UNITED STATES AIR FORCE
JOINT BASE ELMENDORF-RICHARDSON
ALASKA

ENVIRONMENTAL RESTORATION PROGRAM

DENSE NONAQUEOUS PHASE LIQUID (DNAPL) EVALUATION REPORT
DP098

FINAL

APRIL 2018

FINAL

DNAPL EVALUATION REPORT
DP098

JOINT BASE ELMENDORF-RICHARDSON, ALASKA

Prepared for
Air Force Civil Engineer Center

Contract No. FA8903-09-D-8589 / Task Order 0016

APRIL 2018

EXECUTIVE SUMMARY

Site DP098 is a 27-acre site located in the northwest area of Joint Base Elmendorf-Richardson (JBER) on the former Elmendorf Air Force Base (JBER-E), east of Knik Arm and just west of Fairchild Avenue. The Record of Decision (ROD) for DP098, was signed in May 2004 by the United States Air Force (USAF), United States Environmental Protection Agency (EPA), and the Alaska Department of Environmental Conservation (ADEC), (USAF, 2004). The ROD presents the selected remedy for environmental contamination at DP098 and includes chemical-specific applicable and/or relevant and appropriate requirements (ARARs) for contaminants of concern (COCs), information concerning source material removal, monitored natural attenuation (MNA), and land use controls (LUCs).

Petroleum hydrocarbons were first discovered at DP098 in 1995 during the replacement of a 3,000-gallon underground storage tank (UST) located at the southwest corner of Building 18224. During subsequent field investigations between 1997 and 1999, chlorinated aliphatic hydrocarbons and their degradation products (collectively referred to as CAHs) were also detected in soil and groundwater. The ROD indicates two primary buildings on the site: Building 18224, which served as a vehicle maintenance facility during the 1950s and 1960s and now supports site operations; and Building 18220, an office building. Petroleum hydrocarbon contamination as a light non-aqueous phase liquid (LNAPL) is interpreted to be the result of releases from former USTs servicing Building 18224. CAH contamination is thought to have been primarily associated with the floor drainage system of Building 18224, which received liquids, including chlorinated solvents, during maintenance and cleaning operations, and subsequently discharged to the drain tile northwest of the building. As-built documents indicate that building drain systems at the site were connected to six discharge lines although not all were associated with CAH discharges. Each drain tile system consisted of a floor drain connected to perforated piping that drained liquids away from the building. This disposal method was a standard practice in the past. As-built documents indicate two drain tiles associated with Building 18224: one that discharged north of the building, and one that discharged northwest of the building. Four drain tiles are associated with the historical Building 18220: one discharged to the east of the building; another to the south of the west end of the building; one to the northwest of the west end of the building; and the fourth discharged southwest of the northwest corner. Note: The 2013 Base Atlas (USAF, 2013a) shows Buildings 18220 and 18216 as being included within the historical Building 18220 designation.

The ROD indicates that groundwater and soil contamination are expected to remain at the site at concentrations exceeding the Remedial Action Objectives for the next 35 to 75 years (USAF, 2004). The ROD selected remedy is: Source Material Removal (completed); Monitored Natural Attenuation [1) natural attenuation of contaminants in groundwater, soil, and sediment, (ongoing); 2) a treatability study to determine the effectiveness of the natural attenuation at/around the 190-foot topographic contour (completed); and 3) an evaluation /compilation of groundwater data collected during the first five years of monitoring (completed)]; and land use controls.

Historical contaminants include those associated with petroleum-based products and industrial solvents. The presence of the petroleum hydrocarbons is interpreted to be facilitating the degradation of the chlorinated solvents at the site; therefore, treatment of the petroleum LNAPL is not a current remedial objective. In the DP98 ROD, the COCs identified for soil are 1,1-dichloroethene (DCA), cis-1,2-dichloroethene (DCE), trichloroethene (TCE), tetrachloroethene (PCE), and the COCs identified for groundwater are DCA, DCE, TCE, PCE, and vinyl chloride (USAF, 2004).

Soil and Groundwater Conditions

DP098 lies on the northwest flank of the Elmendorf Moraine on top of a low hill, at about the 200-foot elevation. The ground surface slopes gently to the northwest for a distance of about 350 feet beyond Building 18224, and then drops steeply about 20 feet into a wetland. Soils at the site include fill material in the vicinity of the buildings and possibly extending about 350 feet to the north of the buildings, underlain by a bout of glacial till composed of gravelly, sandy silts and silty, gravelly sands with scattered cobbles. The fine-grained silts and clays of the Bootlegger Cove Formation are encountered at the 83 to 112-foot depth, and they appear to be more than 30 feet thick in the single site boring that penetrated into the formation (USAF, 2003).

The site is underlain by two aquifers, a shallow unconfined aquifer and a deeper, confined aquifer. These aquifers are separated by the Bootlegger Cove Formation, which functions as a confining layer (and extends under most of JBER-E). There is no communication between the shallow and deep aquifers in the area of investigation. All references to groundwater in this document relate to the shallow aquifer unless otherwise specified.

The depth to groundwater near Building 18224 is between 5 and 10 feet below ground surface (bgs). To the north, just before the break in slope that descends to a wetland, the depth to groundwater is approximately 15 feet, and groundwater surfaces as intermittent seeps from the edge of the wetland at the bottom of the slope. The wetland extends from the base of the slope about 500 feet in a northerly direction, where surface water is impounded in a small kettle pond. In the area of the drain tile outfall northwest of Building 18224, groundwater flows northwest to the wetland.

DNAPL Evaluation Activities

In an effort to optimize the exit strategy for DP098, a dense non-aqueous phase liquid (DNAPL) evaluation has been conducted. The objective of this evaluation is to determine whether a DNAPL source for CAH contamination is present at a depth greater than 30 feet bgs. This evaluation was conducted in the vicinity of a drain tile outfall that extended from the northwest side of Building 18224. The results have been used to help define the vertical extent of a new CAH source area and further delineate the extent of CAH contamination at depths of 40–70 feet bgs. TCE was detected above the DP98 ROD cleanup level at down to 68.5 feet bgs in one of the six soil borings advanced. There were no exceedances of ROD cleanup levels in soils below 68.5 feet bgs. The Bootlegger Cove Formation was not reached in any of the borings.

Two monitoring wells were installed in the vicinity of the drain tile outfall northwest of Building 18224 shown in as-built drawings. One monitoring well was installed to a depth of 40 feet bgs and the other to 80 feet bgs. The shallow well (DP98MW-07) is screened from 30–40 feet, and the deeper well (DP98MW-08) is screened from 65–80 feet. The screened intervals were chosen to assess the interconnectivity of the aquifer and confirm if the presence of a deeper DNAPL source was contributing to contamination deeper in the aquifer. Groundwater samples were collected from both monitoring wells. The analytical results of the groundwater sample from DP98MW-07 indicate concentrations of DCE and TCE above ROD cleanup levels. Gasoline-range organics (GRO) concentrations were above the Chapter 18 of the Alaska Administrative Code Section 75 (18 AAC 75) Table C groundwater cleanup level. The analytical results for the groundwater sample collected from DP98MW-08 were below cleanup levels.

Conclusions

The data set for DP098 supports the following conclusions:

- Diesel-range organics (DRO) and GRO contamination are present in soils from about 165 to 196 feet above mean sea level (amsl).
- Soil contamination remains above cleanup levels for DCE, PCE, and TCE with maximum concentrations of 1.8 milligrams per kilogram (mg/kg), 41 mg/kg, and 94 mg/kg, respectively. The deepest contamination above ROD cleanup levels was TCE encountered in 15DP098-SB-01 at 68.5 feet bgs (about 128 feet amsl). Detections of TCE in the saturated soils below the LNAPL contamination depth limit of about 165 feet amsl indicate the existence of a deeper, independent CAH source; however, no deep CAH DNAPL source was encountered between 40 and 80 feet bgs (158–118 feet amsl). While it is likely that DNAPL is present below the LNAPL, it is not practicable to precisely identify the source location and extent.
- The highest soil concentrations of TCE found were present within the petroleum hydrocarbon contaminated zone at 14DP098-SB-03 at 29–29.5 feet bgs (~169.5 ft amsl). The combined TCE and petroleum concentration is approximately 250 mg/kg. While the presence of a NAPL mixture is indicated at low concentrations, it is insufficient to saturate the soil matrix pore spaces, would only be present as disconnected blobs or ganglia within the pore spaces, and would not be expected to flow horizontally or vertically. Groundwater concentrations of DCE and TCE exceeded ROD cleanup levels and elevated groundwater concentrations of GRO were present in the sample collected from the newly installed monitoring well DP98MW-07 screened from 30–40 feet bgs (168–168 feet amsl). No

exceedances of cleanup levels were indicated in the groundwater sample collected from the newly installed monitoring well DP98MW-08 screened from 65–80 feet bgs (133–118 feet amsl).

- Previous treatability studies to reduce dissolved phase TCE concentrations have indicated that between four methods tested, the injection of a mixture of hematite, gypsum, and emulsified vegetable oil within the TCE plume area was the most successful. Bioaugmentation could be a viable option to enhance emulsified vegetable oil injection.

Recommendations

<u>Based on the conclusions of the DNAPL Evaluation, the following recommendations have been made:</u>

- No further characterization of the upgradient source area is recommended as the challenges associated with identifying DNAPL in a heterogeneous moraine with small scale differences in hydraulic conductivity and the resulting preferential pathways make it impracticable.

- Additional soil sampling and analysis for TCE from shallow borings (approximately 30 feet deep) approximately 10 feet south of 41755WL-04 and adjacent to 41755WL-08 could be useful to evaluate whether CAHs in soil are contributing to this part of the plume.

- Continue groundwater monitoring at the site per the DP98 ROD.

- Complete a cost benefit analysis of enhanced treatment in the upgradient area.

