FINAL 2017

LONG TERM MANAGEMENT REPORT

BASE LIVING AREA (ZONE 1)
BASE INDUSTRIAL AREA (ZONE 2)
SOUTH BLUFF TREATMENT SYSTEM (ZONE 3)
BLUFFS O&M
NAKNEK RIVER STORAGE AREA (ZONE 4)
RAPCON & RED FOX CREEK (ZONE 5)
NAKNEK REC CAMP LAND FILL (ZONE 6)
LAKE CAMP (ZONE 7)

KING SALMON DIVERT, ALASKA

SEPTEMBER 2018

CONTRACT NO. FA8903-14-D-0041, TO 0004

FINAL 2017

LONG TERM MANAGEMENT REPORT

BASE LIVING AREA (ZONE 1)
BASE INDUSTRIAL AREA (ZONE 2)
SOUTH BLUFF TREATMENT SYSTEM (ZONE 3)
BLUFFS O&M
NAKNEK RIVER STORAGE AREA (ZONE 4)
RAPCON & RED FOX CREEK (ZONE 5)
NAKNEK REC CAMP LAND FILL (ZONE 6)
LAKE CAMP (ZONE 7)

KING SALMON DIVERT, ALASKA

SEPTEMBER 2018

Prepared for
United States Air Force
Pacific Air Forces Regional Support Center
&
Air Force Civil Engineer Center
10471 20th Street
JBER, AK 99506-2200

Prepared by
Paug-Vik Services, LLC
6250 Tuttle Place, Suite 5
Anchorage, Alaska 99507

Contract No. FA8903-14-D-0041, TO 0004

PREFACE AND DISCLAIMER

Paug-Vik Services, LLC (Paug-Vik) prepared this report through a contract with the Air Force Civil Engineering Center (AFCEC), contract number FA8903-14-D-0041, task order 0004. Paug-Vik and its subcontractors performed this work for the United States Air Force (USAF) under the Environmental Restoration Program (ERP). This comprehensive report presents long-term management activities conducted in 2017 at seven King Salmon Divert (KSD) groundwater zones.

This report provides a description of work and results performed by contract field personnel during the project. Where relevant, this work generally followed guidance contained in the AFCEE *Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater* (Wiedemeier et al., 1999), the *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater* (Wiedemeier et al., 1998), and the AFCEE Handbook for the IRP, Remedial Investigation and Feasibility Studies (RI/FS), dated September 1993.

This document has been prepared for the United States Air Force for the purpose of aiding in the implementation of the Environmental Restoration Program (ERP). The limited objectives of this document and the ongoing nature of the ERP, along with the evolving knowledge of site conditions and chemical effects on the environment and human health, must be considered when evaluating this document since subsequent facts may become known which may make this document incomplete or inaccurate.

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

Section 1

Section 2

Section 3

Section 4

Section 5

Section 6

Section 7

Section 8

ABBREVIATIONS AND ACRONYMS

611 CES	611th Civil Engineer Squadron
AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
ADWS	Alaska Drinking Water Standards
AFB	Air Force Base
AFCEE	Air Force Center for Engineering and the Environment
AFCEC	Air Force Civil Engineer Center
ARARs	Applicable or Relevant and Appropriate Requirements
AST	Aboveground Storage Tank
AWQS	Alaska Water Quality Standards
bgs	Below Ground Surface
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
COC	Contaminants of Concern
COPCs	Contaminants of Potential Concern
DCE	Dichloroethene
DO	Dissolved Oxygen
DOD	Department of Defense
DRO	Diesel-Range Organics
EDB	1,2-dibromoethane
ERP	Environmental Restoration Program
ERPIMS	Environmental Resources Program Information Management System
FPP	Floating Petroleum Product
FS	Feasibility Study
FSP	Field Sampling Plan
GRO	Gasoline-Range Organics
IDW	Investigation-Derived Waste
KSA	King Salmon Airport
KSD	King Salmon Divert
LFI	Limited Field Investigation
LTM	Long-Term Monitoring
MNA	Monitored Natural Attenuation
ND	Not Detected
NOAA	National Oceanic and Atmospheric Administration
OASIS	OASIS Environmental, Inc.
OSWER	Office of Solid Waste and Emergency Response
ORNL	Oak Ridge National Laboratory
ORP	Oxidation-Reduction Potential
PAH	Polynuclear/polycyclic aromatic hydrocarbon
PCBs	Polychlorinated biphenyl
PCE	Tetrachloroethylene
PDC	Paug-Vik Development Corporation
PEL	Probable Effects Level
pH	Measure of acidity and alkalinity
POC	Point of Compliance
POL	Petroleum, Oil, Lubricants
PVS	Paug-Vik Services, LLC
QA	Quality Assurance

QAPP	Quality Assurance Project Plan
QAR	Quality Assurance Review
QC	Quality Control
RAO	Remedial Action Objective
RG	Remediation Goal
RI/FS	Remedial Investigation/Feasibility Study
RL	Reporting Limit
ROD	Record of Decision
RPO	Remedial Process Optimization
SAIC	Science Applications International Corporation
SQB	Sediment Quality Benchmark
SQuiRT	Screening Quick Reference Table
TAH	Total aromatic hydrocarbons
TAqH	Total aqueous hydrocarbons
TCE	Trichloroethene
TDS	Total Dissolved Solids
toc	Top of Casing
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
USAF	United States Air Force
USEPA	U.S. Environmental Protection Agency
UST	Underground Storage Tank
VOA	Volatile Organic Analysis
VOCs	Volatile Organic Compounds

UNITS OF MEASURE

ft	Feet
mg/Kg	Milligrams analyte per kilogram of sample
mg/L	Milligrams analyte per liter of sample
µg/L	Micrograms analyte per liter of sample
µS/cm	Microsiemens per centimeter
mV	Millivolts
°C	Degrees Celsius
°F	Degrees Fahrenheit

EXECUTIVE SUMMARY

This comprehensive management report presents analytical and field data collected during the 2017 field season from seven groundwater zones at King Salmon Divert, Alaska (KSD). Descriptions of the sampling events and results from each site are summarized below.

Each appendix is separated into sections based upon groundwater zone. Sample data collection sheets are included in Appendix A. Chain of custody records documenting activities during the field season are in Appendix B. Analytical summary tables of results for groundwater, surface water, and sediment collected during the field activities are presented in Appendix C. A Quality Assurance Review of the analytical results from samples collected and Alaska Department of Environmental Conservation (ADEC) Laboratory Data Review Checklists are presented in Appendix D. PRoUCL Statistical Tests for Trend Analysis for Zone 1, Zone 2, Zone 4, Zone 5 (RAPCON), and Zone 7 are presented in Appendix E. Photographic documentation of field activities is presented in Appendix F. Complete laboratory data reports are provided on the accompanying DVD-R.

The Air Force is currently under contract through the Corps of Engineers to complete an Explanation of Significant Difference for Zone 3, as well as Records of Decision for Zone 5 and Zone 7.

GROUNDWATER ZONE 1 – BASE LIVING AREA

Groundwater samples were collected from nine Zone 1 A-Aquifer monitoring wells in September 2017, and analyzed for volatile organic compounds (VOCs), diesel-range organics (DRO), geochemical indicators of intrinsic remediation, and other inorganic analytes. Groundwater samples were also collected from three B-Aquifer wells and analyzed for VOCs and DRO. An institutional control inspection was performed to verify that no drinking water wells have been installed in the A or B Aquifers.

The results from these efforts indicate that none of the sample results from the A-Aquifer monitoring wells exceeded the ADEC groundwater cleanup levels for benzene, toluene, ethylbenzene, and xylenes (BTEX) components. Two well points and two monitoring wells exceeded the cleanup level of DRO. TCE was observed above the ADEC Table C cleanup level of 2.8 µg/L at ETMW-02 (56/65 µg/L), MW89-1 (3.6 µg/L), MW-6 (20 µg/L), and MW-28 (110 µg/L). TCE was not detected above the action level of 2.7 µg/L in any of the four point-of-compliance (POC) well points. POC results ranged from ND to 2.4 µg/L. Inorganic parameters provide some evidence that natural attenuation of petroleum hydrocarbons is occurring in the A-Aquifer. The majority of concentration trends are stable or decreasing. This indicates that intrinsic remediation is keeping contaminant concentrations stable or decreasing at this site.

TCE was found at a concentration of 83 µg/L in MW-41, and 51 (52) µg/L in MW13-09B. These results exceed the cleanup level of 2.8 µg/L. TCE contamination in Zone 1 is at the center of an ongoing RI/FS, under a separate contract.

Monitoring and recovering product at Seeps 1 and 2 was done in June 2017. A total of ~0.3 liter of product was removed from PR-11, PR-12, PR-13, and PR-32 at Seep 1.

GROUNDWATER ZONE 2 - BASE INDUSTRIAL AREA & ESKIMO CREEK DUMP

Groundwater samples were collected from eleven Zone 2 A-Aquifer monitoring wells in mid-September of 2017, and analyzed for VOCs, DRO, gasoline-range organics (GRO), geochemical indicators of intrinsic remediation, and other inorganic analytes.

Five wells exceeded the ADEC cleanup level for GRO and two exceeded the ADEC cleanup level for DRO. MW-708 had the highest concentration of GRO (30 mg/L), followed by B-02 (13/14 mg/L), and AP-11 (13 mg/L).

Six wells exceeded the ADEC cleanup level of 2.8 µg/L for TCE. Those concentrations ranged between 3 µg/L to 15 µg/L. TCE results in a seventh well was 1.6 µg/L, while the remaining four wells were non-detect.

Monitoring wells 629, 708, and MW00-03 exceeded the cleanup level of 4.6 µg/L for benzene.

Surface water samples were collected from three locations along Eskimo Creek and analyzed for VOCs. TCE was not detected in any of the samples. Two locations exceeded the water quality criteria for naphthalene.

