluation of Remedial Alternatives

As discussed previously, remedial alternatives are developed by combining remedial technologies and process options identified in Section 5 for groundwater, soil and sediment. Alternatives are presented below for each remediation area within OU-E. AOIs that were addressed in the OU-E RAW are discussed collectively.

Areas addressed in the RAW include Lowland Terrestrial Soil, Ponds 1 through 4 (Southern Ponds) Aquatic Sediment, Pond 7 Aquatic Sediment, and Riparian Aquatic Sediment, where excavation and disposal are approved and planned for implementation in 2017. An evaluation of remedial alternatives is provided in the RAW and a contingency remedy of institutional controls is planned in the event that RAW implementation does not result in unrestricted use.

- North Pond and Pond 6 Aquatic Sediment
  - No Action
  - Institutional Controls
  - Vegetated Soil Cover
  - Excavation and Disposal

- Pond 8 Aquatic Sediment
  - No Action
  - Institutional Controls
  - In-situ Soil Mixing
  - Excavation and Disposal
  - Vegetated Soil Cover

- OU-E Groundwater
  - No Action
  - Restricted Use
  - Monitored Natural Attenuation (MNA)
  - Enhanced Aerobic Bioremediation
  - Enhanced Anaerobic Bioremediation
  - In-situ Chemical Oxidation (ISCO)
  - Groundwater Extraction and Treatment (GWET)

The remedial alternatives were compared against the nine screening criteria presented in Section 6, and are developed and evaluated in Section 7.

7.1 AOIs addressed in the RAW

7.1.1 Lowland Terrestrial Soil

A remedial action has been presented in the approved OU-E RAW for this AOC. Implementation is planned for 2017. Approximately 1,410 cubic yards are planned to be excavated over an area of 7,900 square feet and disposed at an appropriate facility. Soil will be excavated using conventional construction equipment and transported to an appropriate non-hazardous waste disposal facility. The excavation areas will be backfilled with clean imported soil and compacted to the original surface elevation. Confirmation sampling will be performed to confirm that concentrations at the excavation limits are below the not to exceed remedial goals included in the OU-E RAW. Remaining COI concentrations are expected to continue to decline naturally through existing biological and geochemical processes. The need for addition soil removal or land use controls will be evaluated based on the confirmation sampling results.

7.1.2 Ponds 1 through 4 (Southern Ponds) Aquatic Sediment

A remedial action has been presented in the approved OU-E RAW for this AOI. Implementation is planned for 2017. Approximately 45 cubic yards are planned to be excavated over an area of 800 square feet and disposed at an appropriate facility. Sediment will be excavated using conventional construction equipment and transported to an appropriate non-hazardous waste disposal facility. The excavation areas will be backfilled with clean imported soil to the original surface elevation. Confirmation sampling will be performed to confirm that concentrations at the excavation limits are below the not to exceed remedial goals included in the OU-E RAW. Remaining COI concentrations are expected to continue to decline naturally through existing biological and geochemical processes. The need for addition sediment removal or land use controls will be evaluated based on the confirmation sampling results.

7.1.3 Pond 7 Aquatic Sediment

A remedial action has been presented in the approved OU-E RAW for this AOI. Implementation is planned for 2017. 1,540 cubic yards are planned to be excavated over an area of 5,500square feet and disposed at an appropriate facility. Sediment will be excavated using conventional construction equipment and transported to an appropriate non-hazardous waste disposal facility. The excavation areas will be backfilled with clean imported soil to the approved elevation. Confirmation sampling will be performed to confirm that concentrations at the excavation limits are below the not to exceed remedial goals included in the OU-E RAW. Remaining COI concentrations are expected to continue to decline naturally through existing biological and geochemical processes. The need for addition sediment removal or land use controls will be evaluated based on the confirmation sampling results.

7.1.4 Riparian Aquatic Sediment

A remedial action has been presented in the approved OU-E RAW for this AOI. Implementation is planned for 2017. Approximately 7cubic yards are planned to be excavated over an area of 370 square feet and disposed at an appropriate facility. Confirmation sampling will be performed to confirm that concentrations at the excavation limits are below the not to exceed remedial goals included in the OU-E RAW. The need for addition sediment removal or land use controls will be evaluated based on the confirmation sampling results.

7.1.5 Threshold, Balancing, and Modifying Criteria

A comparison of the threshold, balancing, and modifying criteria was conducted for excavation and disposal, and is summarized below.

- **Threshold Criteria**
  - Overall protectiveness of human health and the environment: The COI-concentrations in soil, which drove the risk-based PRAs, will be directly removed and disposed of offsite in a permitted landfill. This remedial action will remove contaminated soil and sediment within these AOIs that may have an impact to human health and the environment, as confirmed by confirmation sampling, and therefore human health and the environment are anticipated to be protected following implementation. This remedial action is ranked high for this criterion.
  - Compliance with ARARs: Excavation and disposal is in compliance with the ARARs.
- **Balancing Criteria**
  - Long-term effectiveness and permanence: No O&M is required for the excavation and disposal alternative, so it is considered effective in the long term. If necessary based on evaluation after completion of the remedial action, site use and soil disturbing activities in the PRAs may be controlled by land use controls, further ensuring long-term effectiveness. Therefore, this remedial action is ranked high for this criterion.
  - Reduction of toxicity, mobility, or volume: Excavation and disposal will remove soil and sediment that exceeds the not to exceed goals presented in the OU-E RAW, thereby reducing the volume of contaminated soil and sediment. The remedial action will remove soil and sediment with high concentrations of the COIs, therefore reducing the toxicity and mobility of the COIs at the site. Overall, this remedial action is ranked high for this criterion.
  - Short-term effectiveness: The Excavation and Disposal alternative is ranked moderate for short-term effectiveness as construction workers would be temporarily exposed to COI-affected media during implementation. Administrative and engineering controls would be in-place during excavation and disposal to provide protection to workers to limit any potential exposure pathways in the short term.
  - Implementability: The Excavation and Disposal alternative is ranked high for implementability as it is readily implementable with standard construction equipment, backfilling materials would be locally obtainable, and waste likely qualifies as non-hazardous waste for reduced disposal hazards and transport.

- Cost: Excavation and disposal is ranked moderate as it is typically more expensive than other remedial alternatives. However, there are no O&M costs associated with excavation and disposal, which have more uncertainty than implementation costs, and therefore there is less uncertainty for the excavation and disposal remedial action than other alternatives.

- **Modifying Criteria**

  - State and agency acceptance: The OU-E RAW has been approved by DTSC (DTSC, 2016), and therefore this remedial action is ranked high for this criterion.

  - Community acceptance: The OU-E RAW underwent a public review and comment period and all comments were addressed prior to approval. Therefore, this remedial alternative is ranked high for this criterion.

7.1.6 Future Remedial Action Plan

Following implementation of the OU-E RAW remedial action, the OU-E Remedial Action Plan (RAP) will be prepared. The RAP will include a summary of the completed remedial action and assess if further action is required. Alternatives to be evaluated and the scenario in which they are likely to be recommended in the RAP include the following:

- No further action: confirmation sampling indicates that remaining exposure point concentrations in soil and sediment are below chemical specific remedial goals for unrestricted use and individual locations do not exceed the not to exceed goals.

- Deed restrictions with land use controls: confirmation sampling indicates that remaining exposure point concentrations in soil and sediment exceed goals for unrestricted use but individual locations do not exceed the not to exceed goals.

- Additional soil/sediment removal, capping, treatment, or other contingency remedies: confirmation sampling indicates that remaining concentrations in soil and sediment exceed the not to exceed goals. This alternative will be considered but is not expected to be required because the OU-E RAW proposed excavation until confirmation sampling indicates that concentrations at the excavation limits are below the not to exceed goals. In the event that not-to-exceed goals are exceeded in a larger area than expected, such that excavation and disposal is no longer feasible, a contingency remedy may be required and evaluated as part of the RAP.

Either no action or land use controls are anticipated to be sufficient to protect human health and the environment after implementation of the approved remedial action; this assessment will be confirmed after the remedial action is completed.

7.2 North Pond and Pond 6 Aquatic Sediment

Remedial technologies for this AOC were preliminarily screened in Section 5.1 and summarized on Table 5-2. This section presents an evaluation of the selected alternatives for the North Pond and Pond 6 AOC based on the screening criteria presented in Section 6.

7.2.1 Development and Evaluation of Remedial Alternatives

7.2.1.1 Alternative 1 - No Action

The No Action alternative is intended to serve as a baseline which to compare the risk reduction effectiveness of potential technologies, as required by USEPA and NCP regulations (USEPA, 1988). In this baseline, no remedial efforts would be performed. No efforts would be undertaken to contain, remove, or monitor any areas with impacted aquatic sediment at the site. The site would be maintained by Georgia-Pacific in its current condition for the foreseeable future. An evaluation of this alternative is provided in the following sections.

7.2.1.1.1 Overall Protection of Human Health and the Environment

The No Action alternative was retained per requirement of the NCP for baseline comparison and does not meet the threshold criteria. Although natural biodegradation would likely occur, no actions would be taken to monitor or confirm attenuation. Degradation may not occur within a reasonable timeframe, and thus the RAOs for unrestricted use are not met.

7.2.1.1.2 Compliance with ARARs

ARARs would not be met for the No Action alternative.

7.2.1.1.3 Long-Term Effectiveness and Permanence

As described in Section 7.2.1.1.1, the degradation rate is unknown and would not be monitored, and therefore the RAOs for unrestricted use are not met. This alternative ranks low for long-term effectiveness and permanence.

7.2.1.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Although natural biodegradation would likely occur, no actions would be taken to monitor, and degradation may not occur within a reasonable timeframe, and thus no reduction of toxicity, mobility, or volume could be confirmed to justify potential long-term effectiveness. The No Action alternative ranks low for reduction of toxicity, mobility, or volume criteria.

7.2.1.1.5 Short-Term Effectiveness

The No Action alternative received a high ranking for the short-term effectiveness criteria – as no actions are being performed. Because no actions are being performed, the No Action alternative provides no additional short-term risks during implementation.

7.2.1.1.6 Implementability

The No Action alternative received a high ranking for the implementability criteria – as no actions are being performed. The No Action alternative is easily implemented.

7.2.1.1.7 Cost

The No Action alternative is not associated with any implementation cost, and is ranked high for this criterion.

7.2.1.1.8 Overall Rating

Overall, the No Action alternative ranks low due to the lack of monitoring to confirm a reduction in concentrations and other factors, as described above.

7.2.1.2 Alternative 2- Institutional Controls

The Institutional Controls alternative evaluates the risk associated with affected sediment and provides a deed restriction and SMP for future site use which limits land use and controls activities in areas where the risk from one or more exposure pathways is deemed unacceptable. The deed restriction and SMP would be consistent with the *Mill Site Specific Plan* (Mill Site Coordinating Committee, 2012; Figure 2-1) for future site use. The SMP would provide detailed procedures for sediment disturbing activities and design criteria for development within the restricted area. The SMP would describe required sampling and criteria for reuse of disturbed sediment. Notification to DTSC and sediment removal may occur as part of future redevelopment activities and changes in use in order to achieve acceptable risk for the changed conditions. Sediment COI concentrations would continue to decline naturally through existing biological and geochemical processes. An evaluation of this alternative is provided in the following sections.

7.2.1.2.1 Overall Protection of Human Health and the Environment

The Institutional Controls alternative is anticipated to be protective of human health and the environment as it provides restrictions for access to the affected sediment and guidelines for disturbing the sediment. Additionally, sediment COI concentrations would continue to decline naturally through existing biological and geochemical processes. This alternative meets the RAOs.

7.2.1.2.2 Compliance with ARARs

This alternative is in compliance with the projected ARARs.

7.2.1.2.3 Long-Term Effectiveness and Permanence

The Institutional Controls alternative received a moderate ranking for the long-term effectiveness criterion as the proposed deed restriction and SMP would provide adequate protection of potential receptors in the long term.

7.2.1.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The Institutional Controls alternative was ranked moderate for the reduction of toxicity, mobility, or volume through treatment criterion as no COI-impacted media would be physically removed or treated. As demonstrated in the BHHERA, COI concentrations in North Pond and Pond 6 sediment do not present significant risk to receptors and the opportunity to further reduce toxicity or risk from sediment is small.

7.2.1.2.5 Short-Term Effectiveness

The Institutional Controls alternative received a high ranking for the short-term effectiveness criteria, as it does not consider exposing construction workers to COI-impacted media as sediment is left in place.

7.2.1.2.6 Implementability

The Institutional Controls alternative received a high ranking for the implementability criteria, as it is easily implementable.

7.2.1.2.7 Cost

The Institutional Controls alternative ranked high, as the cost is comparatively lower than other process options.

7.2.1.2.8 Overall Rating

Overall, the Institutional Controls alternative ranks high. Although it is ranked low for the reduction of toxicity, mobility and volume criterion, institutional controls should provide adequate elimination of potential exposure pathways for future receptors.

7.2.1.3 Alternative 3 – Vegetative Soil Cover and Institutional Controls

The Vegetated Soil Cover alternative proposes to provide a vegetative cover to cover each individual pond (a total treatment area of approximately 10,000 sf) to restrict exposure of potential receptors to affected media, and would limit potential direct contact with affected sediment or infiltration of water. The vegetative cover would consist of a surface barrier of approximately 2 feet of soil and plant life that form extensive root systems through low-permeability soils. This alternative would be coupled with institutional controls, and would provide a deed restriction to prohibit development, removal of the cover, or other soil disturbing activities in the affected area. A risk evaluation would be performed, with results reported in a comprehensive SMP that limits future use of the affected area. Sediment COI concentrations would continue to decline naturally through existing biological and geochemical processes. O&M activities (e.g., inspection, re-seeding) may be required following implementation. An evaluation of this alternative is provided in the following sections.

7.2.1.3.1 Overall Protection of Human Health and the Environment

The Vegetated Soil Cover and Institutional Controls alternative is anticipated to be protective of human health and the environment as it provides restrictions for access to the affected sediment and guidelines for disturbing the sediment. Additionally, sediment COI concentrations would continue to decline naturally through existing biological and geochemical processes. This alternative likely meets the RAOs.

7.2.1.3.2 Compliance with ARARs

This alternative is in compliance with the projected ARARs.

7.2.1.3.3 Long-Term Effectiveness and Permanence

The Vegetated Soil Cover alternative received a moderate ranking for long-term effectiveness and performance, as the cover would likely have a useful life exceeding 30 years but may require O&M. The Vegetated Soil Cover alternative would also implement the SMP to restrict site use and soil disturbing activities, including those that would diminish the integrity of the cover.

7.2.1.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The Vegetated Soil Cover alternative received a moderate ranking for reduction of toxicity, mobility, or volume criteria. The mobility would likely be reduced following implementation of the vegetative cover as water infiltration is mitigated, but does not directly reduce the toxicity or volume through treatment.

7.2.1.3.5 Short-Term Effectiveness

The Vegetated Soil Cover and Institutional Controls alternative received a high ranking for the short-term effectiveness criteria, as it does not consider exposing construction workers to COI-impacted media as sediment is left in place.

7.2.1.3.6 Implementability

The Vegetated Soil Cover and Institutional Controls alternative received a moderate ranking for the implementability criteria, as it is easily implementable with standard construction equipment and cover materials would be locally obtainable; however, required permitting and mitigation requirements would be significant.

7.2.1.3.7 Cost

The Vegetated Soil Cover and Institutional Controls alternative ranked moderate, as the cost is comparatively lower than other process options. However, the Vegetated Soil Cover alternative may require O&M activities and consequently costs are more uncertain in comparison with institutional controls.

7.2.1.3.8 Overall Rating

Overall, the Vegetated Soil Cover and Institutional Controls alternative ranks moderate. It is ranked moderate for the reduction of toxicity, mobility and volume criterion, and should provide adequate elimination of potential exposure pathways for future receptors. However, the benefits of a physical cover are offset by the effort and disruption associated with implementation and potentially regular O&M.

7.2.1.4 Alternative 4 - Excavation and Disposal of Sediment and Institutional Controls

The Excavation and Disposal alternative involves the excavation and offsite disposal of sediment in the North Pond and Pond 6, which amounts to approximately 1,800 cy with excavation to a maximum depth of 5 feet bgs in an approximate 10,000 sf footprint (Figures 2-25 through 2-27). Sediment would be excavated using conventional construction equipment and would be either temporarily stockpiled and managed to prevent dust and odors or directly loaded into truck beds. Dewatering and or stabilization with Portland cement may be necessary for some of the excavated material. Immediately after loading, the truck beds would be covered with a tarp and transported to an appropriate non-hazardous waste disposal facility. The excavation areas may be backfilled with clean imported soil or the pond depth may be allowed to increase depending on the resulting geometry and agency permit requirements. This alternative also provides a deed restriction to prohibit development or other sediment disturbing activities in the affected area. A risk evaluation would be performed, with results reported in a comprehensive SMP that limits future use of the affected area. Remaining COI concentrations would continue to decline naturally through existing biological and geochemical processes. An evaluation of this alternative is provided in the following sections.

7.2.1.4.1 Overall Protection of Human Health and the Environment

Sediment would be directly removed and disposed of offsite in a permitted landfill, and therefore human health and the environment would be protected following implementation.

7.2.1.4.2 Compliance with ARARs

This alternative is in compliance with the projected ARARs.

7.2.1.4.3 Long-Term Effectiveness and Permanence

O&M is not required after completion of the excavation and disposal and sediment would be removed, as confirmed by confirmation sampling, and therefore this alternative is ranked high for long-term effectiveness and permanence. Institutional controls to restrict site access and sediment disturbance would further increase the effectiveness of this alternative in the long-term.

7.2.1.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Excavation and disposal would remove sediment, thereby reducing the volume of affected sediment and the toxicity and mobility of the COIs remaining. Overall, this alternative ranks high for this criterion. As demonstrated in the BHHERA, COI concentrations in the North Pond and Pond 6 sediments do not present significant risk to receptors; therefore, the reduction of toxicity or risk from excavated sediment is small.

7.2.1.4.5 Short-Term Effectiveness

Construction workers would be temporarily exposed to COI-affected sediment during implementation, and therefore this alternative is ranked moderate for short-term effectiveness.

7.2.1.4.6 Implementability

The Excavation and Disposal alternative is ranked moderate for implementability as it is readily implementable with standard construction equipment, backfilling materials would be locally obtainable, and waste likely qualifies as non-hazardous waste for reduced disposal hazards and transport; however, required permitting and mitigation requirements would be significant.

7.2.1.4.7 Cost

Excavation and Disposal is ranked low as it is typically the most expensive process option compared to other remedial alternatives.

7.2.1.4.8 Overall Rating

Overall, the Excavation and Disposal alternative ranks moderate. It is ranked high for many criteria and should provide adequate elimination of potential exposure pathways for future receptors. However, the benefits of this alternative are offset by the higher cost, effort, and ecological and community disruption as compared to other alternatives evaluated.

7.2.2 Selection of Preferred Alternative

The Institutional Controls alternative is the preferred alternative for the North Pond and Pond 6 AOC. Although it is associated with a slightly lower reduction of toxicity, mobility and volume, institutional controls would provide adequate elimination of potential exposure pathways for future receptors. The benefits of a physical cover are offset by the effort and disruption required for implementation and potentially regular O&M. The benefits of Excavation and Disposal are offset by the effort and disruption required for implementation and the need to transport and dispose the sediment at a landfill. The cost difference between the alternatives is not justified by any significant benefits of the Vegetated Soil Cover or Excavation and Disposal alternatives.

7.3 Pond 8 Aquatic Sediment

Remedial technologies for this AOC were preliminarily screened in Section 5.1 and summarized on Table 5-2. This section presents an evaluation of the selected alternatives for the Pond 8 AOC based on the screening criteria presented in Section 6.

7.3.1 Development and Evaluation of Remedial Alternatives

7.3.1.1 Alternative 1 - No Action

The No Action alternative is intended to serve as a baseline which to compare the risk reduction effectiveness of potential technologies, as required by USEPA and NCP regulations (USEPA, 1988). In this baseline, no remedial efforts would be performed. No efforts would be undertaken to contain, remove, or monitor any areas with impacted aquatic sediment at the site. The site would be maintained by Georgia-Pacific in its current condition for the foreseeable future. An evaluation of this alternative is provided in the following sections.

7.3.1.1.1 Overall Protection of Human Health and the Environment

The No Action alternative was retained per requirement of the NCP for baseline comparison and does not meet the threshold criteria. Although natural biodegradation would likely occur, no actions would be taken to monitor or confirm attenuation. Degradation may not occur within a reasonable timeframe, and thus the RAOs for unrestricted use are not met.

7.3.1.1.2 Compliance with ARARs

ARARs would not be met for the No Action alternative.

7.3.1.1.3 Long-Term Effectiveness and Permanence

The degradation rate is unknown and would not be monitored, and therefore the RAOs for unrestricted use are not met. This alternative ranks low for long-term effectiveness and permanence.

7.3.1.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Although natural biodegradation would likely occur, no actions would be taken to monitor, and degradation may not occur within a reasonable timeframe, and thus no reduction of toxicity, mobility, or volume could be confirmed to justify potential long-term effectiveness. The No Action alternative ranks low for reduction of toxicity, mobility, or volume criteria. As demonstrated in the BHHERA, COI concentrations in Pond 8 sediment do not present significant risk to receptors and the opportunity to further reduce toxicity or risk from sediments is small.

7.3.1.1.5 Short-Term Effectiveness

The No Action alternative received a high ranking for the short-term effectiveness criteria – as no actions are being performed. Because no actions are being performed, the No Action alternative provides no additional short-term risks during implementation.

7.3.1.1.6 Implementability

The No Action alternative received a high ranking for the implementability criteria – as no actions are being performed. The No Action alternative is easily implemented.

7.3.1.1.7 Cost

The No Action alternative is not associated with any implementation cost, and is ranked high for this criteria.

7.3.1.1.8 Overall Rating

Overall, the No Action alternative ranks low due to the lack of monitoring to confirm a reduction in concentrations and other factors, as described above.

7.3.1.2 Alternative 2 - Institutional Controls

The Institutional Controls alternative evaluates the risk associated with affected sediment and provides a deed restriction and SMP for future site use which limits land use and controls activities in areas where the risk from one or more exposure pathways is deemed unacceptable. To address California Department of Water Resources, Division of Safety of Dams (DSOD) requirements, the Mill Pond Dam would be modified to include separation of the pond into east and west sections and the addition of a soil buttress at the northeast end and at the crib wall near the ocean. The dam modifications would not affect existing sediment and the Mill Pond would continue to receive and treat storm water from the site and the City of Fort Bragg. These features are not expected to require significant soil removal or destruction of habitat. The deed restriction and SMP would be consistent for future site use. Concentrations of COIs in sediment in Pond 8 were shown to represent limited risk to receptors for the reasonable foreseeable use in the OU-E BHHERA. The SMP would provide detailed procedures for sediment disturbing activities and design criteria for development within the restricted area. The SMP would describe required sampling and criteria for reuse of disturbed sediment. Notification to DTSC and sediment removal may occur as part of future redevelopment activities and changes in use in order to achieve acceptable risk for the changed conditions. Sediment COI concentrations would continue to decline naturally through existing biological and geochemical processes. An evaluation of this alternative is provided in the following sections.

7.3.1.2.1 Overall Protection of Human Health and the Environment

The Institutional Controls alternative is anticipated to be protective of human health and the environment as it provides restrictions for access to the affected sediment and guidelines for disturbing the sediment. Additionally, sediment COI concentrations would continue to decline naturally through existing biological and geochemical processes. This alternative likely meets the RAOs.

7.3.1.2.2 Compliance with ARARs

This alternative is in compliance with the projected ARARs.

7.3.1.2.3 Long-Term Effectiveness and Permanence

The Institutional Controls alternative received a high ranking for the long-term effectiveness criterion as the proposed deed restriction and SMP would provide adequate protection of potential receptors in the long term.

7.3.1.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The Institutional Controls alternative was ranked moderate for the reduction of toxicity, mobility, or volume through treatment criterion as no COI-impacted media would be physically removed or treated, but sediment containment reduces the potential mobility. As demonstrated in the

BHHERA, COI concentrations in Pond 8 sediment do not present significant risk to receptors and the opportunity to further reduce toxicity or risk from sediment is small.

7.3.1.2.5 Short-Term Effectiveness

The Institutional Controls alternative received a high ranking for the short-term effectiveness criteria, as it does not consider exposing construction workers to COI-impacted media as sediment is left in place.

7.3.1.2.6 Implementability

The Institutional Controls alternative received a high ranking for the implementability criteria, as it is easily implementable.

7.3.1.2.7 Cost

The Institutional Controls alternative ranked high, as the cost is comparatively lower than other process options.

7.3.1.2.8 Overall Rating

Overall, the Institutional Controls alternative ranks high. Although it is ranked low for the reduction of toxicity, mobility and volume criterion, institutional controls would provide adequate elimination of potential exposure pathways for future receptors.

7.3.1.3 Alternative 3 – In-situ Soil Mixing of Sediment

The ISM alternative proposes to treat sediment in place through stabilization by the addition of binders and Portland cement (a total treatment volume of approximately 106,000 cubic yards) to restrict exposure of potential receptors to affected media, and would limit potential direct contact with affected sediment, or infiltration of water. The ISM treatment would consist of mixing sediment with augers or excavation equipment to bind sediment within a low strength concrete material and would provide a deed restriction to prohibit development, damage to stabilized material, or other soil disturbing activities in the affected area. ISM would destroy Pond 8 wetland habitat and require mitigation in the form of wetlands creation at an alternate location. A risk evaluation would be performed, with results reported in a comprehensive SMP that limits future use of the affected area. Sediment COI concentrations would be inaccessible as a result of the treatment. The deed restriction and SMP would be consistent with future site use. An evaluation of this alternative is provided in the following sections.

7.3.1.3.1 Overall Protection of Human Health and the Environment

The ISM alternative is anticipated to be protective of human health and the environment as it restricts access to the affected sediment and binds COIs in a concrete-like matrix. This alternative likely meets the RAOs.

7.3.1.3.2 Compliance with ARARs

This alternative is in compliance with the projected ARARs, though may be difficult to permit within the California Coastal Zone as ISM will result in the disruption and destruction of wetland habitat which may require significant mitigation that may not be possible when considering the multiple and sometimes conflicting policies of all relevant agencies. Generally, use of concrete in aquatic environments is strictly limited and at the volume necessary to treat Pond 8 sediment may result in pH excursions that would temporarily adversely affect water quality and be incompatible with some ARARs.

7.3.1.3.3 Long-Term Effectiveness and Permanence

The ISM alternative received a high ranking for long-term effectiveness and performance, as the treated sediment would be durable and encapsulated in a low strength concrete-like mixture that resembles stiff soil. The ISM alternative would also require institutional controls to implement the SMP to restrict site use, including those that would disturb treated sediment.

7.3.1.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The ISM alternative received a moderate ranking for reduction of toxicity, mobility, or volume criteria. The mobility would likely be significantly reduced following implementation of the ISM treatment as water infiltration is mitigated and sediment is stabilized, but does not directly reduce the toxicity or volume through treatment. Volume of the treated material would increase by approximately 50 percent. As demonstrated in the BHHERA, COI concentrations in the Pond 8 sediments do not present significant risk to receptors and the opportunity to further reduce toxicity or risk from sediment is small.

7.3.1.3.5 Short-Term Effectiveness

The ISM alternative received a low ranking for the short-term effectiveness criteria, as it involves disturbance of sediment exposing construction workers to COI-impacted media during treatment. The addition of the large volume of Portland cement needed to perform ISM could temporarily affect geochemistry in the immediate vicinity of the treatment area due to the high pH associated with the cement addition.

7.3.1.3.6 Implementability

The ISM alternative received a low ranking for the implementability criteria, as it would require the destruction of 280,000 sf of existing wetland. Storm water flow through Pond 8 would need to be rerouted. Storm water studies have shown that non-point sources of COIs are present in storm water at the site at concentrations similar to those found in Pond 8 sediment. Pond 8 provides a significant treatment benefit for storm water. Direct discharge of storm water to the ocean or restored streams and wetlands would require the City of Fort Bragg to provide pretreatment for storm water. This approach is unlikely to be accepted by permitting agencies without significant mitigation.

7.3.1.3.7 Cost

The ISM alternative ranked low, as the cost is comparatively higher than other process options.

7.3.1.3.8 Overall Rating

Overall, the ISM alternative ranks low. It is ranked moderate for the reduction of toxicity, mobility and volume criterion, and should provide adequate elimination of potential exposure pathways for future receptors. However, the benefits of a ISM are offset by the effort and disruption associated with implementation and the relatively small reduction of risk achieved.