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LIST OF ACRONYMS

°F	Fahrenheit
µg/L	micrograms per liter
18 AAC 75	Chapter 18 of the Alaska Administrative Code Section 75
AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
AECOM	AECOM Technology Corporation
AFB	Air Force Base
AFCEC	Air Force Civil Engineer Center
amsl	above mean sea level
ARAR	Applicable or Relevant and Appropriate Requirement
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene and xylenes
CAFS	Clear Air Force Station
CAH	chlorinated aliphatic hydrocarbon
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
CSM	conceptual site model
DCA	1,1-dichloroethene
DCE	cis-1,2-dichloroethene
DHC	Dehalococcoides
DNAPL	dense non-aqueous phase liquid
DRO	diesel-range organics
EE/CA	Engineering Evaluation/Cost Analysis
EPA	United States Environmental Protection Agency
ESF	Environmental Staging Facility
FFA	Federal Facility Agreement
FID	flame ionization detector
GPS	global positioning system
GRO	gasoline-range organics
HRC	Hydrocarbon Risk Calculator
IDW	investigative-derived waste
JBER	Joint Base Elmendorf-Richardson

LIST OF ACRONYMS (CONTINUED)

JBER-E	JBER-Elmendorf
JBER-R	JBER-Richardson
LNAPL	light non-aqueous phase liquid
LUC	Land Use Control
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
MIP	Membrane Interface Probe
MNA	monitored natural attenuation
mV	millivolts
NAPL	non-aqueous phase liquid
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric Turbidity Units
ORP	Oxidation Reduction Potential
PAH	polynuclear aromatic hydrocarbons
PBR	Performance-Based Remediation
PCE	tetrachloroethene
PID	photoionization detector
PPE	personal protective equipment
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPO	Remedial Process Optimization
RRO	residual-range organics
RTK	real-time kinematic
SC	site closure
SERA	State-Elmendorf Environmental Restoration Agreement
SVOC	semivolatile organic compound
TCE	trichloroethene
TOC	total organic carbon
UFP-QAPP	Uniform Federal Policy-Quality Assurance Project Plan
USAF	United States Air Force

LIST OF ACRONYMS (CONTINUED)

USGS	United States Geological Survey
UST	underground storage tank
VOC	volatile organic compound
WESTON	Weston Solutions, Inc.

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TITLE AND APPROVAL PAGE

Document Name:	DNAPL EVALUATION REPORT – Site DP098
Site Name/Project Name:	Performance-Based Remediation (PBR) for Alaska Group PBR – Joint Base Elmendorf-Richardson (JBER), Alaska
Site Location/Number:	0009FC DP98/ F2MUAA2037B001
Contract Number:	FA8903-09-D-8589
Task Order Number:	0016
Lead Organization:	Air Force Civil Engineer Center (AFCEC)
Federal Regulatory Agency:	United States Environmental Protection Agency (EPA)
State Regulatory Agency:	Alaska Department of Environmental Conservation (ADEC)
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Preparation Date:	April 2018

This *DP098 DNAPL Evaluation Report* was prepared by qualified persons, as required by Title 18 of the Alaska Administrative Code (AAC) Chapter 75 Section 360 (18 AAC 75.360) and defined in 18 AAC 75.380(b)(9)(e). USAF, ADEC, and United States Environmental Protection Agency (EPA) approval of the Final *DP098 DNAPL Evaluation Report* will be assumed by their email concurrence with responses to comments on the Draft *DNAPL Evaluation Report*. No USAF, ADEC, or EPA signatures will be required on this page.

Reporting Organization's Project Manager:

Signature ____________________________________

Phillip Stallings
Weston Solutions, Inc.

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1.0 INTRODUCTION

Site DP098 (previously referred to as DP98) is located in the northwestern area of Joint Base Elmendorf-Richardson (JBER) on the former Elmendorf Air Force Base (JBER-E), east of Knik Arm and just west of Fairchild Avenue (Figure 1-1). The Record of Decision (ROD) for DP098, was signed in May 2004 by the United States Air Force (USAF), United States Environmental Protection Agency (EPA), and the Alaska Department of Environmental Conservation (ADEC), (USAF, 2004). The ROD indicates two primary buildings on the site: Building 18224, which served as a vehicle maintenance facility during the 1950s and 1960s and now supports site operations; and Building 18220, an office building. The ROD selected remedy is: Source Material Removal (completed); Monitored Natural Attenuation [includes: 1) natural attenuation of contaminants in groundwater, soil, and sediment, and groundwater (ongoing); 2) a treatability study to determine the effectiveness of the natural attenuation at/around the 190-foot topographic contour (completed); and 3) an evaluation /compilation of groundwater data collected during the first five years of monitoring (completed)]; and land use controls.

Petroleum hydrocarbons were first discovered at DP098 in 1995 during the replacement of a 3,000-gallon underground storage tank (UST) located at the southwest corner of Building 18224. Chlorinated aliphatic hydrocarbons and their degradation products (collectively referred to as CAHs) also were detected in soil and groundwater during subsequent field investigations between 1997 and 1999. Petroleum hydrocarbon contamination is interpreted to be the result of petroleum-related light non-aqueous phase liquid (LNAPL) releases from former USTs that serviced Building 18224. As-built documents indicate that building drain systems at the site were connected to six discharge lines. Each drain tile system consisted of a floor drain connected to perforated piping that drained liquids away from the building. This disposal method was a standard practice in the past. CAH contamination is thought to have been primarily associated with the floor drainage system of Building 18224, which received liquids, including chlorinated solvents, during maintenance and cleaning operations, and subsequently discharged to the drain tile northwest of the building. As-built documents indicate two drain tiles associated with Building 18224: one that discharged north of the building, and one that discharged northwest of the building. Four drain tiles are associated with the historical Building 18220: one discharged to the east of the building; another to the south of the west end of the building, one to the northwest of the west end of the building; and the fourth discharged southwest of the northwest corner (now designated as Building 18216). Commingling of these two contaminant types occurs down to about 30 feet below ground surface (bgs). CAHs are dissolved into the petroleum LNAPL, which acts as a source for this shallow CAH contamination. CAHs without petroleum hydrocarbons are present below 30 feet bgs, and no source for these deeper CAHs has been identified. Note: The 2013 Base Atlas (USAF, 2013a) shows Buildings 18220 and 18216 as being included within the historical Building 18220 designation.

This report presents the results of the 2014 and 2015 dense non-aqueous phase liquid (DNAPL) evaluation activities and assesses site characteristics and contamination levels for contaminants of concern (COCs) for soil and groundwater, as determined by the DP98 ROD. Site characterization activities were conducted under the *Basewide Uniform Federal Policy-Quality Assurance Project Plan* (UFP-QAPP) (USAF, 2013b) and the *UFP-QAPP DP098 DNAPL Evaluation Work Plan* (USAF, 2014a). The *Basewide UFP-QAPP* was approved by EPA and ADEC on April 1, 2013 and April 16, 2013, respectively. The *UFP-QAPP DP098 DNAPL Evaluation Work Plan* was approved by EPA and ADEC on January 23, 2014 and September 25, 2013, respectively.

Work was conducted by Weston Solutions, Inc. (WESTON®) under the JBER and Clear Air Force Station (CAFS) Performance-Based Remediation (PBR) project. This work has been authorized by the Air Force Civil Engineer Center (AFCEC) under Contract Number FA8903-09-D-8589, Task Order Number 0016. The Air Force's objective for DP098 is to achieve site closure (SC) sooner than predicted in the DP98 ROD.

1.1 Purpose

The purpose of this report is to present the results of the 2014 and January 2015 field work used to better delineate the nature and extent of CAH contamination at Site DP098, in an effort to optimize the cleanup of DP098. This evaluation was conducted within the framework of the ADEC's cleanup process (Title 18 of the Alaska Administrative Code [AAC] Chapter 75 Sections 325 to 390 [18 AAC 75.325-390] and 18 AAC 78.600).

Per the DNAPL Evaluation Work Plan, the objective of the DP098 DNAPL Evaluation was to determine whether a DNAPL source for CAHs was present at depths below 30 feet bgs in the vicinity of a former drain tile outfall northwest of Building 18224; to vertically define the potential CAH source area; and to delineate the CAH contamination at depths of 40–70 feet bgs. In 2014, five soil borings were installed and soil samples collected for analyses to depths between 60 and 70 feet bgs. In January 2015, in an attempt to verify the presence of a possible DNAPL source indicated by an earlier membrane interface probe investigation, a sixth boring was completed and sampled to 80 feet bgs. ROD soil cleanup levels for TCE were exceeded in soil sample results down to 68.5 feet bgs. This boring was completed as groundwater monitoring well DP98MW-08 to monitor water deeper in the aquifer. Groundwater monitoring well (DP98MW-07) was also installed immediately adjacent to DP098MW-08 to monitor the intermediate depth groundwater just below the petroleum hydrocarbon contamination. The Bootlegger Cove Formation was not reached in any of the borings. Additional detail on borings, monitoring well installation, and sampling is included in Sections 3 and 4.

1.2 Organization of Report

Details regarding the report organization are as follows:

- **Section 1.0 – Introduction –** Presents the purpose of this report and report organization.
- **Section 2.0 – JBER-Elmendorf General Site Description and Regulatory Background** – Presents information on the local climate, general geology, hydrogeology, and hydrology; a site overview; and the regulatory framework and criteria in place.
- **Section 3.0 – Field Activities and Data Presentation Formats** - Briefly describes site investigation field methods.
- **Section 4.0 – DNAPL Evaluation Results and Findings –** Presents the site-specific geology, hydrology, and hydrogeology; soil and groundwater analytical results from the 2014/2015 field investigation; soil and groundwater results from previous investigations; and interprets results to develop an understanding of the nature of contamination at the site.
- **Section 5.0 – Conclusions –** Presents the conclusions of the report, including the nature and extent of contaminants.
- **Section 6.0 – Recommendations –** Presents recommendations base on the report findings.
- **Section 7.0 – References –** Presents references used in the preparation of this report.

Figures, tables, and appendices follow Section 7.0.

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2.0 JBER-ELMENDORF GENERAL SITE DESCRIPTION AND REGULATORY BACKGROUND

2.1 JBER General Site Conditions

2.1.1 Location and Description

JBER comprises the former JBER-E and former Fort Richardson (JBER-R), located adjacent to the city of Anchorage, Alaska. As a result of the 2005 Department of Defense Base Realignment and Closure Commission recommendation, the two installations merged to form JBER on October 1, 2010.

JBER is bounded by the Municipality of Anchorage to the south, Knik Arm to the north and west, and primarily undeveloped lands to the east. Most of the surrounding undeveloped land is part of Chugach State Park and the Chugach Mountain Range. The installation encompasses 74,000 acres of land, with elevations ranging from sea level along the Knik Arm shoreline to 3,800 feet above mean sea level in the Chugach Mountains to the south and east.