As has been observed in previous years, the combined lines of evidence of stable to decreasing petroleum hydrocarbon plumes and changes in groundwater chemistry strongly support the occurrence of intrinsic bioremediation of the petroleum hydrocarbons at this site. Decreasing TCE concentration trends suggest that intrinsic remediation of this chlorinated compound has occurred and is occurring. Intrinsic remediation of petroleum and chlorinated hydrocarbons is expected to continue in Zone 2.

An institutional control inspection was performed with no observations of IC noncompliance.

GROUNDWATER ZONE 3 – SOUTH BLUFF

One sample was collected from the South Bluff Treatment System lift station in September, and another sample was collected in March. Two more quarterly sampling events are scheduled, and those results will be discussed in separate letter reports. DRO, acetone, TCE, arsenic, and barium were detected in the September effluent sample at levels below the effluent limitations. Chromium was detected at 0.53 µg/L which is above the effluent limitation of 0.35 µg/L. Arsenic, barium, chromium, iron, TCE and benzene were detected in the March sample below the effluent limit.

Slopes, vegetation, erosion-control features, culverts, downdrains, toe roads, and access at the Bluffs were inspected. The gabion wall at the South Bluff has been undercut by King Salmon Creek. There were no observations of drinking water wells or excavations out of compliance with institutional controls.

GROUNDWATER ZONE 4 – NAKNEK RIVER STORAGE

Samples were collected from three A-Aquifer wells, two B-Aquifer wells, three residential wells, and three surface water/sediment locations. Product recovery system maintenance and landfill inspections were performed along with an institutional control inspection to verify that no new drinking water wells have been installed in contaminated aquifers.

Product was detected at MW-57 again this year and the well was not sampled. Product thickness measured 0.09 ft, which does not warrant removal. DRO was detected above cleanup levels in monitoring wells 502 and MW-51. GRO was detected in all three wells above the cleanup level of 1.3 mg/L found in the final ROD, but below the current ADEC cleanup level of 2.2 mg/L.

Low levels of DRO were detected in one B-Aquifer monitoring well and one residential well. These results were flagged by the lab as being between the detection limit and the reporting limit. DRO was also detected in the method blank. All detections are well below the RAOs for DRO.

Petroleum hydrocarbon concentrations in surface water decreased as water flowed through the wetlands (sampling location OT30-01 is upgradient of the wetlands and sampling location OT30-03 is downgradient of the wetlands). OT30-01 exceeded the ADEC Regulatory Criteria of 15 µg/L for total aqueous hydrocarbons (TAqH). GRO and DRO were detected in both samples. The sediment sample from OT30-01 exceeded the criteria naphthalene.

As has been observed in previous years, the combined lines of evidence of stable to decreasing hydrocarbon plumes and changes in groundwater chemistry strongly support the occurrence of intrinsic bioremediation in the hydrocarbon-impacted areas of this groundwater system. Intrinsic bioremediation of fuel-impacted groundwater is expected to continue in Zone 4.

For the fifth consecutive year, OT30-04, located at the base of the Naknek River bank below MW-57, has been included in the sampling program. While ADEC has no standards for GRO or DRO in surface water or sediments, surface water at OT30-04 had GRO and DRO levels of 0.83 mg/L and 6.3 mg/L respectively. Sheen was also present. Sediment had GRO and DRO levels of 88 mg/kg and 1,700 mg/kg, respectively. Sampling results from OT30-04 suggest that the DRO plume at MW-57 is having an impact on the river bank at that location. POL contaminated soil removal is planned for this area under a separate contract.

An institutional control inspection verified that no new drinking water wells have been installed in the in contaminated aquifers. The former landfill areas were inspected and the product recovery pillows were replaced.

GROUNDWATER ZONE 5 – RAPCON & RED FOX CREEK

Samples were collected from six A-Aquifer wells, one surface water/sediment location, and a second sediment only location near Red Fox Creek. An institutional control inspection was also performed to confirm that no drinking water wells have been installed or excavating has occurred.

All six of the monitoring wells were sampled for DRO. Four of the groundwater samples had DRO concentrations that met or exceeded the cleanup level of 1.5 mg/L. Four of the monitoring wells were sampled for GRO; one exceeded the cleanup level of 2.2 mg/L. Three wells were analyzed for VOCs; none of the results exceeded the cleanup level for TCE. Overall, there was an increase over 2016 concentrations of DRO and a decrease of GRO concentrations.

The surface water sample RFC-04 exceeded the ADEC Regulatory Criteria for TAH and TAqH. RFC-04 also had a surface water exceedance for m,p-xylene. TCE was detected in the surface water at 0.16 (0.18) μg/L. The RFC-04 sediment sample exceeded criteria for naphthalene, 2-methylnaphthalene, acenaphthylene, and fluorine. TCE was not detected. Acetone exceeded the screening criteria in the RFC-05 sediment sample, and a low level of TCE was detected.

As has been observed in previous years, the combined lines of evidence of stable to decreasing hydrocarbon plumes and changes in groundwater chemistry suggest that intrinsic bioremediation in the hydrocarbon-impacted areas of this groundwater system is occurring. Intrinsic bioremediation of fuel-impacted groundwater is expected to continue in Zone 5.

A land use inspection confirmed that no drinking water wells have been installed or excavating has occurred.

GROUNDWATER ZONE 6 – NAKNEK REC CAMP LANDFILL

Institutional controls listed in the Zone 6 ROD prohibit drinking water wells within 100 feet of the boundaries of the former generator pad and landfill, excavation of soils deeper than five feet bgs in the area of the former generator pad, and excavation or construction in the area of the landfill. On September 15, 2017, the area that was formerly used as a landfill was inspected. The area is overgrown with indigenous vegetation with little evidence of debris. There were no observations of noncompliance of institutional controls at the former landfill or generator pad.

GROUNDWATER ZONE 7 – LAKE CAMP

Groundwater samples were collected from eight monitoring wells at Lake Camp and analyzed for DRO and MNA parameters. Monitoring wells GP01 and MW22 exceeded the RAO of 1.5 mg/L for DRO at 4.1 mg/L and 2.2 mg/L, respectively. These results are increases over last year's results.

Institutional controls prohibit the installation of water supply wells as long as the aquifer fails ADEC Table C cleanup levels, and restricts excavating without a proper soil management plan. There were no observations of noncompliance within the site boundaries.

1 INTRODUCTION

King Salmon is located on the Alaska Peninsula adjacent to Bristol Bay and Katmai National Park and Preserve, approximately 280 miles southwest of Anchorage, and 15 miles east of Kvichak Bay (Figure 1-1). King Salmon Divert (KSD) is located adjacent to the community of King Salmon and encompasses approximately 220 acres along the northern bank of the Naknek River, approximately 15 miles upstream from the mouth of the river and the community of Naknek.

Environmental Restoration Program (ERP) sites at KSD have been grouped into seven environmental management zones called groundwater zones (five at KSD and additional zones at the Naknek Recreation Camp I [Rapids Camp – Zone 6] and Naknek Recreation Camp II [Lake Camp – Zone 7]) (Figure 1-2). Each zone is a geographically and hydrogeologically contiguous area that is amenable to investigative and remedial management as a single unit.

1.1 GROUNDWATER ZONE 1 – BASE LIVING AREA

Groundwater Zone 1 coincides with the KSD Base Living Area. Five source areas have potentially contributed to the contamination at Groundwater Zone 1:

- Dry Well Site (DP023).
- Eskimo Creek (SS011).
- POL Tanks (SS015).
- MOGAS Station (SS019).
- Building 649 (Bowling Alley)

Historical spills and operational practices at Zone 1 resulted in contamination of groundwater with petroleum-based products and chlorinated solvents, specifically floating petroleum product (FPP) on the groundwater, diesel range organics (DRO), and volatile organic compounds (VOC), including trichloroethylene (TCE) dissolved in the groundwater. A comprehensive description of 2017 field activities and results are located in Section 2: *Zone 1 - Base Living Area.*

1.2 GROUNDWATER ZONE 2 – BASE INDUSTRIAL AREA

Groundwater Zone 2 coincides with the KSD Base Industrial Area. Four source areas have potentially contributed to the contamination at Groundwater Zone 2:

- Refueler Shop (SS021).
- Old Power Plant (SS020).
- Eskimo Creek Dump (LF022).
- Dry well site at Building 158 (DP-13).

Contaminants of concern (COCs) identified for the Base Industrial Area include benzene, ethylbenzene, toluene, gasoline range organics (GRO), DRO, TCE, and cis-1,2-dichloroethene (DCE) dissolved in the groundwater; TCE and DCE in surface water; and DRO, benzene, ethylbenzene, toluene, and TCE in soil. A comprehensive description of 2017 field activities and results are located in Section 3: *Zone 2 - Base Industrial Area and Eskimo Creek Dump*.

1.3 GROUNDWATER ZONE 3 – NORTH & SOUTH BLUFFS

Groundwater Zone 3 includes the North Bluff (LF014) and South Bluff (LF005) sites located along the eastern bank of King Salmon Creek, approximately one-half to three-quarters of a mile north-northeast of the main runway. The Bluff sites were reportedly used for disposal of debris, 55-gallon drums, metal, and wood from the 1940s through the 1970s. Residual liquids (primarily petroleum) that may have been present in the drums at the time of disposal have been identified as potential sources of contamination. Other potential contaminants include residual paints, paint thinners, solvents, batteries, insecticides, polychlorinated biphenyls (PCBs), and herbicides. A description of 2017 field activities is located in Section 4: *Zone 3 – North and South Bluffs*.

Groundwater Zone 3 also includes a pump and treat system (the South Bluff Treatment System or SBTS) designed to capture water from a seep near King Salmon Creek, treat it, and then discharge the effluent to a wetland area. An extended period of monitoring showed that any contaminants detected in the water coming out of the seep were below the applicable cleanup level. For this reason, the treatment part of the SBTS was mothballed. Water is still being captured at the seep and discharged to the wetland without treatment. Monitoring of the untreated water was suspended in July, 2013, and resumed in September 2015.