7.3.1.4 Alternative 4 – Excavation and Disposal

The Excavation and Disposal for unrestricted use alternative involves the excavation and offsite disposal of sediment in Pond 8 until confirmation sampling indicates remaining concentrations of COIs in sediment allow for unrestricted use classification. The distribution of dioxin in sediment is relatively uniform laterally and vertically throughout the 106,000 cubic yards of sediment in the pond. Sediment would be excavated using conventional construction equipment and would be either temporarily stockpiled and managed to prevent dust and odors or directly loaded into truck beds. Dewatering and or stabilization with Portland cement may be necessary for some of the excavated material. Immediately after loading, the truck beds would be covered with a tarp and transported to an appropriate non-hazardous waste disposal facility. The excavation areas may be backfilled with clean imported soil or the pond depth may be allowed to increase depending on the resulting geometry and agency permit requirements. To address California Department of Water Resources, Division of Safety of Dams (DSOD) requirements, the Mill Pond Dam would be modified to include separation of the pond into east and west sections and the addition of a soil buttress at the northeast end and at the crib wall near the ocean. The modified Dam would preserve existing wetland features and the storm water treatment capacity of the existing system. Dam improvements are not expected to require significant soil removal or destruction of habitat. Excavation and disposal would be consistent with future site use. Remaining COI concentrations in sediment would continue to decline naturally through existing biological and geochemical processes. An evaluation of this alternative is provided in the following sections.

7.3.1.4.1 Overall Protection of Human Health and the Environment

The affected sediment would be directly removed and disposed of offsite in an accredited non-hazardous landfill, and therefore human health and the environment would be protected following implementation.

7.3.1.4.2 Compliance with ARARs

This alternative is in compliance with the projected ARARs.

7.3.1.4.3 Long-Term Effectiveness and Permanence

O&M is not required after completion of the excavation and disposal and affected sediment would be removed, as confirmed by confirmation sampling, and therefore this alternative is ranked high for long-term effectiveness and permanence. Removing affected sediment to allow unrestricted land use would be expected to reduce risk such that institutional controls are not necessary.

7.3.1.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Excavation and disposal for unrestricted use would remove affected sediment, thereby reducing the volume of affected sediment and the toxicity and mobility of the COIs remaining. Overall, this alternative ranks high for this criterion. As demonstrated in the BHHERA, COI concentrations in Pond 8 sediment do not present significant risk to receptors; therefore, the reduction in toxicity or risk from sediments is small.

7.3.1.4.5 Short-Term Effectiveness

Construction workers would be temporarily exposed to COI-affected sediment during implementation, and therefore this alternative is ranked moderate for short-term effectiveness.

7.3.1.4.6 Implementability

The Excavation and Disposal for unrestricted use alternative is ranked low for implementability. It is readily implementable with standard construction equipment, backfilling materials would be locally obtainable, and waste likely qualifies as non-hazardous waste for reduced disposal hazards and transport; however, required permitting and mitigation requirements would be significant.

7.3.1.4.7 Cost

Excavation and disposal for unrestricted use is ranked low as it is typically more expensive than other remedial alternatives.

7.3.1.4.8 Overall Rating

Overall, the Excavation and Disposal for unrestricted use alternative ranks moderate. It is ranked high for many criteria and should provide adequate elimination of potential exposure pathways for future receptors. However, the benefits of this alternative are offset by the high cost as compared to other alternatives evaluated and the relatively small reduction of risk achieved.

7.3.1.5 Alternative 5 – Vegetated Soil Cover and Institutional Controls

The Vegetative Soil Cover alternative proposes to provide a vegetative cover to cover the pond (a total treatment area of approximately 280,000 sf) to restrict exposure of potential receptors to affected media, and would limit potential direct contact with affected sediment, or infiltration of water. The Vegetated Soil Cover would consist of a surface barrier of soil approximately 2 feet thick and plant life that form extensive root systems through low-permeability soils. Based on geotechnical testing, a soil cover would require dewatering, compaction, and treatment of the sediment to support the weight of the cover and avoid damage to the cover and sediment displacement. The addition of soil cover materials and the strengthening of underlying sediment would significantly reduce the volume and area of the pond requiring mitigation in the form of wetland creation in an alternate location. This alternative would be coupled with institutional controls, and would provide a deed restriction to prohibit development, removal of the cover, or other soil disturbing activities in the affected area. A risk evaluation would be performed, with results reported in a comprehensive SMP that limits future use of the affected area. Sediment

COI concentrations would continue to decline naturally through existing biological and geochemical processes. O&M activities (e.g., inspection, repairs, re-seeding) would be required following implementation. The deed restriction and SMP would be consistent with future site use. An evaluation of this alternative is provided in the following sections.

7.3.1.5.1 Overall Protection of Human Health and the Environment

The Vegetated Soil Cover and Institutional Controls alternative is anticipated to be protective of human health and the environment as it provides restrictions for access to the affected sediment and guidelines for disturbing the sediment. Additionally, sediment COI concentrations would continue to decline naturally through existing biological and geochemical processes. This alternative likely meets the RAOs.

7.3.1.5.2 Compliance with ARARs

This alternative is in compliance with the projected ARARs, though may be difficult to permit within the California Coastal Zone as covers will result in the disruption and destruction of wetland habitat which would require significant mitigation that may not be possible when considering the multiple and sometimes conflicting policies of all relevant agencies. Generally, use of concrete in aquatic environments, if needed to support the soil cover, is strictly limited and at the volume necessary to treat Pond 8 sediment may result in pH excursions that would temporarily adversely affect water quality and be incompatible with some ARARs.

7.3.1.5.3 Long-Term Effectiveness and Permanence

The Vegetated Soil Cover alternative received a low ranking for long-term effectiveness and performance, as the cover would likely have a relatively short useful life and require significant O&M. Storm water flow through Pond 8 is highly variable based on the developed nature of the watershed. During large storms, high velocity flows from storm drains discharge beneath the water surface near the sediment interface and would be likely to scour the cap during each wet season resulting in significant cap repair annually. Further, storm water studies have shown non-point sources of COIs are present in storm water at concentrations similar to those found in Pond 8 sediment. Deposition of COIs above the cap would contaminate the area above unrestricted use remedial goals. The Vegetated Soil Cover alternative would also require institutional controls to implement the SMP to restrict site use and cap disturbing activities, including those that would diminish the integrity of the cover.

7.3.1.5.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The Vegetated Soil Cover alternative received a moderate ranking for reduction of toxicity, mobility, or volume criteria. The mobility would likely be reduced following implementation of the Vegetated Soil Cover as water infiltration is mitigated, but does not directly reduce the toxicity or volume through treatment. As demonstrated in the BHHERA, COI concentrations in the Pond 8 sediments do not present significant risk to receptors and the opportunity to further reduce toxicity or risk from sediment is small.

7.3.1.5.5 Short-Term Effectiveness

The Vegetated Soil Cover and Institutional Controls alternative received a low ranking for the short-term effectiveness criteria, as it would likely require the addition of binders and Portland cement to the underlying sediment to support the weight of the cover. The addition of the large volume of Portland cement needed to strengthen the sediment could temporarily affect geochemistry in the immediate vicinity of the treatment area due to the high pH associated with the cement addition.

7.3.1.5.6 Implementability

The Vegetated Soil Cover and Institutional Controls alternative received a low ranking for the implementability criteria, as it would require the disturbance or destruction of 280,000 sf of existing wetland. The average depth of water in Pond 8 is approximately 6 inches, though deeper in some areas than others. Placement of sufficient soil to restrict access to sediments and to establish the vegetated cover would likely result in an upland habitat over most of the pond. This approach is unlikely to be accepted by permitting agencies without significant mitigation.

7.3.1.5.7 Cost

The Vegetated Soil Cover and Institutional Controls alternative ranked low, as the cost is comparatively higher than other process options, but less than full sediment removal. Long term O&M costs are uncertain and likely to be significant.

7.3.1.5.8 Overall Rating

Overall, the Vegetated Soil Cover and Institutional Controls alternative ranks moderate. It is ranked moderate for the reduction of toxicity, mobility and volume criterion, and should provide adequate elimination of potential exposure pathways for future receptors. However, the benefits of a physical cover are offset by the effort and disruption associated with implementation and potentially regular O&M and the relatively small reduction of risk achieved.

7.3.2 Selection of Preferred Alternative

The Institutional Controls alternative is the preferred alternative for the Pond 8 AOC as it provides adequate elimination of potential exposure pathways for future receptors without the destruction of wetlands and associated mitigation.

7.4 OU-E Groundwater

Remedial technologies for this AOC were screened in Section 5.2, as summarized in Table 5-3. This section presents an evaluation of the selected alternatives for the OU-E Groundwater AOC based on the threshold and balanced criteria presented in Section 6.

7.4.1 Development and Evaluation of Remedial Alternatives

7.4.1.1 Alternative 1 - No Action

The No Action alternative is intended to serve as a baseline which to compare the risk reduction effectiveness of potential technologies, as required by USEPA and NCP regulations (USEPA, 1988). In this baseline, no remedial efforts would be performed. No efforts would be undertaken to contain, remove, or monitor any areas with impacted groundwater at the site. The site would be maintained by Georgia-Pacific in its current condition for the foreseeable future. An evaluation of this alternative is provided in the following sections.

7.4.1.1.1 Overall Protection of Human Health and the Environment

The No Action alternative was retained per requirement of the NCP for baseline comparison and does not meet the threshold criteria. Although natural biodegradation would likely occur, no actions would be taken to monitor or confirm attenuation. Degradation may not occur within a reasonable timeframe, and thus the RAOs for unrestricted use are not met.

7.4.1.1.2 Compliance with ARARs

ARARs would not be met for the No Action alternative.

7.4.1.1.3 Long-Term Effectiveness and Permanence

The degradation rate is unknown and would not be monitored, and therefore the RAOs for unrestricted use are not met. This alternative ranks low for long-term effectiveness and permanence.

7.4.1.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Although natural biodegradation would likely occur, no actions would be taken to monitor, and degradation may not occur within a reasonable timeframe, and thus no reduction of toxicity, mobility, or volume could be confirmed to justify potential long-term effectiveness. However, reductions are expected to occur as a result of naturally occurring processes. The No Action alternative ranks moderate for reduction of toxicity, mobility, or volume criteria.

7.4.1.1.5 Short-Term Effectiveness

The No Action alternative received a high ranking for the short-term effectiveness criteria – as no invasive remedial actions are being performed. Because no actions are being performed, the No Action alternative provides no additional short-term risks during implementation.

7.4.1.1.6 Implementability

The No Action alternative received a high ranking for the implementability criteria – as no invasive remedial actions are being performed. The No Action alternative is easily implemented.

7.4.1.1.7 Cost

The No Action alternative is not associated with any implementation cost, and is ranked high for this criteria.

7.4.1.1.8 Overall Rating

Overall, the No Action alternative ranks low due to the lack of monitoring to confirm a reduction in concentrations and other factors, as described above.

7.4.1.2 Alternative 2 – Restricted Use

The Restricted Use alternative places a deed restriction on the AOC, prohibiting the use of groundwater to eliminate exposure to COIs. Groundwater use would be restricted until WQOs are achieved or agency approval for unrestricted use is received. Groundwater use at the site would be restricted as necessary in the vicinity of the affected areas. Note that in some areas of the site concentrations are below drinking water standards or other use criteria even though above WQOs. Use of such water may be deemed acceptable on a case by case basis. Groundwater COI concentrations would continue to decline naturally through existing biological and geochemical processes. An evaluation of this alternative is provided in the following sections.

7.4.1.2.1 Overall Protection of Human Health and the Environment

This alternative restricts the use of groundwater such that human health and the environment are protected, and therefore meets this criterion.

7.4.1.2.2 Compliance with ARARs

ARARs would be met as restrictions would be established to be in compliance with the local, state, and federal requirements.

7.4.1.2.3 Long-Term Effectiveness and Permanence

The Restricted Use alternative received a moderate ranking for the long-term effectiveness criterion as the proposed deed restriction and SMP would provide adequate protection of potential receptors in the long term.

7.4.1.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The Restricted Use alternative was ranked moderate for the reduction of toxicity, mobility, or volume through treatment criterion as no COI-impacted media would be physically removed or treated, but reductions would occur as a result of naturally occurring processes.

7.4.1.2.5 Short-Term Effectiveness

The Restricted Use alternative received a high ranking for the short-term effectiveness criteria – as no invasive remedial actions are being performed. Because no invasive remedial actions are being performed, the Restricted Use alternative provides no additional short-term risks during implementation.

7.4.1.2.6 Implementability

The Restricted Use alternative received a high ranking for the implementability criteria – as no invasive remedial actions are being performed. The Restricted Use alternative is easily implemented.

7.4.1.2.7 Cost

The Restricted Use alternative is ranked high, as the cost associated with implementing and maintaining a deed restriction on groundwater is relatively low.

7.4.1.2.8 Overall Rating

Overall, the Institutional Controls alternative ranks moderate. Institutional controls would provide adequate restriction of potential exposure pathways for future receptors, but rank moderate for the reduction of toxicity, mobility and volume criterion.

7.4.1.3 Alternative 3 - Monitored Natural Attenuation and Institutional Controls

The MNA alternative monitors and documents the natural decline in COI concentrations beyond RAP submittal until further monitoring is deemed unnecessary to demonstrate achievement of RAOs in a reasonable time frame. This alternative also places a deed restriction on the AOC, prohibiting the use of groundwater in the vicinity of affected areas to restrict exposure to COIs. Groundwater use would be restricted until WQOs are achieved or agency approval for unrestricted use is received. Note that in some areas of the site concentrations are below drinking water standards or other use criteria even though above WQOs. Use of such water may be deemed acceptable on a case by case basis. Under this alternative, natural attenuation by existing physical, biological and geochemical processes would reduce the concentrations in groundwater within a reasonable timeframe. Monitoring would be performed to evaluate changes in COI concentrations until RAOs can be met. Performance criteria for MNA are to achieve stable or decreasing trends in COI concentrations, such that WQOs will be attained in a reasonable time frame. trend. As determined appropriate, detailed discussion of additional data collection and trend analysis for this AOC would be provided in ongoing semiannual groundwater monitoring reports. An evaluation of this alternative is provided in the following sections.

7.4.1.3.1 Overall Protection of Human Health and the Environment

The MNA alternative meets the threshold criteria as human health and the environment are protected through monitoring and restrictions.

7.4.1.3.2 Compliance with ARARs

ARARs would be met as the alternative would be designed to be in compliance with the local, state, and federal requirements.

7.4.1.3.3 Long-Term Effectiveness and Permanence

The MNA alternative received a moderate ranking for the long-term effectiveness criterion as the proposed restrictions and monitoring program would provide adequate protection of potential receptors in the long term. MNA would confirm natural attenuation and quantify long-term effectiveness via monitoring.

7.4.1.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The MNA alternative was ranked moderate for the reduction of toxicity, mobility, or volume through treatment criterion as no COI-impacted media would be actively removed or treated, but reductions would occur as a result of naturally occurring processes.

7.4.1.3.5 Short-Term Effectiveness

The MNA alternative received a high ranking for the short-term effectiveness criteria – as no invasive remedial actions are being performed. Because no invasive remedial actions are being performed, the MNA alternative provides no additional short-term risks during implementation.

7.4.1.3.6 Implementability

The MNA alternative received a high ranking for the implementability criteria – as no invasive remedial actions are being performed. The MNA alternative is easily implemented.

7.4.1.3.7 Cost

The MNA alternative was ranked high. The driving cost is associated with periodic groundwater monitoring for a 30-year period.

7.4.1.3.8 Overall Rating

Overall, the MNA alternative ranks moderate. This alternative ranks moderate for many criteria, including the long-term effectiveness and permanence criterion, the reduction of toxicity, mobility, or volume criterion, the implementability criterion, and the cost criterion.

7.4.1.4 Alternative 4 – Air Sparge and Soil Vapor Extraction, Monitored Natural Attenuation, and Institutional Controls

Air Sparge and Soil Vapor Extraction (AS/SVE) involves the installation of vapor extraction wells along with air injection wells. This technology is commonly used to treat groundwater where volatile organic compounds or petroleum related constituents are present in sufficient concentrations to be removed through volatilization into entrained air in the saturated zone and removal and treatment in the vadose zone. This alternative applied to petroleum hydrocarbons in the IRM/West of IRM AOIs for residual diesel fuel in groundwater. AS/SVE would not be an appropriate remedy for Barium detected at MW-4.1

An evaluation of this alternative is provided in the following sections.

7.4.1.4.1 Overall Protection of Human Health and the Environment

The AS/SVE alternative meets the threshold criteria as human health and the environment are protected through remediation.

7.4.1.4.2 Compliance with ARARs

ARARs would be met as the alternative would be designed to be in compliance with the local, state, and federal requirements.

7.4.1.4.3 Long-Term Effectiveness and Permanence

The AS/SVE alternative was ranked high for long-term effectiveness and permanence as treatment would likely accelerate the degradation of COIs and performance monitoring would occur. Additionally, a deed restriction would be implemented to eliminate potential exposure pathways to receptors until WQOs are achieved or agency approval for unrestricted use is received.

7.4.1.4.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The AS/SVE, alternative was ranked high as this alternative consists of active remediation to directly reduce the toxicity, mobility, and/or volume through treatment that will be monitored to ensure accelerated biodegradation to WQOs are achieved or agency approval.

7.4.1.4.5 Short-Term Effectiveness

The AS/SVE alternative was ranked moderate for the short-term effectiveness criterion as this alternative has the potential to expose construction workers to COI-affected media during implementation.

7.4.1.4.6 Implementability

The implementability is considered moderate as additional delineation, design, system construction, and long term O&M would be required for this alternative. Given the relatively low concentrations remaining in groundwater, the system would achieve minimal mass removal rates and would likely operate for a long time to achieve a measurable change in site conditions. This time frame may not be substantially different from the MNA alternative.

7.4.1.4.7 Cost

The AS/SVE alternative was ranked low as it is associated with moderate to high upfront costs for design and implementation. MNA is assumed to be required for a period of 10 years.

7.4.1.4.8 Overall Rating

Overall, the AS/SVE alternative ranks moderate. It is ranked high for many criteria and should provide adequate elimination of potential exposure pathways for future receptors. However, the benefits of this alternative are offset by the high level of effort, site disruption, and cost relative to benefits as compared to other alternatives evaluated.

7.4.1.5 Alternative 5 - Enhanced Aerobic Bioremediation, Monitored Natural Attenuation, and Institutional Controls

The Enhanced Aerobic Bioremediation alternative consists of subsurface delivery of oxygen to enhance the aerobic biological degradation of COIs. A calcium peroxide slurry is assumed to be the substrate of oxygen to enhance bioremediation. Destruction of COI mass in-situ would accelerate clean up by treating dissolved phase COIs and accelerating mass transfer from immobile sources to groundwater to be treated, facilitating further treatment and attenuation. The Enhanced Aerobic Bioremediation alternative assumes additional COI delineation, installation of injection wells, and two injection events (25 percent well coverage) followed by ten years of MNA. Additional injection events may be required for accelerated treatment. This alternative applied to petroleum hydrocarbons in the IRM/West of IRM AOIs for residual diesel fuel in groundwater. Enhanced Aerobic Bioremediation would not be an appropriate remedy for Barium detected at MW-4.1. An evaluation of this alternative is provided in the following sections.

7.4.1.5.1 Overall Protection of Human Health and the Environment

The Enhanced Aerobic Biodegradation alternative meets the threshold criteria as human health and the environment are protected through remediation.

7.4.1.5.2 Compliance with ARARs

ARARs would be met as the alternative would be designed to be in compliance with the local, state, and federal requirements.

7.4.1.5.3 Long-Term Effectiveness and Permanence

The Enhanced Aerobic Biodegradation alternative was ranked high for long-term effectiveness and permanence as treatment would likely accelerate the degradation of COIs and performance monitoring would occur. Additionally, a deed restriction would be implemented to eliminate potential exposure pathways to receptors until WQOs are achieved or agency approval for unrestricted use is received.

7.4.1.5.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The Enhanced Aerobic Biodegradation, alternative was ranked high as this alternative consists of active remediation to directly reduce the toxicity, mobility, and/or volume through treatment that will be monitored to ensure accelerated biodegradation to WQOs are achieved or agency approval.

7.4.1.5.5 Short-Term Effectiveness

The Enhanced Aerobic Biodegradation alternative was ranked moderate for the short-term effectiveness criterion as this alternative has the potential to expose construction workers to COI-affected media during implementation. Treatment also generates short-term secondary water quality effects that would attenuate over time, but make the water unusable for a period during and following treatment.

7.4.1.5.6 *Implementability*

The implementability is considered moderate as additional delineation and multiple site implementation visits would be required for this alternative, and the substances would require additional health and safety precautions to handle the substrates in bulk.

7.4.1.5.7 *Cost*

The Enhanced Aerobic Biodegradation alternative was ranked low as it is associated with moderate to high upfront costs for design and implementation, MNA is assumed to be required for a period of 10 years, and additional injection events may be required to accelerate the biodegradation process.

7.4.1.5.8 *Overall Rating*

Overall, the Enhanced Aerobic Biodegradation alternative ranks moderate. It is ranked high for many criteria and should provide adequate elimination of potential exposure pathways for future receptors. However, the benefits of this alternative are offset by the high level of effort, site disruption, and cost relative to benefits as compared to other alternatives evaluated.

7.4.1.6 Alternative 6 - Enhanced Anaerobic Bioremediation, Monitored Natural Attenuation, and Institutional Controls

The Enhances Anaerobic Bioremediation alternative consists of subsurface injections of an anaerobic electron acceptor such as sulfate to enhance the anaerobic biological degradation of COIs. A magnesium sulfate (Epsom salt) slurry is assumed to be the substrate of the electron acceptor to enhance bioremediation. Destruction of COI mass in-situ would accelerate clean up by treating dissolved phase COIs and accelerating mass transfer from immobile sources to groundwater to be treated, facilitating further treatment and attenuation. The Enhanced Anaerobic Bioremediation alternative assumes additional COI delineation, installation of injection wells, and two injection events (25 percent well coverage) followed by ten years of MNA. Additional injection events may be required for accelerated treatment. This alternative applied to petroleum hydrocarbons in the IRM/West of IRM AOIs for residual diesel fuel in groundwater. Enhanced Anaerobic Bioremediation would not be an appropriate remedy for Barium detected at MW-4.1. An evaluation of this alternative is provided in the following sections.

7.4.1.6.1 *Overall Protection of Human Health and the Environment*

The Enhanced Anaerobic Biodegradation alternative meets the threshold criteria as human health and the environment are protected through remediation.

7.4.1.6.2 *Compliance with ARARs*

ARARs would be met as the alternative would be designed to be in compliance with the local, state, and federal requirements.

7.4.1.6.3 Long-Term Effectiveness and Permanence

The Enhanced Anaerobic Biodegradation alternative was ranked high for long-term effectiveness and permanence as treatment would likely accelerate the degradation of COIs and performance monitoring would occur. Additionally, a deed restriction would be implemented to eliminate potential exposure pathways to receptors until WQOs are achieved or agency approval for unrestricted use is received.

7.4.1.6.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The Enhanced Anaerobic Biodegradation alternative was ranked high as this alternative consists of active remediation to directly reduce the toxicity, mobility, and/or volume through treatment that will be monitored to ensure accelerated biodegradation to WQOs are achieved or agency approval.

7.4.1.6.5 Short-Term Effectiveness

The Enhanced Anaerobic Biodegradation alternative was ranked moderate for the short-term effectiveness criterion as this alternative has the potential to expose construction workers to COI-affected media during implementation. Treatment also generates short-term secondary water quality effects that would attenuate over time, but make the water unusable for a period during and following treatment.

7.4.1.6.6 Implementability

The implementability is considered moderate as additional delineation and multiple site implementation visits would be required for this alternative, and the substances would require additional health and safety precautions to handle the substrates in bulk.

7.4.1.6.7 Cost

The Enhanced Anaerobic Biodegradation alternative was ranked low as it is associated with moderate to high upfront costs for design and implementation, MNA is assumed to be required for a period of 10 years, and additional injection events may be required to accelerate the biodegradation process.

7.4.1.6.8 Overall Rating

Overall, the Enhanced Anaerobic Biodegradation alternative ranks moderate. It is ranked high for many criteria and should provide adequate elimination of potential exposure pathways for future receptors. However, the benefits of this alternative are offset by the high level of effort, site disruption, and cost relative to benefits as compared to other alternatives evaluated.

7.4.1.7 Alternative 7 - In-situ Chemical Oxidation, Monitored Natural Attenuation, and Institutional Controls

The ISCO alternative consists of subsurface injections of a highly reactive chemical oxidant to enhance the direct chemical oxidation and aerobic biological degradation of COIs. An activated sodium persulfate slurry is assumed to be the substrate of the chemical oxidation reaction.

Destruction of COI mass in-situ would accelerate clean up by quickly treating dissolved phase COIs and accelerating mass transfer from immobile sources to groundwater to be treated, facilitating further treatment and attenuation. The ISCO slurry is assumed to be advanced via direct push at delineated areas within the OU-E Groundwater AOC. One injection event is assumed in which each delineated area would receive 100 percent coverage. Additional injection events may be required for accelerated treatment. This alternative applied to petroleum hydrocarbons in the IRM/West of IRM AOIs for residual diesel fuel in groundwater. ISCO would not be an appropriate remedy for Barium detected at MW-4.1. An evaluation of this alternative is provided in the following sections.

7.4.1.7.1 Overall Protection of Human Health and the Environment

The ISCO alternative meets the threshold criteria as human health and the environment are protected through remediation.

7.4.1.7.2 Compliance with ARARs

ARARs would be met as the alternative would be designed to be in compliance with the local, state, and federal requirements.

7.4.1.7.3 Long-Term Effectiveness and Permanence

The ISCO alternative was ranked high for long-term effectiveness and permanence as treatment would likely accelerate the degradation of COIs and performance monitoring would occur. Additionally, a deed restriction would be implemented to eliminate potential exposure pathways to receptors until WQOs are achieved or agency approval for unrestricted use is received.

7.4.1.7.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The ISCO alternative was ranked high as this alternative consists of active remediation to directly reduce the toxicity, mobility, and/or volume through treatment that will be monitored to ensure accelerated biodegradation to WQOs are achieved or agency approval.

7.4.1.7.5 Short-Term Effectiveness

The ISCO alternative was ranked moderate for the short-term effectiveness criterion as this alternative has the potential to expose construction workers to COI-affected media and hazardous treatment chemicals during implementation. Treatment also generates short-term secondary water quality effects that would attenuate over time, but make the water unusable for a period during and following treatment.

7.4.1.7.6 Implementability

The implementability is considered moderate as additional delineation and multiple site implementation visits would be required for this alternative, and the substances would require additional health and safety precautions to handle the substrates in bulk.

7.4.1.7.7 Cost

The ISCO alternative was ranked low as it is associated with moderate to high upfront costs for design and implementation, MNA is assumed to be required for a period of 10 years, and additional injection events may be required to accelerate the biodegradation process.

7.4.1.7.8 Overall Rating

Overall, the ISCO alternative ranks moderate. It is ranked high for many criteria and should provide adequate elimination of potential exposure pathways for future receptors. However, the benefits of this alternative are offset by the high level of effort, site disruption, and cost relative to benefits as compared to other alternatives evaluated.

7.4.1.8 Alternative 8 - Groundwater Extraction and Treatment, Monitored Natural Attenuation, and Institutional Controls

The GWET alternative provides hydraulic containment of groundwater and monitors and documents the natural decline in COI concentrations. Natural attenuation by dilution and existing biological and geochemical processes would reduce COI concentrations while the operation of a GWET system would control migration of COIs in groundwater. Due to mass transfer kinetics, GWET is unlikely to substantially accelerate the groundwater remediation process. Aquifer testing and delineation would be conducted prior to system install. The GWET System is assumed to consist of three extraction wells, a disinfection system, air stripper, granulated activated carbon, and a discharge line of treated water to a surface water source in the IRM/West of IRM area. A separate system consisting of one to two extraction wells, an ion-exchange or lime softening system to remove dissolved barium, and a discharge line of treated water to a surface water source would be installed in the vicinity of MW-4.1 in the newly created wetland establishment area. Monitoring would be performed to evaluate changes in COI concentrations within groundwater or risks to human health or the environment until a reduction of COI concentrations to meet RAOs in a reasonable timeframe can be demonstrated. Operation is assumed for a period of 30 years. An evaluation of this alternative is provided in the following sections.

7.4.1.8.1 Overall Protection of Human Health and the Environment

The GWET alternative meets the threshold criteria as human health and the environment are protected through remediation.

7.4.1.8.2 Compliance with ARARs

ARARs would likely be met as the alternative would be designed to be in compliance with the local, state, and federal requirements; however, it may be impractical to permit system installation in the wetland establishment area created as part of the OU-E RAW implementation.

7.4.1.8.3 Long-Term Effectiveness and Permanence

The GWET alternative was ranked high for long-term effectiveness and permanence as treatment would likely accelerate the degradation of COIs and performance monitoring would occur. Additionally, a deed restriction would be implemented to eliminate potential exposure pathways to receptors until WQOs are achieved or agency approval for unrestricted use is received.

7.4.1.8.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The GWET alternative was ranked moderate as this alternative consists of active remediation to directly reduce the toxicity, mobility, and/or volume of target chemicals through treatment that will be monitored to ensure accelerated biodegradation to WQOs are achieved or agency approval. However, the treatment process would include the addition of hazardous chemical reagents to the process water; generate spent filtration media, such as bag filters for particulate, spent carbon for thermal regeneration; and result in wastewater associated with the reduction of hard water scale in system equipment and byproducts of the ion-exchange or lime softening process that would require discharge or disposal. Some of these may carry greater risk than the current groundwater conditions.