2.1.2 Physical Characteristics

JBER can be characterized as having a transitional climate between the marine climate zone along the southern coast and the continental climate zone in the interior of Alaska. Average July low and high temperatures are 52 degrees Fahrenheit (°F) and 66°F, and average January low and high temperatures are 11°F and 23°F, as recorded at Ted Stevens Anchorage International Airport for the period of record of 1981 to 2010 (National Oceanic and Atmospheric Administration [NOAA], 2013). Extreme temperatures during this period have ranged from -38°F to 86°F. Average annual precipitation in the Anchorage area is about 16.6 inches, with a range of 13 to 20 inches (higher precipitation may be expected in higher elevation areas). Most of the precipitation falls from July through September when the wind is from the southwest. Snowfall averages 66 inches, which is about one-third (5.5 inches) of the total precipitation. The depth of snow on the ground does not normally exceed 24 inches.

2.1.3 Regional Geology and Soils

JBER-E is located within the Susitna Lowlands, a broad lowland area west of the Chugach Mountains (Warhaftig, 1965). A general geologic map depicting the JBER geology excerpted from a larger United States Geological Survey map (United States Geological Survey [USGS], 1972) is provided as Figure 2-1. The southern third of the installation lies on the Anchorage glacio-fluvial outwash plain. The Elmendorf Moraine (a glacial end moraine) crosses JBER from the southwest to the northeast, and ground moraine and glacio-fluvial soils (unconsolidated deposits between bedrock and the earth’s surface) cover the northern portion of JBER. The runways and most of the JBER facilities lie on the relatively flat outwash plain. The outwash soils consist predominantly of sandy gravels and gravelly sands deposited by streams draining glaciers advancing out of the Knik and Matanuska valleys about 12,000 years ago. The outwash varies in thickness across JBER-E, but tends to be relatively thin just south of the Elmendorf Moraine and increases to a thickness of up to about 60 feet near Ship Creek. Ship Creek, which flows roughly along the southern margin of JBER-E, has deposited an alluvial fan that overlies the outwash where the creek flows out of the Chugach Mountains to the east; and has eroded or incised into the outwash and deposited alluvial floodplain soils on top of the Bootlegger Cove Formation in its western reaches. The Elmendorf Moraine is a low, hummocky ridge composed of a heterogeneous mixture of sand, gravel, silt, and clay, with cobbles and boulders. The moraine was deposited by the glaciers advancing out of the Knik and Matanuska Valleys. The ground moraine north of the end moraine is dominated by low, rolling hills composed of materials similar to those forming the end moraine, and may be mantled with glacio-fluvial soils. Fine-grained glacio-marine and glacio-lacustrine sediments of the Bootlegger Cove Formation underlie the outwash and the moraine.

The outwash and glacio-fluvial soils have relatively low fines content, high bulk densities, and low moisture contents, while the moraine soils have higher silt and clay contents, and higher moisture contents, along with relatively high bulk densities.

2.1.4 Regional Hydrogeology and Groundwater Use

JBER-E is underlain by two aquifers: a shallow water table aquifer and a deeper, confined aquifer. These aquifers are separated by the Bootlegger Cove Formation, which functions as an aquiclude separating the shallow water table aquifer from a deeper, confined aquifer across most of JBER-E. The shallow aquifer is not currently used as a groundwater source on the Base. Water use on the Base is either supplied from the Ship Creek Dam or from the deep aquifer. There is no communication between shallow and deep aquifers in the area of investigation. All references to groundwater in this document relate to the shallow aquifer, unless otherwise specified. Groundwater flow in the outwash plain is generally toward the south or southwest, while groundwater flow in the moraine areas is more variable, and is best characterized using localized data.

The outwash soils, the glacio-fluvial soils north of the Elmendorf Moraine, the Ship Creek alluvium, and the Ship Creek alluvial fan have relatively high hydraulic conductivity values, while the moraine has variable but significantly lower hydraulic conductivity values. In general, the Bootlegger Cove Formation may be characterized as having a very low hydraulic conductivity (although interbedded sand layers exist within the formation).

2.1.5 Regional Hydrology

Surface water bodies on JBER-E include Ship Creek, Six Mile Lake, Six Mile Creek, and several other small lakes north of the Elmendorf Moraine.

Ship Creek flows from the Chugach Mountains to the east of JBER across the southern margin of JBER to Cook Inlet on the west side of JBER. Ship Creek is described as a losing stream where it flows across its alluvial fan at the foot of the mountains (because water from the stream recharges groundwater), and as a gaining stream west of Boniface Road area, where groundwater tends to flow into the stream channel. Ship Creek serves as the main source of drinking water for JBER. Water is taken from the creek at a diversion dam located approximately 10.5 miles upstream from the mouth. A water treatment plant near the dam processes the drinking water.

Six Mile Lake and Six Mile Creek drain much of JBER-E north of the Elmendorf Moraine. Flow in the creek is from east to west, and the creek discharges to the Knik Arm.

2.2 Regulatory Framework

Investigation and remediation activities at JBER are being conducted by the USAF under the Environmental Restoration Program funded by the Environmental Restoration Account.

Elmendorf Air Force Base (AFB) and Fort Richardson were placed on the National Priorities List in 1990 and 1994, respectively. As a result of this listing, the USAF, EPA Region 10, and ADEC signed a Federal Facility Agreement (FFA) for Elmendorf AFB in November 1991; and the Army, EPA Region 10, and ADEC signed an FFA for Fort Richardson in December 1994. An FFA sets deadlines, objectives, responsibilities, and procedural framework for cleanup of sites regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The FFAs ensure that environmental impacts associated with past practices at JBER are investigated and appropriate actions are completed to protect human health and the environment.

At this site CERCLA COCs are present and are regulated under the CERCLA process.

2.2.1 DP098 Record of Decision

The governing document for this site is the DP98 ROD (USAF, 2004), which establishes cleanup levels for the hazardous substances at the site, signed by the EPA, the ADEC, and the USAF.

2.2.1.1 Soil

The selected soils remedy identified for DP098 includes the following:

- Source material removal limited to soil within a 25-foot radius of historical soil boring DP98-SB01, where the greatest trichloroethene (TCE) concentrations were detected, adjacent to the end of the drain tile northwest of Building 18224.
- Natural attenuation for low concentration contaminants remaining at DP098 after the limited soil removal was completed. Natural attenuation in soil would not be monitored prior to collecting confirmation samples. Confirmation sampling will be conducted to confirm effectiveness of the natural attenuation of soil only after groundwater chemical-specific applicable or relevant and appropriate requirements (ARARs) have been achieved.

- Land Use Controls (LUCs) designed to prevent activities that could affect the performance of the other components of the selected remedy, prevent the migration of contaminants in groundwater, and maintain current land uses at DP098 to protect human health and the environment.

2.2.1.2 Sediment

The selected sediment remedy identified for DP098 includes the following:

- Natural attenuation for low concentration contaminants remaining at DP098 after the limited soil removal was completed. Natural attenuation in sediment would not be monitored prior to collecting confirmation samples. Confirmation sampling will be conducted to confirm effectiveness of the natural attenuation of sediment only after groundwater chemical-specific ARARs in the table below have been achieved.
- LUCs designed to prevent activities that could affect the performance of the other components of the selected remedy, prevent the migration of contaminants in groundwater, and maintain current land uses at DP098 to protect human health and the environment.

2.2.1.3 Groundwater

The selected groundwater remedy identified for DP098 includes the following:

- Natural attenuation for low concentration contaminants remaining at DP098 after the limited soil removal is completed. The Air Force has been monitoring the actual performance of the natural attenuation remedy by adhering to the following:
    - Surface water samples are being collected from the kettle pond annually as a point of compliance and sampled for the same sampling suite as the groundwater COCs.
    - The analytical testing of groundwater samples has been occurring to monitor concentrations of the COCs, daughter products, and other analytes, as appropriate. Analytes and field parameters are being measured to track changes in contaminant migration as well as to monitor the progress of natural attenuation.
- LUCs designed to prevent activities that could affect the performance of the other components of the selected remedy, prevent the migration of contaminants in groundwater, and maintain current land uses at DP098 to protect human health and the environment.

In 2004, the estimated time to complete cleanup was 18 to 48 years for soil outside the excavated area and 35 to 75 years for groundwater. During the estimated 75 years necessary to complete cleanup, LUCs are to be maintained in order to limit potential exposure to contaminated media.

The ROD groundwater, sediment, and soil cleanup levels for DP098 are presented in the following table.

Chemical-Specific ARARs for Contaminants of Concern

Media	Chemical of Concern	Unit	Cleanup Level
Soil	1,1-dichloroethene	mg/kg	0.03
	cis-1,2-dichloroethene	mg/kg	0.2
	tetrachloroethene	mg/kg	0.03
	trichloroethene	mg/kg	0.027
Sediment	cis-1,2-dichloroethene	mg/kg	0.2
	trichloroethene	mg/kg	0.027
Groundwater	1,1-dichloroethene	mg/L	0.007
	cis-1,2-dichloroethene	mg/L	0.07
	trichloroethene	mg/L	0.005
	Tetrachloroethene	mg/L	0.005
	vinyl chloride	mg/L	0.002

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3.0 FIELD ACTIVITIES AND DATA PRESENTATION FORMATS

Site characterization field activities included site reconnaissance visits, utility locates, soil boring and sampling, monitoring well installation, groundwater sampling, investigative-derived waste (IDW) disposal, and surveying. The general field methods are described below, followed by a description of the data presentation formats. Site-specific field activities are described in Section 4.4.

The primary WESTON personnel responsible for sample collection are listed below. All other personnel involved in sample collection worked under the direct supervision of the personnel listed below. All sampling was performed under the direction of qualified personnel.

Name	Project Title/Role	Qualifications/Years of Experience
Anne Thompson	Field Team/ Lead Sampler	B.S., Geohydrology 8 years of experience
Aaron Mroz	Field Team/ Lead Sampler	B.S., Environmental Science 9 years of experience

3.1 Pre-Investigation Activities

An initial site visit was performed by WESTON field personnel on June 12, 2014 to identify and mark planned soil boring locations, based on global positioning system (GPS) coordinates and/or swing-ties from existing structures or landmarks. Locations were field-checked against proposed soil boring locations provided in the *UFP-QAPP DP98 DNAPL Evaluation Work Plan* (USAF, 2014a). Potential hazards and access constraints were assessed, and boring locations were shifted as needed.

A JBER Base Civil Engineer Work Clearance Request (dig permit) was acquired to identify potential current and abandoned underground utilities or pipelines before drilling began.

3.2 Field Investigation Methods

3.2.1 Soil Sampling

Soil borings for 2014/2015 field work were drilled using a Geoprobe® 8040 direct push drill rig. Soil samples were obtained by driving a stainless steel sample barrel into the soil using hydraulic down-pressure and a drive hammer. Soil cores were collected in a 5-foot long, 2¼-inch diameter stainless steel sample barrel with a 1⅝-inch inside diameter disposable acetate liner. This method is capable of collecting a continuous soil core (in 5-foot sections) from the surface to the end depth of the boring. After extruding the acetate liner from the barrel, the liner was cut open, and the soils were quickly screened along the length of the recovered soil using a photoionization detector (PID) for the 2014 samples. Because of the PID's low sensitivity to low CAH concentrations, a PID and a flame ionization detector (FID) were both used in 2015 as a screening refinement.