1.4 GROUNDWATER ZONE 4 – NAKNEK RIVER STORAGE

Groundwater Zone 4 refers to the groundwater flow system that underlies the portion of KSD located between King Salmon Creek and Eskimo Creek, approximately one mile southwest of the main KSD base area and north of the Naknek River. Included within Zone 4 are:

- Naknek River Storage Sites (SS012U and SS012L).
- Landfill No. 5 (LF008).

The Naknek River Storage Sites were formerly two tank farms containing underground storage tanks (USTs) and aboveground storage tanks (ASTs) used for storage of petroleum, oil, and lubricants (POLs). A pipeline system connected these tanks to the main base. The dates of the landfill operation are unknown, but the wastes reportedly consisted of empty POL drums covered with sand.

Contaminated groundwater at Zone 4 has been observed in three localized plumes. The primary COCs are DRO, GRO, benzene, toluene, and TCE.

A comprehensive description of 2017 field activities and results are located in Section 5: *Zone 4 – Naknek River Storage*.

1.5 GROUNDWATER ZONE 5 – RAPCON/RED FOX CREEK

Groundwater Zone 5 contains the KSD Fire Training Areas and Landfills. Eight source areas have potentially contributed to the contamination in this zone:

- Fire Training Area 1 and RAPCON (FT001).
- Fire Training Area 2 (FT002).
- Fire Training Area 3 (FT003).
- Fire Training Area 4 (FT004).
- Lower Landfill No. 2 (LF002).
- Upper Landfill No. 2 (LF002).
- Landfill No. 3 (LF003).
- Circle Landfill (LF006).

The 2017 long-term monitoring program covers the RAPCON site and a nearby section of Red Fox Creek. RAPCON is located on the northwest side of Red Fox Creek. A 500-gallon diesel UST once located here was removed in 1994. The COCs for both soil and groundwater at this site are DRO, GRO, benzene, TCE, and toluene. Tetrachloroethylene (PCE) is also a COC in the soil. Surface water and sediment samples have been collected from a drainage ditch that flows by the RAPCON site and into Red Fox Creek to document any impact to Red Fox Creek resulting from groundwater contamination at the RAPCON site. A comprehensive description of 2017 field activities and results are located in Section 6: *RAPCON and Red Fox Creek.*

1.6 GROUNDWATER ZONE 6 – RAPIDS CAMP

Groundwater Zone 6 (Rapids Camp) is located on the northern bank of the Naknek River, roughly four miles southeast of KSD. The camp occupies about 12.5 acres of land and was established in 1952, as part of a USAF program to build facilities for “morale, recreation, and welfare.” Included were boat docks, fish camps, lodging, and a fuel storage area. The camp was closed in 1977, and all structures and tanks have been removed. All groundwater contaminant concentrations in the Rapids Camp area were below the appropriate regulatory requirements, and in 2008, eight monitoring wells were decommissioned. The only remaining data needs are satisfied by long-term monitoring of the landfill site.

A comprehensive description of 2017 field activities is located in Section 8: *Zone 6 – Rapids Camp*.

1.7 GROUNDWATER ZONE 7 – LAKE CAMP

Lake Camp occupies approximately 10 acres of land on the west shore of the Naknek River, approximately nine miles east of the KSD main base area. Historically, this area was used as a recreational camp. Included within Zone 7 are:

- Former Vehicle Maintenance Facility (SS004)
- Former Generator Pad (SS005)

- Drum Landfill (LF001)

In 2009, approximately 1,155 cubic yards of POL-contaminated soil were excavated from sites SS004 and SS005, and 75 drums were removed from site LF001. The contaminant of concern (COC) identified for these sites is DRO. A comprehensive description of 2017 field activities and results are located in Section 8: *Zone 7 – Lake Camp.*

1.8 GROUNDWATER HYDROLOGY

At least three aquifer units are known to exist in the King Salmon area. These aquifers consist of unconsolidated, well-sorted to poorly sorted silty and gravelly sands separated by aquitard units consisting of silty sands, silts, and clays.

1.8.1 A-Aquifer

The shallowest aquifer, the A-Aquifer, is unconfined and exposed in many areas within KSD. The total depth to the A-Aquifer ranges from surface at water bodies and wetlands, to 45 feet below ground surface (bgs) along the northern margin of KSD. The saturated thickness ranges from zero to fifteen feet. Groundwater movement is generally toward local topographic lows and surface drainages such as wetlands, rivers, creeks, and ditches, and is most likely recharged by precipitation and influent stream flow. There are several residential drinking water wells screened in the A-Aquifer in the community surrounding KSD.

The A-Aquitard is between seven and twenty-two feet thick and underlies the A-Aquifer. The surface of the aquitard is not horizontal, which may affect local groundwater flow direction and contaminant distribution.

1.8.2 B-Aquifer

Underlying the A-Aquitard, the top of the B-Aquifer has been encountered at depths ranging from 50 to 80 feet bgs. The known thickness of this aquifer ranges from fifteen to forty feet. Numerous residential drinking-water supply wells are screened in the B-Aquifer. Residential areas near the north bank of the Naknek River in Groundwater Zone 4 are down gradient of potential KSD contamination sources.

The B-Aquitard underlies the B-Aquifer. The thickness of the aquitard varies from ten to 120 feet; only two KSD water supply wells are known to have penetrated the B-Aquitard.

1.8.3 C-Aquifer

The C-Aquifer underlies the B-Aquitard at a depth of approximately 200 feet bgs. KSD's water-supply wells are reported to terminate in the C-Aquifer, which is thought to be a confined aquifer. Aquifer thickness and flow direction are unknown for the C-Aquifer.

1.9 SURFACE WATER HYDROLOGY

Surface water is abundant in the King Salmon area and includes numerous fresh-water lakes, streams, and wetland areas.

1.10 SAMPLING PROGRAM

Sampling activities were performed in accordance with the project work plans: 2017 Long Term Management (Paug-Vik, 2017a), the Field Sampling Plan (FSP) (Paug-Vik, 2017b), and the Quality Assurance Project Plan (QAPP) (Paug-Vik, 2017c). Any deviations from the work plan are listed in each section.

Samples were sent to TestAmerica Laboratories, Inc., (TestAmerica) in Sacramento, California.

1.10.1 Water-Level Measurements

Prior to sampling, depth to groundwater measurements were completed for all of the groundwater monitoring locations sampled. Depth to water, measurement time, date, and location were recorded on the zone-specific groundwater parameter data sheets provided in Appendix A.

1.10.2 Monitoring Well & Well Point Sample Collection

Monitoring wells were sampled using the methods outlined in Section 2.1 of the FSP. A-Aquifer groundwater monitoring wells and wells points were purged and sampled with a peristaltic pump following low-flow methods. B-Aquifer monitoring wells were purged and sampled using low-flow methods and a Grunfos® pump. Groundwater samples were placed in the appropriately prepared/preserved containers for storage and shipment to the analytical laboratory. Dissolved metal samples were field-filtered using a peristaltic pump and a new in-line 0.45-micron filter.

1.10.3 Surface Water & Sediment Sample Collection

Surface water and sediment samples were collected in Zones 4 and 5. Surface water samples were collected with a peristaltic pump and dedicated tubing. Sediment samples were collected using clean scoops and placing sediment into appropriately prepared/preserved sample jars for storage and shipment to the laboratory. Data collected at the sample site was documented on Surface Water/Sediment Sample Data Sheets provided in Appendix A.

1.10.4 Sample Handling

All samples collected during this project were placed into containers prepared by the laboratory that had required chemical preservatives added by the laboratory. Table 1.1 provides a list of sample containers, preservatives, and holding times for each of the analyses required during this project.

An effort was made to maintain samples at a temperature of 4±2° C at all times using gel ice. Samples were placed into coolers with gel ice as soon as they were collected. At least six frozen gel ice packs accompanied each standard size cooler during shipment to ensure that the coolers arrived at the laboratory within the require temperature range. Proper cooler temperatures were also dependent on flight schedules and potential delays associated with shipping from a remote location to the laboratory in California.

Table 1-1 Recommended Holding Times, Containers, and Preservatives

Parameters	Method	Container	Preservative Soil	Preservative Water	Holding Time	Container Size Soil	Container Size Water
Volatile Organic Compounds (VOCs)	8260B	Glass, TLC (soil) TLS (water)	Methanol Cool, 4°C	HCL No Head Space	7 days no preservation, 14 days w/ preservation	(1)-4 oz. Amber w/ Septa Lid	(3)-40 mL VOAs
Gasoline-Range Organics (GRO)	AK 101	Glass, TLC (soil) TLS (water)	Methanol Cool, 4°C	HCL No Head Space	14 days (water) 28 days (soil)	(1)-4 oz. Amber w/ Septa Lid	(3)-40 mL VOAs
Diesel-Range Organics (DRO) & Residual-Range Organics (RRO)	AK 102/ AK 103	Amber Glass, TLC	Cool, 4°C	HCL to pH < 2 Cool, 4°C	14 days then 40 (water) 14 days then 40 (soil)	(1)-8 oz. Amber	(2)– 125 mL Amber
Polycyclic Aromatic Hydrocarbons (PAH)	8270 SIM	Amber Glass, TLC	Cool, 4°C	Cool, 4°C 0.008% $Na_2S_2O_3$	7 days then 40 (water) 14 days then 40 (soil)	(1)-4 oz Amber	(2)–1 liter Amber
RCRA 8 + Iron Metals	6020/ 7000	Plastic/ Glass	Cool, 4°C	HNO_3, Field-filtered	6 months (water) 6 months (soil)	(1)-4oz Amber	(1)-500 mL Poly
Pesticides & Polychlorinated Biphenyls (PCBs)	8081B/ 8082A	Amber Glass, TLC	Cool, 4°C	Cool, 4°C	None, 40 days to analysis of extract (water & soil)	(1)-4oz Amber	(2)–1 liter Amber
1,2-Dibromomethane (EDB)	504.1	Glass TLC	Cool, 4°C	$Na_2S_2O_3$, Cool, 4°C	28 days (soil and water)	(1)-4oz Amber	(3)-40 mL VOAs
PFOA & PFOS	537	HDPE with unlined no Teflon lid	Cool, 4°C	Cool, 4°C	7 days to extraction 30 days to analyze extract (soil and water)	(1)-4oz HDPE	(2)– 125 mL HDPE

TLS – Teflon-lined septa TLC – Teflon-lined cap
7 days then 40 – 7 days until extraction and analysis 40 days after extraction

1.11 INSTITUTIONAL CONTROLS

Institutional controls (ICs) for all seven groundwater zones include the prohibition of unauthorized excavations and the installation of drinking water wells in contaminated aquifers. There was no evidence of any non-compliance with ICs in any of the groundwater zones. In addition, annual land fill inspections are conducted at the North and South Bluffs in Zone 3 and at the former landfills in Zone 4 and Zone 6.