7.4.1.8.5 Short-Term Effectiveness

The GWET alternative was ranked moderate for short-term effectiveness as this alternative has the potential to expose construction workers to COI-affected media during implementation.

7.4.1.8.6 Implementability

The GWET alternative was ranked moderate for implementability as aquifer testing and delineation is required, as well as a constant power source and O&M visits on a regular basis. Additionally, a GWET system to address barium at MW-4.1 would require construction in wetland areas surrounding the well.

7.4.1.8.7 Cost

The GWET alternative is ranked low for high upfront design and implementation costs, as well as the ongoing O&M costs for an assumed 30-year period.

7.4.1.8.8 Overall Rating

Overall, the GWET alternative ranks moderate. It is ranked high for many criteria and should provide adequate elimination of potential exposure pathways for future receptors. However, the benefits of this alternative are offset by the high level of effort, site disruption, and cost relative to benefits as compared to other alternatives evaluated.

7.4.2 Selection of Preferred Alternative

The MNA alternative is the recommended alternative for the OU-E Groundwater AOC. Although the MNA alternative is associated with a slightly lower reduction of toxicity, mobility and volume, MNA would provide adequate mitigation of potential exposure pathways for future receptors. The benefits of the active remediation alternatives are offset by the short-term effectiveness and potential implementability issues, and the cost difference is not justified by significant benefits and is associated with a degree of uncertainty.

Section 8: Summary of Recommended Alternatives

Below is a summary of AOC/AOI recommendations and key advantages of the recommended alternatives described in Section 7. These recommendations are also presented in Table 8-1. Cost estimates for the recommended alternatives are included in Appendix A. For AOCs/AOIs with approved remedial actions, the selected alternative is listed below; these remedial actions are described further in the OU-E RAW and are expected to be implemented in 2017.

- AOCs/AOIs addressed in the OU-E RAW [Lowland Terrestrial Soil AOC, Pond 7 Aquatic Sediment AOI, Ponds 1 through 4 (Southern Ponds) Aquatic Sediment AOI, and Riparian Aquatic Sediment AOI]
  - Lowland Terrestrial Soil Primary COIs: lead, Ba(P) TEQ, dioxin TEQ
  - Pond 7 Aquatic Sediment Primary COIs: arsenic, barium, dioxin TEQ
  - Ponds 1 through 4 (Southern Ponds) Aquatic Sediment Primary COIs: arsenic, dioxin TEQ
  - Riparian Aquatic Sediment Primary COIs: arsenic, zinc, PAHs, dioxin TEQ
- Approved Alternative: Excavation and Disposal
  - Eliminates exposure pathways for potential future on and offsite receptors via direct soil physical removal of hot spots and institutional controls that limit future use and control soil disturbing activities. Provide protection of human health and the environment. Provides direct reduction of toxicity, mobility, and volume.
  - Implemented easily and readily with standard construction equipment. Backfilling materials are locally obtainable; waste likely qualifies as non-hazardous waste.
  - Will assess if deed restrictions with land use controls are necessary as contingency remedy after implementation of the remedial action is completed.
- Pond 8, North Pond and Pond 6 Aquatic Sediment AOCs
  - Pond 8 Aquatic Sediment Primary COIs: dioxin TEQ
  - North Pond and Pond 6 Aquatic Sediment Primary COIs: arsenic, dioxin TEQ
- Recommended Alternative: Institutional Controls
  - Eliminates exposure pathways for potential future on and offsite receptors via institutional and administrative management and provides protection of human health and the environment.
  - Includes implementation of a SMP to restrict site use and soil and sediment disturbing activities.

  - Easily implementable and effective in the short term as no workers are exposure to COI-affected media during implementation.

  - Allows possible future restoration of Maple and Alder Creeks while preserving existing wetland habitats.

  - Cost effective.

- OU-E Groundwater

  - Primary COIs: fuel-related constituents, barium

- Recommended Alternative: Monitored Natural Attenuation

  - Demonstrates a direct reduction of toxicity, mobility, and volume over time via natural biodegradation.

  - A deed restriction would prohibit the use of groundwater to eliminate exposure to COIs. Groundwater use would be restricted as described in the Mill Site Specific Plan (Mill Site Coordinating Committee, 2012) until WQOs are achieved or agency approval for unrestricted use is received.

  - Easily implementable and effective in the short term as no workers are exposure to COI-affected media during implementation.

  - Cost effective.

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Table 3-1: Applicable or Relevant and Appropriate Requirements (ARARs) and "To be Considered" (TBC) Factors

Standard, Requirement, Criteria, Limitation	Citation	Description	Type of ARARs
Federal			
Clean Air Act	42 USC 7401-7642	Emission standards from stationary and mobile sources	Chemical
Clean Water Act	33 USCA 1251-1376 40 CFR 100-149	Regulations requiring development and implementation of a storm water pollution prevention plan	Action
National Archaeological and Historical Preservation Action	16 USC 469 36 CFR 65	Provides requirements if significant scientific/cultural/historical artifacts are found	TBC
Occupational Health and Safety	29 CFR 1910.120	Establishes requirements for health and safety training	Action
Regional Screening Levels	USEPA Region 9, 2015	Risk-based concentrations that are intended to assist risk assessors and others in initial screening-level evaluations of environmental measurements.	TBC
Resource Conservation and Recovery Act (RCRA)	42 USC 6901 et. seq. 40 CFR 258	Establishes criteria for generation, management, and disposal of non-hazardous solid waste	Chemical/ Action
	42 USC 6901 et. seq. 40 CFR 261	Establishes criteria to determine whether solid waste exhibits characteristics that makes it a regulated hazardous waste	Chemical/ Action
	42 USC 6901 et. seq. 40 CFR 263	Standards applicable to transporters of hazardous waste	Chemical/ Action
Risk Assessment Guidance for Superfund; Ecological Risk Assessment Guidance for Superfund; Ecological Soil Screening Levels	USEPA, 1989, 1997, 2010	Guidance and framework to assess human and ecological risks	TBC
Toxic Substances Control Act	40 CFR 761.60, 761.61, 761.75	Regulations that determine the appropriate characterization, cleanup, and disposal requirements for PCBs	Chemical/ Action
State and Local			
Ambient Air Quality Standards	HSC 39000-44071 MCAQMD Regulations 1-5	Establishes standards for emissions of chemical vapors and dust	Chemical
California Coastal Act	Public Resources Code Division 20	Establishes permitting requirements and conditions for any "development" which remedial activities qualify as.	Location/ Action
California Environmental Quality Act	PRC Division 13	Mandates environmental impact review of projects approved by governmental agencies	Action
California Hazardous Substances Account Act	HSC 25300-25395.15	Establishes site mitigation and cost recovery programs	Action
California Hazardous Waste Control	HSC 5100-25250.26	Establishes hazardous waste control measures	Action
California Human Health Screening Levels (CHHSLs)	CalEPA, 2010	Risk-based concentrations for human receptors that are intended to assist risk assessors and others in initial screening-level evaluations of environmental measurements.	TBC
City of Fort Bragg Grading Permit Requirements and Procedures	Title 18, Chapter 18.60 et. seq.	Establishes requirements for excavation and grading.	Location/ Action
Cover, grading, and alternative design requirements	27 CCR 21090(a)(1) through (3) and (b)(1)	Establishes criteria for cover and grading. Alternative cover designs are also acceptable.	Action
Discharges of Hazardous Waste to Land	Title 23, California Code of Regulations, Division 3, Chapter 15	Applies to discharge of waste	Action
Emission Standard	MCAQMD Regulation 1 Chapters 1, 2 and 4.	Establishes emission standards and permitting requirements for equipment and dust.	Action
Identification and listing of hazardous waste	HSC 25100 et. seq. 22 CCR 66261	Establishes criteria for characterization and classification of remediation waste.	TBC
Manifest System, Record-Keeping, Reporting and Transportation of Hazardous Waste	22 CCR Chapter 13	Governs transportation of hazardous materials	Action
Occupational Health and Safety	8 CCR GISO 5192	Establishes worker health and safety requirements	Action
Porter-Cologne Water Quality Control Act	California Water Code, Section 13000	Establishes policy for preservation and enhancement of the beneficial uses of the waters of the state	SWRCB

Table 3-1: Applicable or Relevant and Appropriate Requirements (ARARs) and "To be Considered" (TBC) Factors

Standard, Requirement, Criteria, Limitation	Citation	Description	Type of ARARs
Relevant Policies for the Protection and Conservation of Fish and Wildlife	California Fish and Game Code Section 2014	Requires conservation of natural resources and prevention of the willful or negligent destruction of birds, mammals, fish, reptiles, or amphibia.	Location/ Action
	California Fish and Game Code Section 1600	Establishes protection and conservation of the fish and wildlife resources.	Location/ Action
Remedial Action Plan Policy	EO-95-007-PP	Guidance and framework to develop a remedial action plan	TBC
Requirements for Substances Deleterious to Fish and Wildlife	California Fish and Game Code Section 5650	Makes it unlawful to deposit into, permit to pass into, or place where it can pass into the waters of the state certain specified pollutants.	Chemical/ Action
Site Investigation and Remediation Order	Docket No. HSA-RAO 06-07-150	Establishes requirements for investigation and site remediation	Action
State PCB Requirements	22 CCR 66261.113	Establishes standards to disposal of PCBs	Chemical/ Action
State Water Resources Control Board (SWRCB) Resolution No. 68-16	SWRCB, 1968	Establishes policy for the regulation of discharges to waters of the state.	TBC
SWRCB Resolution No. 92-49	SWRCB, 1996 California Water Code Section 13304	Establishes policies and procedures for investigation and cleanup and abatement of discharges.	TBC
Stockpiling Requirements of Contaminated Soil	HSC 25123.3(a)(20)	Establishes standards for stockpiling of non-RCRA contaminated soil	Location/ Action
Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities; Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities	DTSC, 1996 CalEPA, 2015	Guidance and framework to assess human and ecological risks	TBC
Title 22, California Hazardous Waste Control Act of 1972	22 CCR 66260.1 et seq.	Establishes criteria for determining waste classification for the purposes of transportation and disposal of wastes	Chemical/ Action
	22 CCR 66262.1 et seq.	Establishes standards applicable to generators of hazardous waste	Action
	22 CCR Chapter 18	Identifies hazardous waste restricted from land disposal unless specific treatment standards are met	Chemical/ Action
Title 27, Division 2 of the California Code of Regulations	27 CCR 20005 et seq.	Regulation of solid waste	Chemical/ Action
Water Quality Control Plan for the North Coast Region	NCRWQCB, May 2011	Beneficial uses, water quality objectives, and implementation plans	Chemical/ Action

Notes:

ARAR - Applicable or Relevant and Appropriate Requirements
CalEPA - California Environmental Protection Agency
CCR – California Code of Regulation
CFR – Code of Federal Regulation
CHHSLs - California Human Health Screening Levels
DTSC - Department of Toxic Substances Control
GISO - General Industry Safety Order
HSC - Health and Safety Code
MCAQMD – Mendocino County Air Quality Management District
NCRWQCB - North Coast Regional Water Quality Control Board
PCB - polychlorinated biphenyl
PRC - Public Resource Code
RCRA - Resource Conservation and Recovery Act
SWRCB – State Water Resources Control Board
TBC - to be considered
USC – United States Code
USCA – United States Code Annotated
USEPA - United States Environmental Protection Agency

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Table 5-1: Preliminary and Detailed Screening of Process Options Screening - Soil

General Response Action	Remedial Technology	Process Option	Description	Effectiveness Evaluation		Implementability Evaluation		Relative Cost Evaluation		Retained?	Decision Rationale
No Action	No Action	No Action	No remedial action	---		---		---		Yes	Required by NCP and USEPA guidance as baseline for comparison to other process options.
Institutional Controls	Institutional Controls	Land Use Controls	Institutional controls include a variety of measures designed to restrict current and future property owners from taking actions that would expose potential receptors to unacceptable risk, interfere with effectiveness of the final remedial action, and/or convert the site to an end use that is not consistent with the level of remediation. The primary objective of institutional controls is to limit potential for exposure to COIs by restricting access to impacted areas.	Moderate	Standard practice for protecting human health and the environment, effectiveness governed by maintenance of institutional controls.	High	Easily implemented	Low	Low capital and O&M costs.	Yes	Institutional controls impose restrictions on land use. LUCs provide protection of human health and the environment by restricting land use until constituent concentrations in soil meet the requirements for unrestricted use.
Containment	Covers	Vegetative Cover	A vegetative cover restricts exposure pathways of potential receptors to affected media.	Moderate	Covers are an effective means of restricting exposure and allow natural attenuation to occur.	High	Readily implementable.	Moderate	Low capital and O&M costs.	Yes	Conventional technology; can be used in conjunction with other technologies.
In-situ Treatment	Physical	Soil Mixing	In-situ soil mixing encapsulates contaminants in solidified media by in-situ mixing of impacted soil with solidifying reagents (e.g., cement, bentonite). This process option does not destroy COIs, but incorporates them into a dense, homogeneous, low-permeability structure that reduces concentrations and mobility	Moderate - High	Provides effective mitigation of risks to receptors.	Moderate -Low	Applicable to all constituents	Moderate - High	High capital costs.	Yes	ISM provides effective mitigation of risks to receptors, and is applicable to all COIs within each AOC.
		Soil Vapor Extraction	Utilizes induced vacuum in the vadose zone to capture volatiles in the subsurface.	Low - Moderate	Variability of constituents triggering exceedances within each area, SVE, MPE, and thermal will not be effective at remediating most COIs present in OU-E.	Moderate - High	Implementation of extraction is limited to constituent with sufficient volatility to be removed in the vapor phase.	Moderate to high	Capital cost associated with treatment system installation is expensive per level of effectiveness on a comparative basis.	No	The capital cost associated with treatment system installation is too expensive per level of effectiveness on a comparative basis to be considered for partial implementation
		Mulitphase Extraction								No	
		Thermal								No	
	Biological	Mycoremediation	Uses fungi such as mushrooms to potentially remove, transfer, stabilize, and destroy COIs in soil.	Low		Low	Mycoremediation within OU-E is not feasible throughout the full depth of affected soil. Further, Mycoremediation was not shown to be effective in previous studies.	Moderate	Cost to apply Mycoremediation would be high relative to other options based on the low treatment effectiveness measured in the previous studies.	No	A total of 30 fungal strains were evaluated for growth potential using site soils and sediments; nine of these fungal strains were collected from the site. The 10 strains that showed the greatest growth potential in site soils and sediments were selected for the dioxin/furan degradation phase of the study. Comparison of analytical results for spiked samples containing fungi to spiked control samples not containing fungi found no discernable degradation of dioxins/furans after incubation.
	Chemical	Chemical Oxidation	Chemical oxidation involves mixing additives (such as sodium persulfate) in-situ to induce reduction/oxidation reactions that chemically convert hazardous contaminants to non-hazardous or less toxic compounds that are more stable or inert.	Low	Effective on small portion of constituents in soil and effectiveness must be evaluated by treatability test or bench scale study. Would generate secondary effects that degrade soil and groundwater quality.	Low - Moderate	Implementation for a small portions of areas of concern	Moderate - High	High implementation costs.	No	Considering implementability concerns and the potential for generation of byproducts.
Ex-Situ Treatment	Physical	Landfarming	Process option that consists of spreading the excavated soils in windrows to stimulate aerobic microbial activity through aeration and/or the addition of minerals, nutrients, and moisture to expedite treatment.	Moderate	Effective for reduction of volatile COIs. Ineffective for metals and dioxin.	Moderate - High	Readily implementable and effective for reduction of volatile constituents. Site disturbance is high as soil needs to be spread to be effective.	High	Excavation and land farming costs can be similar to excavation and disposal depending on the timeframe required for COIs to degrade.	Yes	Land farming may be similar in cost to offsite disposal, but is only effective for a limited number of COIs.
		Biopiling	Involves heaping impacted excavated soils into aboveground storage cells and stimulating aerobic microbial activity via aeration and/or addition of minerals, nutrients, and moisture.	Moderate	Requires bench-scale study and/or a pilot test prior to the determination of site-specific effectiveness.	Moderate-high	Implementable with similar space and site disturbance issues as landfarming.	High	High capital and O&M costs.	No	Uncertain and comparative moderate to high costs compared to other ex-situ treatment/disposal methods.
Removal	Excavation & Disposal	Excavation & Disposal	Physical removal of impacted soil with offsite landfill disposal.	High	Immediately effective	Moderate - High	Readily implementable and effective for reduction of all constituents.	High	High capital and O&M costs.	Yes	Excavation is technically implementable and would provide immediate and permanent removal of COIs from the site.

Notes:
Green shading indicates that the process option will be further evaluated as a stand-alone alternative.
Yellow shading indicates that the process option will be partially incorporated into the development of action-based alternatives
Red shading indicates that the process option was eliminated in the preliminary screening stage.

Acronyms:
COI - chemical of interest
DGR - directed groundwater recirculation
ISB - in-situ bioremediation
LUC - land use control
NCP - National Contingency Plan
O&M - operation and maintenance
SVE - soil vapor extraction
USEPA - United States Environmental Protection Agency
VAFB - Vandenberg Air Force Base
VOC(s) - volatile organic compounds

Table 5-2: Preliminary and Detailed Screening of Process Options - Sediment

General Response Action	Remedial Technology	Process Option	Description	Effectiveness Evaluation		Implementability Evaluation		Relative Cost Evaluation		Retained?	Decision Rationale
No Action	No Action	No Action	No remedial action	---		---		---		Yes	Required by NCP and USEPA guidance as baseline for comparison to other process options.
Institutional Controls	Institutional Controls	Land Use Controls	Institutional controls include a variety of measures designed to restrict current and future property owners from taking actions that would expose potential receptors to unacceptable risk, interfere with effectiveness of the final remedial action, and/or convert the site to an end use that is not consistent with the level of remediation. The primary objective of institutional controls is to limit potential for exposure to COIs by restricting access to impacted areas.	Moderate	Standard practice for protecting human health and the environment, effectiveness governed by maintenance of institutional controls.	High	Easily implemented	Low	Low capital and O&M costs.	Yes	Institutional controls impose restrictions on land use. LUCs provide protection of human health and the environment by restricting land use until constituent concentrations in sediment meet the requirements for unrestricted use.
Containment	Covers	Vegetative Cover	A vegetative cover prevents exposure pathways of potential receptors to affected media.	Moderate	A vegetative cover restricts exposure pathways of potential receptors to affected media. Covers installed in aquatic environments with variable storm water flow may be eroded over time.	Moderate - Low	Covers are an effective means of restricting exposure, however placement of covers on geotechnically weak sediments is difficult.	High	Capital cost to install caps over sediment can require sediment stabilization, drainage, or other costs of performing work "in the wet". O&M costs may be high as erosion of caps in dynamic environments may require repair or replacement periodically.	Yes	A cover would effectively restrict the potential risk to receptors in accordance with RAOs until cleanup goals are achieved.
In-situ Treatment	Physical	Soil Mixing	ISM technology can be used to immobilize organic and inorganic compounds in saturated sediments, using reagents to produce an inert, geotechnically strong, and relatively less permeable material, such as Portland cement.	High	Incorporates COIs into a dense, homogeneous, low-permeability structure that reduces concentrations and mobility.	Moderate - Low	In-situ mixing can be performed with an excavator bucket or a large diameter crane-mounted auger depending on depth and volume. Work in aquatic environments would destroy habitat and would require significant mitigation.	High	Implementation cost is high to treat wet sediment.	Yes	ISM requires significant volumes of binders and Portland cement to be effective and would require mitigation of habitat loss, but would effectively restrict exposure to COIs.
	Biological	Mycoremediation	Uses fungi such as mushrooms to potentially remove, transfer, stabilize, and destroy COIs in sediment.	Low	A laboratory study of mycoremediation was prepared by NewFields for use of mushrooms and fungi to remediate dioxins and furans at the Site (NewFields, 2011). The primary objective of this study was to evaluate the potential for various strains of fungi to degrade dioxins/furans in site soils to evaluate whether mycoremediation could be an effective remedial process option at the site. Mycoremediation was not effective during the study.	Low	Mycoremediation within the Pond AOIs with impacts to sediment is not feasible as the sediments are typically submerged. Further, Mycoremediation was not shown to be effective in previous studies.	High	Contact with sediment would require removal from the aquatic environment at high implementation cost.	No	A total of 30 fungal strains were evaluated for growth potential using site soils and sediments; nine of these fungal strains were collected from the site. The 10 strains that showed the greatest growth potential in site soils and sediments were selected for the dioxin/furan degradation phase of the study. Comparison of analytical results for spiked samples containing fungi to spiked control samples not containing fungi found no discernable degradation of dioxins/furans after incubation.
	Chemical	Chemical Oxidation	Chemical oxidation involves mixing additives (such as sodium persulfate) in-situ to induce reduction/oxidation reactions that chemically convert hazardous contaminants to non-hazardous or less toxic compounds that are more stable or inert.	Low	Achieving significant distribution of reagents is likely not feasible within fine-grained matrices characteristic of the sediments at the site. Chemical Oxidation would not be effective for all COIs.	Low	Injecting oxidizing chemicals in sediment would be harmful to the existing biota and would not be permittable.	High	High implementation cost	No	Injecting oxidizing reagents in pond sediment would not be an acceptable discharge to waters of the State and US and would not be permittable.
Ex-Situ Treatment	Physical	Landfarming Biopiling	Physical removal and tilling of impacted sediment. Affected sediment is periodically turned over to re-aerate. Amendments may be added to aid the composting processes.	Low	The nature of COIs driving risk within the sediment AOIs, biological treatment will not be sufficient to reduce COI concentrations to meet target cleanup goals and achieve RAOs.	Moderate - High	Can be readily implemented for sediment	Moderate	Moderate capital and high O&M cost	No	Landfarming and biopiling both rely upon biological treatment of COIs to achieve effective mass reduction. Based on the nature of COIs driving risk within the sediment AOIs, biological treatment will not be sufficient to reduce COI concentrations to meet target cleanup goals and achieve RAOs.
Removal	Excavation & Disposal	Excavation & Disposal	Physical removal of impacted sediment with offsite landfill disposal.	High	Immediately effective and readily implementable.	Moderate - High	Readily implementable.	High	Moderate - high capital cost and low O&M cost.	Yes	Excavation is technically implementable and would provide immediate and permanent removal of COIs from the site.

Notes:

Green shading indicates that the process option will be further evaluated as a stand-alone alternative.

Red shading indicates that the process option was eliminated in the preliminary screening stage.

Acronyms:

COI - chemical of interest
DGR - directed groundwater recirculation
ISB - in-situ bioremediation
LUC - land use control
NCP - National Contingency Plan
O&M - operation and maintenance
RAO - Remedial Action Objective
SVE - soil vapor extraction
USEPA - United States Environmental Protection Agency
VAFB - Vandenberg Air Force Base
VOC - volatile organic chemical
VOCs - volatile organic compounds

Table 5-3: Preliminary and Detailed Screening of Process Options - Groundwater

General Response Action	Remedial Technology	Process Option	Description	Effectiveness Evaluation		Implementability Evaluation		Relative Cost Evaluation		Retained?	Decision Rationale
No Action	No Action	No Action	No remedial action	---		---		---		Yes	Required by NCP and USEPA guidance as baseline for comparison to other process options.
Institutional Controls	Institutional Controls	Land Use Controls	Institutional controls are administrative actions that minimize exposure by limiting land or resource use; institutional controls maintain protectiveness by modifying or guiding human behavior.	Moderate	Standard practice for protecting human health and the environment, effectiveness governed by maintenance of institutional controls.	Moderate - High	Generally implementable but requires close coordination of regulatory authorities.	Low	Low capital and O&M costs.	Yes	Standard practice for management of former industrial sites.
Monitored Natural Attenuation	Monitored Natural Attenuation	Monitored Natural Attenuation	Monitoring events are performed to confirm that COI concentrations are attenuating over time via natural subsurface processes.	Moderate	Natural attenuation processes is effective for reduction of COIs.	High	Readily implementable.	Low	Low capital and O&M costs; existing infrastructure can be used for groundwater monitoring.	Yes	Conventional technology; can be used in conjunction with other technologies.
Containment	Barrier	Diversion Barrier	Installation of an impermeable containment barrier downgradient of COI-impacted soil/groundwater extending through the water table to COI prevent mobility.	Moderate - High	Effective for restricting movement of COIs.	Moderate	May require specialized equipment to construct slurry walls or sheet pile walls. May not be implementable in wetland areas.	Moderate	High capital cost for barrier installation	No	COIs migration is already limited at the site and implementation may be difficult in the OU-E lowland.
In-situ Treatment	Physical	Air Sparge/Soil Vapor Extraction	Injection of air below the groundwater table to physically strip volatile COIs from groundwater. Air sparging also has a limited ability to increase background oxygen concentrations and promotes aerobic biodegradation processes.	Moderate	Effective for mass removal of petroleum constituents in groundwater, would not be effective for dissolved metals.	Moderate - High	Is readily implementable for fuel constituents in groundwater in the IRM and West of IRM AOIs	Low	High capital and O&M costs.	Yes	Effective for TPH constituents in IRM and West of IRM AOI.
		Thermal	Thermal remediation relies upon heating groundwater using a variety of technologies to enhance volatization of constituents and capturing COIs with SVE	Moderate - High	Effective for mass removal in groundwater	Moderate - High	Is readily implementable for fuel constituents in groundwater in the IRM and West of IRM AOIs	High	Significant capital and O&M costs for implementation	No	Capital and O&M cost and thermal remediation poses several health and safety and permitting concerns for implementation.
	Biological	Enhanced Aerobic Bioremediation	The injection of a substrate (such as calcium peroxide) to stimulate native microorganisms and degrade COIs via the addition of oxygen as an electron acceptor.	Moderate - High	Effective and implementable for remediation of VOCs and other fuel-related constituents.	Moderate - High	Effective and implementable for remediation of VOCs and other fuel-related constituents.	Moderate	Moderate capital and O&M costs	Yes	Effective for TPH constituents in IRM and West of IRM AOI.
		Enhanced Anaerobic Bioremediation	The injection of a substrate (such as magnesium sulfide) to stimulate native microorganisms and degrade COIs via the addition of an electron acceptor in a low-oxygen or oxygen-free environment.		Injection of a non-oxygen electron acceptor to stimulate enhanced anaerobic bioremediation is likely to affect secondary water quality parameters in the short term.			Moderate	Moderate capital and O&M costs	Yes	Effective for TPH constituents in IRM and West of IRM AOI.
		Phytoremediation	Uses plants to potentially remove, transfer, stabilize, and destroy COIs in shallow groundwater.	Moderate	Effectiveness of phytoremediation at the site is unknown, and would require treatability studies to establish remedial timeframes.	Moderate	The average depth of groundwater near the OU-E Groundwater AOC, a tree/shrub plantation with roots extending 10 to 15 feet bgs would likely be the main application for treatment.	Low	Low capital and O&M costs.	No	The effectiveness of phytoremediation at the site is unknown, and would require treatability studies to establish remedial timeframes. Not retained given the uncertainty associated with the remedial approach in achieving RAOs.
	Chemical	Chemical Oxidation	Use of chemical oxidant (ozone, hydrogen peroxide, persulfate, or permanganate) to oxidize COIs in-situ.	Moderate	ISCO is an established technology that can be effective for petroleum constituents.	Moderate - High	Several chemical reagents and delivery methods available.	Moderate	Moderate capital and O&M costs	Yes	Persulfate has multiple advantages for safe controlled effective oxidation of petroleum hydrocarbons and is incorporated into remedial alternative
		Permeable Reactive Barrier	Consists of a subsurface emplacement of reactive materials (zero valent iron) built below ground to intercept and treat COI-affected groundwater. A PRB is built by excavating a narrow trench perpendicular to the path of the COIs in groundwater.	Low	Effectiveness is tied to groundwater flushing across the AOC and reactivity with the barrier materials.	Low	Challenging to implement in the site setting at OU-E	Moderate	High capital and O&M cost	No	Based on effectiveness and implementability considerations.
Ex-Situ Treatment	Groundwater Extraction & Treatment	Pump & Treat (reinjection)	COIs in extracted groundwater are removed through a series of process methods including physical, chemical, or biological treatment, such as granular activated carbon and air stripping. Treated groundwater is reinjected into groundwater table.	High	Technology are proven to effective.	High	Feasible at site	High	High capital and O&M costs.	No	on-site disposal is more readily implemented
		Pump & Treat (disposal)	COIs in extracted groundwater are removed through a series of process methods including physical, chemical, or biological treatment, such as granular activated carbon and air stripping.	High	Technology are proven to effective.	High	Feasible at site	High	High capital and O&M cost	Yes	on-site disposal is more readily implemented

Notes:

Green shading indicates that the process option will be further evaluated as a stand-alone alternative.

Red shading indicates that the process option was eliminated in the preliminary screening stage.