Samples were generally taken from a predetermined interval, or from the interval with the highest FID/PID readings. A portion of the soil core (typically from near the middle of the core or from a portion of the core with a relatively high initial reading) was placed in a plastic bag for FID/PID headspace screening. The results from the initial screening along the length of the core were recorded in a column near the center of the borehole log form. The results of the plastic bag headspace screening, the lab sample number, and the lab analysis methods were listed near the right margin of the borehole log form. Continuous logging of soil type and stratigraphy, color, grain size distribution, moisture content, occurrence of groundwater, and visual observations of staining or liquid phase contamination were also recorded in the field on the borehole log form. Soil boring logs are included in Appendix A.

Soil samples were collected at discrete intervals for GRO, diesel-range organics (DRO), residual-range organics (RRO), VOCs, and Low Level VOCs. Samples collected for GRO, DRO, and RRO were collected using dedicated sampling spoons or scoops, and samples collected for Low level VOCs were collected using dedicated 5-gram Terra Core samplers; all samples were collected and placed into the appropriate laboratory jarware per sampling protocols described in the JBER Basewide UFP-QAPP (USAF, 2014a). Samples were submitted to the analytical laboratory for analysis by methods listed in Table 18-1 of the approved DP98 UFP-QAPP.

For the 2015 boring, additional field screening was performed. Dye tests utilizing SUDAN red dye test kits were performed at multiple intervals to determine the presence or absence of non-aqueous phase liquid (NAPL). Dye kits are used by adding dye and water to the soil in a vial and agitating. The dye will adhere to the NAPL so it is visible to the naked eye. FLUTe™ strips were also used to determine whether there were any intervals of NAPL-containing soil that may have been missed by the FID and/or PID screening. FLUTe™ strips are made of a fabric that reacts with the NAPL to produce a visible stain. Upon the initial screening with the FID and PID, samples were collected, and the remaining core was wrapped with plastic wrap, including a FLUTe™ strip in contact with the core. Following a period of at least one hour, the strip was removed and inspected for staining.

In 2014/2015, all samples were assigned a unique identification number in the field, as follows:

- The first two digits identify the sample year.
- The next four alpha-numeric places identify the USAF site name.
- The next four alpha-numeric places (offset by hyphens) identify the soil boring number.
- The next sequence of 2 to 6 numbers (offset by hyphens) identifies the depth of the sample in feet.
- The last digit identifies whether the sample was an original (0) or a duplicate (1).

Soil borings were abandoned by placing 3/8-inch bentonite chips from the bottom of the boring to about 1 foot below grade, and by placing silica sand from about 1 foot below grade to the ground surface. Additionally, asphalt patches were used where needed to repair asphaltic concrete.

3.2.2 Monitoring Well Installation and Development

Two monitoring wells were drilled with 4.25-inch inner diameter hollow-stem auger flights. Once at depth, each monitoring well was constructed with pre-packed well screen with Schedule 40 polyvinyl chloride (PVC) riser. The pre-packs are made of 0.10-inch machine-slotted screen and 10/20 grade sand. Sand was added 1 to 2 feet above the screen. The well seal above the sand was constructed using tremied bentonite slurry at DP98MW-08 and by placing and hydrating 3/8-inch bentonite chips at well DP98MW-07. The monitoring wells were completed with a flush-mounted protective cover, and cemented in place. Newly installed wells were developed beginning six days following installation.

During the development of DP98MW-07, the well purged dry after two hours. Purging continued after the well recharged and turbidity readings of greater than 1,000 Nephelometric Turbidity Units (NTU) were obtained (Note that the inequality sign appears to be reversed on the development log). More than 38 gallons of water were purged from the well during the development. The high turbidity present at the time of sample collection is thought to be due to the presence of fine-grained formation material being drawn through the filter pack and the slow recharge rate being insufficient to clear the fines. It is possible that high turbidity at the time of sampling could bias the sample high. This well also exhibited significant drawdown during development and low-flow sampling; the well purged dry several times.

During development of DP98MW-08, a very negative Oxidation Reduction Potential (ORP) of -582 millivolts (mV) was recorded during the development of monitoring well DP98MW-08; a negative ORP of -250 mV was recorded at the end of purging prior to sampling. Monitoring well construction details and development forms are presented in Appendix A. All DP098 monitoring wells are listed with their screened interval in Table 3-1.

3.2.3 Groundwater Sampling

Following monitoring well development, samples were collected from each well using low-flow techniques, including the measurement of depth-to-water and the water quality parameters (pH, conductivity, temperature, dissolved oxygen, and oxidation-reduction potential) during purging. Groundwater sampling records are included in Appendix A. High turbidity values were recorded during the sampling of monitoring well DP98MW-07; it is possible that the sample results may be biased high due to these conditions. This well also purged dry during low-flow sampling. It is also possible that sampling this well after it has purged dry and fully recharged could have caused the sample to be biased low due to volatilization as the water enters the well. ADEC sampling guidance was followed, and a groundwater sample was collected from DP098MW-07 after the well had recharged to at least 80% of the well volume.

3.2.4 Surveying

Each soil boring location was surveyed by WESTON staff using a survey-grade, real-time kinematic (RTK) GPS. The surveyed boring coordinates have approximate sub-inch horizontal and one-inch vertical accuracies. New monitoring well locations and top of casing elevations were surveyed by a Licensed Surveyor using a survey-grade RTK GPS with post-processing. The surveyed monitoring well coordinates are accurate to less than 1 inch horizontally and 1/8-inch vertically, which satisfies ADEC location requirements for horizontal accuracy of 1.0 feet and vertical accuracy of 0.01 foot (ADEC, 2013). The survey coordinates and elevation measurements are provided in Table 3-2.

3.2.5 Waste Handling and Disposal

Waste generated during site characterization activities included general refuse (i.e., expended personal protective equipment [PPE], paper towels, plastic bags, and plastic water containers) and IDW (i.e., soil drill cuttings, purge water from well sampling, and wastewater from decontamination activities).

Consistent with the *JBER Basewide UFP-QAPP* (USAF, 2013b), wastes were taken to the JBER Environmental Staging Facility (ESF) located at Building 955 on Warehouse Street near the intersection with Otter Lake Road. Access to the facility is coordinated through the current operations contractor, AECOM Technology Corporation (AECOM). Specific wastes were handled as described below:

- General refuse and expended PPE were disposed of in JBER refuse waste containers at the ESF or in refuse containers at the WESTON job trailer located at the Operable Unit 1 Landfill.
- Soil cuttings generated during drilling were placed into 5-gallon buckets and transported to the ESF. The soil was then transferred to 55-gallon drums labeled with the date, project site, borehole number(s), matrix, and contractor point of contact.
- The sample results were used to characterize the soil in the drums for appropriate disposal. The soil analytical results were provided to AECOM.
- Decontamination, development, and purge water were collected in 55-gallon or 5-gallon containers and transported to the ESF, transferred into open-top 55-gallon drums, and labeled. Decontamination water was then batch-treated with other IDW water. After treatment, the water was sampled for constituents listed in the JBER water discharge permit and discharged to the sanitary sewer system, after verifying constituents were below permit requirements.

3.3 Data Presentation and Interpretation Formats

Site investigation data are presented in maps, cross-sections, tables, and text, using the formats described in this section.

3.3.1 Chemical Analysis and Data Tables

The data tables use **bold red font** for all COC concentrations that exceed the ROD cleanup levels. Light yellow shading is used to indicate GRO, DRO, and RRO results interpreted to be within the NAPL-contaminated source area. This report uses a working definition of the NAPL source area for DRO, GRO, and RRO source areas as the area above the 18 AAC 75 Table B2 migration to groundwater screening levels of 250 milligrams per kilogram (mg/kg), 300 mg/kg, and 11,000 mg/kg respectively. PID or FID field screening results greater than 25 parts per million (ppm) have also been used to infer the presence of NAPL.

Field duplicate samples were collected at a rate of one duplicate per 10 original samples. For each original and duplicate sample pair, only the "best result" is presented in the primary data tables, and the best result is associated with the original sample number (the original and duplicate results are presented in the laboratory data (Appendix B). The presentation of only the best result and the best result selection logic follows the ADEC technical memorandum entitled, *Guidelines for Data Reporting, Data Averaging, and Treatment of Non-Detect Values* (ADEC, 2012). The "best result" value is the higher of the original or duplicate result if both results are detections; the detected value if one result is a detect and one result is a non-detect; and the lower if either the original or duplicate sample did not detect the analyte. The "best result" is presented in tables and figures.

The ADEC requires methanol field preservation for all volatile soil sample analysis. However, there are numerous analytes with detection levels that do not meet applicable cleanup levels with methanol preservation. Therefore, ADEC may approve the use of low-level sample collection and analysis for volatile soil samples on a site-specific basis. The EPA requires low-level volatile soil sample collection and analysis to meet sensitivity requirements at CERCLA sites. To meet all regulatory agency requirements, the collection and analysis of both methanol-preserved and low-level volatile samples was required. The DP098 work plan required that all soil samples collected for volatile organic compound (VOC) analyses be analyzed by Method SW8260B with methanol preservation and low-level SW8260B.

3.3.2 Site Map

Locations of soil borings and monitoring wells, as well as the horizontal extent of the LNAPL-contaminated soil source area and interpreted extent of the chlorinated solvent contamination, are shown on a site map (Figure 4-1). Laboratory results and information from boring logs, including field-screening data and soil descriptions, have been used to identify both the LNAPL extent and the solvent-contaminated area. Additional information regarding the identification of the solvent-contaminated plume and a description of the criteria used for determining the presence or absence of NAPL are presented in Section 4.6.1.

On Figure 4-1, soil borings are shown using circular symbols, and monitoring wells are shown using cross-hair symbols. Green centers for soil boring and monitoring well symbols indicate that vadose zone soils do not contain LNAPL. Yellow centers for soil boring and monitoring well symbols indicate that vadose zone soils do contain LNAPL. Locations interpreted to contain LNAPL contamination in the zone of seasonal water table fluctuation are identified with a red ring around the map symbol. Locations interpreted as not having LNAPL contamination in the zone of seasonal water table fluctuation are identified with a blue ring. The interpreted presence or absence of LNAPL is based on screening results (PID, visual, and olfactory) as described in the previous section. An orange ring indicates chlorinated solvent concentrations below ROD cleanup levels, and a purple ring indicates chlorinated solvent concentrations above ROD cleanup levels (see the sample map legend below).