1.12 WASTE HANDLING

Purge water and decontamination liquids were treated using an on-site filtration system as specified in Section 8.2.2 of the FSP. The purge water was filtered through a new drum of granulated activated carbon (GAC). Approximately 81 gallons of purge water/decontamination liquid were generated and treated. Samples of purge water were collected before and after treatment and analyzed for GRO, DRO, PAHs, and VOCs. Results are shown in Table 1-1. Treated purge water was discharged to the sanitary sewer system located in Zone 1 after receiving clean confirmation sample results. Other non-hazardous-type field investigation-derived waste (IDW) was also handled in accordance with procedures specified in the FSP.

Table 1-2 Purge Water Analytical Results Summary

Analyte	Cleanup Level[1] (mg/L)	Before Tx Result September (mg/L)	After Tx Result September (mg/L)
GRO	2.2	0.087	ND
DRO	1.5	**6.1**	0.075
Benzene	0.0046	ND	ND
Toluene	1.1	0.0001	ND
Ethylbenzene	0.015	0.00015	ND
Total Xylenes	0.19	0.019	ND
Trichloroethylene	0.0028	**0.0037**	ND

1. Cleanup level based on ADEC 18 AAC 75 Table C, Groundwater Cleanup Levels (as revised October 2017).
mg/L – Milligrams per liter.
Tx – Treatment using the activated carbon drum.
ND – Not detected.

1.13 ASSESSMENT OF DATA QUALITY

A quality assurance review (QAR) was performed to determine any data problems and evaluate the impact of these problems on the intended uses of the data. This QAR is presented in Appendix D. The QAR discusses the data quality assurance/quality control (QA/QC) procedures and presents the results of the QA/QC analysis. Additionally, Alaska Department of Environmental Conservation (ADEC) Laboratory Data Review Checklists have been completed for each laboratory work order associated with this project and are also located in Appendix D. The laboratory analytical data reports for this project are contained electronically on the DVD-R that accompanies this report.

This analytical program included the collection of project samples, QC samples (duplicates), and trip blanks. The duplicate samples were collected at a minimum frequency of ten percent of the project samples per site. The QA/QC procedures for the project were performed in accordance with the QAPP (Paug-Vik, 2017c).

Overall, QA/QC data associated with the base wide sampling program indicate that measurement data are acceptable and defensible for project use. The overall completeness calculated for this project was 99 percent. Based on the data assessment, some of the analytical results were flagged with qualifiers to indicate potential problems with the qualified results. Data qualifiers are displayed with the analytical results that are provided in Appendix C tables.

1.14 MONITORED NATURAL ATTENUATION

Monitored Natural Attenuation (MNA), also commonly known as intrinsic remediation (volatilization, dispersion, dilution, sorption, and biodegradation), refers to the natural chemical, physical, and biological processes that reduce or eliminate contamination in soil, surface water, or groundwater. Intrinsic remediation results from several subsurface attenuation mechanisms that are either destructive or nondestructive to the contaminant. Destructive attenuation removes contaminant mass from the soil or water. Biodegradation is the most important destructive attenuation mechanism (Wiedemeier, et al., 1999). Nondestructive attenuation mechanisms include sorption, dispersion, dilution, and volatilization.

In bioremediation, microorganisms obtain energy by oxidation of an electron donor and reduction of an electron acceptor. Electron donors are fuel hydrocarbons or other organic carbon compounds; they act as a microbial substrate or food source during microbial reactions. The electron acceptors are elements or compounds that are required to complete the electron transfer reaction (coupled redox reaction). In natural groundwater systems, the electron acceptors (in order of preference based on the energy derived from the redox reaction) consist of oxygen, nitrate, manganese, ferric iron (iron [III]), sulfate, and carbon dioxide. Biodegradation of fuel hydrocarbons is usually limited by electron acceptor availability.

Three lines of evidence can be used to support the occurrence of intrinsic remediation: 1) loss of contaminant mass; 2) changes in geochemical parameters; and 3) direct microbial evidence such as microcosm studies. The intrinsic remediation mechanisms bring about measurable changes in the groundwater chemistry in the affected area. By measuring these geochemical changes at the site, intrinsic remediation can be quantitatively evaluated. In general, geochemical indicators for intrinsic remediation can be broken down into three categories.

- Indicators of biological activity such as dissolved oxygen (DO), nitrate, manganese, ferrous iron, sulfate/sulfide, and methane.
- Indicators, such as alkalinity, temperature, pH, and redox potential, used to evaluate the environmental conditions of an aquifer and determine if they are favorable for biological activity.
- Indicators, such as chloride and conductivity, used to determine whether the sampling locations are all within the same groundwater or hydrogeologic unit.

1.14.1 DO and Redox Potential

DO is the most thermodynamically favored electron acceptor in the biodegradation of organic compounds since microorganisms derive the most energy from the reduction of dissolved oxygen. Under aerobic biodegradation, oxygen is reduced to carbon dioxide and water as the dissolved oxygen is removed from the groundwater. Based on stoichiometric relationships it is generally assumed that 3.1 grams of oxygen are required to biodegrade one gram of benzene, toluene, ethylbenzene, and total xylenes (BTEX) compounds. This relationship varies depending on the molecular structure of the hydrocarbon source. A correlation between depleted DO levels and the continued presence of petroleum hydrocarbon concentrations is a strong indication that aerobic biodegradation of the dissolved hydrocarbons has occurred and continues to occur at the site.

Another parameter closely associated with dissolved oxygen concentrations is the redox potential. The redox potential of a groundwater system depends on which electron acceptor (oxygen, nitrate, iron, sulfate, or carbon dioxide) is being reduced. Relatively large positive redox potentials are often referred to as an aerobic environment, whereas low or negative redox potentials are referred to as an anaerobic environment. Some microbial processes only operate in a prescribed range of redox conditions.

1.14.2 Nitrate

After DO is depleted in the treatment zone, anaerobic biodegradation processes can continue hydrocarbon biodegradation. Usually, anaerobic bacteria cannot function in the presence of more than 0.5 mg/L of dissolved oxygen (Wiedemeier, et al., 1999); however varieties of facultative bacteria are known to function at higher dissolved oxygen levels. Under anaerobic conditions, nitrate is the most desired electron acceptor due to the amount of energy gained from its reduction. The anaerobic biodegradation of nitrate is termed denitrification, and it occurs when nitrate is reduced by bacteria to nitrous oxide or nitrogen gas (Hem, 1986). Based on stoichiometric relationships it is generally assumed that 4.9 grams of nitrate are required to biodegrade one gram of BTEX compounds. This relationship varies depending on the molecular structure of the hydrocarbon source.

1.14.3 Manganese

After nitrate, manganese (Mn^{+4}) is the next most thermodynamically favored electron acceptor for microbial energy metabolism. Manganese is generally available in the aquifer material. When manganese is used as an electron acceptor during the anaerobic biodegradation of fuel contamination, Mn^{+4} is reduced to Mn^{+2}. Increased dissolved manganese concentrations can be used as an indicator of anaerobic biodegradation of fuel hydrocarbons or other organic carbon compounds.

Reduced manganese (Mn^{+2}) is soluble in water in the absence of DO. If groundwater with high reduced manganese concentrations comes into contact with oxygen, the manganese is oxidized and forms a manganese oxide precipitate (black-colored solid) commonly observed in bogs and wetland areas.

1.14.4 Ferrous Iron

After manganese, ferric iron (oxidized form of iron called iron [III]) is the next most thermodynamically favored electron acceptor for microbial energy metabolism. Ferric iron is generally available from the mineral grains in the aquifer material. When iron is used as an electron acceptor during the anaerobic biodegradation of fuel contamination, ferric iron, iron (III) is reduced to ferrous iron, iron (II). Based on stoichiometric relationships it is generally assumed that 21.8 grams of ferrous iron are produced to biodegrade one gram of BTEX compounds. This relationship varies depending on the molecular structure of the hydrocarbon source. Increased ferrous iron concentrations can be used as an indicator of anaerobic biodegradation of fuel hydrocarbons or other organic carbon compounds. Generally, ferrous iron concentrations greater than 1.0 mg/L (depending on background concentrations) can be used as an indicator that anaerobic biodegradation is occurring (Wiedemeier, et al, 1999). Ferrous iron is soluble in water in the absence of dissolved oxygen. If groundwater with high ferrous iron concentrations comes into contact with oxygen, the ferrous iron is oxidized and forms a ferric hydroxide precipitate (rust-colored solid) commonly observed in bogs and wetland areas.

1.14.5 Sulfate/Sulfide

Sulfate-reducing bacteria use sulfate for anaerobic biodegradation of fuel contamination. The sulfate is reduced to sulfide, and the reduction in sulfate concentrations or increase in sulfide concentrations can be used as an indicator of anaerobic degradation of fuel contamination. Sulfate-reducing microorganisms are sensitive to environmental conditions, including temperature, inorganic nutrients, and pH. An imbalance in suitable environmental conditions may severely limit the significance of fuel hydrocarbon degradation via sulfate reduction in many groundwater systems. Based on stoichiometric relationships it is generally assumed that 4.7 grams of sulfate are required to biodegrade one gram of BTEX compounds. This relationship varies depending on the molecular structure of the hydrocarbon source.