Acronyms:

COI - chemical of interest
DGR - directed groundwater recirculation
ISB - in-situ bioremediation
LUC - land use control
NCP - National Contingency Plan
O&M - operation and maintenance
SVE - soil vapor extraction
USEPA - United States Environmental Protection Agency
VAFB - Vandenberg Air Force Base
VOC - volatile organic chemical

Table 7-1: Comparison of Remedial Alternatives

Media	AOC	Risk Summary	Alternative	Description	Threshold (Yes or No) Criteria		Balancing (Low, Moderate, or High) Criteria				
					Overall Protection of Human Health and the Environment	Compliance with ARARs	Long Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short Term Effectiveness	Implementability	Cost
Aquatic Sediment	North Pond and Pond 6	Arsenic and dioxin TEQ are the primary risk drivers in Pond 6 sediment, while arsenic was the primary risk contributor in North Pond sediment. Risks evaluated in the BHHERA indicate ELCR of 2E10-6.	No Action	Site remains as is; provide no additional control or action to protect human health or the environment from affected sediment.	No	No	Low	Low	High	High	$0
			Institutional Controls	Restrict future land use via deed restriction and implement risk management plan for soil/sediment based on COIs and associated risks.	Yes	Yes	Moderate	Moderate	High	High	$120,000
			Vegetative Cover and Institutional Controls	Eliminate exposure pathways through vegetative containment, and implementation of a deed restriction and risk management plan for soil/sediment based on COIs and associated risks.	Yes	Yes	Moderate	Moderate	High	Moderate	$392,400
			Excavation and Disposal	Eliminate exposure pathways through soil excavation and disposal offsite at a permitted landfill.	Yes	Yes	High	High	Moderate	Moderate	$426,500
	Pond 8	Dioxin TEQ is the primary risk drivers in sediment. Risks evaluated in the BHHERA indicate ELCRs are 2E-6 cumulative with the primary contributors of 1E-6 for dioxin and 1E-6 for arsenic. Arsenic concentrations are at background.	No Action	Site remains as is; provide no additional control or action to protect human health or the environment from affected sediment.	No	No	Low	Low	High	High	$0
			Institutional Controls	Restrict future land use via deed restriction and implement risk management plan for soil/sediment based on COIs and associated risks.	Yes	Yes	High	Moderate	High	High	$120,000
			In-Situ Soil Mixing and Institutional Controls	Proposes to treat sediment in place through stabilization by the addition of binders and Portland cement to restrict exposure of potential receptors to affected media, and would limit potential direct contact with affected sediment, or infiltration of water.	Yes	Yes	High	Moderate	Low	Low	$11,673,000
			Excavation and Disposal	Eliminate exposure pathways through excavation and disposal offsite at a permitted landfill.	Yes	Yes	High	High	Low	Low	$17,223,000
			Vegetated Soil Cover and Institutional Controls	Alternative proposes to provide a vegetative cover to cover the pond to restrict exposure of potential receptors to affected media, and would limit potential direct contact with affected sediment, or infiltration of water.	Yes	Yes	Low	Moderate	Low	Low	$8,306,000
Groundwater	IRM and West of IRM TPHd and Lowland Barium	Fuel-related constituents (TPHd) and Barium are the residual COCs. Concentrations of Barium show downward trends near the WQO, which is also the MCL. Concentrations of TPHd show downward trends near the WQO, which is based on the taste and odor threshold.	No Action	Site remains as is; provide no additional control or action to protect human health or the environment from affected groundwater.	No	No	Low	Moderate	High	High	$0
			Restricted Use	A deed restriction on the AOC, prohibiting the use of groundwater to eliminate exposure to COIs.	Yes	Yes	Moderate	Moderate	High	High	$65,000
			Monitored Natural Attenuation and Institutional Controls	Periodic sampling of groundwater to evaluate natural biological and chemical remediation of COIs with contingency for potential future remedial actions, and restrict future groundwater use by establishing a deed restriction prohibiting use of onsite groundwater.	Yes	Yes	Moderate	Moderate	High	High	$67,000
			Air Sparge and Soil Vapor Extraction, MNA, and Institutional Controls	Air Sparge and Soil Vapor Extraction (AS/SVE) involves the installation of vapor extraction wells along with air injection wells. This technology is commonly used to treat groundwater where volatile organic compounds or petroleum related constituents are present in sufficient concentrations to be removed through volatilization into entrained air in the saturated zone and removal and treatment in the vadose zone. Only effective for petroleum related compounds.	Yes	Yes	High	High	Moderate	Moderate	$1,196,000

Table 7-1: Comparison of Remedial Alternatives

Media	AOC	Risk Summary	Alternative	Description	Threshold (Yes or No) Criteria		Balancing (Low, Moderate, or High) Criteria				
					Overall Protection of Human Health and the Environment	Compliance with ARARs	Long Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short Term Effectiveness	Implementability	Cost
Groundwater (cont'd)	IRM and West of IRM TPHd and Lowland Barium	Fuel-related constituents (TPHd) and Barium are the residual COCs. Concentrations of Barium show downward trends near the WQO, which is also the MCL. Concentrations of TPHd show downward trends near the WQO, which is based on the taste and odor threshold.	Enhanced Aerobic Bioremediation, MNA, and Institutional Controls	Injection of calcium peroxide solution for treatment of contaminants followed by periodic groundwater sampling to confirm that WQOs will be reached within a reasonable timeframe. Periodic sampling of groundwater to evaluate natural biological and chemical remediation of COIs with contingency for potential future remedial actions, and restrict future groundwater use by establishing a deed restriction prohibiting use of onsite groundwater. Only effective for petroleum related compounds.	Yes	Yes	High	High	Moderate	Moderate	$332,000
			Enhanced Anaerobic Bioremediation, MNA, and Institutional Controls	Anaerobic bio-oxidation of COIs followed by treatment through natural attenuation mechanisms. Periodic sampling of groundwater to evaluate natural biological and chemical remediation of COIs with contingency for potential future remedial actions, and restrict future groundwater use by establishing a deed restriction prohibiting use of onsite groundwater. Only effective for petroleum related compounds.	Yes	Yes	High	High	Moderate	Moderate	$312,000
			In-Situ Chemical Oxidation, MNA, and Institutional Controls	Injection of highly reactive oxidation solution for treatment of contaminants followed by periodic groundwater sampling to confirm that WQOs will be reached within a reasonable timeframe. Periodic sampling of groundwater to evaluate natural biological and chemical remediation of COIs with contingency for potential future remedial actions, and restrict future groundwater use by establishing a deed restriction prohibiting use of onsite groundwater. Only effective for petroleum related compounds.	Yes	Yes	High	High	Moderate	Moderate	$332,000
			Groundwater Extraction and Treatment, MNA, and Institutional Controls	Extraction of COI-affected groundwater, treatment via granular activated carbon/air stripping system or ion-exchange, and discharge of treated groundwater. Periodic sampling of groundwater to evaluate natural biological and chemical remediation of COIs with contingency for potential future remedial actions, and restrict future groundwater use by establishing a deed restriction prohibiting use of onsite groundwater.	Yes	Yes	High	Moderate	Moderate	Moderate	$3,481,000

Notes:
Recommended alternatives are outlined with bold lines.
Green shading indicates that the screening criteria is met or has a high ranking in preference.
Yellow shading indicates that the screening criteria is likely met or has a moderate ranking in preference.
Red shading indicates that the screening criteria may not be met or has a low ranking in preference.

Acronyms:
AOC - area of concern
AOI - area of interest
ARARs - Applicable or Relevant and Appropriate Requirements
B(a)P - benzo(a)pyrene
bgs - below ground surface
BHHERA - Baseline Human Health and Ecological Risk Assessment - Operable Unit E (ARCADIS, 2015)
COI - chemical of interest
cy - cubic yard
dioxin - polychlorinated dibenzo-p-dioxin (in case of TEQ, 2,3,7,8-tetrachlorodibenzo-p-dioxin [2,3,7,8-TCDD] in particular)
ELCR - excess lifetime cancer risk
ERA - ecological risk assessment
IRM - interim remedial measure
NCP - National Oil and Hazardous Substances Pollution Contingency Plan
PAH -polycyclic aromatic hydrocarbon
PRA - presumptive remedy area
sf - square feet
TEQ - toxic equivalent
TPHd - total petroleum hydrocarbons as diesel
WQO - Water Quality Objective

Reference:
ARCADIS. 2015. *Baseline Human Health and Ecological Risk Assessment – Operable Unit E* , Former Georgia-Pacific Wood Products Facility, Fort Bragg, California. Prepared for Georgia-Pacific LLC. August.

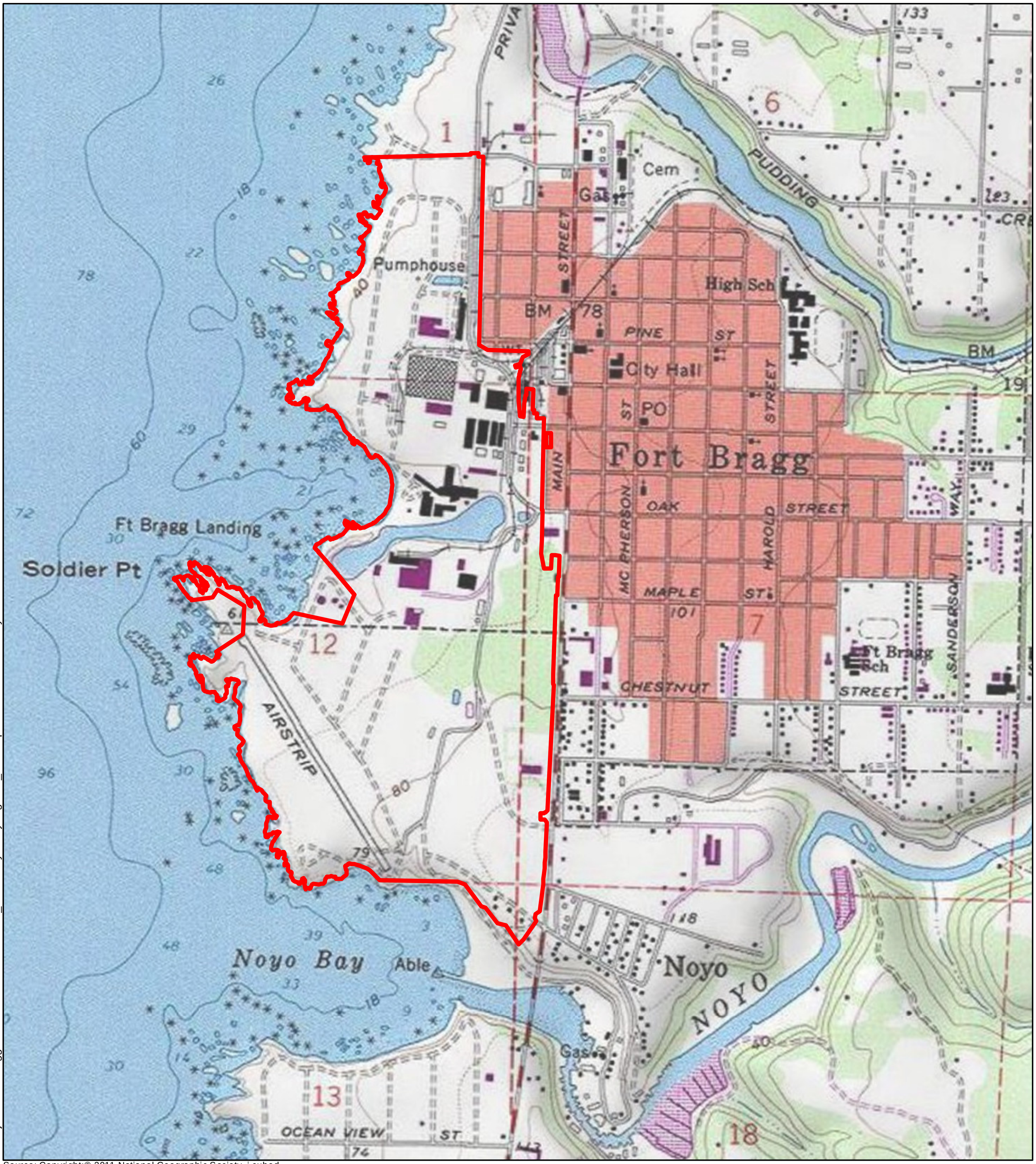
Table 8-1: Remedial Alternative Recommendations Summary

Media	AOC	Primary Risk Drivers	ELCR	Alternative	Objective	Threshold (Yes or No) Criteria		Balancing (Low, Moderate, or High) Criteria				
						Overall Protection of Human Health and the Environment	Compliance with ARARs	Long Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short Term Effectiveness	Implementability	Cost
Sediment	North Pond and Pond 6	Arsenic and dioxin TEQ	2E-06	Institutional Controls	Restrict future land use via deed restriction and implement risk management plan for soil/sediment based on COIs and associated risks.	Yes	Yes	Moderate	Moderate	High	High	$120,000
Sediment	Pond 8	Dioxin TEQ	2E-6 (1E-6 each for Dioxin and Arsenic, Arsenic concentrations are at background)	Institutional Controls	Restrict future land use via deed restriction and implement risk management plan for soil/sediment based on COIs and associated risks.	Yes	Yes	High	Moderate	High	High	$120,000
Groundwater	IRM and West of IRM	Fuel-related constituents (primarily TPHd) and Barium	NA	Monitored Natural Attenuation and Institutional Controls	Periodic sampling of groundwater to evaluate natural biological and chemical remediation of COIs with contingency for potential future remedial actions, and restrict future groundwater use by establishing a deed restriction prohibiting use of onsite groundwater.	Yes	Yes	Moderate	Moderate	High	High	$67,000

Notes:
Green shading indicates that the screening criteria is met or has a high ranking in preference.
Yellow shading indicates that the screening criteria is likely met or has a moderate ranking in preference.
Red shading indicates that the screening criteria may not be met or has a low ranking in preference.

Acronyms:
AOC - area of concern
ARARs - Applicable or Relevant and Appropriate Requirements
COI - chemical of interest
dioxin - polychlorinated dibenzo-p-dioxin (in case of TEQ, 2,3,7,8-tetrachlorodibenzo-p-dioxin [2,3,7,8-TCDD] in particular)
ELCR - Excess Lifetime Cancer Risk
IRM - interim remedial measure
TEQ - toxic equivalent
TPHd - total petroleum hydrocarbons as diesel

Reference:
ARCADIS. 2015. *Baseline Human Health and Ecological Risk Assessment – Operable Unit E* , Former Georgia-Pacific Wood Products Facility, Fort Bragg, California. Prepared for Georgia-Pacific LLC. August.



Z:\Projects\FortBragg\MillSite\Events\20170430_FeasibilityStudy\Fig1-01_SiteMap.mxd Printed by: MarioO

Source: Copyright:© 2011 National Geographic Society, i-cubed

N

0 750 1,500

Scale: Feet

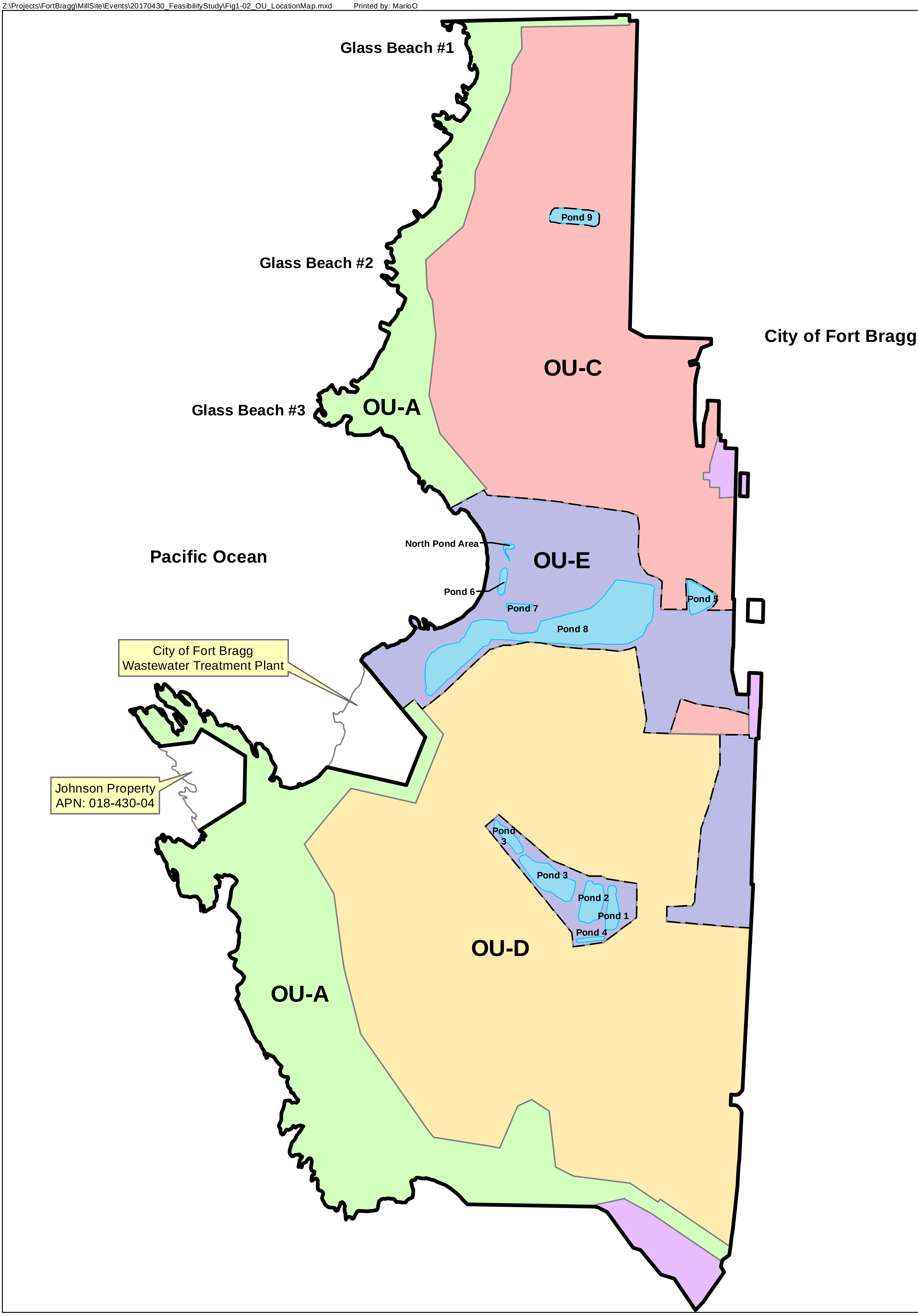
Kennedy/Jenks Consultants

Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

Site Location Map

1665018*16

Figure 1-1



Legend

- Site Boundary
- Pond

OPERABLE UNITS

- OU-A
- "OFFSITE" NON-INDUSTRIAL (OU-B)
- NORTHERN (OU-C)
- SOUTHERN (OU-D)
- CENTRAL/AQUATIC (OU-E)

Abbreviation:
OU = Operable Unit

N

0 300 600
Scale: Feet

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Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

Operable Units Location Map

1665018*16

Figure 1-2

Z:\Projects\FortBragg\MillSite\Events\20170430_FeasibilityStudy\Fig1-03_OUEAreasofConcern.mxd Printed by: MarioO

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Legend

- SITE BOUNDARY
- AOI BOUNDARY
- OU-E BOUNDARY
- PONDS
- AREA OF CONCERN BOUNDARY

AREAS OF CONCERN:

- A OUE LOWLAND
- B SOUTHERN PONDS
- C POND 5
- D POND 6
- E POND 7
- F NORTH POND
- G POND 8
- H POND 9

ACRONYMS:
AOI - AREA OF INTEREST
OU - OPERABLE UNIT

N

0 200 400
Scale: Feet

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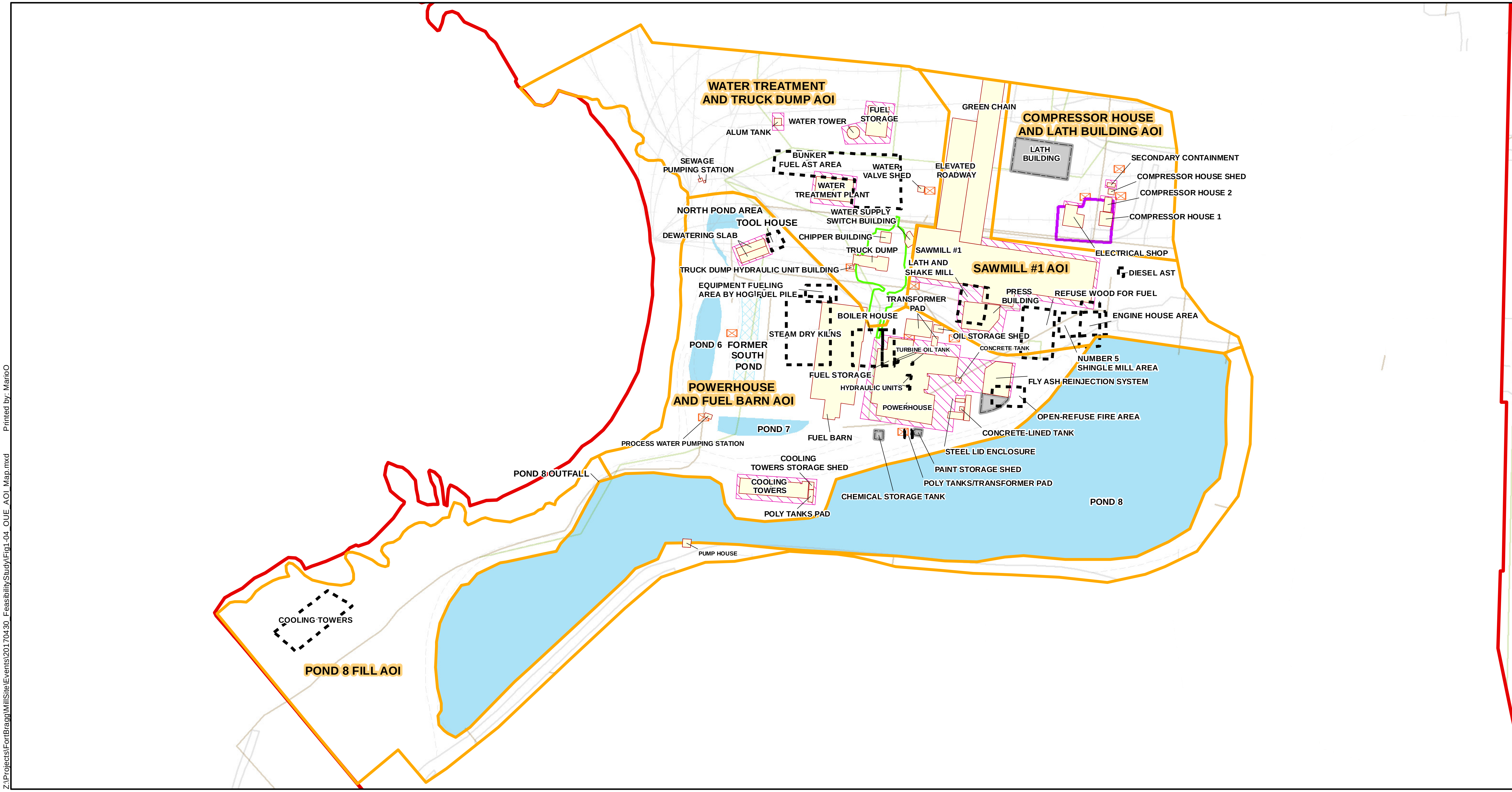
Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

OU-E Area of Interest Map and Associated Features

1665018*16

Figure 1-3



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Legend

- AOI BOUNDARY
- SITE BOUNDARY
- STRUCTURE
- FORMER STRUCTURE
- FORMER STRUCTURE-FOUNDATION INTACT
- OTHER OPERABLE UNITS/AOIs
- POND
- FORMER POND
- COMPRESSOR HOUSE EXCAVATION BOUNDARY
- FUEL LINE EXCAVATION BOUNDARY
- APPROXIMATE CAP BOUNDARIES
- FORMER INDUSTRIAL USE (APPROXIMATE LOCATION)
- PLANT DRAIN SYSTEM LINE
- SANITARY SEWER LINE
- UNPAVED ROADWAY
- PAVED ROADWAY
- FORMER RAIL LINES
- FORMER TRANSFORMER LOCATION (APPROXIMATE)

ABBREVIATIONS:

AOI = Area of Interest
AST = Aboveground Storage Tank

N

0 80 160
Scale: Feet

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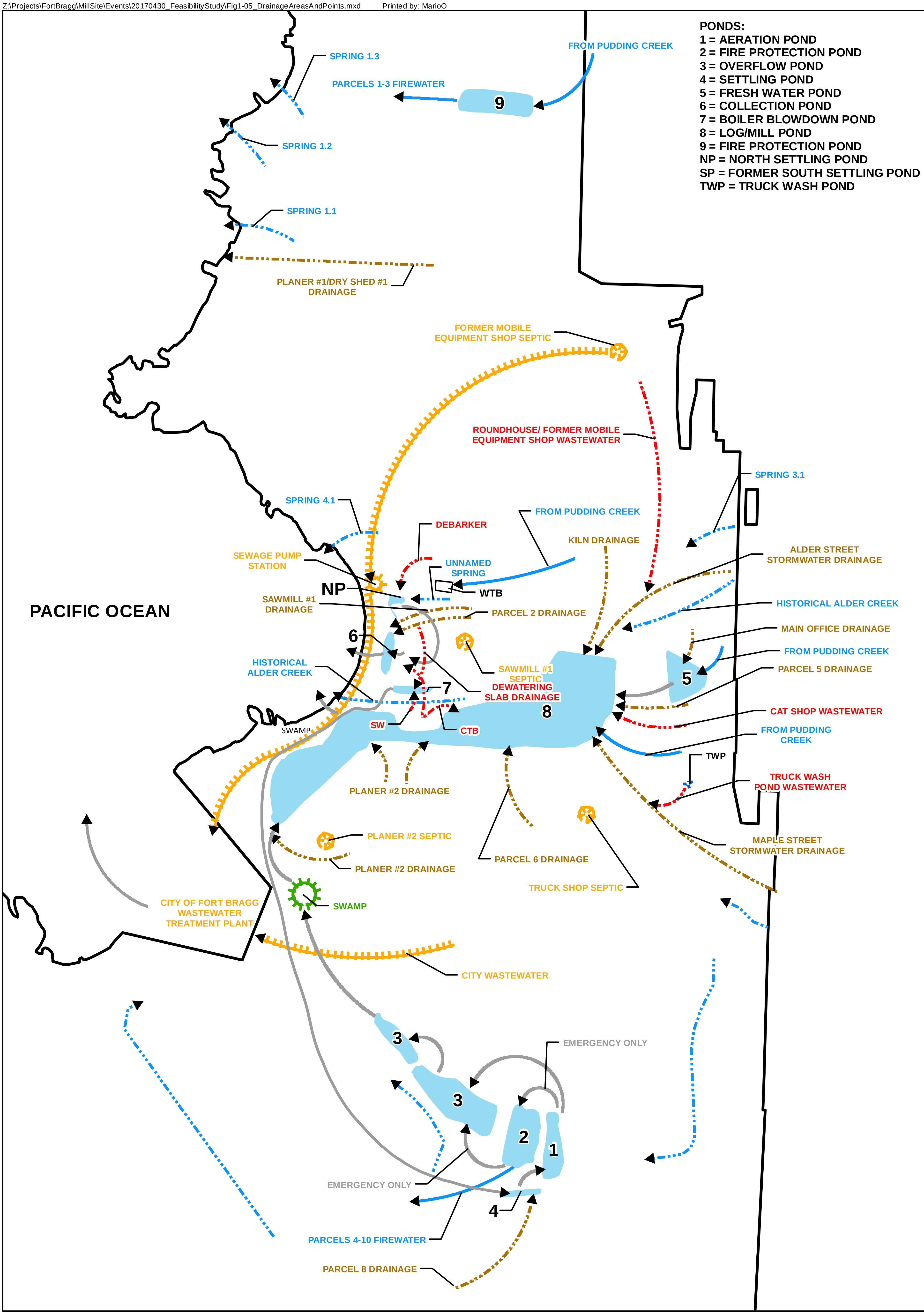
Feasibility Study Operable Unit E
Fort Bragg, California

OU-E Terrestrial AOIs and Associated Features

1665018*16

Figure 1-4

Z:\Projects\FortBragg\MillSite\Events\20170430_FeasibilityStudy\Fig1-05_DrainageAreasAndPoints.mxd Printed by: MarioO



Legend

- Schematic Representation Of Hydraulic Connection
- Fresh Water
- Stormwater
- Septic System/ Domestic Wastewater
- Industrial Wastewater
- Natural Drainage/Wetland
- SWAMP
- Site Boundary
- Pond

Notes:
1. Flow Lines And Routes Are Schematic Representations And Should Not Be Construed To Indicate Actual Physical Conditions

Acronyms:
CTB - Cooling Tower Blowdown
SW - Scrubber Washwater
WTB - Water Treatment Building