Historical data used to create Figures are included as Appendix C.

Sample Map Legend

Symbols	Description
🟡 ⊕	Yellow centers for soil boring and monitoring well symbols where vadose, soils are interpreted to contain LNAPL.
🟢 ⊕	Green centers for soil boring and monitoring well symbols where vadose zone soils are interpreted to not contain LNAPL.
○	Blue rings around, soil boring and monitoring well symbols where saturated zone soils are interpreted not to contain LNAPL.
⭕	Red rings around, soil boring and monitoring well symbols where saturated zone soils are interpreted to contain LNAPL.
○	Orange outer rings around soil boring and monitoring well symbols where soils do not to contain solvent concentrations above ROD cleanup levels.
○	Purple outer rings around soil boring and monitoring well symbols where soils contain solvent concentrations above ROD cleanup levels.

3.3.3 Cross-Section

Cross-sections are used to help show the vertical distribution of the solvent-contaminated area in the approximate direction of groundwater flow. The cross-section is a graphical data presentation tool and is not drawn to a precise scale (e.g., where several borings are close together, the distance between drawings may be exaggerated so that the data may be legibly displayed). The cross-section shows soil borings and monitoring wells. The boring and monitoring well numbers are shown immediately above the boring or well. Discrete soil samples from the borings and monitoring wells are shown as shaded boxes with laboratory DRO and TCE concentrations (in mg/kg) to the left of the sample location, and PID plastic bag headspace results in ppm are shown to the right of the sample location (FID headspace results in ppm shown for the 2015 soil boring). PID results greater than 25 ppm are generally interpreted as indications of NAPL presence. The screening and analytical results are color-coded: yellow and green highlighting indicates vadose zone samples with and without LNAPL contamination, respectively; red and blue highlights indicate samples from the seasonally saturated zone with and without petroleum hydrocarbon LNAPL contamination, respectively. The laboratory concentrations indicating that chlorinated solvent contamination are above cleanup levels are color-coded purple, and chlorinated solvent concentrations below cleanup levels are color-coded orange.

The extent of smear zone LNAPL contamination is shown on the cross-section using dashed red lines. In general, the dashed red line encompasses the sample locations showing LNAPL contamination and excludes the areas interpreted to be uncontaminated (note that there can be uncontaminated samples collected within an LNAPL-contaminated soil source area). The purple-dashed line denotes the extent of chlorinated solvent contamination interpreted from analytical results. The cross-section also displays the seasonal water table fluctuation and the approximate direction of groundwater flow.

Two cross sections were produced (Figure 4-3a and Figure 4-3b) and are discussed in Section 4.6.1.

Historical data used to create Figures 4-3a and 4-3b are included as Appendix C.

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4.0 DNAPL EVALUATION RESULTS AND FINDINGS

This section presents site-specific geology, hydrogeology, and hydrology; lists the previous investigations conducted at the site; presents the soil and groundwater analytical data from the previous investigations and the 2014/2015 investigation; and identifies the extent of the contaminated soils and groundwater. The characterization of the site presented herein uses all data collected at the site to present an understanding of the site that is suitable for optimizing the exit strategy.

4.1 Site Description

Buildings at the 27-acre site include Building 18220 (formerly Building 41-760), Building 18216 (formerly part of 18220), Building 18224 (formerly Building 41-755), and a small guard building. The land north of these facilities is undeveloped. Contamination at the site appears to originate from Building 18224, which was used as a vehicle maintenance facility in the 1950s, and its associated USTs. Two USTs used to store diesel fuel were located at the southwest corner of Building 18224. One UST was removed, while the other UST was abandoned in place in 1995 and is thought to have been the source of petroleum contamination at DP098. The CAHs that have also been identified in soil and groundwater are interpreted to have been discharged to the floor drains of Building 18224 during maintenance and cleaning operations, which ultimately discharged to a drainage system northwest of the building. In the 1970s, this was considered to be a normal practice.

The drainage system consisted of six drain tiles located across the site, and only one is associated with CAH contamination investigated in this DNAPL Evaluation. Each drainage system consisted of a floor drain connected to perforated piping that drained liquids away from the building. One drain tile is associated with Building 18224 that discharged northwest of the building. Three drain tiles are associated with Building 18220, one discharged to the east, another to the south, and the third to the northwest of Building 18220. One drain tile discharged west of Building 18216 (Figure 4-1). Historic usage of these floor drains commonly involved discharging liquids, such as cleaning solvents, to these floor drains.

4.2 Site Physical Characteristics

4.2.1 Geology and Soils

DP098 lies on the northwest flank of the Elmendorf Moraine on top of a low hill, at about the 200-foot elevation. The ground surface slopes gently to the northwest for a distance of about 350 feet beyond Building 18224, and then drops steeply about 20 feet into a wetland area about 400 feet from Building 18224. Soils at the site include imported fill material in the vicinity of the buildings. The DP098 Remedial Investigation / Feasibility Study (RI/FS) (USAF, 2003) includes a comprehensive geological description of the site. The RI/FS indicates that the imported fill is underlain by glacial till of the Elmendorf End Moraine, which includes clayey gravelly silt and gravelly sand, silty clay, and gravelly silty sand. The moraine deposits overlie the silty clays of the Bootlegger Cove Formation. In general, lithological units within the Elmendorf Moraine tend to dip to the north and can be laterally discontinuous. Descriptions of these units are included below and further referenced in Section 4.6.1.

- Imported Fill Material – 10 to 16 feet thick below the southern portions of the Facility, and 1 to 8 feet thick below the slope portions of the site.
- Clayey Gravelly Silt and Gravelly Sand – 5 to 25 feet thick below the southern portions of the Facility, 10 to 30 feet thick below the slope portions of the site, 15 to 35 feet thick below the northern portions beyond the slope, and 5 to 35 feet thick below the wetland portion of the site. This material represents the uppermost geologic unit of the Elmendorf End Moraine (mapped unit Qey of Cederstrom, Trainer, and Waller [1964]) sediments.
- Silty Clay – 10 to 12 feet of silty clay was found to occur locally below the southern portion of the Facility and in the central portion of the wetlands area. Up to 5 feet of the silty clay was penetrated in well boring 41755-WL23 in the wetlands at a depth of 18 to 23 feet. This material comprises the second geologic unit of Qey sediments.
- Gravelly Silty Sand – 30 to 35 feet thick below the southern portions of the Facility; 18 to 25 feet thick below the slope portions of the site; and up to 65 feet thick below the northern and wetlands portions of the site beyond the slope. This material comprises the lowermost geologic unit of Qey sediments.
- Silty Clay – up to 30 feet thick below the southern portions of the Facility. This material represents the Bootlegger Cove Formation (mapped unit Qeo of Cederstrom, Trainer, and Miller [1964]). The geologic contact between the younger Qey sediments and older silty clay facies of Qeo was penetrated only in pilot boring (DP98-PB14) at an approximate elevation of 90 feet amsl during the 2002 field investigation.

The fine-grained silts and clays of the Bootlegger Cove Formation were encountered at the 83- to 112-foot depth, and they appear to be more than 30 feet thick in the single site boring that penetrated the formation.

Peat lenses have been identified in the wetland area north of the site.

Figure 4-3a includes lithological information adapted from Cross-section B-B' from the DP098. The full set of RI/FS cross-sections are also included in Appendix D.

4.2.2 Hydrogeology and Groundwater

The site is underlain by two aquifers, a shallow unconfined aquifer and a deeper, confined aquifer. These aquifers are separated by the Bootlegger Cove Formation, which functions as a confining layer (and extends under most of JBER-E). There is no communication between the shallow and deep aquifers in the area of investigation. Only one water table aquifer is recognized above the Bootlegger Cove formation at the site, and only this aquifer is discussed in this report. One boring (DP98-PB14) was completed into the Bootlegger Cove Formation during the RI/FS. In that boring the Bootlegger was encountered at approximately 120 feet bgs (88 feet amsl).

Near Building 18224, the depth to groundwater is between 5 and 10 feet bgs. About 350 feet to the north, just before the break in slope that descends to a wetland, the depth to groundwater is approximately 15 feet. At DP098, the groundwater is highest during the fall and lowest during the winter months. Winters with high snowfall totals will create high water events in the late spring months. The groundwater emerges as intermittent seeps during high groundwater events in the fall and occasionally in the spring, along the edge of the wetland at the bottom of the slope. In the area of the drain tile outfall northwest of Building 18224, groundwater flows northwest to the wetland, as indicated by the blue flow direction arrows and groundwater contours in Figure 4-1. The wetland extends from the base of the slope about 500 feet in a northerly direction, where surface water is impounded in a small kettle pond.

4.3 Summary of Previous Investigations

4.3.1 Previous Activities

Previous environmental site investigations conducted at DP098 are described below:

- In 1995, investigation of two USTs near the southwest corner of Building 18224 encountered DRO levels up to 9,700 mg/kg (USAF, 1995). The 3,000-gallon tank was removed, along with 65 cubic yards of contaminated soil, and replaced with a new 4,000-gallon tank in the same excavation. The adjacent 25,000-gallon tank was emptied and abandoned in place.
- In the 1996 State-Elmendorf Environmental Restoration Agreement (SERA) Phase IV investigation, 13 soil borings revealed extensive DRO contamination. Monitoring wells, installed in many of the borings, revealed benzene, toluene, ethylbenzene, and xylenes (BTEX) and DRO contamination in groundwater. Other borings were used for soil-gas sampling or were abandoned. Some monitoring wells were constructed to function as air injection wells, but injection of air was never reported. Samples were not analyzed for VOCs (including CAHs). Free product accumulated in monitoring wells 41755WL-01 and 41755WL-03; a passive bailer installed in 41755WL-01 captured 3.75 gallons of product in nine months (USAF, 1996).
- In the 1997 SERA Phase VI investigation, a 62-point passive soil-gas survey identified two distinct areas of possible petroleum contamination northwest of Building 18224, at distances of approximately 100 and 430 feet from the building. The passive sorbents were analyzed for total petroleum hydrocarbons and BTEX. The sorbents were also analyzed for CAHs following the discovery of a possible disposal area in the northwest portion of the

investigation area. The results identified the presence of CAHs at DP098. Based on the sorbent results, a limited subsurface investigation was conducted and groundwater samples were collected for analyses from monitoring wells 41755WL-06 through 41755WL-09. The analytical results indicated TCE concentrations of 5 micrograms per liter (µg/L). A sample of surface water from the wetland contained cis-1,2-dichloroethene (DCE) at 9.1 µg/L (USAF, 1998).