1.14.6 Methane

The final anaerobic biodegradation process is methanogenesis (carbon dioxide reduction), also called methane fermentation. Methanogenesis results in the consumption of carbon dioxide and the production of methane. This process generally occurs only after the aforementioned electron acceptors have been depleted and requires strongly anaerobic conditions. Based on stoichiometric relationships it is generally assumed that 0.78 grams of methane are produced to biodegrade one gram of BTEX compounds. This relationship varies depending on the molecular structure of the hydrocarbon source. In the presence of petroleum hydrocarbons, methane in groundwater provides strong evidence that anaerobic microbial degradation of fuel hydrocarbons is occurring through methanogenesis (Wiedemeier, et al., 1999).

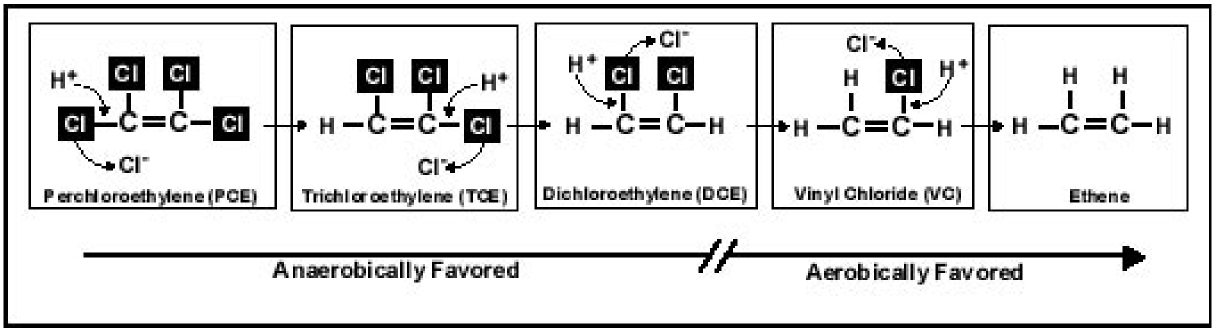
1.14.7 Alkalinity

Alkalinity is a measure of the ability of water to buffer changes in pH caused by the addition of biologically generated acids. Biodegradation of organic compounds produces carbon dioxide which, when mixed with water in the proper conditions, produces carbonic acid. In aquifers that have carbonate minerals as part of the matrix, carbonic acid dissolves the calcium carbonate, thereby increasing the alkalinity of the groundwater. Alkalinity is generally expressed in terms of calcium carbonate ($CaCO_3$).

1.15 EVIDENCE OF REDUCTIVE DECHLORINATION FOR CHLORINATED SOLVENTS

1.15.1 Reductive Dechlorination Process

The most important process for the natural biodegradation of the more highly chlorinated solvents (e.g., PCE and TCE) is reductive dechlorination. During this process, the chlorinated hydrocarbon is used as an electron acceptor, not as a carbon source, and a chlorine atom is removed and replaced with a hydrogen atom. A separate carbon source (e.g., naturally-occurring organic carbon or fuel hydrocarbons) is also required. In general, reductive dechlorination occurs by sequential dechlorination from PCE to TCE to cis-1,2-DCE to vinyl chloride to ethene. The dechlorination sequence is illustrated in the following figure.

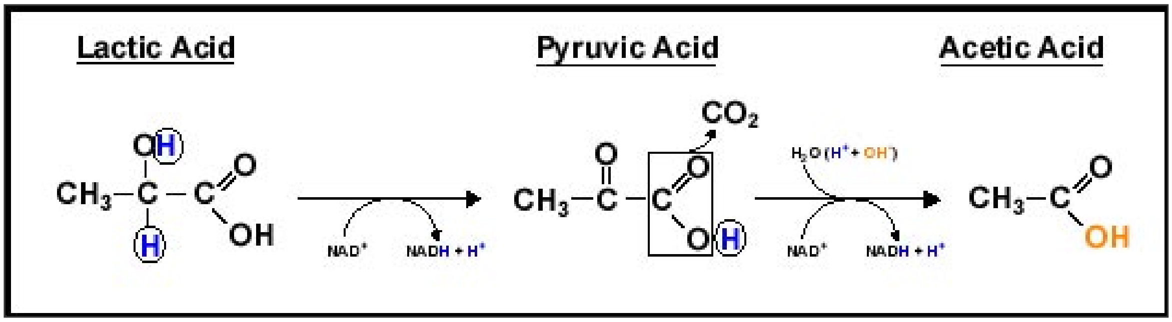


Source: www.regenesis.com/HRCtech/hrctb113.htm

Reductive dechlorination has been demonstrated to occur under nitrate and iron-reducing conditions, but the most rapid rates occur under sulfate-reducing and methanogenic conditions (Wiedemeier, et al., 1998). Because chlorinated hydrocarbons are used as electron acceptors during reductive dechlorination, there must be an appropriate source of carbon for microbial growth in order for this process to occur. Potential carbon sources include natural organic matter, fuel hydrocarbons, or other anthropogenic organic compounds such as those found in landfill leachate.

Bacteria capable of degrading chlorinated aliphatic hydrocarbons require specific geochemical conditions (e.g., near absence of oxygen, availability of free hydrogen ions, and other nutrients). A detailed description of this process follows:

- If the aquifer is aerobic, the total organic carbon (TOC) load provided to the aquifer by fuel hydrocarbons or other organic substrate will provide a food source for resident aerobic bacteria. The bacteria will metabolize the TOC, utilizing most or all of the available oxygen in the process, and drive the aquifer anaerobic.
- Once the aquifer is anaerobic, anaerobic bacteria will mediate the degradation of TOC to lactic acid. The lactic acid also acts as a nutrient source for anaerobic bacteria. As the bacteria metabolize lactic acid, hydrogen ions are released, and the lactic acid degrades to pyruvic acid (primarily). The pyruvic acid degrades to acetic acid; and there is a secondary series of reactions (lactic acid to butyric acid to propionic acid) that also occurs. As shown on the following illustration, most of these reactions release hydrogen ions, which are then available for dechlorination of chlorinated ethenes (such as TCE).
- Multiple studies cited by Koenigsberg and Farone (2000), and others suggest that there is competition between the anaerobic bacteria that degrade chlorinated ethenes (called reductive dehalogenators) and anaerobic bacteria that convert carbon dioxide to methane (called methanogens). It is believed that a relatively low concentration of hydrogen favors the reductive dehalogenators over the methanogens.



Notes: C: Carbon; O: Oxygen; H: Hydrogen; NAD: Nicotinamide Adenine Dinucleotide (a coenzyme occurring in living cells that is utilized alternately as an oxidizing or reducing agent in metabolic processes); NADH: Reduced form of NAD

Source: www.regenesis.com/HRCtech/hrctb113.htm

Changes in groundwater geochemistry, contaminant concentrations, and metabolic acid concentrations provide evidence to indicate how well the reductive dechlorination process is working. The groundwater geochemical data provide a qualitative indicator of the potential success of reductive dechlorination. Table 1-2 provides a list of geochemical parameters and threshold values necessary for reductive dechlorination to occur. A comparison of the groundwater geochemical data between background and fuel hydrocarbon contaminated wells is used to determine whether the fuel hydrocarbon contamination has enhanced the biological conditions for reductive dechlorination by driving the aquifer conditions anaerobic.

Table 1-3 Reductive Dechlorination Parameters of Importance

Parameter	Description	Threshold Level (Wiedemeier et al., 1996)	Significance of Threshold Level
Geochemical Indicators of Natural Attenuation			
pH	pH is a measure of the acidity or alkalinity of the groundwater.	5<pH<9	Optimal range for reductive pathway
Temperature	Groundwater temperature affects the metabolic rate of bacteria. Groundwater temperatures less than 5°C tend to inhibit biodegradation. Biodegradation rates typically double for every 10°C increase in water temperature.	> 20°C	Biochemical process accelerated
DO	Depressed DO levels indicate that the reductive pathway is possible	< 0.5 mg/L	Reductive pathway is not suppressed.
ORP	ORP is an indicator of oxidation potential (aerobic) or reductive potential (anaerobic) of the groundwater system.	< 50 mV < -100 mV	Reductive pathway possible Reductive pathway likely
Nitrate	After DO has been depleted, nitrate may be used as an electron acceptor for anaerobic biodegradation.	< 1 mg/L	At higher concentrations nitrate may compete with reductive pathway
Sulfate	After DO and nitrate have been depleted in the treatment zone, sulfate may be used as an electron acceptor for anaerobic biodegradation (sulfate reduction).	< 20 mg/L	At higher concentrations may compete with reductive pathway
Dissolved iron (ferrous iron)	Ferrous iron (iron II) is produced when ferric iron (iron III) is used as an electron acceptor during anaerobic biodegradation.	>1 mg/L	Indicative that reductive pathway is possible
Methane	The presence of methane in groundwater is indicative of strongly reducing conditions. Methanogenesis generally occurs after the oxygen, nitrate, and sulfate have been depleted in the treatment zone.	> 0.5 mg/L	Indicative that reductive pathway is likely but may also compete with reductive dechlorination process
Ethane, ethene	Produced during reductive dechlorination	> 0.01 mg/L	Indicative that reductive pathway is likely
TOC	Carbon is the energy source that drives reductive dechlorination.	> 20 mg/L	Energy source needed to drive reductive dechlorination
Volatile Organic Acids			
Lactic acid	Nutrient and hydrogen ion source for dechlorinating microbes. Lactic acid is released during anaerobic biodegradation of organic substrate.	Not applicable	Presence indicates anaerobic biodegradation of organic substrate
Pyruvic acid	As lactic acid is metabolized by anaerobic microbes, it is degraded to pyruvic acid.	Not applicable	Presence indicates presence and degradation of lactic acid
Acetic acid	As pyruvic acid is metabolized by microbes, it is degraded to acetic acid.	Not applicable	Presence indicates presence and degradation of pyruvic acid
Butyric acid	In a secondary reaction, lactic acid also degrades to butyric acid and propionic acid.	Not applicable	Presence indicates presence and degradation of lactic acid
Propionic acid	In a secondary reaction, lactic acid also degrades to butyric acid and propionic acid.	Not applicable	Presence indicates presence and degradation of lactic acid
Contaminants/Degradation Products (VOCs)			
PCE	Not present in Zone 1, 2, or 5 groundwater.	Not applicable	