N

0 200 400
Scale: Feet

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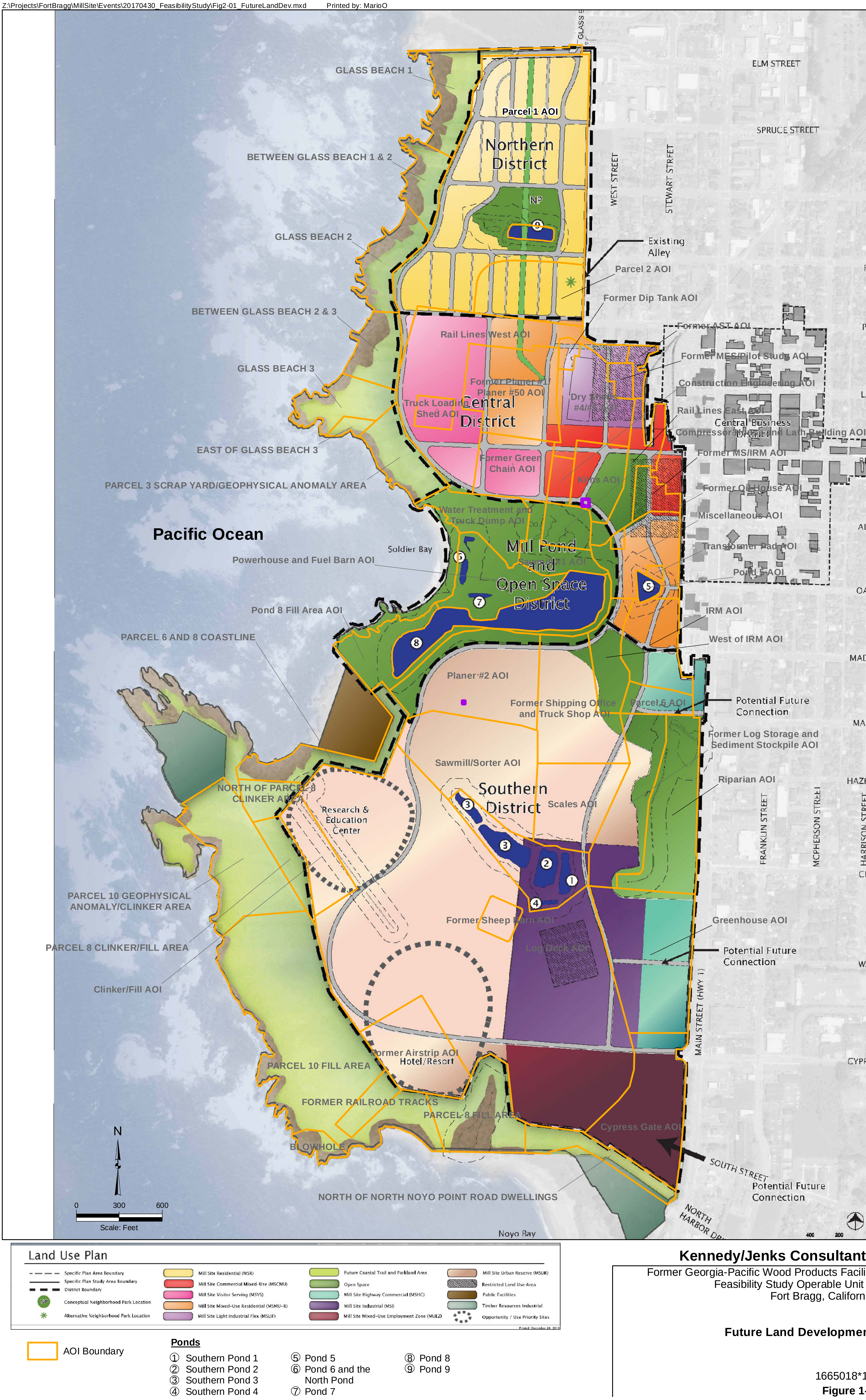
Feasibility Study Operable Unit E
Fort Bragg, California

Drainage Areas and Discharge Points

1665018*16

Figure 1-5

Z:\Projects\FortBragg\MillSite\Events\20170430_FeasibilityStudy\Fig2-01_FutureLandDev.mxd Printed by: MarioO



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Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

Future Land Development

1665018*16

Figure 1-2

Z:\Projects\FortBragg\MillSite\Events\20170430_FeasibilityStudy\Fig2-02_WetlandsNorthern.mxd Printed by: MarioO

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

NOTES:
1. WATERS/WETLANDS BOUNDARIES PREVIOUSLY DELINEATED BY WRA (2009) WERE APPROVED BY THE USACE ON MARCH 15, 2010. HOWEVER, NOT ALL DELINEATED WATERS/WETLANDS WERE CLAIMED AS JURISDICTIONAL BY THE USACE. USACE FILE # 2009-00372N.
2. ESHA - ENVIRONMENTALLY SENSITIVE HABITAT AREAS
3. THREE-PARAMETER WETLANDS ARE DEFINED AS WETLANDS WHERE:
   1) EVIDENCE OF WETLAND HYDROLOGY, HYDRIC SOIL, AND HYDROPHYTIC VEGETATION WERE PRESENT DURING FIELD INVESTIGATIONS, OR
   2) LACK OF EVIDENCE FROM ONE OR MORE OF THE THREE PARAMETERS WAS DUE TO PROBLEMATIC/DISTURBED CONDITIONS.

REFERENCES:

WRA 2009. DELINEATION OF POTENTIAL SECTION 404 JURISDICTIONAL WETLANDS AND WATERS. FORMER GEORGIA- PACIFIC FORT BRAGG WOOD PRODUCTS FACILITY, FORT BRAGG, MENDOCINO COUNTY, CALIFORNIA. PREPARED FOR GEORGIA-PACIFIC, LLC. SEPTEMBER.

ARCADIS. 2011. ENVIRONMENTALLY SENSITIVE HABITAT AREAS DELINEATION REPORT. PREPARED FOR GEORGIA-PACIFIC LLC. APRIL.

Legend

- Soil Pit Location
- Operational Unit

Potential Environmentally Sensitive Habitat Areas (ESHA)

- Delineated Wet ESHA (ARCADIS 2011; not yet approved)
- Delineated waters/ Wetlands (WRA 2009; approved by the USACE 3/15/10)
- Seasonal Wetland
- Wetland Seep
- Industrial Pond
- Three-parameter wetland

N

0 115 230

Scale: Feet

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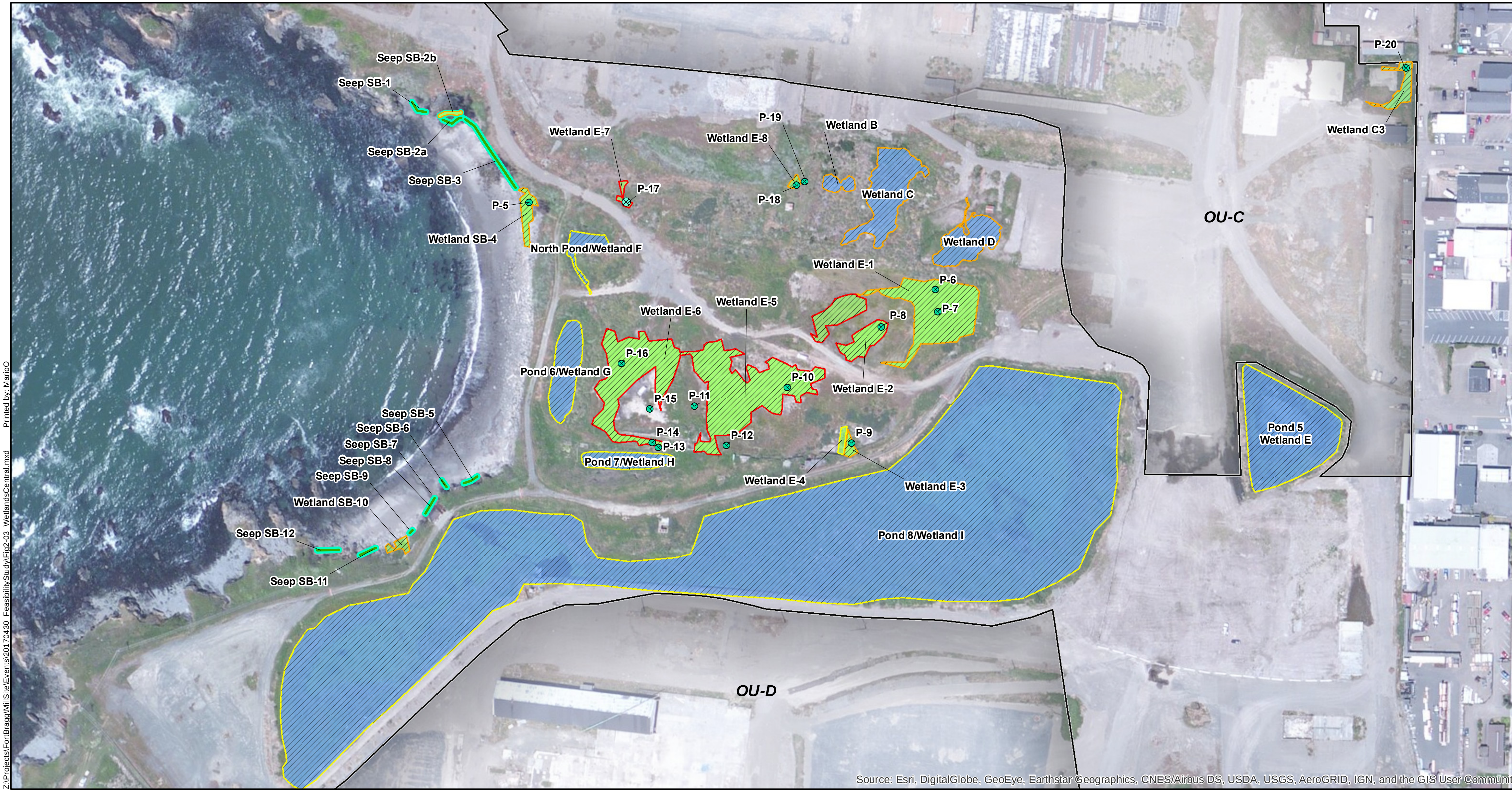
Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

Wetlands and Other Wet Environmentally Sensitive Habitat Area – Northern

1665018*16

Figure 2-2



Z:\Projects\FortBragg\MillSite\Events\20170430_FeasibilityStudy\Fig2-03_WetlandsCentral.mxd
Printed by: MarioO

Legend

- Soil Pit Location
- Operational Unit

Potential Environmentally Sensitive Habitat Areas (ESHA)

- Width Of Delineated Groundwater Seep/Waters Of The State (Arcadis 2010; Not Yet Approved)
- Delineated Wet ESHA (ARCADIS 2011; not yet approved)
- Delineated waters/ Wetlands (WRA 2009; approved by the USACE 3/15/10)
- Seasonal Wetland
- Wetland Seep
- Industrial Pond
- Bedrock Groundwater Seep
- Three-parameter wetland

NOTES:
1. NOT ALL DELINEATED WATERS/WETLANDS APPROVED BY THE USACE ARE WATERS/WETLANDS OF THE U.S.
2. ESHA - ENVIRONMENTALLY SENSITIVE HABITAT AREAS
3. THREE-PARAMETER WETLANDS ARE DEFINED AS WETLANDS WHERE:
   1) EVIDENCE OF WETLAND HYDROLOGY, HYDRIC SOIL, AND HYDROPHYTIC VEGETATION WERE PRESENT DURING FIELD INVESTIGATIONS, OR
   2) LACK OF EVIDENCE FROM ONE OR MORE OF THE THREE PARAMETERS WAS DUE TO PROBLEMATIC/DISTURBED CONDITIONS.

N

0 85 170

Scale: Feet

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Feasibility Study Operable Unit E
Fort Bragg, California

Wetlands and Other Wet Environmentally Sensitive Habitat Area – Central

1665018*16

Figure 2-3

Z:\Projects\FortBragg\MillSite\Events\20170430_FeasibilityStudy\Fig2-04_Wetlands_South.mxd Printed by: MarioO

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

NOTES:
1. NOT ALL DELINEATED WATERS/WETLANDS APPROVED BY THE USACE ARE WATERS/WETLANDS OF THE U.S.
2. THREE-PARAMETER WETLANDS ARE DEFINED AS WETLANDS WHERE:
   1) EVIDENCE OF WETLAND HYDROLOGY, HYDRIC SOIL, AND HYDROPHYTIC VEGETATION WERE PRESENT DURING FIELD INVESTIGATIONS, OR
   2) LACK OF EVIDENCE FROM ONE OR MORE OF THE THREE PARAMETERS WAS DUE TO PROBLEMATIC/DISTURBED CONDITIONS.

* WETLAND CHARACTERISTICS FOR WETLAND D-2 WERE ASSESSED FROM SOIL BORING P-22. DUE TO THE PRESENCE OF DENSE SHRUB AND BRAMBLE, WETLAND BOUNDARIES FOR WETLAND D-2 WERE DELINEATED FROM SOIL BORINGS P-21 AND P-22 AND VEGETATIVE CHARACTERISTICS IN AERIAL PHOTOGRAPHY. THEREFORE, THE BOUNDARIES OF WETLAND D-2 MAY CONTAIN AN UPLAND AND WETLAND MOSAIC.

REFERENCES:

WRA 2009. DELINEATION OF POTENTIAL SECTION 404 JURISDICTIONAL WETLANDS AND WATERS. FORMER GEORGIA- PACIFIC FORT BRAGG WOOD PRODUCTS FACILITY, FORT BRAGG, MENDOCINO COUNTY, CALIFORNIA. PREPARED FOR GEORGIA-PACIFIC, LLC. SEPTEMBER.

ARCADIS. 2011. ENVIRONMENTALLY SENSITIVE HABITAT AREAS DELINEATION REPORT. PREPARED FOR GEORGIA-PACIFIC LLC. APRIL.

Legend

- Soil Pit Location
- Operational Unit
- Riparian Area

Potential Environmentally Sensitive Habitat Areas (ESHA)

- Width of Delineated Groundwater Seep/Waters of the State (ARCADIS 2011; not yet approved)
- Delineated Wet ESHA (ARCADIS 2011; not yet approved)
- Delineated waters/ Wetlands (WRA 2009; approved by the USACE 3/15/10)
- Seasonal Wetland
- Wetland Seep
- Industrial Pond
- Seasonal Wetland Ditch
- Riparian Wetland
- Bedrock Groundwater Seep
- Perennial Waters
- Three-parameter wetland
- Area not evaluated based on ongoing construction activities

N

0 160 320

Scale: Feet

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Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

Wetlands and Other Wet Environmentally Sensitive Habitat Area – Southern

1665018*16

Figure 2-4

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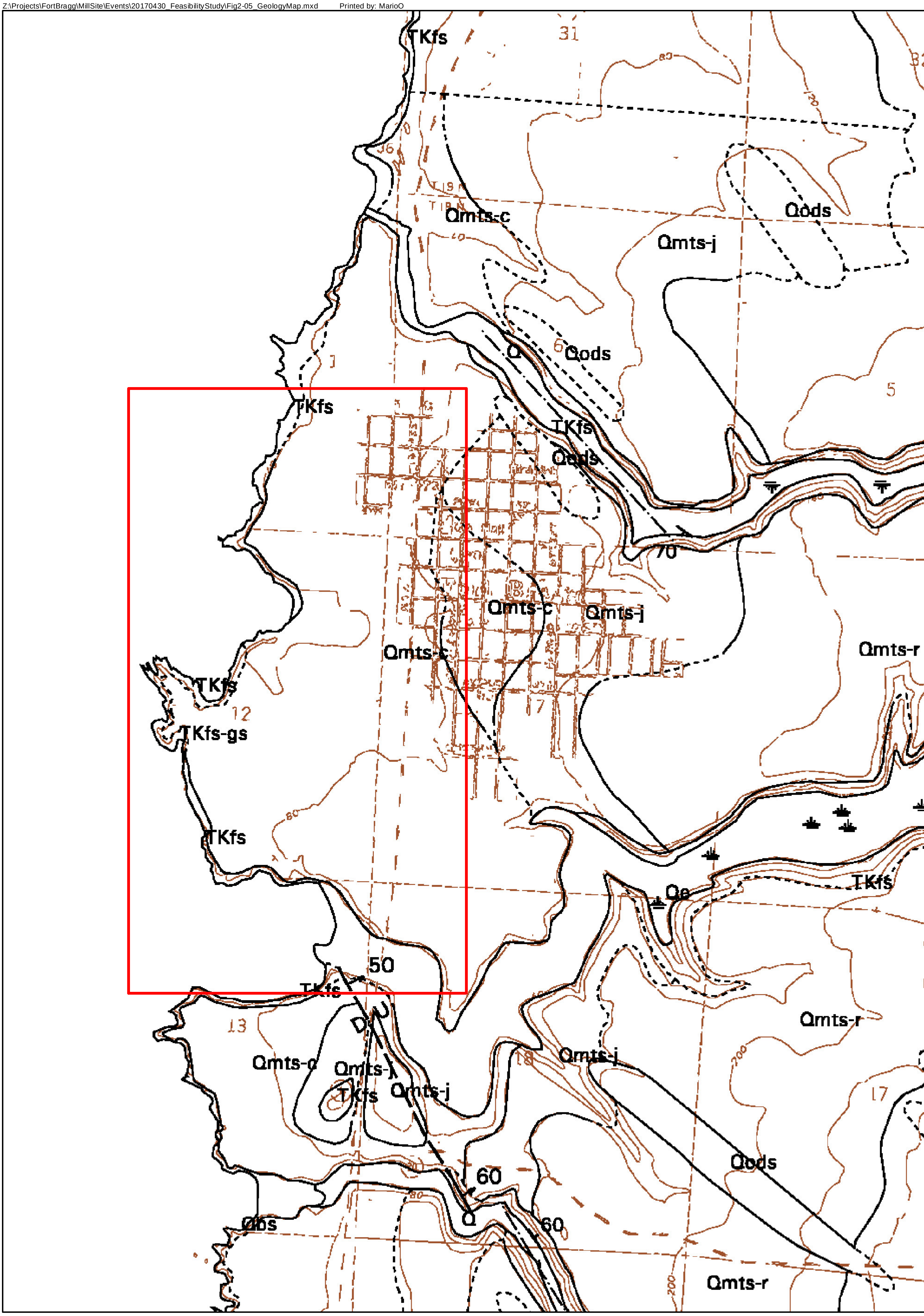

Legend

Approximate Site Area

NOTES:

1. SOURCE: 1983, DMG OPEN-FILE REPORT 83-05, GEOLOGY AND GEOMORPHIC FEATURES RELATED TO LANDSLIDING, FORT BRAGG 7.5' QUADRANGLE, MENDOCINO COUNTY, CALIFORNIA

2. TKfs = COASTAL BELT FRANCISCAN COMPLEX
   TKfs-gs = COASTAL BELT FRANCISCAN COMPLEX, GREENSTONE
   Qmts-c = MARINE TERRACE DEPOSITS, CASPAR POINT
   Qmts-r = MARINE TERRACE DEPOSITS, CASPAR RAILROAD
   Qmts-j = MARINE TERRACE DEPOSITS, JUG HANDLE FARM
   Qods = OLDER DUNE SANDS

N

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Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

Geology Map

1665018*16

Figure 2-5

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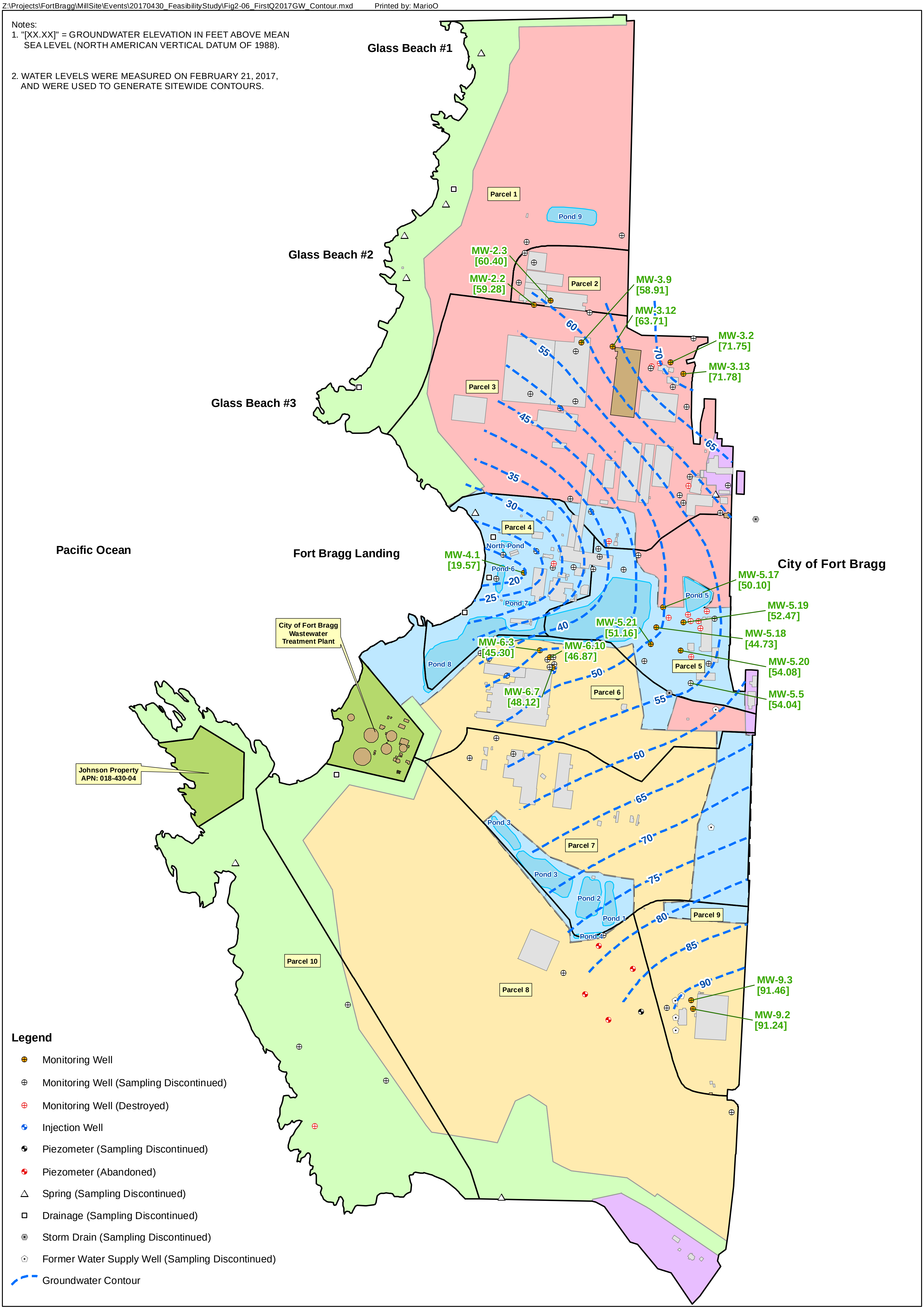

Legend

- Facility Parcel
- Property Owned by Others
- Structure
- Former Structure
- Pond

Operable Units

- Coastal Trail/Park Acquisition (OU-A)
- "Offsite" Non-Industrial (OU-B)
- Northern (OU-C)
- Southern (OU-D)
- Ponds/Park (OU-E)

N

0 300 600

Scale: Feet

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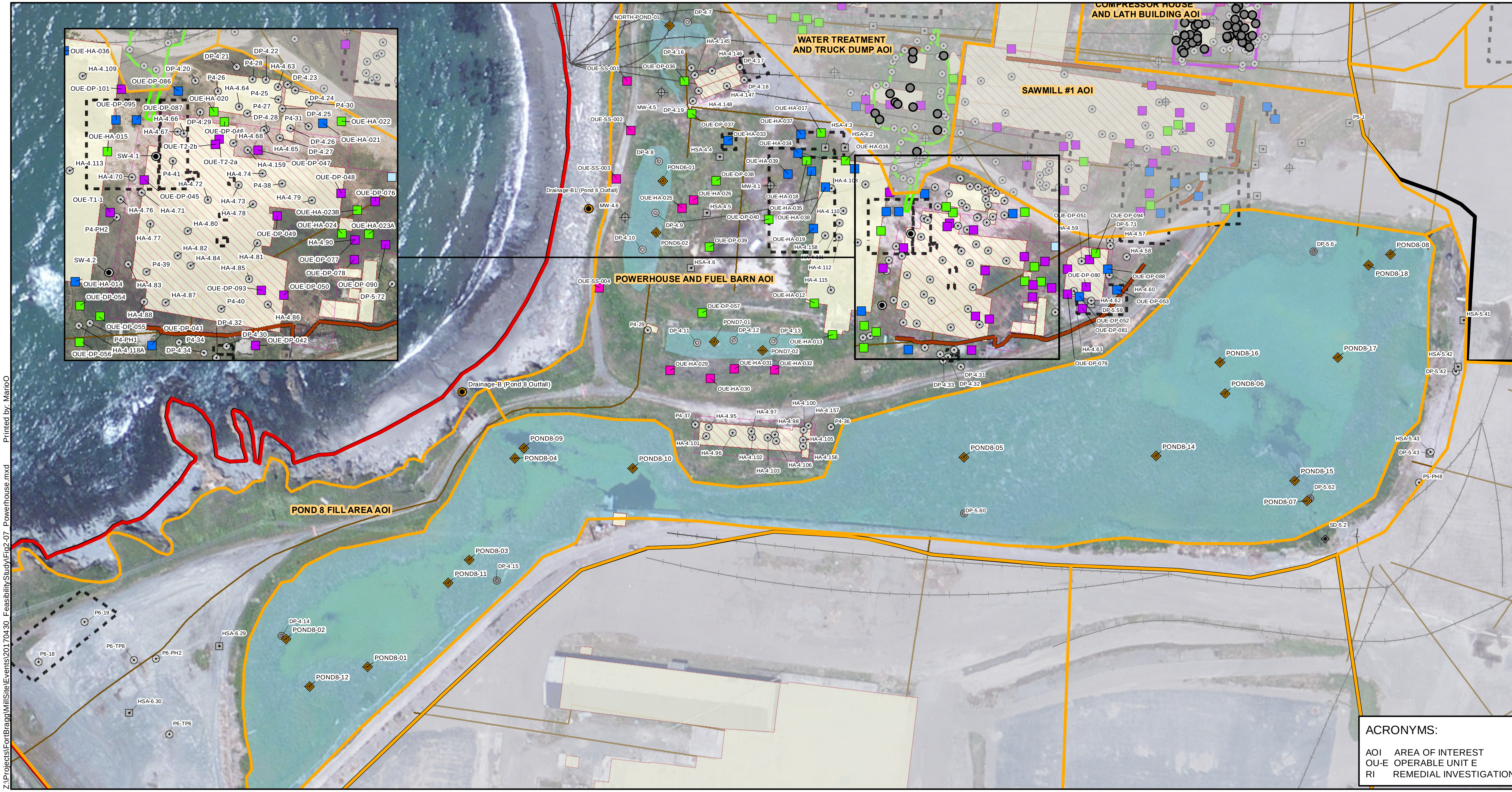
Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

First Quarter 2017
Groundwater Contour Map

1665018*16

Figure 2-6

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Z:\Projects\FortBragg\MillSite\Events\20170430_FeasibilityStudy\Fig2-07_Powerhouse.mxd Printed by: MarioO

Legend

Historical Sample Locations
- Soil
- Groundwater
- Soil & Groundwater
- Sediment
- Sediment/Surface Water
- Surface Water
- Monitoring Well
- Abandoned Monitoring Well
- Excavated Sample Locations

RI Sample Locations
- Surface And Subsurface Soil
- Surface And/Or Subsurface Soil And Groundwater Grab
- Subsurface Soil Sample Only
- Discrete Soil Sample For Composite
- Groundwater Only
- Surface Soil Sample Only
- Sediment
- Surface Water

- Site Boundary
- Other Operable Units/AOIs
- OU-E Boundary
- AOI Boundary
- Former Structure
- Former Industrial Use (Approximate Location)
- Former Structure-Foundation Intact
- Pond
- Compressor House Excavation Boundary
- Fuel Line Excavation Boundary
- Capped Areas
- Plant Drain System Line
- Former Rail Lines
- Retaining Wall

N

0 60 120
Scale: Feet

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Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

Powerhouse and Fuel Barn AOI and Pond 8 Fill Area AOI – Soil, Sediment, Groundwater and Surface Water Sampling Locations

1665018*16

Figure 2-7

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Z:\Projects\FortBragg\MillSite\Events\20170430_FeasibilityStudy\Fig2-08_SouthernPondsSamplingLocs.mxd Printed by: MarioO

Legend

2003-2009 Sample Locations

- Sediment
- Sediment/Surface Water

- Other Operable Units/AOIs
- OU-E Boundary
- Former Structure
- Pond

- Plant Drain System Line
- Former Rail Lines

N

0 60 120

Scale: Feet

Kennedy/Jenks Consultants

Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

Southern Ponds – Sediment and Surface Water Sampling Locations

1665018*16

Figure 2-8

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Legend

2003-2009 Sample Locations

- Sediment
- Sediment/Surface Water

- Site Boundary
- OU-E Boundary
- Existing Structure
- Former Structure
- Former Structure - Foundation Intact
- Pond
- Pond 5 and Pond 9
- Compressor House Excavation Boundary
- Fuel Line Excavation Boundary
- approximate cap boundaries
- Former Industrial Use (Approximate Location)
- Plant Drain System Line
- Sanitary Sewer Line
- Unpaved Roadway
- Paved Roadway
- Former Rail Lines