- In the 1998 SERA Phase VII investigation, sample analyses from three soil borings (423BH02 through 423BH04) around Building 18224 indicated DRO exceeding 18 AAC 75 Table B soil cleanup levels in 423BH02. VOCs were not analyzed in the soil samples (USAF, 1999).
- In the 1999 SERA Phase VIII investigation, a soil boring was advanced adjacent to monitoring well 41755WL-04. The soil sample results from 22 feet bgs indicated TCE and DCE exceeded ADEC's cleanup levels. Groundwater samples were collected from 12 monitoring wells (41755WL-01 through 41755WL-12). The analytical results for CAHs in monitoring wells 41755WL-02, 41755WL-03, 41755WL-04, 41755WL-05, and 41755WL-08 exceeded ADEC's groundwater cleanup levels (USAF, 2000).
- In 2000, an Engineering Evaluation / Cost Analysis (EE/CA) was conducted to determine all sources of contamination and to evaluate the nature and extent of both hydrocarbon and chlorinated solvent contamination in soil, groundwater, sediment, and surface water. Following a 130-point soil-gas survey, 20 soil borings were advanced, and soil samples for GRO, DRO, RRO, VOCs, semivolatile organic compounds (SVOCs), and metals were collected. Selected samples were also analyzed for monitored natural attenuation (MNA) parameters (chloride, sulfate, nitrate, phosphate, heterotrophic plate count, sheen screen, and total organic carbon [TOC]). Twenty of the 39 soil samples exceeded the 18 AAC 75 soil cleanup levels for DRO, TCE, or DCE, defining the leading edge of the plume in the vicinity of 41755WL-07. Seven of the borings were completed as monitoring wells and sampled along with the 12 existing wells for GRO, DRO, RRO, VOCs, SVOCs, polynuclear aromatic hydrocarbons (PAHs), metals, and these MNA parameters (chloride, sulfate, nitrate/nitrite, total phosphorus, ferrous iron, and TOC). The results of groundwater samples from nine wells exceeded the 18 AAC 75 Table C groundwater cleanup levels for GRO, DRO, benzene, PCE, TCE, DCE, 1,1-dichloroethene, or vinyl chloride. Based on these results, the EE/CA identified a diesel plume originating near Building 18224 and a chlorinated solvent plume originating from a drain tile that extended northwest from Building 18224. Groundwater data bounded the plumes laterally and indicated that the chlorinated ethene plume did not extend beyond 41755WL-16, but did not quantitatively identify the downgradient extent of the diesel plume. Four sediment and four surface water samples were analyzed for GRO, DRO, RRO, VOCs, SVOCs, PAHs (waters only), and metals. Two sediment locations exceeded the ADEC's cleanup level for DRO, but were insufficient to delineate the nature and extent of such contamination. RRO was detected at

three sediment locations and exceeded the cleanup level in one surface water sample, providing evidence of discharge of contaminated water to the surface environment. Hydrostratigraphic investigations included slug tests in 16 wells and detailed logging of all boreholes. The rate and mechanism of natural attenuation (called "intrinsic remediation" in the EE/CA) were evaluated based on the expected rate of migration; the declining concentrations of primary contaminants and increasing concentrations of breakdown products; and the presence of geochemical conditions conducive to degradation. The EE/CA concluded that PCE and TCE were attenuating, but that DCE and vinyl chloride may be accumulating (USAF, 2001).

- An RI/FS conducted in 2002 built upon the investigative foundation of the EE/CA, refining the estimated nature and extent of contamination in support of remedy selection. Four new monitoring wells sampled conditions deeper in the aquifer (to depths of 85 feet bgs). Twelve new well points at the edge of the wetland and six surface water and sediment samples facilitated the evaluation of risk to human health and the environment. A pumping test evaluated the hydraulic properties of the aquifer. A pilot boring drilled to 150 feet bgs provided lithological information to help plan screen settings for the deep monitoring wells. The RI/FS developed a hydrogeological site model for DP098 as part of the discussion of the nature and extent of contamination. Use of contaminant-specific transport properties, site-specific hydraulic properties, and organic carbon content resulted in cleanup estimates for TCE of 55 years and DRO of 75 years (USAF, 2003).
- In 2004, a Phase 1 Remedial Process Optimization (RPO) report provided recommendations to optimize the groundwater monitoring program and continued to provide support for the reductive dechlorination pathways through the evaluation of sample data. The report outlined the need for a larger data set before a proposed cleanup date could be calculated for the VOC plume at DP098 (USAF, 2005a).
- In 2004, a bench-scale microcosm study was conducted and determined that COC degradation was occurring by both biotic and abiotic breakdown processes; however, the dehaloccoides population was presumed to be small, and growth rate was slow. The rate of degradation of COCs was also slowed by colder simulated groundwater temperatures that are not conducive to in-situ biodegradation. The expected benefit of substrate addition to enhance the rate of attenuation could not be demonstrated conclusively (USAF, 2005b).
- In 2005, a limited source area removal action took place. A total of 512 cubic yards of soil were excavated from the outfall area of the drain tile extending northwest from Building 18224 shown in as-built drawings (USAF, 2006).
- In 2005 and 2006, an Enhanced Natural Attenuation Treatability Study was conducted. This in-situ study was initiated in July 2005 where approximately 2,250 gallons of an oil-in-water emulsion (containing vegetable oil and sodium lactate) and a water push of 1,500 gallons (containing sodium lactate) were injected into three wells in the shallow aquifer.

An initial groundwater sampling event was conducted immediately prior to injection. Performance monitoring events were conducted during September 2005 (two months after injection), May/June 2006 (10 months after injection), and September 2006 (14 months after injection). The treatability study tested the hypothesis that more strongly reducing conditions would break down the accumulating DCE and vinyl chloride (VC). Dehalococcoides (DHC) bacteria were inferred to be potentially present due to the presence of intermediate dechlorination products. The report indicated that DHC may not be active, due to low groundwater temperatures or inappropriate geochemical conditions. The study concluded that TCE had been transformed to DCE, but there was not substantial transformation of VC to ethene[*], indicating that a complete reductive dechlorination pathway was not occurring. As alternatives, the study suggested that persistence of DCE may reflect insufficiently reducing conditions, perhaps due to buffering by ferric iron and oxidized manganese, or it may reflect the effects of low sulfate and cold temperatures (USAF, 2007a; Parsons, 2009).

- In 2007, GRO and DRO were added to the groundwater sample analyte list, along with ROD COCs, to better understand their relationship to the chlorinated solvent plume. In preparation for the first five-year review (due in 2008), monitoring in 2007 sampled a more extensive group of wells for both COCs and added DRO for this sample event to reassess the extent of the COC plume, rate of degradation and migration, and changes in the DRO plume. Results for COCs generally confirm the long-term trends previously reported in annual groundwater sampling events. The DRO plume is shrinking slowly and will continue to play a role in maintaining reducing conditions for the next several decades (USAF, 2007b).
- In 2007, a deep soil investigation of DNAPL was conducted using membrane interface probes (MIP) to profile the previously uninvestigated area to the base of the shallow aquifer. Profile MIP01 was installed to 76 feet bgs, MIP02 to 60 feet bgs, MIP03 to 67 feet bgs, MIP04 to 73 feet bgs, and MIP05 was installed to 72 feet bgs. The results of the investigation interpreted that chlorinated solvent contamination was encountered at depth, but confirmatory analytical samples were not collected. There was an unresolved question

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[*] The Treatability Study for MNA (2007) indicated that ethane and ethene were initially analyzed in 2001. The results indicated a low ethane concentration (1.1 µg/L) in only one well (41755WL-04). As part of the DP098 Treatability Study for MNA (USAF, 2007a), low level ethene concentrations were detected in several samples. The highest concentration was detected in DP98MW-04 (27 µg/L) with several low level concentrations (<3 µg/L) in other wells. Subsequent MNA sample analysis (including ethene) conducted as part of the 2015 CERCLA RA-OM Annual LTM field effort indicated a low level presence of ethene in 41755WL-04 (59–82 µg/L), and DP98-INJ02 (66 µg/L) with very low concentrations (<3 µg/L) present in several other wells. These results, coupled with the presence of intermediate degradation products of TCE, suggest the presence of DHC.

whether DNAPL had been detected at depth or whether the MIP had malfunctioned (Appendix E, USAF, 2008).

- In 2009, temporary well points were installed to investigate the extent of VOC contamination at DP098. The analytical results for all groundwater samples collected from the temporary well points did not completely delineate the extent of the VOC plume due to cleanup level exceedances in four of the well points. Soil samples were also collected in the biodegradation test area (USAF, 2010).
- A Biogeochemical Transformation of Chlorinated Solvents Study was conducted in 2010, where three in-situ test cells were injected with different substrates. In all of the test cells, the rates of anaerobic degradation of TCE and DCE were enhanced by at least an order of magnitude relative to natural attenuation at the site. The total molar concentrations of CAHs with the reaction zones increased by 45% in one test cell, and decreased by 61% and 36% in the other two test cells. The test cell injected with hematite, gypsum, and emulsified vegetable oil appeared to perform the best during the study (USAF, 2012).

4.3.2 Remedial Activities

Several remedial activities have occurred at DP098. They are as follows:

- In 1995, 65 cubic yards of contaminated soil were removed following the removal of the 3,000-gallon UST and abandonment of the adjacent 25,000-gallon UST (USAF, 1995).
- Recovery of free-product from the fine-grained soils adjacent to the USTs was conducted from 1996–2002; recovering 12.3 gallons of petroleum.
- In 2005, a limited source removal took place in which 512 cubic yards of contaminated soils were excavated from the outfall of the drain tile that extends northwest from Building 18224 (USAF, 2006).
- Since 2003, groundwater monitoring has been conducted annually. Long-term monitoring of the COCs and Man-Kendall trend tests at the 95% level of significance suggested that the leading edge of the plume (monitoring well 41755WL-08) has an increasing level of TCE and DCE. Based on Man-Kendall analysis trends, the COCs in the other monitoring wells at DP098 have either a decreasing trend or no trend (USAF, 2015).

4.3.3 Data Gaps

During the work plan preparation, the vertical and horizontal extent of potential CAH-DNAPL contamination were unknown. The 2007 MIP profiles indicated the potential for DNAPL at approximately 40–60 feet bgs and again at a depth of about 75 feet bgs. As part of this study, soil borings and monitoring wells were installed in an inferred source area to investigate the potential for a deeper CAH source in this area.