Parameter	Description	Threshold Level (Wiedemeier et al., 1996)	Significance of Threshold Level
TCE	Primary contaminant in Zones 1, 2, and 5 groundwater.	Not applicable	Compare levels among upgradient/ downgradient wells over time
cis-1,2-DCE	TCE daughter product; presence indicates TCE degradation has occurred	Not applicable	Compare levels among upgradient/ downgradient wells over time
trans-1,2-DCE	TCE daughter product; presence indicates TCE degradation has occurred	Not applicable	Compare levels among upgradient/ downgradient wells over time
1,2-DCA	A possible (although uncommon) cis-1,2-DCE daughter product. 1,2-DCA is a less common daughter product than vinyl chloride.	Not applicable	Compare levels among upgradient/ downgradient wells over time
Vinyl chloride	DCE daughter product; presence indicates DCE degradation has occurred	Not applicable	Compare levels among upgradient/ downgradient wells over time

1.15.2 Oxidation (Mineralization) of DCE

Although reductive dechlorination is the primary mechanism for biodegradation of TCE, the less chlorinated daughter products DCE and vinyl chloride (VC) can degrade either by reductive dechlorination or by oxidation processes. In oxidation processes, the DCE and VC are mineralized directly to carbon dioxide. The primary biodegradation mechanism is dependent upon site geochemistry and microbiology.

1.15.3 Cometabolic Biodegradation of TCE

Although reductive dechlorination is the primary mechanism for biodegradation of TCE under anaerobic conditions, other aerobic biodegradation pathways are also known to exist. Cometabolic aerobic biodegradation of TCE has been demonstrated using two bacterial strains: toluene degraders and methanotrophs (methane oxidizing bacterium).

1.16 FIELD-MEASURED PARAMETERS

During groundwater purging activities or while collecting surface water samples, water-quality parameters were measured to determine groundwater and surface water consistency and characteristics relevant to assessing intrinsic remediation. These field parameters included pH, temperature, conductivity (total dissolved solids), dissolved oxygen, and oxidation-reduction (redox) potential. Qualitative field measurements of color and turbidity were also recorded during the purging and sampling process for each groundwater and surface water-sampling site. Field measurement results can be found on the sample data sheets in Appendix A.

pH: Groundwater pH is an environmental indicator that has an effect on the presence and activity of microbial populations. This is especially true for pH-sensitive methanogens. Bacteria capable of degrading petroleum hydrocarbons prefer pH values between 6 and 8 standard units.

Temperature: Groundwater temperature directly affects the solubility of oxygen in water and the metabolic activity rate of bacteria. Oxygen is more soluble at colder temperatures. Temperatures less than 4.4 degrees Celsius (˚C) (40 degrees Fahrenheit [˚F]) tend to inhibit the rate of biodegradation, and the biodegradation rate typically doubles for every 10˚C increase in water temperature.

Conductivity: Conductivity can be reported as total dissolved solids (TDS), which is a general water quality indicator. Elevated TDS levels can be associated with groundwater contamination.

DO: DO is used as an indicator for aerobic biodegradation of dissolved hydrocarbons. Depleted or low DO levels are evidence of aerobic biodegradation.

Redox Potential: Redox potential, also known as reduction potential, is the tendency of a chemical species to acquire electrons and thereby be reduced. Relatively large positive redox potentials are indicators of an aerobic environment, whereas negative redox potentials are of an anaerobic environment.

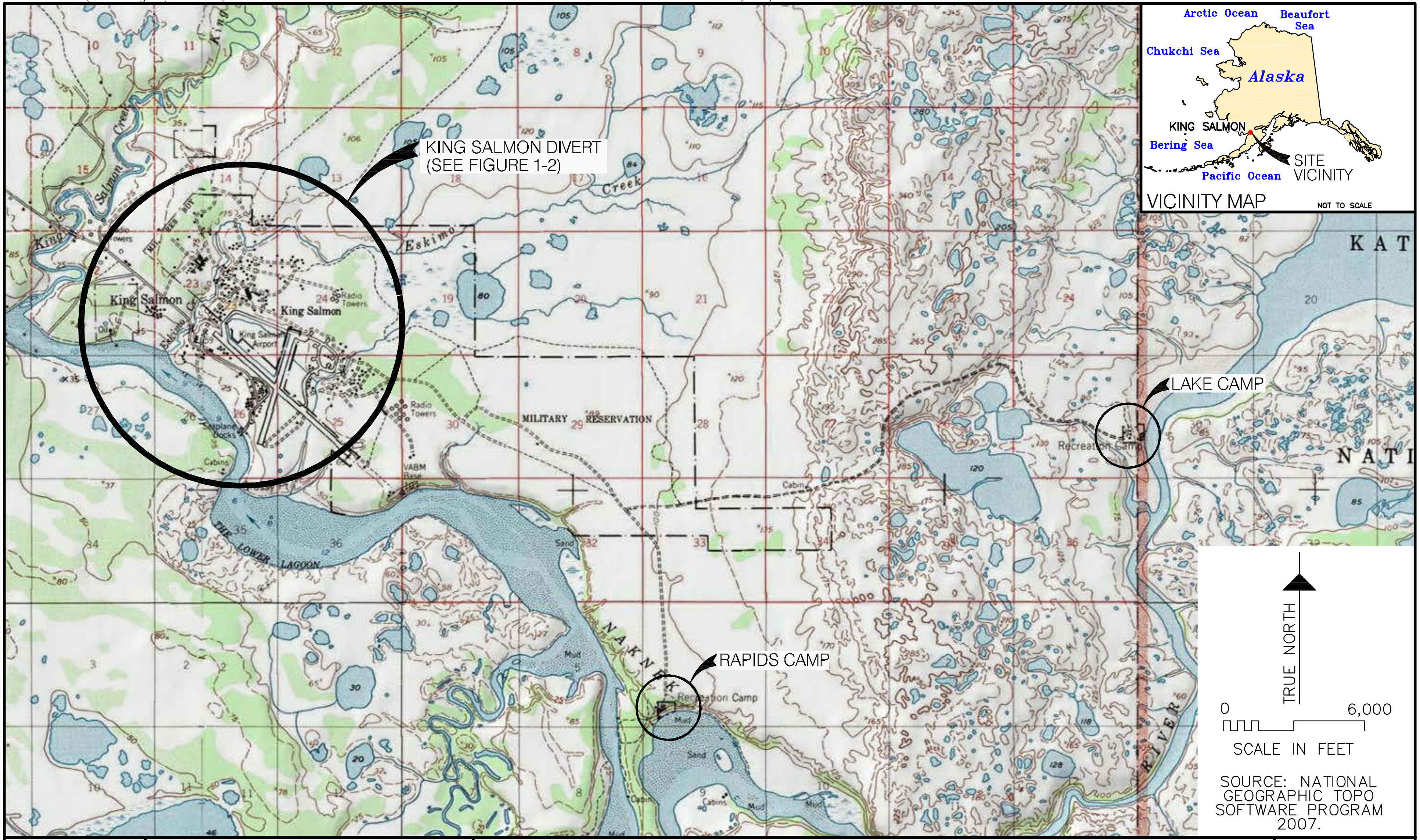
1.17 PROUCL TREND ANALYSIS

The statistical software ProUCL Version 5.0.00 was used to assess concentration trends in Zones 1, 2, 4, 5, and 7. ProUCL 5.1 is a comprehensive statistical software package for analysis of environmental data sets with and without nondetect (ND) observations.

ProUCL uses the Mann-Kendall test to evaluate concentration trends. The Mann-Kendall Statistic (also referred to as an “S” statistic) is a measure of trend: a large positive S statistic indicates a strong increasing trend and a large negative S statistic indicates a strong decreasing trend. A trend is significant if, at a given confidence level and number of observations (generally four), the absolute value of the S statistic exceeds a minimum threshold. Output from the ProUCL analysis is provided in Appendix E.

Mann-Kendall Trend Tables specific to Zones 1, 2, 4, 5, and 7 summarize the concentration trends observed in key monitoring wells with historical concentrations of contaminants near or above RAOs. The tables list the numbers of wells exhibiting a specific concentration trend for each analyte. For wells that are depicted as having *No Trend*, there is insufficient evidence to identify a significant trend at the specified level of significance. Well location data sets, which did not have the minimum number of four observations, or where the results were all below the detection limit for a specific analyte, are not included in the trend summary table.

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18-KS-LTM-RPT-F1-1.DWG PLOT: 1/10/18.



SOURCE: NATIONAL GEOGRAPHIC TOPO SOFTWARE PROGRAM 2007.