N

0 175 350

Scale: Feet

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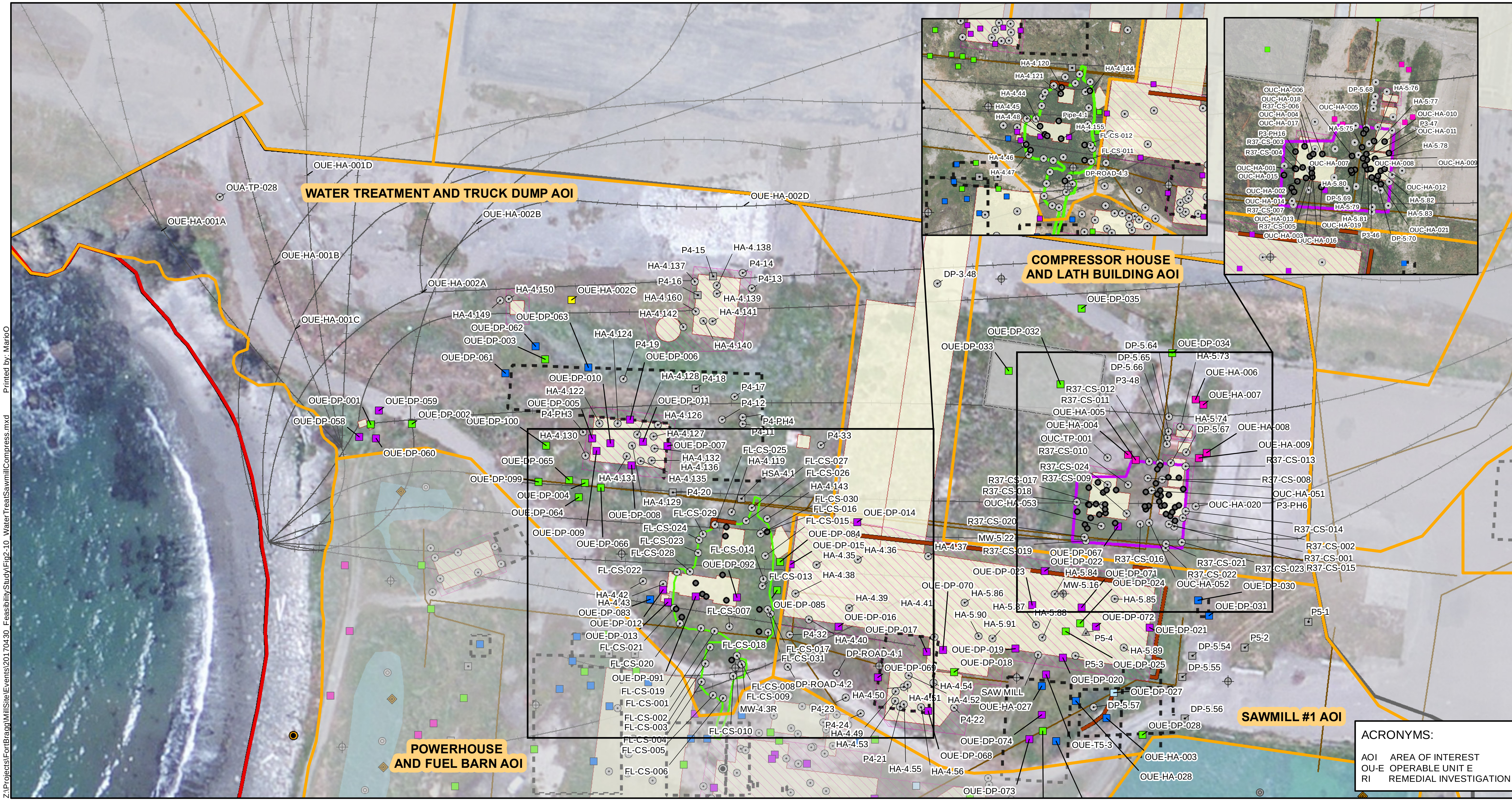
Pond 5 and Pond 9 – Sediment and Surface Water Sampling Locations

1665018*16

Figure 2-9

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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Legend

Historical Sample Locations
- Soil
- Groundwater
- Soil & Groundwater
- Sediment
- Sediment/Surface Water
- Surface Water
- Monitoring Well
- Abandoned Monitoring Well
- Excavated Sample Locations

RI Sample Locations
- Surface And Subsurface Soil
- Surface And/Or Subsurface Soil And Groundwater Grab
- Subsurface Soil Sample Only
- Discrete Soil Sample For Composite
- Groundwater Only
- Surface Soil Sample Only
- Sediment
- Surface Water

- Site Boundary
- Other Operable Units/AOIs
- OU-E Boundary
- AOI Boundary
- Former Structure
- Former Industrial Use (Approximate Location)
- Former Structure-Foundation Intact
- Pond
- Compressor House Excavation Boundary
- Fuel Line Excavation Boundary
- Capped Areas
- Plant Drain System Line
- Former Rail Lines
- Retaining Wall

N

0 45 90
Scale: Feet

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Water Treatment and Truck Dump, Compressor House and Lath Building, and Sawmill #1 AOIs – Soil, Sediment and Surface Water Sampling Locations

1665018*16

Figure 2-10

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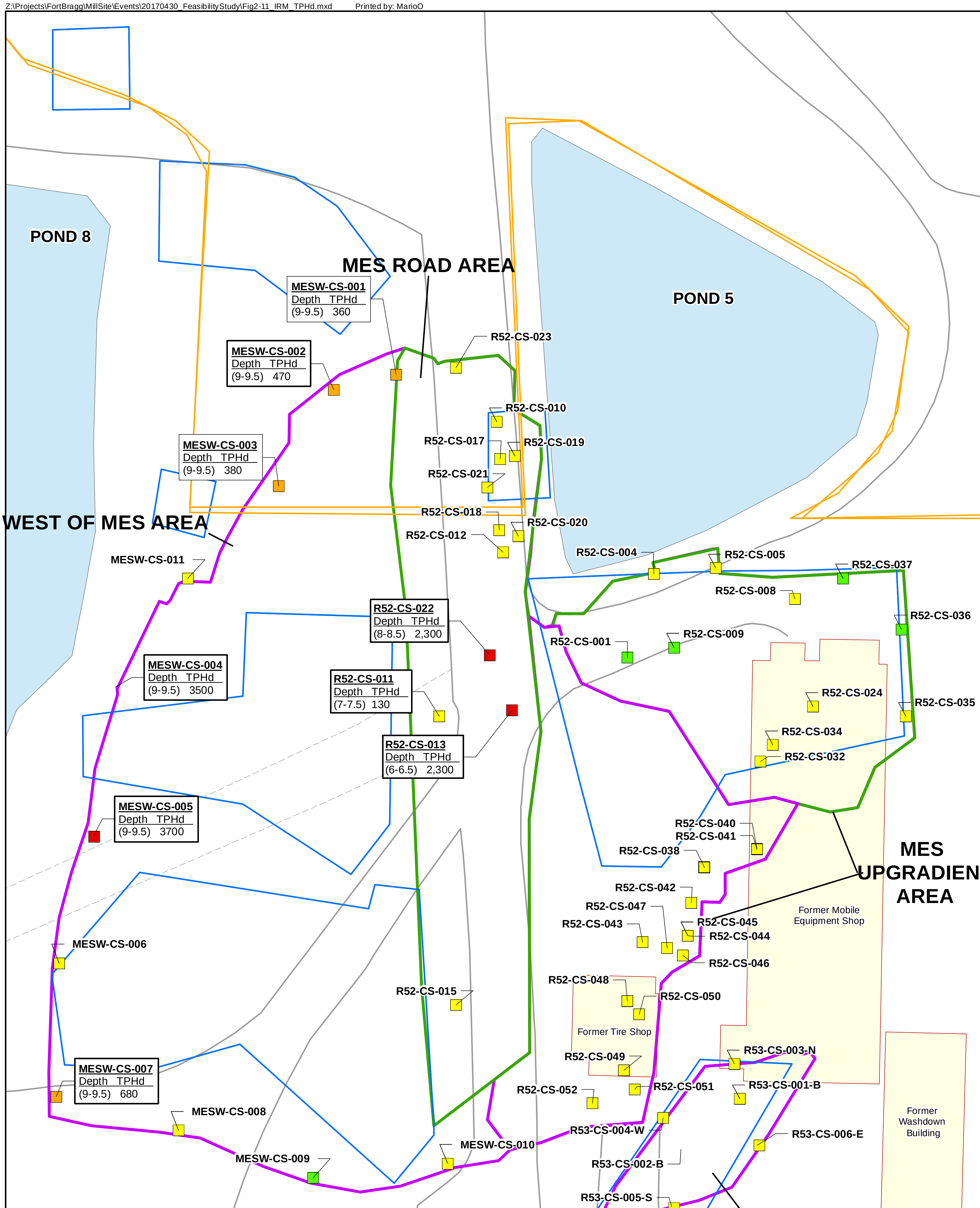

NOTES:

1. TPHd = PETROLEUM HYDROCARBONS AS DIESEL. CONCENTRATIONS ARE IN mg/kg (MILLIGRAMS PER KILOGRAM).
2. TPHd CONCENTRATIONS SCREENED AGAINST HIGHEST EXCEEDANCE OF RBSCs FOR THEIR RESPECTIVE FRACTIONS: C10-C12: 30 mg/kg; C12-C16: 90mg/kg; C16-C24: 191 mg/kg.
3. TEXT BOXES PRESENT C16-C24 SAMPLE CONCENTRATIONS (in mg/kg) THE C16-C24 DATA IS PRESENTED BECAUSE THIS FRACTION IS GENERALLY DRIVING SCREENING LEVEL EXCEEDANCES.
4. DEPTHS ARE IN FEET BELOW GROUND SURFACE.

Legend

- Not Detected
- Detected Below Screening Level
- Detected Above Screening Level
- Detected Above 10x Screening Level
- Former Rail Line
- Unpaved Roadway
- Paved Roadway
- OU Boundary
- Planned Excavation Area
- Surveyed 2008 Excavation Area
- Surveyed 2009 Excavation Area
- Former Structure
- Pond

MESW-CS-007 — Sample ID
Depth TPHd
(9-9.5) 680 — TPHd Concentration in (mg/kg); Depth in ft bgs

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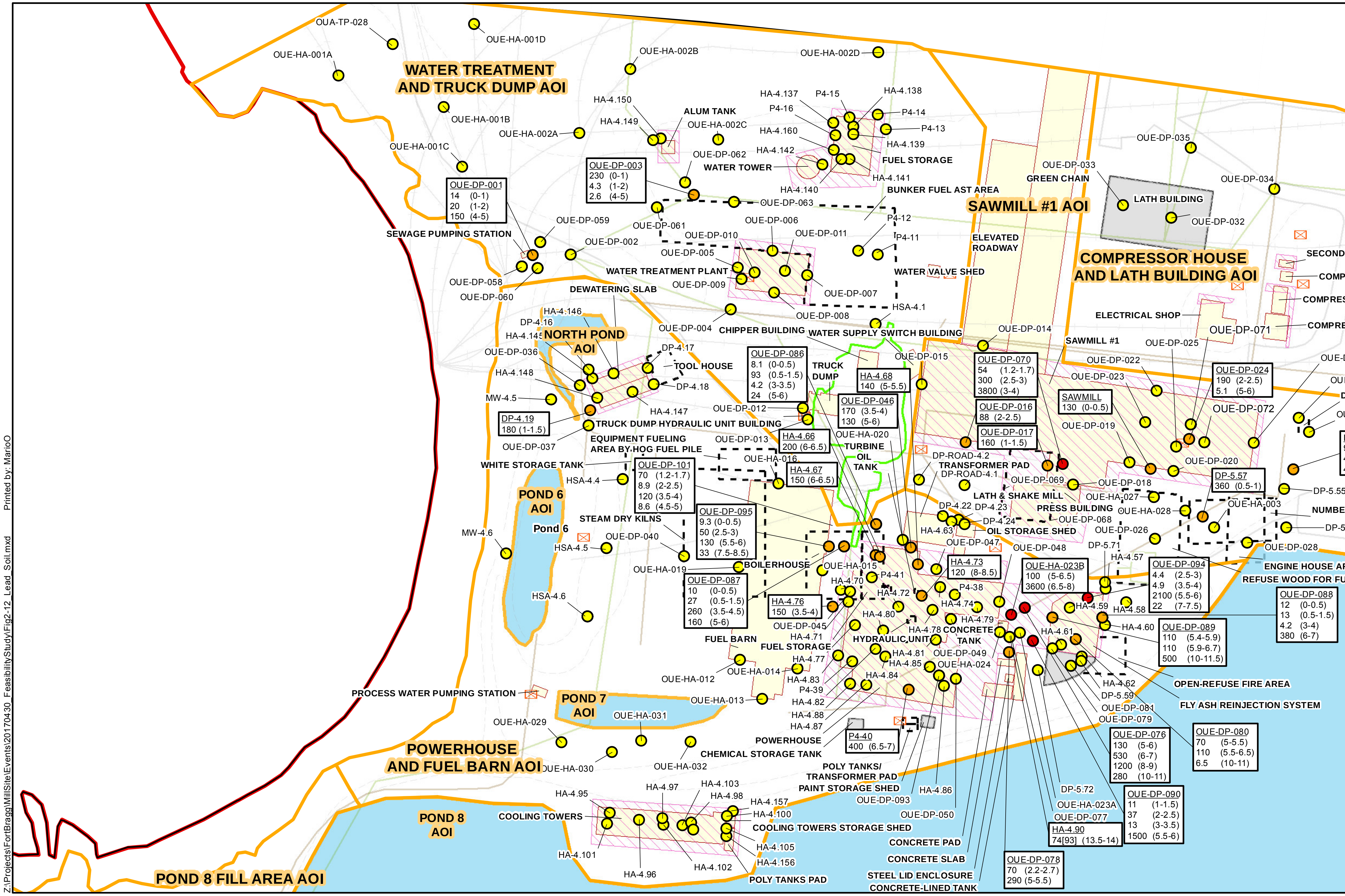
IRM and West of IRM Excavation Confirmation Samples - TPHd

1665018*16

Figure 2-11



NOTES:

1. LEAD CONCENTRATIONS SCREENED AGAINST CHHSLr VALUE OF 80 mg/kg.
2. DATA FOR EXCAVATED SAMPLES ARE NOT PRESENTED
3. DEPTHS PRESENTED AS FEET BELOW CURRENT SURFACE
4. RESULTS IN BRACKETS ARE FROM A DUPLICATE SAMPLE COLLECTED AT THE SAME LOCATION AS PARENT SAMPLE

ABBREVIATIONS:

AOC	AREAS OF CONCERN
AOI	AREA OF INTEREST
CHHSLr	CALIFORNIA HUMAN HEALTH SCREENING LEVEL (RESIDENTIAL)
mg/kg	MILLIGRAMS PER KILOGRAM
ft bgs	FEET BELOW GROUND SURFACE

Legend

- Not Detected
- Detected ≤ Screening Level
- Detected > Screening Level
- Detected > 10 X Screening Level
- Site Boundary
- OUE Boundary
- AOI Boundary
- Existing Structure
- Former Structure
- Former Structure - Foundation Intact
- Pond
- Fuel Line Excavation Boundary
- Approximate Cap Boundaries
- Former Industrial Use (Approximate Location)
- Former Transformer Location Approximate)
- Plant Drain System Line
- Sanitary Sewer Line
- Unpaved Roadway
- Paved Roadway
- Former Rail Lines

HA-4.68 — Sample ID
140 (5.5-6) — Depth (ft bgs); Lead Concentration in mg/kg

N

0 55 110
Scale: Feet

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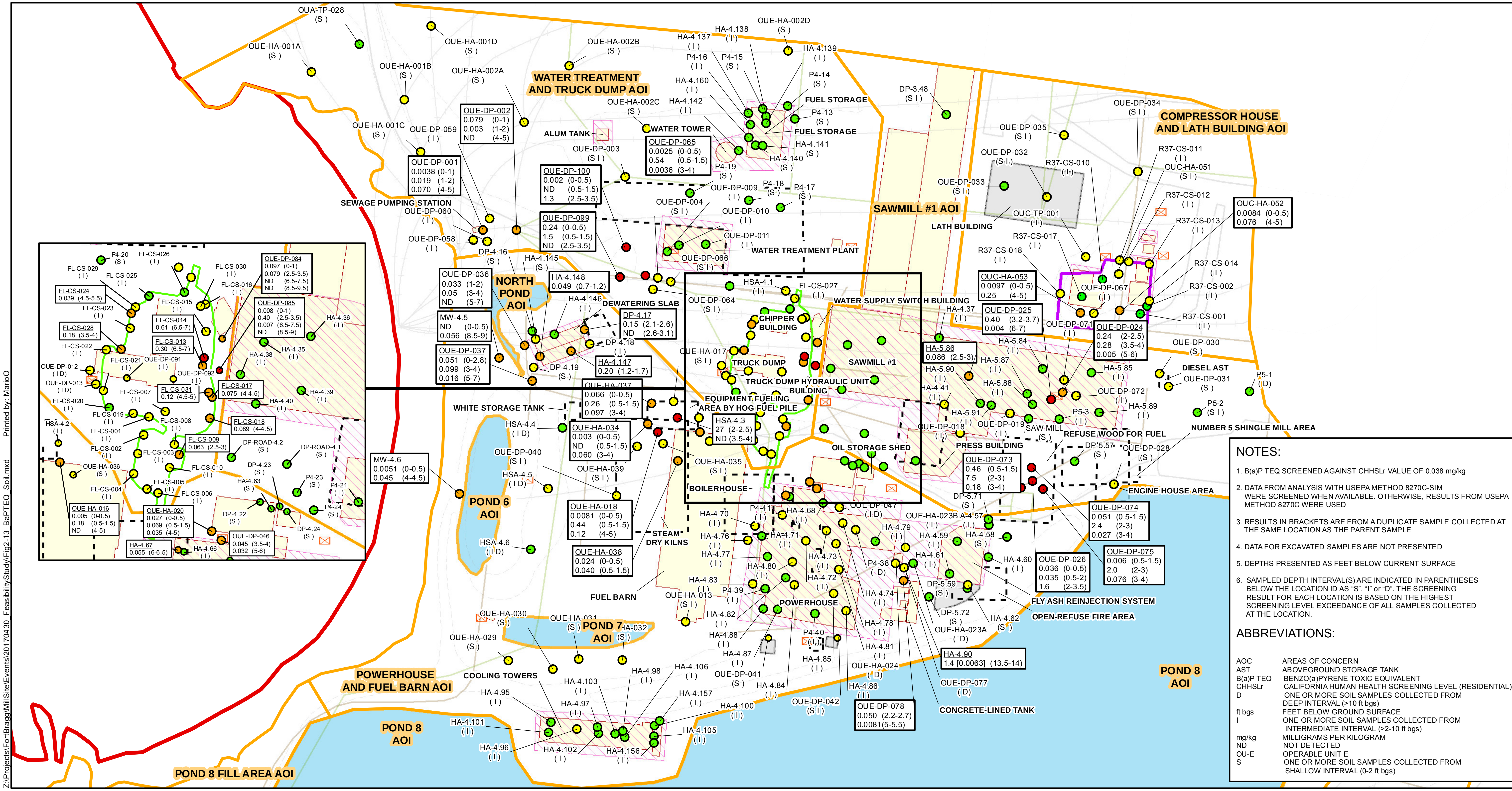
Lead Concentrations in Soil

1665018*16

Figure 2-12



Legend

- Not Detected
- Detected ≤ Screening Level
- Detected > Screening Level
- Detected > 10 X Screening Level
- Site Boundary
- OUE Boundary
- AOI Boundary
- Existing Structure
- Former Structure
- Former Structure - Foundation Intact
- Pond
- Compressor House Excavation Boundary
- Fuel Line Excavation Boundary
- Approximate Cap Boundaries
- Former Industrial Use (Approximate Location)
- Former Transformer Location (Approximate)
- Plant Drain System Line
- Sanitary Sewer Line
- Unpaved Roadway
- Paved Roadway
- Former Rail Lines

FL-CS-014 — Sample ID
0.61 (6.5 - 7) — Depth (ft bgs); B(a)P TEQ in mg/kg

N

0 55 110
Scale: Feet

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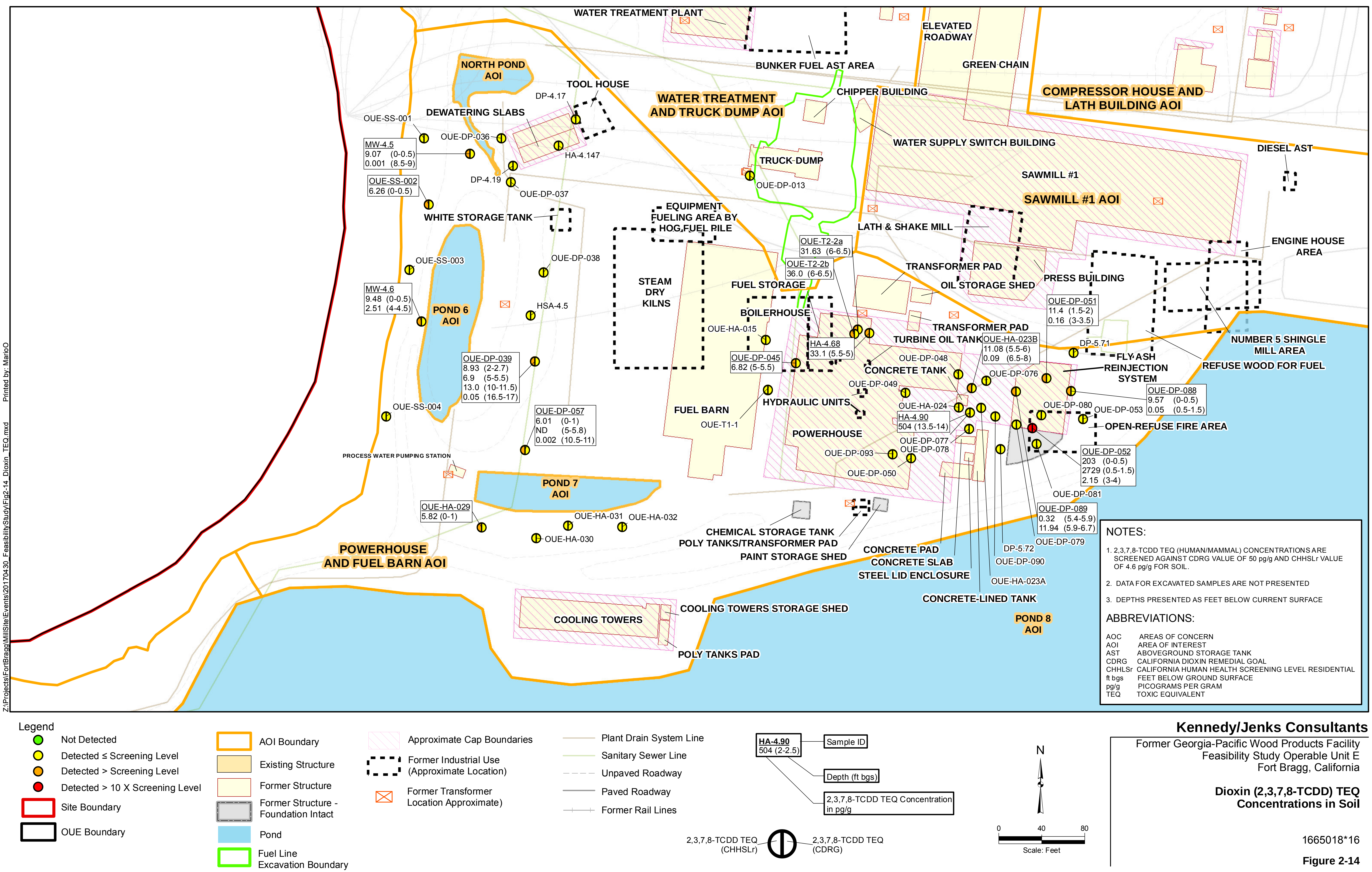
Feasibility Study Operable Unit E
Fort Bragg, California

B(a)P TEQ Concentrations in Soil

1665018*16

Figure 2-13



WATER TREATMENT PLANT
ELEVATED ROADWAY
BUNKER FUEL AST AREA
GREEN CHAIN
NORTH POND AOI
TOOL HOUSE
WATER TREATMENT AND TRUCK DUMP AOI
CHIPPER BUILDING
COMPRESSOR HOUSE AND LATH BUILDING AOI
DP-4.17
DEWATERING SLABS
OUE-SS-001
WATER SUPPLY SWITCH BUILDING
OUE-DP-036
DIESEL AST
MW-4.5
9.07 (0-0.5)
0.001 (8.5-9)
HA-4.147
TRUCK DUMP
SAWMILL #1
OUE-SS-002
6.26 (0-0.5)
DP-4.19
OUE-DP-013
OUE-DP-037
SAWMILL #1 AOI
WHITE STORAGE TANK
EQUIPMENT FUELING AREA BY HOG FUEL PILE
LATH & SHAKE MILL
OUE-T2-2a
31.63 (6-6.5)
ENGINE HOUSE AREA
OUE-SS-003
OUE-DP-038
OUE-T2-2b
36.0 (6-6.5)
TRANSFORMER PAD
STEAM DRY KILNS
FUEL STORAGE
OIL STORAGE SHED
PRESS BUILDING
MW-4.6
9.48 (0-0.5)
2.51 (4-4.5)
POND 6 AOI
HSA-4.5
BOILERHOUSE
OUE-DP-051
11.4 (1.5-2)
0.16 (3-3.5)
OUE-HA-015
TRANSFORMER PAD
HA-4.68
33.1 (5.5-5)
TURBINE OIL TANK
OUE-HA-023B
11.08 (5.5-6)
0.09 (6.5-8)
DP-5.71
NUMBER 5 SHINGLE MILL AREA
OUE-DP-039
8.93 (2-2.7)
6.9 (5-5.5)
13.0 (10-11.5)
0.05 (16.5-17)
OUE-DP-045
6.82 (5-5.5)
OUE-DP-048
FLY ASH REINJECTION SYSTEM
CONCRETE TANK
OUE-DP-076
REFUSE WOOD FOR FUEL
OUE-DP-049
OUE-DP-088
9.57 (0-0.5)
0.05 (0.5-1.5)
OUE-SS-004
HYDRAULIC UNITS
OUE-HA-024
OUE-DP-080
OUE-DP-053
FUEL BARN
OUE-DP-057
6.01 (0-1)
ND (5-5.8)
0.002 (10.5-11)
OUE-T1-1
HA-4.90
504 (13.5-14)
OPEN-REFUSE FIRE AREA
POWERHOUSE
OUE-DP-077
OUE-DP-078
PROCESS WATER PUMPING STATION
OUE-DP-093
OUE-DP-052
203 (0-0.5)
2729 (0.5-1.5)
2.15 (3-4)
OUE-DP-050
POND 7 AOI
OUE-DP-081
OUE-HA-029
5.82 (0-1)
OUE-HA-031
OUE-HA-032
OUE-DP-089
0.32 (5.4-5.9)
11.94 (5.9-6.7)
OUE-HA-030
CHEMICAL STORAGE TANK
POLY TANKS/TRANSFORMER PAD
OUE-DP-079
POWERHOUSE AND FUEL BARN AOI
PAINT STORAGE SHED
CONCRETE PAD
DP-5.72
CONCRETE SLAB
OUE-DP-090
STEEL LID ENCLOSURE
OUE-HA-023A
CONCRETE-LINED TANK
COOLING TOWERS STORAGE SHED
POND 8 AOI
COOLING TOWERS
POLY TANKS PAD
NOTES:
1. 2,3,7,8-TCDD TEQ (HUMAN/MAMMAL) CONCENTRATIONS ARE SCREENED AGAINST CDRG VALUE OF 50 pg/g AND CHHSLr VALUE OF 4.6 pg/g FOR SOIL.
2. DATA FOR EXCAVATED SAMPLES ARE NOT PRESENTED
3. DEPTHS PRESENTED AS FEET BELOW CURRENT SURFACE
ABBREVIATIONS:
AOC AREAS OF CONCERN
AOI AREA OF INTEREST
AST ABOVEGROUND STORAGE TANK
CDRG CALIFORNIA DIOXIN REMEDIAL GOAL
CHHSLr CALIFORNIA HUMAN HEALTH SCREENING LEVEL RESIDENTIAL
ft bgs FEET BELOW GROUND SURFACE
pg/g PICOGRAMS PER GRAM
TEQ TOXIC EQUIVALENT
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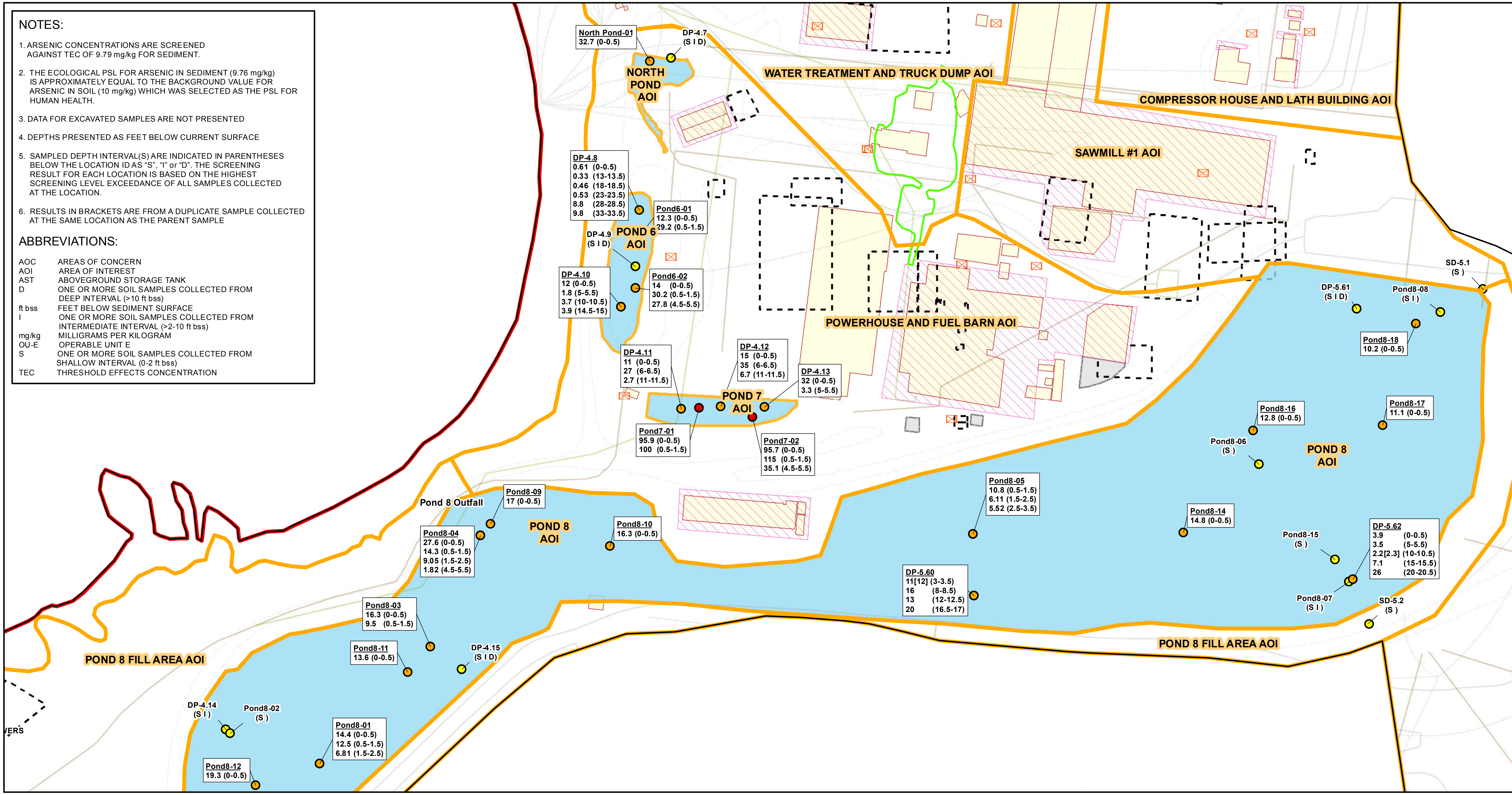
Legend
Not Detected
Detected ≤ Screening Level
Detected > Screening Level
Detected > 10 X Screening Level
Site Boundary
OUE Boundary
AOI Boundary
Existing Structure
Former Structure
Former Structure - Foundation Intact
Pond
Fuel Line Excavation Boundary
Approximate Cap Boundaries
Former Industrial Use (Approximate Location)
Former Transformer Location Approximate)
Plant Drain System Line
Sanitary Sewer Line
Unpaved Roadway
Paved Roadway
Former Rail Lines
HA-4.90
504 (2-2.5)
Sample ID
Depth (ft bgs)
2,3,7,8-TCDD TEQ Concentration in pg/g
2,3,7,8-TCDD TEQ (CHHSLr)
2,3,7,8-TCDD TEQ (CDRG)
N
0 40 80
Scale: Feet
Kennedy/Jenks Consultants
Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California
Dioxin (2,3,7,8-TCDD) TEQ Concentrations in Soil
1665018*16
Figure 2-14