4.4 Field Activities

The field activities were performed between July 14, 2014 and January 23, 2015, in accordance with the *JBER Basewide UFP-QAPP* and the site-specific *UFP-QAPP DP098 DNAPL Evaluation Work Plan* (USAF, 2014a) to evaluate whether a deep DNAPL source was present. Field logbooks, soil boring logs, monitoring well installation sheets, groundwater sampling data sheets, and chain of custody forms are provided in Appendix A.

A total of six borings (14DP98-SB01 through 14DP98-SB05, and 15DP98-SB01) were advanced to depths of 60–80 feet bgs. The soil borings were positioned around the former drain tile northwest of Building 18224. Soil borings 14DP98-SB01 through 14DP98-SB05 were advanced in July 2014, and soil boring 15DP98-SB01 in January 2015. Boring locations (shown in Figures 4-1 and 4-2) were selected to more precisely characterize the vertical limits of contamination and assess current contaminant concentrations. A total of 38 soil samples, including five duplicates, were collected from within the chlorinated solvent-contaminated plume area in 2014–2015. The 2014–2015 boring locations are shown on Figure 4-2a.

From the 2014 soil borings, soil samples were collected from intervals with elevated screening results, thin discontinuous sand layers that could possibly act as preferential pathways, and at intervals near the bottom of the borings for vertical delineation. The soil samples were analyzed for VOCs, low-level VOCs, DRO, GRO, and RRO. An additional boring was installed in January 2015 to verify inconclusive data from the 2007 MIP investigation.

In January 2015, soil boring 15SP98-SB01 was installed in the vicinity of MIP-05, near the end of the former drain tile outfall northwest of Building 18224 and soil boring 14DP98-SB03. For 15DP98-SB01, additional field screening was implemented that consisted of the use of an FID, PID, Sudan Red test kits, and FLUTe™ strips. The Sudan Red and FLUTe™ tests are qualitative field screening methods used to identify the presence of NAPL. After 10 feet bgs, at least one analytical sample was collected from every 5-foot core. Since petroleum hydrocarbon contamination was known to extend to about 30 feet bgs, to help delineate the commingled petroleum hydrocarbon VOC-contaminated area from the deeper VOC, only contaminated area samples collected from 10–40 feet were analyzed for VOCs, low-level VOCs, DRO, GRO, and RRO; while the deeper soil samples were only analyzed for VOCs and low-level VOCs. After achieving 20 feet bgs, two samples per 5-foot interval were collected, and a headspace reading was collected later. The sample with the higher screening result was submitted for laboratory analysis.

In January 2015, two monitoring wells were installed in the vicinity of the drain tile outfall identified northwest of Building 18224 in as-built drawings. Monitoring well DP98MW-07 was installed to a total depth of 40 feet bgs and is screened from 30–40 feet bgs. This monitoring well was intended to sample groundwater below the LNAPL source area. Monitoring well DP98MW-08 was installed adjacent to soil boring 15DP98-SB01 to a total depth of 80 feet bgs and is screened from 65–80 feet bgs. This monitoring well was installed with the purpose of vertically delineating the VOC-contaminated area and to verify inconclusive data from the 2007 MIP investigation. In January 2015, one groundwater sample was collected from each of the newly installed monitoring wells (DP98MW-07 and DP98MW-08). Groundwater samples were analyzed for VOCs, DRO, GRO, and RRO.

Field quality control samples including duplicates, matrix spike/matrix spike duplicates, trip blanks and equipment blanks were collected on a program basis, as described in the work plan.

4.5 Deviations from the Work Plan

The field work was conducted per the project standard operating procedures in the *UFP-QAPP DP098 DNAPL Evaluation Work Plan* (USAF, 2014a). There were no deviations from the work plan other than using the Sudan Red and FLUTe™ NAPL indicators as field screening methods to identify potential NAPL bearing zones.

4.6 Site Characterization Results

4.6.1 Nature and Extent of Contamination

The known horizontal extent of the CAHs and petroleum contamination at DP098, based on current and historical data, are shown on the Site Maps (Figures 4-1 and 4-2) and the Cross-Sections (Figures 4-3a and 4-3b) using color-coded symbols to indicate the presence or absence of chlorinated solvents above cleanup levels and petroleum hydrocarbon LNAPL.

In this report, petroleum-related contaminants in groundwater are discussed in relation to Chapter 18 of the Alaska Administrative Code Section 75 (18 AAC 75) Table C groundwater cleanup levels, but are not considered to be COCs under the ROD. Petroleum-related contaminants in soils are compared to 18 AAC 75 Table B soil cleanup levels to indicate the presence/absence of petroleum contamination but are not considered COCs under the ROD. Where petroleum is present, it would indicate that the conditions for natural attenuation of CAHs are more favorable.

The working definition for LNAPL source areas used in this report is: soil concentrations above 18 AAC 75 Table B2 migration to groundwater levels for DRO and GRO (250 mg/kg and 300 mg/kg respectively), and RRO concentrations above 250 mg/kg. The presence of NAPL was also inferred where PID field screening results greater than 25 ppm were measured.

Due to the close proximity of monitoring wells DP98MW-07, DP98MW-08, and soil boring 15DP98-SB01, data from the boring and wells are shown on the Figures 4-3a and 4-3b cross sections in one column. Figure 4-3a includes lithological information adapted from Cross-section B-B' from the RI/FS (USAF, 2003). The full set of RI/FS cross-sections is also included in Appendix D.

Historical data used to create Figures 4-3a and 4-3b are included as Appendix C.

The FLUTe™ strips and the SUDAN red dye test kit results were all negative, indicating that CAHs are present in concentrations below soil saturation concentrations (i.e., no DNAPL was identified).

4.6.1.1 Nature of Soil Contamination

Both current and historical investigations indicate that two zones of distinct contamination are present at the site and were investigated in 2014/2015: a shallow zone containing CAHs dissolved in petroleum hydrocarbons extends from approximately 1 foot to 30 feet bgs; and a deeper zone containing CAHs with no petroleum hydrocarbon component, extends from approximately 30 feet to 69 feet bgs. Because the CAHs are miscible with the petroleum, no density separation of the CAHs resulting in a DNAPL is expected. In the zone below the commingled petroleum hydrocarbon contamination, the CAHs were only encountered as three-phase concentrations; no distinct DNAPL source was identified with either field screening methods or laboratory analysis. The vertical extent of CAH contamination is shown on Figures 4-3a and 4-3b.

The data set for the 2014/2015 investigation includes 25 soil samples analyzed for DRO, GRO, and RRO. These results are summarized on Table 4-1. Three of these samples indicate DRO exceedances of ADEC's 18 AAC 75 Table B soil cleanup levels.

Thirty-three soil samples were analyzed for VOCs, and the results are summarized on Table 4-2. Ten samples exceeded cleanup levels for DCE with a maximum concentration of 1.8 mg/kg at soil boring 14DP98-SB02. Six samples exceeded cleanup levels for PCE with a maximum concentration of 41 mg/kg at soil boring 14DP98-SB02. Twenty-four samples exceeded cleanup levels for TCE with a maximum concentration of 94 mg/kg at soil boring 14DP98-SB03.

- The maximum TCE concentration found at this site during the 2014–2015 field work was 14DP98-SB03 (94 mg/kg). This was found at a depth of 29–29.5 feet bgs corresponding to the petroleum hydrocarbon contamination. The corresponding petroleum hydrocarbon concentrations were 4.3 mg/kg DRO, 140 mg/kg GRO, and 9.1 mg/kg RRO. A specific gravity estimate for the miscible mixture was completed using concentrations and approximate specific gravity values for each of the major constituents detected (GRO, DRO, RRO, and TCE).

$SG_{\text{Mixture}} = ((\text{DRO}) \times SG_{\text{DRO}} + (\text{GRO}) \times SG_{\text{GRO}} + (\text{RRO}) \times SG_{\text{RRO}} + (\text{TCE}) \times SG_{\text{TCE}})) / ((\text{DRO}) + (\text{GRO}) + (\text{RRO}) + (\text{TCE}))$ or

$SG_{\text{Mixture}} = ((4.3 \times 0.85) + (140 \times 0.739) + (9.1 \times 0.9) + (94 \times 1.46))/ (4.3 + 140 + 9.1 + 94)$

$SG_{\text{Mixture}} = 1.02$

The estimate indicates that the NAPL mixture would have a specific gravity of 1.02 or just slightly heavier than water (SGwater = 1). Specific gravity values for DRO and RRO were cited from Charbeneau, et al., 1999, GRO from Gratt, L.B., 1996, and TCE from Lowe, et al., 1999.

4.6.1.2 Threshold Chemical Concentrations

As a check to determine whether TCE would be present above the threshold value necessary for DNAPL presence, Calculation 2 in Appendix A of the Assessment and Delineation of DNAPL Source Zones at Hazardous Waste Sites (Kueper and Davies, 2009) was used. Because the TCE is present as a multicomponent NAPL, Calculation 2 - Threshold chemical concentration in soil based on partitioning relationships was used. This value (C^T) represents the maximum amount of contaminant *i* that can be present in a porous media sample in the sorbed, aqueous, and vapor phases without a DNAPL phase present (i.e. three phase concentration). Because the concentration used in the calculation was analyzed from a sample collected below the water table, the air-filled porosity value (θ_a) is set to zero. This calculation is presented below.

Calculation for C^T

$C^T_{TCE}= (C_{TCE} / \rho_b)(K_d \rho_b + \theta_w + H'\theta_a)$

Where:

C^T_{TCE} = soil concentration (mg/kg) threshold for TCE [calculated]

C_{TCE} = effective solubility (mg/l) of TCE [calculated below], value used = 435.2

ρ_b = dry soil bulk density (g/cc) [site specific measurement], value for ground moraine used = 1.99 (USAF, 1994)

K_d = soil-water partition coefficient (ml/g) [calculated using K_d = Koc x foc], value used = 0.0677

θ_w = water-filled porosity (unitless) [calculated from site specific measurement of moisture content], value used = 0.25

H' = unitless Henry's constant [handbook], value used = 1.52 x 10^{-01}

θ_a = air-filled porosity (unitless) [site specific measurement], value used = 0 (sample collected below the water table

K_{oc} = organic carbon - water partition coefficient (ml/g), value used = 67.7 (ADEC, 2008)

f_{oc} = fraction organic carbon (unitless). ADEC default value for Alaska soils used 0.001.