DATE
JAN. 2018
CHKD
H.L.H.
DRAWN
C.E.H.
PROJ. NO
17040

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

SITE LOCATION MAP

2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

FIGURE
1-1

EXPLANATION

- - - GROUNDWATER ZONE BOUNDARIES

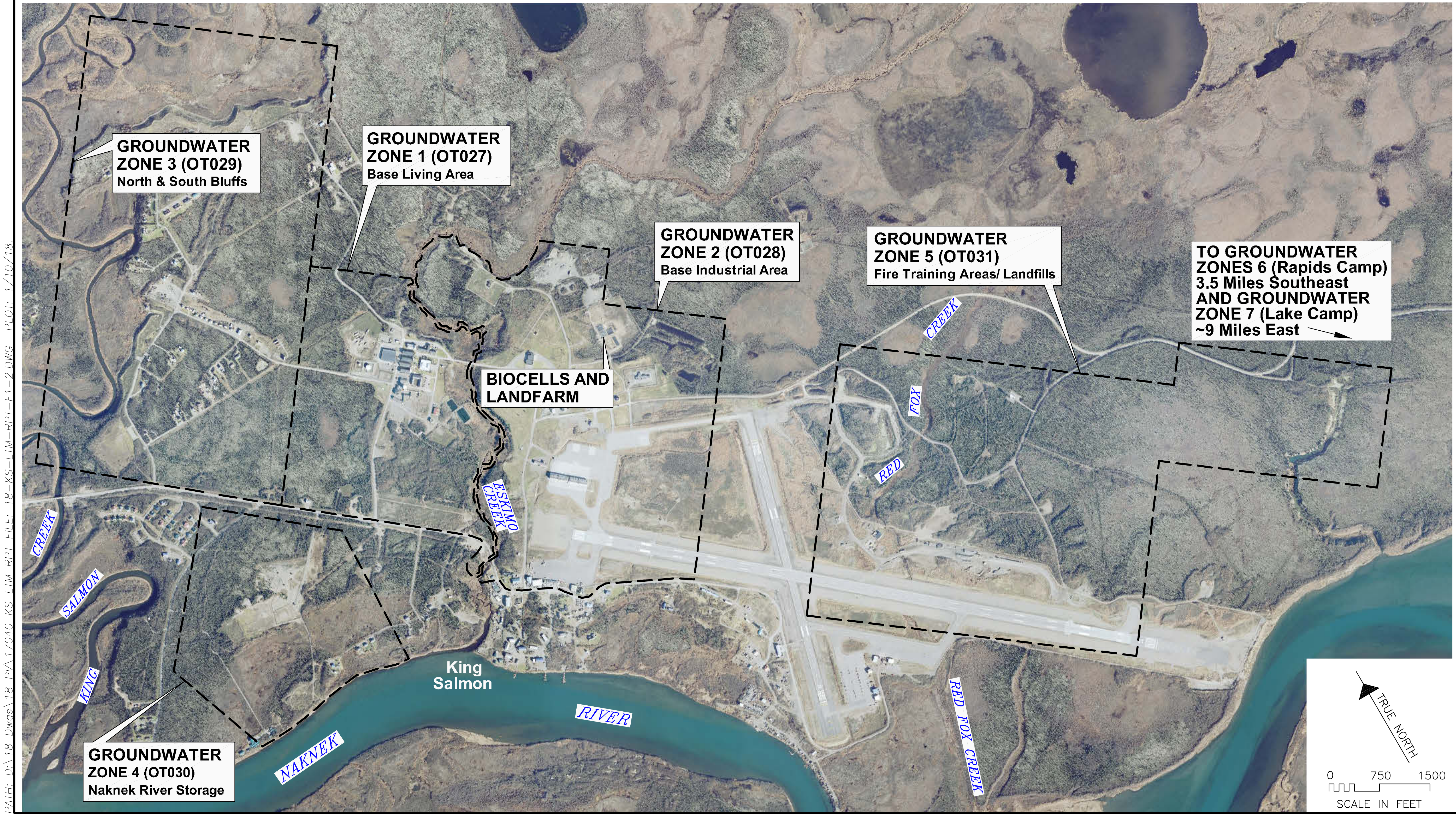


FIGURE 1-2

GROUNDWATER MONITORING ZONES

2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE	CHKD	DRAWN	PROJ. NO
JAN. 2018	H.L.H.	C.E.H.	17040

PATH: D:\18_Dwgs\18_PI\17040_KS_LTM_RPT FILE: 18-KS-LTM-RPT-F1-2.DWG PLOT: 1/10/18

2 ZONE 1 - BASE LIVING AREA

Historical spills and operational practices resulted in contamination of groundwater with petroleum-based products and chlorinated solvents, specifically petroleum product floating on the groundwater, and DRO and VOCs including TCE dissolved in the groundwater. Except as otherwise indicated in this report, this monitoring program was designed in accordance with the *Record of Decision for Interim Remedial Action at King Salmon Air Station, King Salmon Alaska, Installation Restoration Program, Groundwater Zone OT027* (ROD; United States Air Force [USAF], 2000).

2.1 REMEDIAL ACTION OBJECTIVES FOR ZONE 1

RAOs are specific cleanup levels and related requirements to be met in Zone 1. Final RAOs for Zone 1 COCs (e.g., FPP, TCE, and TCE's degradation products) were established in the interim ROD. However, until the ROD is finalized, the RAOs for Zone 1 are the ADEC groundwater cleanup levels listed in 18 AAC 75.345 Table C, and are displayed on Table 2-1 (ADEC, 2017). Preliminary RAOs for other COPCs not addressed in the interim ROD (e.g., BTEX, DRO, GRO, and polynuclear aromatic hydrocarbons [PAHs]) are presented in Table 2-2.

In addition to the regulation-based cleanup levels, action levels were defined for TCE and its degradation products to guide remedial efforts. Action levels are the more stringent standards of ecological surface water quality screening criteria or Alaska Water Quality Standards. If TCE groundwater concentrations at the designated points of compliance (i.e., Seep No. 2 sentry wells adjacent to Eskimo Creek: RPO-1 (POC-1), RPO-2 (POC-2), RPO-3 (POC-3), GP-1, GP-2, WP03-11) consistently exceed the site action levels, remedial actions other than MNA will be implemented. RPO-1, GP-1A, and WP03-11 were the only Seep No. 2 sentry wells included in the 2017 sampling program. WP03-06 was also sampled as a substitute for WP03-09 which was used as a substitute for GP-2 from 2009-2016.

Table 2-1 Groundwater Zone 1 RAOs

Media	Contaminants of Concern	Maximum Conc.	Maximum Conc. Location (Date)	Maximum Conc. 1997/98/99 data	ARARs				FINAL RAOs	
					Ecological Criteria	Basis	Human Health/ADEC Criteria	Basis	Action Level at POC*	Cleanup Level
Floating Petroleum Product	--	--	--	--	—	—	No FPP	18AAC75	NA	No FPP
Groundwater (mg/L) (A- Aquifer)	TCE	7.4	MW-28 (1994)	1.65 (MW-28)	NE	NE	0.0028	18AAC75	0.0027	0.0028
	cis-1,2-DCE	0.0011	MW-402 (1993)	0.0032 (MW-27)	NE	NE	0.036	18AAC75	0.036	0.036
	trans-1,2-DCE	ND	ND	ND	NE	NE	0.36	18AAC75	0.1	0.36
	1,1-DCE	ND	ND	ND	NE	NE	0.028	18AAC75	3.3E-05	0.28
	Vinyl Chloride	ND	ND	ND	NE	NE	0.00019	18AAC75	0.002	0.00019
Groundwater (mg/L) (B-Aquifer)	TCE	0.099	MW-41 (1992)	0.041 (MW-41)	NE	NE	0.0028	18AAC75	NA	0.0028
	cis-1,2-DCE	ND	ND	ND	NE	NE	0.036	18AAC75	NA	0.036
	trans-1,2-DCE	ND	ND	ND	NE	NE	0.1	18AAC75	NA	0.36
	1,1-DCE	ND	ND	ND	NE	NE	0.028	18AAC75	NA	0.28
	Vinyl Chloride	ND	ND	ND	NE	NE	0.00019	18AAC75	NA	0.00019
Surface Water (mg/L)	TCE	0.0153	SW-1 (1997) [a]	0.0153	0.35	Ecotox	0.0027[b]	18AAC70	--	0.0027
	cis-1,2-DCE	ND	ND	ND	0.59	ORNL PRGs	0.07	18AAC70	--	0.07
	trans-1,2-DCE	ND	ND	ND	0.59	ORNL PRGs	0.1	18AAC70	--	0.1
	1,1-DCE	ND	ND	ND	0.025	ORNL PRGs	3.3E-05[b]	18AAC70	--	3.3E-05
	Vinyl Chloride	ND	ND	ND	0.782	ORNL PRGs	0.002[b]	18AAC70	--	0.002
Sediment (mg/Kg)	TCE	0.0018	SWF-15 (1999)	0.0018	0.041[c]	NOAA SQuiRTs	—	—	--	0.04
	cis-1,2-DCE	0.2	SS011-37 (1996)	NA	0.4[b]	SQB	—	—	--	0.4
	trans-1,2-DCE	ND	ND	NA	0.4[b]	SQB	—	—	--	0.4
	1,1-DCE	ND	ND	NA	0.031[b]	SQB	—	—	--	0.031
	Vinyl Chloride	ND	ND	NA	—	—	—	—	--	—

*** The points of compliance are the sentry wells established at the groundwater/surface water interface adjacent to Eskimo Creek. Action levels in these wells are the ecological surface water quality criteria.**

[a] TCE exceeded the RAO in one of six surface water samples collected from Eskimo Creek (SW-1, downgradient of Seep No. 2) during 1996 and 1997. There were no exceedance in 1999 surface water samples collected from Eskimo Creek.

[b] Based on the consumption of water and organisms, and 10^{-6} carcinogenic risk.

[c] Apparent Effects Threshold level for exposure of Neanthes bioassays to TCE in marine sediments (adverse effects to Neanthes bioassays would be expected when exposed to this level of TCE). Freshwater values are not available.

[d] Sediment quality benchmark (SQB) presented by Jones et al, 1997; values normalized to 1% total organic carbon.