NOTES:

1. ARSENIC CONCENTRATIONS ARE SCREENED AGAINST TEC OF 9.79 mg/kg FOR SEDIMENT.
2. THE ECOLOGICAL PSL FOR ARSENIC IN SEDIMENT (9.76 mg/kg) IS APPROXIMATELY EQUAL TO THE BACKGROUND VALUE FOR ARSENIC IN SOIL (10 mg/kg) WHICH WAS SELECTED AS THE PSL FOR HUMAN HEALTH.
3. DATA FOR EXCAVATED SAMPLES ARE NOT PRESENTED
4. DEPTHS PRESENTED AS FEET BELOW CURRENT SURFACE
5. SAMPLED DEPTH INTERVAL(S) ARE INDICATED IN PARENTHESES BELOW THE LOCATION ID AS "S", "I" or "D". THE SCREENING RESULT FOR EACH LOCATION IS BASED ON THE HIGHEST SCREENING LEVEL EXCEEDANCE OF ALL SAMPLES COLLECTED AT THE LOCATION.
6. RESULTS IN BRACKETS ARE FROM A DUPLICATE SAMPLE COLLECTED AT THE SAME LOCATION AS THE PARENT SAMPLE

ABBREVIATIONS:

AOC	AREAS OF CONCERN
AOI	AREA OF INTEREST
AST	ABOVEGROUND STORAGE TANK
D	ONE OR MORE SOIL SAMPLES COLLECTED FROM DEEP INTERVAL (>10 ft bss)
ft bss	FEET BELOW SEDIMENT SURFACE
I	ONE OR MORE SOIL SAMPLES COLLECTED FROM INTERMEDIATE INTERVAL (>2-10 ft bss)
mg/kg	MILLIGRAMS PER KILOGRAM
OU-E	OPERABLE UNIT E
S	ONE OR MORE SOIL SAMPLES COLLECTED FROM SHALLOW INTERVAL (0-2 ft bss)
TEC	THRESHOLD EFFECTS CONCENTRATION



Legend

- Not Detected
- Detected ≤ Screening Level
- Detected > Screening Level
- Detected > 10 X Screening Level
- Site Boundary
- OUE Boundary
- AOI Boundary
- Existing Structure
- Former Structure
- Former Structure - Foundation Intact
- Pond
- Fuel Line Excavation Boundary
- Approximate Cap Boundaries
- Former Industrial Use (Approximate Location)
- Former Transformer Location Approximate)
- Plant Drain System Line
- Sanitary Sewer Line
- Unpaved Roadway
- Paved Roadway
- Former Rail Lines

Pond8-14 14.8 (0-0.5) — Sample ID; Depth (ft bss); Arsenic Concentration in mg/kg

N

0 55 110 Scale: Feet

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Feasibility Study Operable Unit E
Fort Bragg, California

Arsenic Concentrations in Sediment – Ponds 6, 7, 8 and North Pond

1665018*16

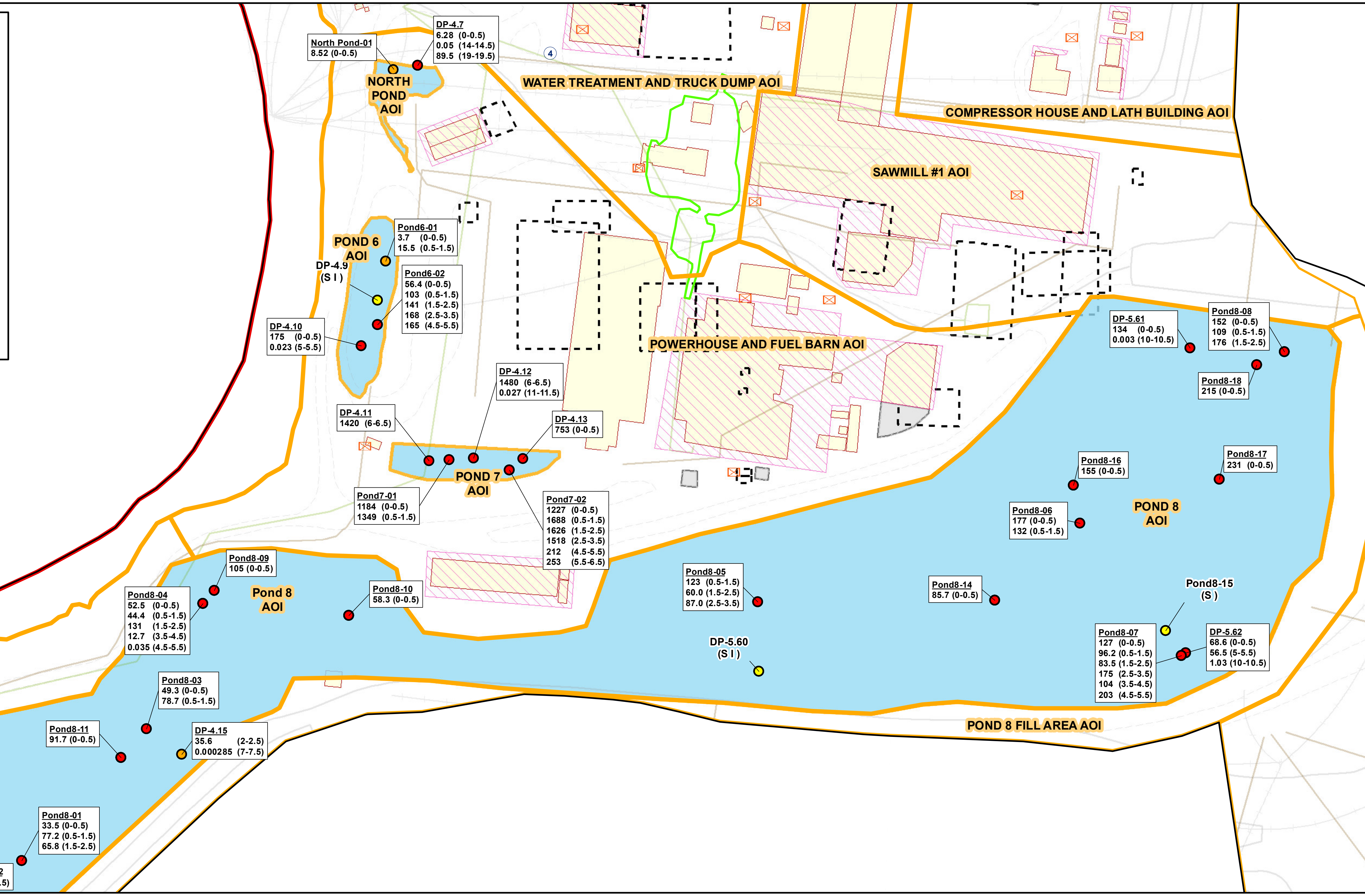
Figure 2-15

NOTES:

1. 2,3,7,8-TCDD TEQ (HUMAN/MAMMAL) CONCENTRATIONS ARE SCREENED AGAINST CHHSLr OF 4.6 pg/g FOR SEDIMENT.
2. DATA FOR EXCAVATED SAMPLES ARE NOT PRESENTED
3. DEPTHS PRESENTED AS FEET BELOW CURRENT SURFACE
4. SAMPLED DEPTH INTERVAL(S) ARE INDICATED IN PARENTHESES BELOW THE LOCATION ID AS "S", "I" or "D". THE SCREENING RESULT FOR EACH LOCATION IS BASED ON THE HIGHEST SCREENING LEVEL EXCEEDANCE OF ALL SAMPLES COLLECTED AT THE LOCATION.

ABBREVIATIONS:

AOI	AREA OF INTEREST
AST	ABOVEGROUND STORAGE TANK
CHHSLr	CALIFORNIA HUMAN HEALTH SCREENING LEVEL (RESIDENTIAL)
D	ONE OR MORE SOIL SAMPLES COLLECTED FROM DEEP INTERVAL (>10 ft bss)
ft bss	FEET BELOW SEDIMENT SURFACE
I	ONE OR MORE SOIL SAMPLES COLLECTED FROM INTERMEDIATE INTERVAL (>2-10 ft bss)
OU-E	OPERABLE UNIT E
pg/g	PICOGRAMS PER GRAM
S	ONE OR MORE SOIL SAMPLES COLLECTED FROM SHALLOW INTERVAL (0-2 ft bss)
TCDD	TETRACHLORODIBENZO- P- DIOXIN
TEQ	TOXIC EQUIVALENT



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Legend

- Not Detected
- Detected ≤ Screening Level
- Detected > Screening Level
- Detected > 10 X Screening Level
- Site Boundary
- OUE Boundary
- AOI Boundary
- Existing Structure
- Former Structure
- Former Structure - Foundation Intact
- Pond
- Fuel Line Excavation Boundary
- Approximate Cap Boundaries
- Former Industrial Use (Approximate Location)
- Former Transformer Location Approximate)
- Plant Drain System Line
- Sanitary Sewer Line
- Unpaved Roadway
- Paved Roadway
- Former Rail Lines

Pond8-14 — Sample ID
85.7 (0-0.5) — Depth (ft bss); 2,3,7,8-TCDD TEQ Concentration in pg/g

N

0 55 110
Scale: Feet

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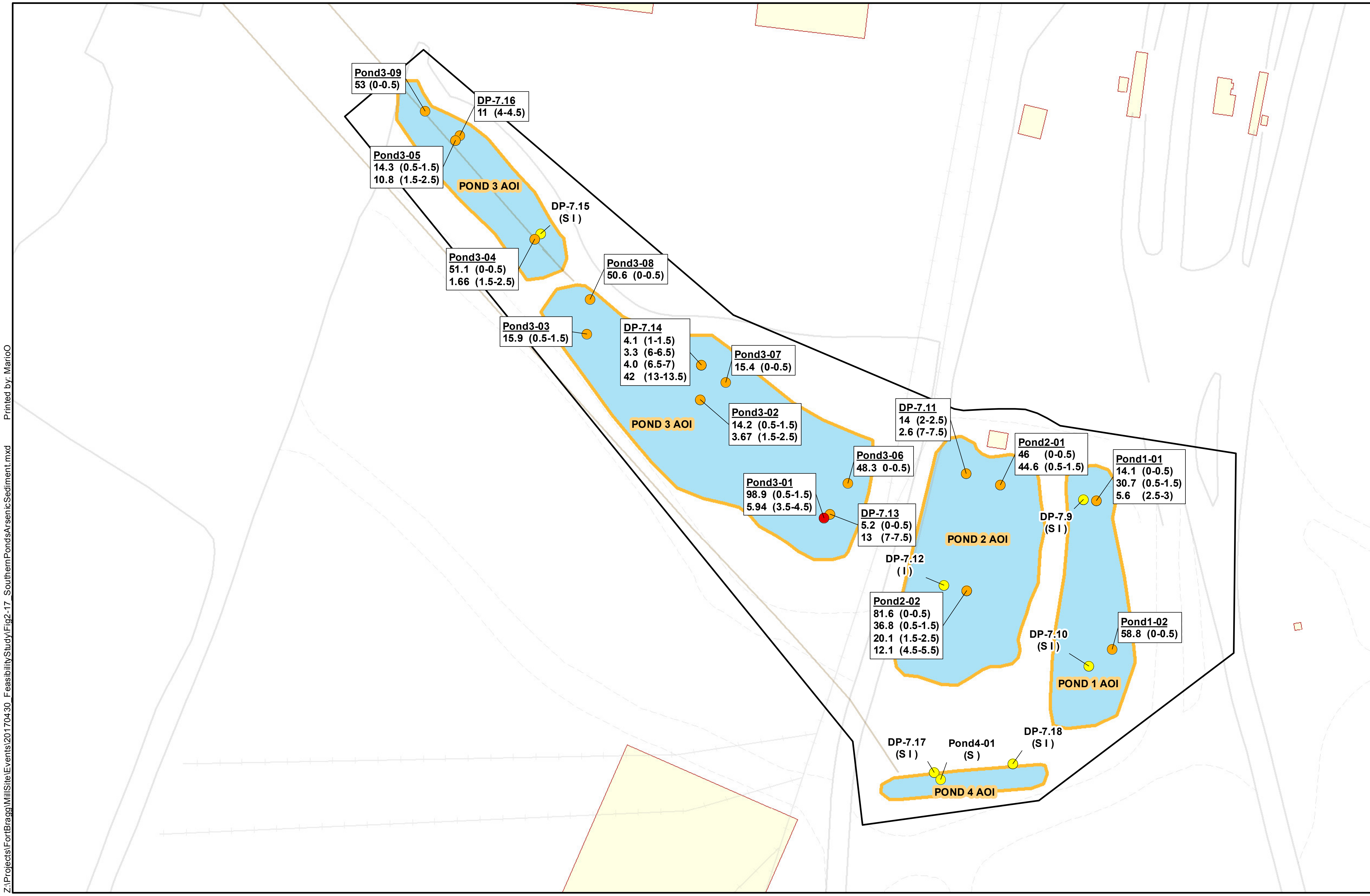
Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

Dioxin (2,3,7,8-TCDD) TEQ Concentrations in Sediment – Ponds 6, 7, 8 and North Pond

1665018*16

Figure 2-16



NOTES:

1. ARSENIC CONCENTRATIONS ARE SCREENED AGAINST TEC OF 9.79 mg/kg FOR SEDIMENT.
2. THE ECOLOGICAL PSL FOR ARSENIC IN SEDIMENT (9.76 mg/kg) IS APPROXIMATELY EQUAL TO THE BACKGROUND VALUE FOR ARSENIC IN SOIL (10 mg/kg) WHICH WAS SELECTED AS THE PSL FOR HUMAN HEALTH.
3. DATA FOR EXCAVATED SAMPLES ARE NOT PRESENTED
4. DEPTHS PRESENTED AS FEET BELOW CURRENT SURFACE
5. SAMPLED DEPTH INTERVAL(S) ARE INDICATED IN PARENTHESES BELOW THE LOCATION ID AS "S", "I" or "D". THE SCREENING RESULT FOR EACH LOCATION IS BASED ON THE HIGHEST SCREENING LEVEL EXCEEDANCE OF ALL SAMPLES COLLECTED AT THE LOCATION.

ABBREVIATIONS:

AOI	AREA OF INTEREST
D	ONE OR MORE SOIL SAMPLES COLLECTED FROM DEEP INTERVAL (>10 ft bss)
ft bss	FEET BELOW SEDIMENT SURFACE
I	ONE OR MORE SOIL SAMPLES COLLECTED FROM INTERMEDIATE INTERVAL (>2-10 ft bss)
mg/kg	MILLIGRAM PER KILOGRAM
OU-E	OPERABLE UNIT E
S	ONE OR MORE SOIL SAMPLES COLLECTED FROM SHALLOW INTERVAL (0-2 ft bss)
TEC	THRESHOLD EFFECTS CONCENTRATION

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Legend

- Not Detected
- Detected ≤ Screening Level
- Detected > Screening Level
- Detected > 10 X Screening Level
- AOI Boundary
- Existing Structure
- Former Structure
- OUE Boundary
- Pond
- Plant Drain System Line
- Sanitary Sewer Line
- Unpaved Roadway
- Paved Roadway
- Former Rail Lines

Pond1-02 — Sample ID
58.8 (0-0.5) — Depth (ft bss); Arsenic Concentration in mg/kg

N

0 55 110
Scale: Feet

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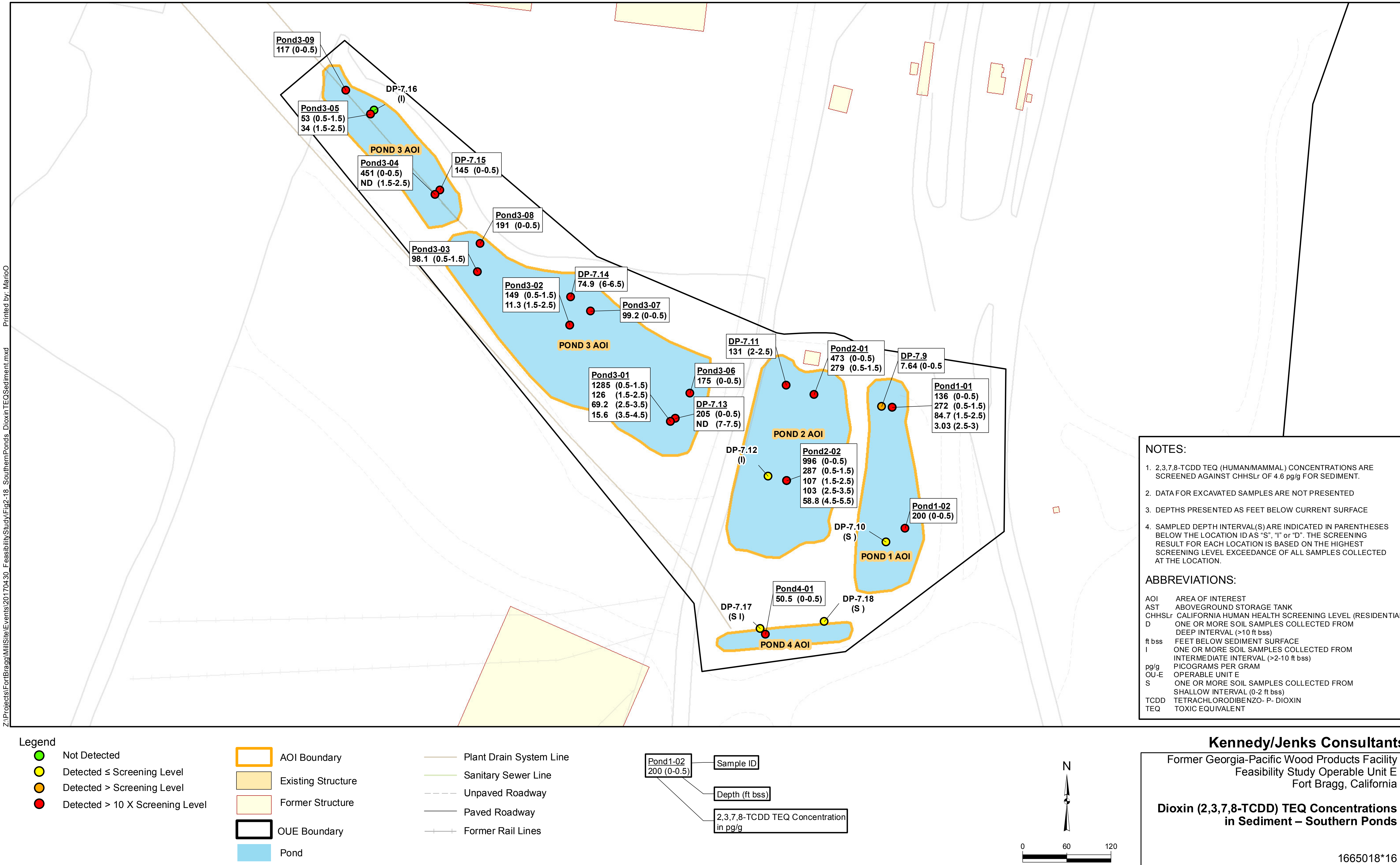
Feasibility Study Operable Unit E
Fort Bragg, California

Arsenic Concentrations in Sediment – Southern Ponds

1665018*16

Figure 2-17



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Feasibility Study Operable Unit E
Fort Bragg, California

Dioxin (2,3,7,8-TCDD) TEQ Concentrations in Sediment – Southern Ponds

1665018*16

Figure 2-18

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Legend

Sample Locations

- Porewater Analyses
- PAH and Black Carbon Analyses
- Arsenic speciation
- SITE BOUNDARY
- OU-E BOUNDARY
- POND

NOTE:
TOTAL ORGANIC CARBON, GRAIN SIZE, pH, DISSOLVED OXYGEN, TEMPERATURE AND OXIDATION/REDUCTION POTENTIAL WAS COLLECTED FROM ALL SAMPLING LOCATIONS.

ACRONYM:
OU-E OPERABLE UNIT E

N

0 60 120
Scale: Feet

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Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

BHHERA Sampling Locations – Ponds 6, 7, 8 and North Pond

1665018*16

Figure 2-19

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Legend

Sample Locations

Porewater Analyses

SITE BOUNDARY

OU-E BOUNDARY

POND

NOTES:
TOTAL ORGANIC CARBON, GRAIN SIZE, pH, DISSOLVED OXYGEN, TEMPERATURE AND OXIDATION/REDUCTION POTENTIAL WAS COLLECTED FROM ALL SAMPLING LOCATIONS.

THE LOCATION OF POND 9-01 IS APPROXIMATE

ACRONYM:
OU-E OPERABLE UNIT E

N

0 175 350
Scale: Feet

Kennedy/Jenks Consultants

Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

BHHERA Sampling Locations – Ponds 5 and 9

1665018*16

Figure 2-20

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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Legend

Sample Locations

- Porewater Analyses
- PAH and Black Carbon Analyses
- Arsenic speciation
- OU-E BOUNDARY
- POND

NOTE:
TOTAL ORGANIC CARBON, GRAIN SIZE, pH, DISSOLVED OXYGEN, TEMPERATURE AND OXIDATION/REDUCTION POTENTIAL WAS COLLECTED FROM ALL SAMPLING LOCATIONS.

ACRONYM:
OU-E OPERABLE UNIT E

N

0 60 120
Scale: Feet

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Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

BHHERA Sampling Locations – Southern Ponds

1665018*16

Figure 2-21

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Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA,

Legend

Sample Locations

- Porewater Analyses
- PAH and Black Carbon Analyses

- Site Boundary
- Pond
- Structure
- Riparian Area
- Riparian Wetland
- Seasonal Wetland Ditch

NOTE:
TOTAL ORGANIC CARBON, GRAIN SIZE, pH, DISSOLVED OXYGEN, TEMPERATURE AND OXIDATION/REDUCTION POTENTIAL WAS COLLECTED FROM ALL SAMPLING LOCATIONS.

N

0 75 150

Scale: Feet

Kennedy/Jenks Consultants

Former Georgia-Pacific Wood Products Facility
Feasibility Study Operable Unit E
Fort Bragg, California

BHHERA Sampling Locations – Riparian

1665018*16

Figure 2-22

OU-E Terrestrial

Potential Exposure Media	Exposure Media	EXPOSURE PATHWAY(S)	Potential Human Receptors: Maintenance/Utility/ Trench Worker	Construction Worker	Commercial/industrial Worker	Passive Adult/Child Recreator	Frequent Adult Recreator	Potential Ecological Receptors: Plants	Soil inverts	Birds	Mammals
Surface and Subsurface Soil	Future Surface Soil (0 to 0.5 or 0 to 2 ft bgs)	Ingestion	✔	✔	✔	✔	✔			✔	✔
		Dermal/Direct Contact	✔	✔	✔	✔	✔	✔	✔	✔*	✔*
		Food/Prey Items								✔	✔
	Airborne Soil Particulates	Inhalation	✔	✔	✔	✔	✔			✔*	✔*
	Future Subsurface Soil* (to 6 or 10 ft bgs)	Ingestion	✔	✔	✔						✔
		Dermal/Direct Contact	✔	✔	✔			✔			✔*
		Food/Prey Items								✔	✔
Leaching from Soil to Groundwater	Airborne Vapors	Inhalation	✔*	✔*	✔*	✔*	✔*			✔*	✔*
	Groundwater	Ingestion									
		Dermal/Direct Contact	✔	✔				✔			

Notes:

—·→ Potentially complete pathway if VOCs are identified as

✔ Potentially complete exposure pathwa

✔* Potentially complete but likely insignficant pathway

(yellow) Additional receptor from those approved in the June 2008 *Site-Wide Risk Assessment Work Plan* (submitted by ARCADIS on behalf of Georgia-Pacific), included in order to assess the potential use of the site as a commerical property.

COPC = chemical of potential concern
ft bgs = feet below ground surface
OU = operable unit
VOC = volatile organic compounds

* Note that where depth of groundwater is shallow, exposure depths will be llmited to 2 feet below the groundwater table.