C^T_{TCE} = (435.2/ 1.99) x (0.067 x 1.99) + 0.25 + 0)

C^T_{TCE} = 84.6 mg/kg

Calculation for C_i (Effective Solubility from Raoult's Law)

$C_{TCE} = m_{TCE}\, S_{TCE} = 0.34 \times 1{,}280 = 435.2$ mg/l

Where:

m_{TCE} =mole fraction (unitless) of TCE in the DNAPL [site specific measurement] value used = 0.34

S_{TCE} = single-component TCE solubility (mg/l) [handbook], value used = 1,280

Mole Fraction (TCE)

$m_{TCE} = (ms_{TCE}/mw_{TCE}) / (ms_{TCE}/mw_{TCE} + ms_{DRO}/mw_{DRO} + ms_{GRO}/mw_{GRO} + ms_{RRO}/mw_{RRO})$

Where:

m_i = mole fraction of component *i*

ms_i = mass fraction of component *i* in the DNAPL

mw_i = molecular weight (g/mole) of component *i*

$m_{TCE} = (0.38/131) / (0.38/131 + 0.02/196 + 0.57/104 + 0.04/338)$

$m_{TCE} = 0.34$

Molecular weights for GRO, DRO, and RRO were adapted from GeoSphere et al., 2006 using the average of the aliphatic molecular weights listed for the equivalent carbon ranges GRO (C_5–C_{10}), DRO (C_{10}–C_{21}), and the listed value for RRO (C_{21}–C_{35})

The calculation for C^T indicated a value of 84.1 mg/kg. This is essentially the same as the highest concentration detected during the investigation (94.1 mg/kg) and indicates that the TCE concentration is slightly above the amount needed to be present as NAPL in the overall NAPL mixture.

An estimate of the TCE percentage in the NAPL was also made using a different model (the ADEC Hydrocarbon Risk Calculator [HRC] Spreadsheet) to evaluate the phase partitioning in this soil sample. The calculator is a three- and four-phase evaluation tool using Volatile Petroleum Hydrocarbon and Extractable Petroleum Hydrocarbon data. Since no Volatile Petroleum Hydrocarbon and Extractable Petroleum Hydrocarbon analyses were performed on the DP098 samples, data were substituted from a petroleum contaminated site with similar subsurface properties. The HRC estimated that, based on the major constituent concentrations in 14DP98-SB03, a TCE mass fraction of 0.39 was present in the NAPL mixture. This would mean that the TCE concentration in the NAPL mixture is approximately 37 mg/kg, with the rest of the TCE (57 mg/kg) present in the adsorbed, vapor, and dissolved phases. A copy of the HRC spreadsheet is included as Appendix E.

The combined TCE and petroleum concentrations is approximately 250 mg/kg. While the presence of a NAPL mixture is indicated at low concentrations, it is insufficient to saturate the soil matrix pore spaces and would only be present as disconnected blobs or ganglia within the pore spaces and would not be expected to flow horizontally or vertically even given the combined specific gravity of 1.02.

4.6.1.3 Extent of Soil Contamination

The data at DP098 show that petroleum hydrocarbon releases have resulted in contamination over an area approximately 480 feet long by 300 feet wide (as indicated by the red dashed line in Figure 4-1). Historical data indicate that the petroleum hydrocarbon release extends to a depth of approximately 30 feet bgs at 41755WL-03. The deepest petroleum contamination observed from the 2014/2015 field effort was approximately 27 feet bgs at 14DP98-SB05. The vertical extent of petroleum contamination is shown in the cross-sections on Figures 4-3a and 4-3b.

Chlorinated solvent releases at DP098 are interpreted to be associated with the historical drain tile systems at this location. In particular, one drain tile that extended northwest from Building 18224 resulted in soil contamination that has migrated to the groundwater. Soils are also contaminated with chlorinated solvents covering an area approximately 450 feet long by 230 feet wide, as indicated by the purple ring symbols and the dashed purple polygon shown on Figure 4-1. Low-level solvent-contaminated soils were also noted in a historical soil sample from soil boring DP98-SB12 located west of Building 18216. This contamination is interpreted to be associated with a drain tile outfall from Building 18216, not from the drain tile outfall northwest of Building 18224. Historical borings and monitoring wells that bound the horizontal extent of the chlorinated solvents are indicated in Figure 4-1 by orange rings. The intent of this DNAPL evaluation was not to delineate the horizontal extent of chlorinated contamination, but rather to delineate the vertical extent of contamination and determine if a distinct deeper DNAPL source exists that contributes to the CAH contamination at the site. No DNAPL source was identified below the LNAPL plume in this investigation.

The TCE soil contamination extends to a depth of 68.5 feet bgs at 15DP98-SB01 and was shallower in all 2014 soil borings (14DP98-SB01 through 14DP98-SB05) as noted in Figures 4-3a and 4-3b. The maximum concentrations occurred between 28 and 30 feet bgs in 14DP98-SB03 (94 mg/kg) and 15DP98-SB01 (50 mg/kg). Analytical results from soil samples collected from the bottom of each of the 2014–2015 soil borings were below the ROD cleanup levels.

The data gap described in Section 4.3.3 regarding a deeper DNAPL source was investigated in an area thought to be a likely location based on the location of the drain tile outfall northwest of Building 18224 and previous MIP-05 indicating the possible presence of DNAPL. This DNAPL evaluation did not identify a specific DNAPL source but does indicate that a deeper source below the LNAPL mixture zone must be present to account for the presence of dissolved phase TCE in the under groundwater. Uncertainty as to the horizontal and vertical extent of a deeper DNAPL source still exists as a data gap.

A data gap associated with TCE concentrations in soils from 0–30 feet bgs in the vicinity of 41755WL08 still exists. A specific source for the CAH contamination in this monitoring well has not been identified. Additional soil sampling and analysis for TCE from a shallow boring (approximately 30 feet deep) approximately 10 feet south of 41755WL-04 and adjacent to 41755WL-08 would also aid in defining the vertical distribution of TCE at these locations.

Due to the subsurface heterogeneity in the moraine and potential for small scale preferential flow within zones of higher permeability, identifying a DNAPL source is challenging. Also, because this is a mature site, if only limited amounts of DNAPL were originally released and have largely dissolved away, the ongoing dissolved phase contamination present below the LNAPL zone could be due to back diffusion from TCE adsorbed to fine-grained material present as silts and clays in the subsurface.

4.6.2 Nature and Extent of the Groundwater Contamination

Water level gauging indicates the static water level in monitoring well DP98MW-08 was approximately 4 feet deeper than in monitoring well DP98MW-07 prior to the development of these wells. This may indicate a downward vertical gradient at this location, but post-development gauging is necessary to confirm the vertical gradient.

At DP98MW-07, DCE and TCE concentrations were above ROD groundwater cleanup levels, and the GRO concentration was above the 18 AAC 75 Table C groundwater cleanup level. No other exceedances of cleanup levels were indicated at DP98MW-07. There were no exceedances of groundwater cleanup levels for any of the analytes sampled for at DP98MW-08. These sample results indicated that groundwater contamination lies above 63 feet bgs (the top of the sand pack for the screened interval for the deep monitoring well DP98MW-08). DRO, GRO, and RRO groundwater sample results are included in Table 4-3; VOC groundwater sample results are included in Table 4-4.

A simplified conceptual site model (CSM) wireframe diagram is provided as Figure 4-4. This updated CSM does not represent a significant change from the previous CSM but combines the two CSMs for human health and the two ecological CSMs presented in the ROD into one diagram.

4.6.3 Data Quality Evaluation

The soil and groundwater samples collected were analyzed by TestAmerica Laboratories, Inc., using locations in West Sacramento, Denver, and Seattle. Upon receipt of the laboratory results, WESTON performed a data quality review and validated the chemical data. The Quality

Assurance / Quality Control (QA/QC) Summary Report form and the ADEC Laboratory Review Checklist forms are included in Appendix B. Only validated, usable data are presented in the project data tables.

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5.0 CONCLUSIONS

The historical data and 2014/2015 data support the following conclusions:

- DRO and GRO contamination were present in soils from about 165–196 feet amsl.
- Soil contamination remains above cleanup levels for DCE, PCE, and TCE with maximum concentrations of 1.8 mg/kg, 41 mg/kg, and 94 mg/kg, respectively. The deepest contamination above ROD cleanup levels was TCE encountered in 15DP098-SB-01 at 68.5 feet bgs (~128 feet amsl). Detections of TCE in the saturated soils below the LNAPL contamination limit of about 165 feet amsl indicate the existence of a deeper, independent CAH source; however, no deep CAH DNAPL source was encountered between 40 and 80 feet bgs (158–118 feet amsl). While it is likely that DNAPL is present below the LNAPL, it is not practicable to precisely identify the source location and extent.
- The highest soil concentrations of TCE found were present within the petroleum hydrocarbon contaminated zone at 14DP098-SB-03 at 29–29.5 feet bgs (~169.5 feet amsl). The combined TCE and petroleum concentration is approximately 250 mg/kg. While the presence of a NAPL mixture is indicated at low concentrations, it is insufficient to saturate the soil matrix pore spaces and would only be present as disconnected blobs or ganglia within the pore spaces and not expected to flow horizontally or vertically.
- Groundwater concentrations of DCE and TCE exceed ROD cleanup levels, and elevated groundwater concentrations of GRO were present in the sample collected from the newly installed monitoring well DP98MW-07 (screened from 30–40 feet bgs [168–158 feet amsl]). No exceedances of cleanup levels were indicated in the groundwater sample collected from the newly installed monitoring well DP98MW-08 screened from 65–80 feet bgs (133–118 feet amsl).
- Previous treatability studies to reduce dissolved phase TCE concentrations have indicated that between four methods tested, the injection of a mixture of hematite, gypsum, and emulsified vegetable oil within the TCE plume area was the most successful. Bioaugmentation could be a viable option to enhance emulsified vegetable oil injection.

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6.0 RECOMMENDATIONS

Based on the conclusions of the DNAPL evaluation, the following recommendations have been made:

- No further characterization of the upgradient source area is recommended as the challenges associated with identifying DNAPL in a heterogeneous moraine with small scale differences in hydraulic conductivity and the resulting preferential pathways make it impracticable.

- Additional soil sampling and analysis for TCE from shallow borings (approximately 30 feet deep) approximately 10 feet south of 41755WL-04 and adjacent to 41755WL-08 could be useful to evaluate whether CAHs in soil are contributing to this part of the plume.

- Continue groundwater monitoring at the site per the DP98 ROD.

- Complete a cost benefit analysis of enhanced treatment in the upgradient area.

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