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Fort Bragg, California

Lowland Terrestrial Conceptual Site Model

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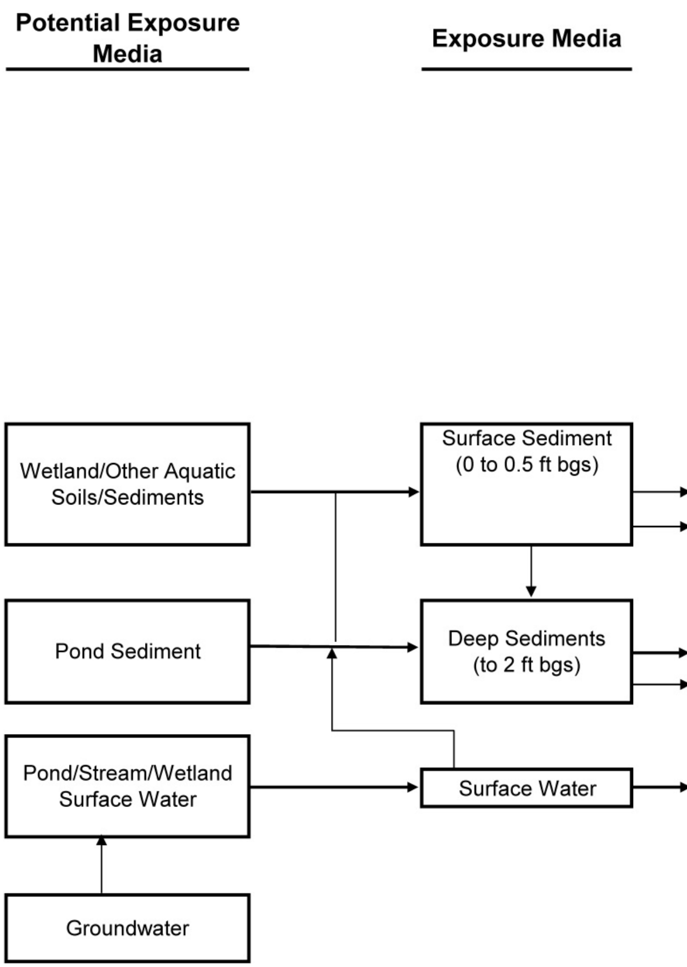
Figure 2-23



OU-E Wetland/Aquatic

Exposure Media	EXPOSURE PATHWAY(S)	Potential Human Receptor: Passive Adult/Child Recreator [a]	Potential Ecological Receptors: Aquatic Plants	Benthic inverts	Amphibians	Birds	Mammals
Surface Sediment (0 to 0.5 ft bgs)	Ingestion	✔			✔	✔	✔
	Dermal/Direct Contact	✔	✔	✔	✔	✔*	✔*
	Food/Prey Items				✔	✔	✔
Deep Sediments (to 2 ft bgs)	Ingestion						✔
	Dermal/Direct Contact		✔				✔*
	Food/Prey Items					✔	✔
Surface Water	Ingestion				✔	✔	✔
	Dermal/Direct Contact	✔	✔	✔	✔	✔*	✔*

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Feasibility Study Operable Unit E
Fort Bragg, California

Notes:

✔ Potentially complete exposure pathway

✔* Potentially complete but likely insignficant pathway

COPC = chemical of potential concern

ft bgs = feet below ground surface

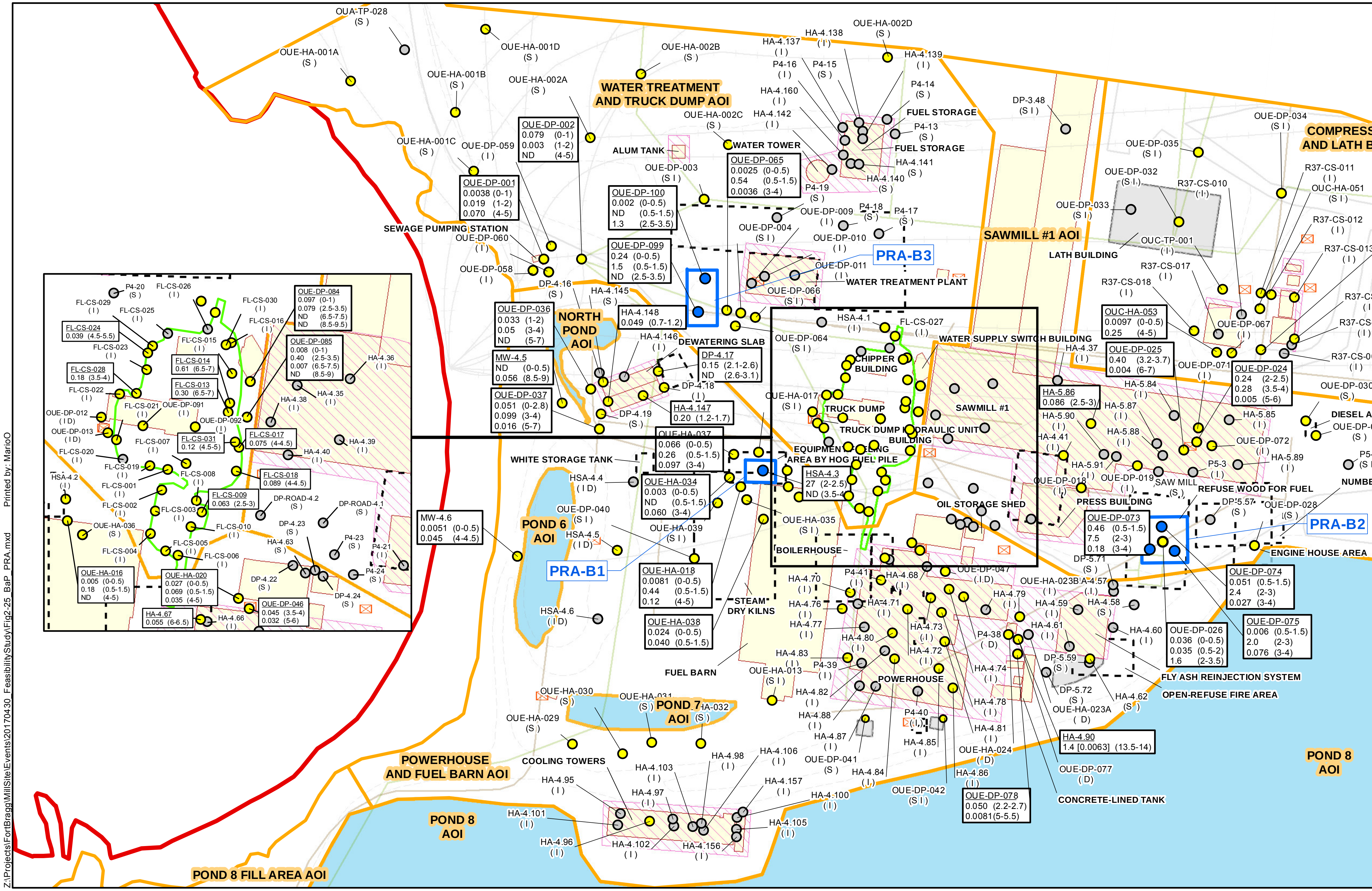
OU = operable unit

[a] Recreators are unlikely to be frequently exposed to surface water and sediment but this pathway will be quantitatively evaluated to be protective.

Aquatic Area Conceptual Site Model

1665018*16

Figure 2-24



NOTES:

1. B(a)P-TEQ PRAs WERE IDENTIFIED AS SAMPLES WITH CONCENTRATIONS GREATER THAN 0.9 mg/kg
2. RESULTS IN BRACKETS ARE FROM A DUPLICATE SAMPLE COLLECTED AT THE SAME LOCATION AS THE PARENT SAMPLE
3. DATA FOR EXCAVATED SAMPLES ARE NOT PRESENTED
4. DEPTHS PRESENTED AS FEET BELOW CURRENT SURFACE
5. SAMPLED DEPTH INTERVAL(S) ARE INDICATED IN PARENTHESES BELOW THE LOCATION ID AS "S", "I" or "D". THE SCREENING RESULT FOR EACH LOCATION IS BASED ON THE HIGHEST SCREENING LEVEL EXCEEDANCE OF ALL SAMPLES COLLECTED AT THE LOCATION.

ABBREVIATIONS:

AOC	AREAS OF CONCERN
AST	ABOVEGROUND STORAGE TANK
B(a)P TEQ	BENZO(A)PYRENE TOXIC EQUIVALENT
D	ONE OR MORE SOIL SAMPLES COLLECTED FROM DEEP INTERVAL (>10 ft bgs)
ft bgs	FEET BELOW GROUND SURFACE
I	ONE OR MORE SOIL SAMPLES COLLECTED FROM INTERMEDIATE INTERVAL (>2-10 ft bgs)
mg/kg	MILLIGRAMS PER KILOGRAM
ND	NOT DETECTED
OU-E	OPERABLE UNIT E
PRA	PRESUMPTIVE REMEDY AREA
S	ONE OR MORE SOIL SAMPLES COLLECTED FROM SHALLOW INTERVAL (0-2 ft bgs)

LEGEND:

- NOT DETECTED
- DETECTED
- HOT SPOT SAMPLE LOCATION
- PRESUMPTIVE REMEDY AREA
- SITE BOUNDARY
- OU-E BOUNDARY
- AOI BOUNDARY
- EXISTING STRUCTURE
- FORMER STRUCTURE
- FORMER STRUCTURE - FOUNDATION INTACT
- POND
- COMPRESSOR HOUSE EXCAVATION BOUNDARY
- FUEL LINE EXCAVATION BOUNDARY
- APPROXIMATE CAP BOUNDARIES
- FORMER INDUSTRIAL USE (APPROXIMATE LOCATION)
- PLANT DRAIN SYSTEM LINE
- SANITARY SEWER LINE
- UNPAVED ROADWAY
- PAVED ROADWAY
- FORMER RAIL LINES
- FORMER TRANSFORMER LOCATION (APPROXIMATE)

FL-CS-014
0.61 (6.5 - 7)

Sample ID
Depth (ft bgs)
B(a)P TEQ in mg/kg

N

0 55 110
Scale: Feet

Z:\Projects\FortBragg\MillSite\Events\20170430_FeasibilityStudy\Fig2-25_BaP_PRA.mxd Printed by: MarioO

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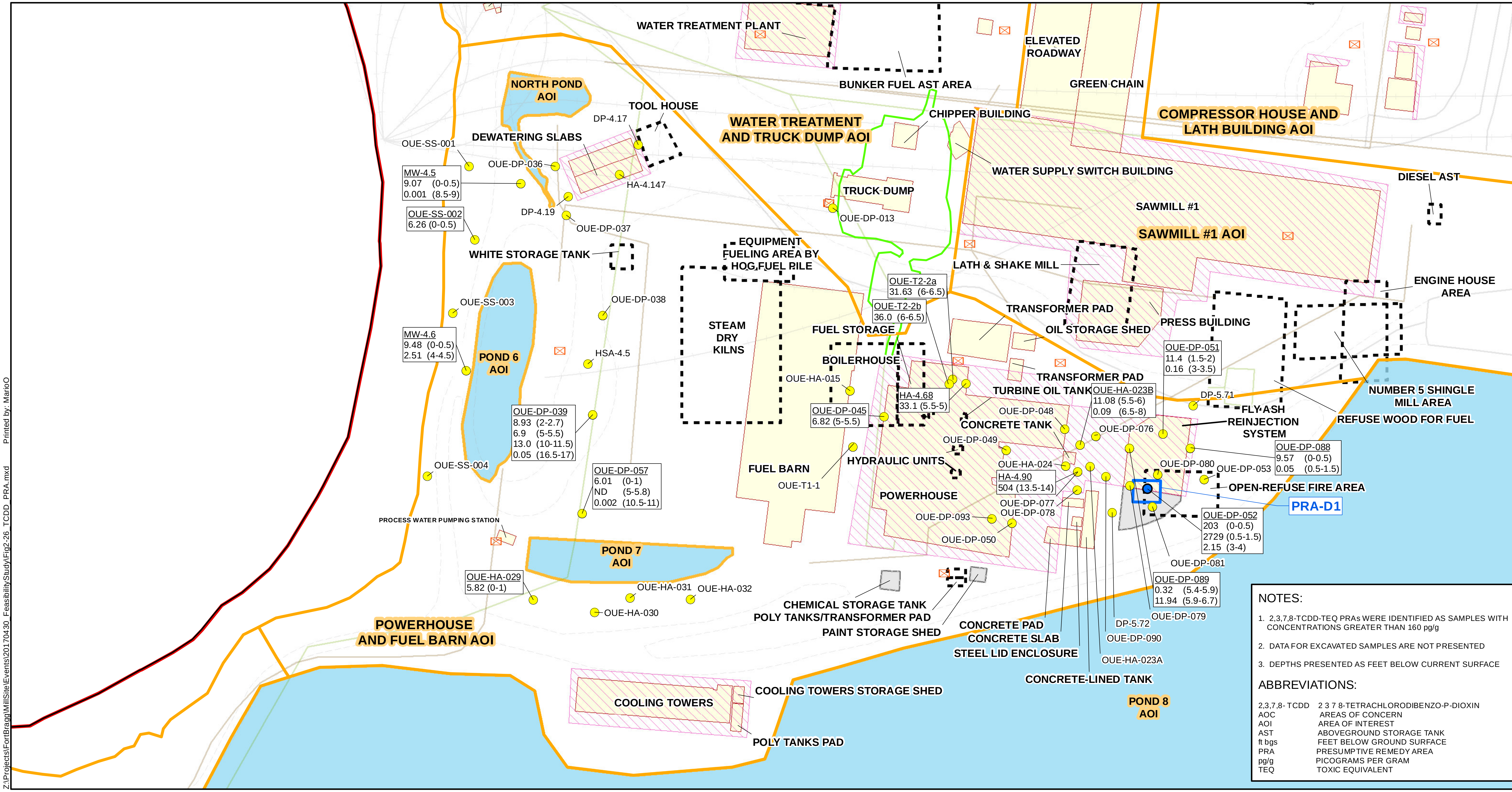
B(a)P TEQ Presumptive Remedy Areas

1665018*16

Figure 2-25



Legend

- Not Detected
- Detected
- Hot Spot Sample Location
- Site Boundary
- OUE Boundary
- Presumptive Remedy Area
- AOI Boundary
- Existing Structure
- Former Structure
- Former Structure - Foundation Intact
- Pond
- Fuel Line Excavation Boundary
- Approximate Cap Boundaries
- Former Industrial Use (Approximate Location)
- Former Transformer Location Approximate)
- Plant Drain System Line
- Sanitary Sewer Line
- Unpaved Roadway
- Paved Roadway
- Former Rail Lines

HA-4.90 — Sample ID
504 (2-2.5) — Depth (ft bgs); 2,3,7,8-TCDD TEQ Concentration in pg/g

N

0 40 80
Scale: Feet

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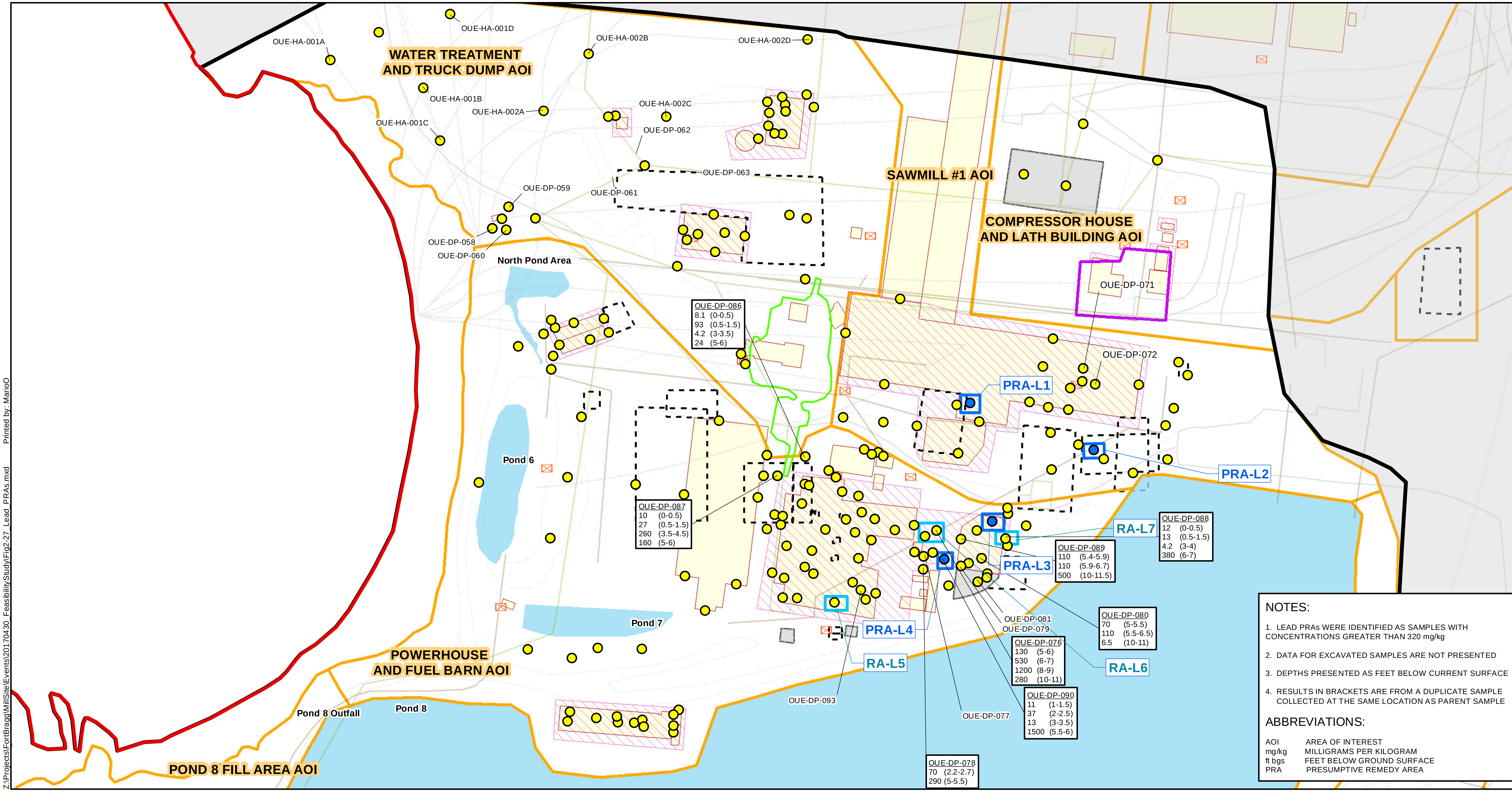
Feasibility Study Operable Unit E
Fort Bragg, California

Dioxin (2,3,7,8-TCDD) TEQ Presumptive Remedy Area

1665018*16

Figure 2-26



Legend

- Not Detected
- Detected
- Hot Spot Sample Location
- Site Boundary
- OUE Boundary
- Presumptive Remedy Area
- AOI Boundary
- Existing Structure
- Former Structure
- Former Structure - Foundation Intact
- Pond
- Fuel Line Excavation Boundary
- Approximate Cap Boundaries
- Former Industrial Use (Approximate Location)
- Former Transformer Location Approximate)
- Additional Removal Areas above Not To Exceed Value
- Plant Drain System Line
- Sanitary Sewer Line
- Unpaved Roadway
- Paved Roadway
- Former Rail Lines

HA-4.68 — Sample ID
140 (5.5-6) — Depth (ft bgs); Lead Concentration in mg/kg

N

0 55 110
Scale: Feet

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Feasibility Study Operable Unit E
Fort Bragg, California

Lead Presumptive Remedy Areas

1665018*16

Figure 2-27

Appendix A
Cost Summary Table - Sediment Remediation Alternatives

Feasibility Study - Operable Unit E
Former Georgia Pacific Wood Products Facility
Fort Bragg, California

Sediment Remediation Alternatives

	North Pond and Pond 6 AOC				**Pond 8 AOC**			
Nature and Extent	**● Arsenic, Dioxin TEQ ● 3,000 sf (North Pond); 7,000 sf (Pond 6) ● 1,800 cy to depth of 5 feet**				**● Dioxin TEQ ● 280,000 sf ● 106,000 cy average depth ~10 ft**			
Remediation Alternative Cost Estimates and Assumptions	**Quantity [1.]**	**Units**	**Unit Rate**	**NPV Cost**	**Quantity [1.]**	**Units**	**Unit Rate**	**NPV Cost**
No Action	**No Action**				**No Action**			
Assumptions:	No remediation activities required				No remediation activities required			
Total Cost				**$ -**				**$ -**
Institutional Controls	**Institutional Controls**				**Institutional Controls**			
Assumptions:	Deed restriction, survey, SMP				Containment, deed restriction, survey, SMP [2.]			
Delineation and survey	1	Lump Sum	$ 10,000	$ 10,000	1	Lump Sum	$ 10,000	$ 10,000
Reporting	1	Lump Sum	$ 50,000	$ 50,000	1	Lump Sum	$ 50,000	$ 50,000
Deed Restriction	1	Lump Sum	$ 20,000	$ 20,000	1	Lump Sum	$ 20,000	$ 20,000
Soil Management Plan	1	Lump Sum	$ 40,000	$ 40,000	1	Lump Sum	$ 40,000	$ 40,000
Total Cost				**$ 120,000**				**$ 120,000**
Vegetative Cover	**Vegetative Cover**				**Vegetative Cover**			
Assumptions:	10,000 sf vegetative cover 2 feet thick, restoration of 0.75 acres as wet meadow				280,000 sf vegetative cover 2 feet thick, restoration of 19 acres with creek restoration			
Design, preparation and oversight (10% of Construction)	1	Lump Sum	$ 22,000	$ 22,000	1	Lump Sum	$ 732,000	$ 732,000
Permitting	1	Lump Sum	$ 50,000	$ 50,000	1	Lump Sum	$ 150,000	$ 150,000
Mobilization/Demobilization	1	Lump Sum	$ 50,000	$ 50,000	1	Lump Sum	$ 120,000	$ 120,000
Installation of Cover	740	Cubic Yards	$ 60	$ 44,400	21,000	Cubic Yards	$ 60	$ 1,260,000
Annual Maintenance (10% cover replacement annually)	30	Years (NPV)	$ 4,500	$ 56,000	30	Years (NPV)	$ 126,000	$ 1,564,000
Restoration	0.75	Acres	$ 80,000	$ 60,000	19	Acres	$ 230,000	$ 4,370,000
Reporting	1	Lump Sum	$ 50,000	$ 50,000	1	Lump Sum	$ 50,000	$ 50,000
Deed Restriction	1	Lump Sum	$ 20,000	$ 20,000	1	Lump Sum	$ 20,000	$ 20,000
Soil Management Plan	1	Lump Sum	$ 40,000	$ 40,000	1	Lump Sum	$ 40,000	$ 40,000
Total Cost				**$ 392,400**				**$ 8,306,000**
Excavation and Disposal	**Excavation and Disposal**				**Excavation and Disposal**			
Assumptions:	Excavation and offsite disposal of 1,800 cy, restoration mitigation of 0.75 acres as wet meadow				Excavation and offsite disposal of 106,000 cy, restoration mitigation of 19 acres as stream restoration [2.]			
Design, preparation and oversight (10% of Construction)	1	Lump Sum	$ 14,000	$ 14,000	1	Lump Sum	$ 608,000	$ 608,000
Permitting	1	Lump Sum	$ 50,000	$ 50,000	1	Lump Sum	$ 150,000	$ 150,000
Mobilization/Demobilization	1	Lump Sum	$ 50,000	$ 50,000	1	Lump Sum	$ 120,000	$ 120,000
Excavation	1,800	Cubic Yards	$ 15	$ 27,000	106,000	Cubic Yards	$ 15	$ 1,590,000
Transportation and Disposal (Class 2 Non-Hazardous)	2,700	Tons	$ 65	$ 175,500	159,000	Tons	$ 65	$ 10,335,000
Restoration	0.75	Acres	$ 80,000	$ 60,000	19	Acres	$ 230,000	$ 4,370,000
Reporting	1	Lump Sum	$ 50,000	$ 50,000	1	Lump Sum	$ 50,000	$ 50,000
Total Cost				**$ 426,500**				**$ 17,223,000**
In-situ Soil Mixing					**In-situ Soil Mixing**			
Assumptions:					106,000 cy in-situ soil mixing, restoration of 19 acres with creek restoration			
Design, preparation and oversight (10% of Construction)					1	Lump Sum	$ 1,038,000	$ 1,038,000
Permitting					1	Lump Sum	$ 150,000	$ 150,000
Mobilization/Demobilization					1	Lump Sum	$ 175,000	$ 175,000
In-situ Soil Mixing					106,000	Cubic Yards	$ 55	$ 5,830,000
Restoration					19	Acres	$ 230,000	$ 4,370,000
Reporting					1	Lump Sum	$ 50,000	$ 50,000
Deed Restriction					1	Lump Sum	$ 20,000	$ 20,000
Soil Management Plan					1	Lump Sum	$ 40,000	$ 40,000
Total Cost								**$ 11,673,000**

Notes:

1. Area and volume estimates were based on available AOC data. Most probable estimates of affected areas were utilized for costing; however, actual costs may increase/decrease based on further characterization efforts. Costs are assumed to be within the -30%, +50% range.

2. Costs do not include modification of the Mill Pond Dam described as part of this alternative.

AOC = area of concern
cy = cubic yards
sf = square feet
SMP = soil management plan
TEQ = toxic equivalency factor

Appendix A
Cost Summary Table - Groundwater Remediation Alternatives

Feasibility Study - Operable Unit E
Former Georgia Pacific Wood Products Facility
Fort Bragg, California

		IRM and West of IRM AOC		Lowland AOC	
	Nature and Extent	• Fuel-related constituents • 20,000 sf impacted groundwater aerial extent • <15 foot depth interval		• Barium • 20,000 sf impacted groundwater aerial extent • <30 foot depth interval	
	Remediation Alternative Cost Estimates and Assumptions	Number of Years	NPV Cost	Number of Years	NPV Cost
Groundwater Remediation Alternatives	**No Action**				
	Assumptions:	No remediation activities required		No remediation activities required	
	Net Present Value		**$ -**		**$ -**
	Restricted Use				
	Assumptions:	Additional delineation, deed restriction, survey and risk management plan		Additional delineation, deed restriction, survey and risk management plan	
	Delineation and survey, deed restriction	1	$ 26,000	1	$ 26,000
	Risk management plan	1	$ 39,000	1	$ 39,000
	Net Present Value		**$ 65,000**		**$ 65,000**
	Monitored Natural Attenuation				
	Assumptions:	Monitoring/reporting for 5 wells every 5 years for 30 years (5 events $4,000 each), NPV		Monitoring/reporting for 1 well every 5 years for 30 years (5 events $1,000 each), NPV	
	Semi-annual monitoring cost	30	$ 12,000	30	$ 3,000
	Delineation and survey, deed restriction	1	$ 26,000	1	$ 26,000
	Net Present Value		**$ 38,000**		**$ 29,000**
	Air Sparge/SVE				
	Assumptions:	Operation for 30 years, 3 total vapor extraction wells, 5 air sparge wells, vapor phase granulated activated carbon, $10,000 per quarter O&M, NPV			
	Well network and vapor pilot testing	1	$ 140,000		
	Design and system installation	1	$ 500,000		
	Deed restriction	1	$ 15,000		
	System Operation and Maintenance	30	$ 496,000		
	Performance monitoring	30	$ 45,000		
	System Decommissioning	1	$ 50,000		
	Net Present Value		**$ 1,196,000**		
	Enhanced Aerobic Bioremediation: 2 Events + MNA				
	Assumptions:	Injection of Calcium Peroxide, 2 events, 25% well coverage, 10 years MNA			
	Design, coordination, preparation, well installation	1	$ 80,000		
	Injection event	2	$ 200,000		
	Performance monitoring + MNA	10	$ 37,000		
	Deed restriction	1	$ 15,000		
	Net Present Value		**$ 332,000**		
	Enhanced Anaerobic Bioremediation: 2 Events + MNA				
	Assumptions:	Injection of Magnesium Sulfate (Epsom Salts) in source area , 2 events, 25% well coverage, 10 years MNA			
	Design, coordination, preparation, well installation	1	$ 80,000		
	Injection event	2	$ 180,000		
	Performance monitoring + MNA	10	$ 37,000		
	Deed restriction	1	$ 15,000		
	Net Present Value		**$ 312,000**		
	In-Situ Chemical Oxidation: 2 Events + MNA				
	Assumptions:	Direct push activated persulfate in affected area, 100% coverage, 1 event, 10 years MNA			
	Design, coordination, preparation, well installation	1	$ 80,000		
	Injection event	1	$ 200,000		
	Performance monitoring + MNA	10	$ 37,000		
	Deed restriction	1	$ 15,000		
	Net Present Value		**$ 332,000**		
	Groundwater Extraction and Treatment				
	Assumptions:	Operation for 30 years, 3 total extraction wells, 25 gpm total flowrate, granulated activated carbon, $6,000 per month O&M, NPV		Operation for 30 years,3 total extraction wells, 25 gpm total flowrate, ion-exchange, installed in wetland area, $6,000 per month O&M, NPV	
	Well network and aquifer testing	1	$ 125,000	1	$ 150,000
	Aquifer modeling plus report	1	$ 75,000	1	$ 75,000
	Design, permitting, and system installation	1	$ 500,000	1	$ 650,000
	Deed restriction	1	$ 15,000	1	$ 15,000
	System Operation and Maintenance	30	$ 893,000	30	$ 893,000
	Performance monitoring	30	$ 45,000	30	$ 45,000
	System Decommissioning	1	$ 50,000	1	$ 50,000
	Net Present Value		**$ 1,653,000**		**$ 1,828,000**

Notes:

1. Area and volume estimates were based on available AOC data. Most probable estimates of affected areas were utilized for costing; however, actual costs may increase/decrease based on further characterization efforts. Costs are assumed to be within the -30%, +50% range.

2. NPV estimates are based on a 9% discount rate and a 2% inflation rate starting with 2018 as "year zero".

AOC = area of concern

gpm = gallons per minute

MNA = monitored natural attenuation

NPV = net present value

sf = square feet