Definitions

18 AAC 75 Oil and Hazardous Substances Pollution Control Regulations (ADEC, 2017)
18 AAC 70 Alaska Water Quality Standards (ADEC, 2017a)
Ecotox – USEPA Tier II Water Quality Criteria for freshwater (USEPA, 1996)
ORNL PRG – Oak Ridge National Laboratory Preliminary Remediation Goals for Ecological Receptors (Jones et al., 1997)
NOAA SQuiRTs – National Oceanic and Atmospheric Administration Screening Quick Ref. Tables (Buchman, 1999)
POC – Point of Compliance
SQB – ORNL Sediment Quality Benchmark (Jones et al, 1997)
TCE – Trichloroethylene
DCE – Dichloroethene
FPP – Floating Petroleum Product
ND – Not detected
NE – Not evaluated
NA – Not analyzed
ARAR – Applicable or Relevant and Appropriate Requirements
— No criteria available
mg/L – milligrams per liter
mg/Kg – milligrams per kilogram

Table 2-2 Preliminary RAOs for other Groundwater Zone 1 COPCs (not included in Interim ROD)

Contaminants of Concern	A-Aquifer Groundwater (mg/L)		Surface Water (mg/L)		Sediments (mg/Kg)	
	Criteria	**Basis**	**Criteria**	**Basis**	**Criteria** (Freshwater Sediment)	**Basis**
Benzene	0.0046	18AAC75	0.005	18AAC70	0.057	OSWER
Ethylbenzene	0.015	18AAC75	0.0073	ORNL SW	0.089	SQB
Toluene	1.1	18AAC75	0.0098	ORNL SW	0.05	SQB
Xylenes	0.19	18AAC75	0.013	ORNL SW	0.025	OSWER
Benzo(a)pyrene	0.000034	18AAC75	0.000014	ORNL SW	0.0324	SQuiRTs
Benzo(a)anthracene	0.00012	18AAC75	0.000027	ORNL SW	0.01572	SQuiRTs
Benzo(b)fluoranthene	0.00034	18AAC75	0.0012	18AAC70	1.8^b	SQuiRTs
Benzo(k)fluoranthene	0.00080	18AAC75	0.012	18AAC70	0.0272	SQuiRTs
Dibenzo(a,h)anthracene	0.000034	18AAC75	0.00012	18AAC70	0.01	SQuiRTs
Indeno(1,2,3-cd)pyrene	0.00019	18AAC75	0.0012	18AAC70	0.0173	SQuiRTs
Naphthalene	0.0017	18AAC75	0.012	18AAC70	0.01465	SQuiRTs
GRO	2.2	18AAC75	No Sheen	18AAC70	NA	
DRO	1.5	18AAC75	No sheen	18AAC70	NA	
TAH	NA		0.01	18AAC70	NA	
TAqH	NA		0.015	18AAC70	NA	

[a] Freshwater sediment criteria does not exist for Benzo(b)fluoranthene, so marine sediment criteria is used.

Definitions

18 AAC 75 Oil and Hazardous Substances Pollution Control Regulations (ADEC, 2017)

18 AAC 70 Alaska Water Quality Standards (ADEC, 2017a)

SQB – Sediment Quality Benchmark from Oak Ridge National Laboratory (ORNL) *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment Associated Biota: 1997 Revision*

SQuiRT – NOAA Screening Quick Reference Tables

ORNL SW – *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Aquatic Biota: 1996 Revision*

OSWER – EPA Office of Solid Waste and Emergency Response Sediment Screening Benchmarks

NA – No criteria available

mg/L – milligrams per liter **mg/Kg – milligrams per kilogram**

2.2 PROJECT TASKS

2.2.1 Groundwater Sampling Program

Nine A-Aquifer groundwater samples and three B-Aquifer groundwater samples were collected. Data collected from each monitoring well/well point were documented on the Zone 1 Groundwater Sample Data Sheets provided Appendix A. Table 2-3: *Groundwater Zone 1 Sample Analysis Summary* includes a complete list of groundwater sample locations and analytical methods.

2.2.2 Institutional Control Inspection

Groundwater use restriction is part of the selected remedy. Only water from the C-Aquifer, the current source of water for KSD, will be used for drinking. Drinking water wells will not be installed in the A and B Aquifers until RAOs are met.

A visual inspection was performed to verify that no water wells have been installed in the A or B Aquifers.

2.2.3 Product Monitoring at Seeps 1 & 2

Approximately 0.3 liter of product was recovered from product probes PR-11, PR-12, PR-13, and PR-32 located at Seep No. 1 in June 2017. PR-14, -15, and -16, at Seep No. 1 had measurable amounts of product, but not enough to remove. Product is removed only from seeps with a product layer more than 0.3 ft.

2.2.4 Work Plan Deviations

MW-23 could not be sampled due to lack of water in the well. There were no viable A-Aquifer wells located nearby to use as a substitute.

WP03-09, previously used as a substitute for GP-2, was jacked out of the ground. WP03-06 was sampled as a substitute.

WP03-11 had an extremely slow recharge. At the lowest setting on the peripump, water drawdown would not stabilize. Water was purged within 2-4 inches of the total depth of well point. Samples for 8260 C, 8260 SIM, 8011, and AK 102 were collected over the course of two days. VOA bottles for VOC analyses were filled completely at each of the sampling events. Any excess water beyond what was used to fill VOA bottles was used to partially fill one AK102 bottle. Samples for RSK-175 (methane), 6010B (dissolved iron and manganese), and alkalinity/chloride were not collected.

The work plan sample analyses summary included 8270D SIM PAHs and 353.2 Nitrate/Nitrite which are not and were not collected in Zone 1. The work plan sample analyses summary also included pesticides and PCBs for the peripump equipment rinse. PCBs and pesticides were not collected in any of the groundwater zones, and therefore deleted from the sample analyses for the peripump equipment rinse. The revised sample analysis summary shown below has been corrected for these issues.

Table 2-3: Groundwater Zone 1 Sample Analyses Summary

				Analytical Methods									
A-Aquifer Wells Location ID	**Comment**	Matrix	Location Type	8260C VOCs	8260C SIM VOCs	8011 EDB & 1,2,3-TCP AK2016	AK101/GRO	AK102/DRO	SM 2320B Alkalinity	300.0 Chloride	RSK-175 Methane	6010B/ Dissolved Fe and Manganese	Sample ID
RPO-1		Groundwater	Well Point	1	1	1		1	1	1	1	1	17KS1ZMWRPO1-110WG
WP03-06*		Groundwater	Well Point	1	1	1		1	1	1	1	1	17KS1ZWP0306-111WG
WP03-11**		Groundwater	Well Point	1	1	1		1	X	X	X	1	17KS1ZWP0311-112WG
GP-1A		Groundwater	Well Point	1	1	1		1	1	1	1	1	17KS1ZMWGP1A-113WG
ETMW-2		Groundwater	Monitoring Well	1	1	1		1	1	1	1	1	17KS1ZETMW2-114WG
MW-9		Groundwater	Monitoring Well	1	1	1		1	1	1	1	1	17KS1ZMW9-115WG
MW89-1		Groundwater	Monitoring Well	1	1	1		1	1	1	1	1	17KS1ZMW891-116WG
MW-6		Groundwater	Monitoring Well	1	1	1		1	1	1	1	1	17KS1ZMW06-117WG
MW-23***		Groundwater	Monitoring Well	X	X	X		X	X	X	X	X	NOT SAMPLED
MW-28	MS/MSD	Groundwater	Monitoring Well	3	3	3		3	3	3	3	3	17KS1ZMW28-119WG
Duplicate Sample		Groundwater	Monitoring Well	1	1	1		1	1	1	1	1	17KS1ZMW99-120WG
Equipment Blank		Water	QA/QC-Peri Pump	1	1	1	1	1	1	1	1	1	17KS1ZEB0923
Trip Blanks		Water	QA/QC	4	4	4	1	1	1	1	1	1	17KS1ZTB-MMDD
A-Aquifer Sample Totals				17	17	17	2	14	13	13	13	14	
B-Aquifer Wells Location ID		Matrix	Location Type	EPA Method 524.2/VOCs	8260C SIM VOCs	8011 EDB & 1,2,3-TCP AK2016	AK101/GRO	AK102/DRO	SM 2320B Alkalinity	300.0 Chloride	RSK-175 Methane	6010B/ Dissolved Fe and Manganese	
MW-41	MS/MSD	Groundwater	Monitoring Well	3				3					17KS1ZMW41-201WG
MW-13-13B		Groundwater	Monitoring Well	1				1					17KS1ZMW1313B-202WG
MW-13-09B		Groundwater	Monitoring Well	1				1					17KS1ZMW1309B-203WG
Duplicate Sample		Groundwater	Monitoring Well	1				1					17KS1ZMW44-204WG
Purge Water Inf		Groundwater	GAC Pre-treatment	1			1	1					17KS1ZPURGEINF0928
Purge Water Eff		Groundwater	GAC Post treatment	1			1	1					17KS1ZPURGEEFF0928
Equipment Blank		Water	QA/QC-Grundfos	1			1	1					17KS1ZEB0924
Equipment Blank		Water	QA/QC-Peri Pump	1									17KS1ZEB0923
Trip Blanks		Water	QA/QC	2			2						17KS1ZTB-MMDD
B-Aquifer Sample Totals				12	0	0	5	9	0	0	0	0	

*WP03-06 was a substitute for WP03-09

**WP03-11 - slow recharge. Could not collect all analytes within a reasonable time frame.

***MW23-06 was not sampled due to lack of water.

2.3 ZONE 1 FINDINGS

Historical and current analytical data for A- and B-Aquifer results are shown on Tables 2-4, 2-7, and 2-8. Figure 2-1 shows DRO and TCE analytical results for the 2017 Zone 1 sampling. Results for MNA parameters are depicted on Figure 2-2 and Table 2-4. Sampling for BTEX constituents was continued in 2017, since the analysis includes TCE. However, the BTEX results are no longer reported since they have never exceeded the RAOs for Zone 1 A-Aquifer.

Field measurements can be found on the Zone 1 Sample Data Sheets in Appendix A. Complete analytical results are provided in Appendix C, Zone 1 Tables. Photographs of field activities are located in Appendix F.

2.3.1 A-Aquifer Analytical Results

2.3.1.1 DRO

Results from four of the nine A-Aquifer monitoring wells/well points sampled were above the ADEC cleanup level of 1.5 mg/L for DRO. DRO concentrations ranged from 0.062 to 4.4 mg/L. On average, these results are slightly lower than last year's results.

2.3.1.2 TCE

Four of the five A-Aquifer monitoring wells had detectable TCE concentrations above the ADEC cleanup level of 2.8 µg/L. Results for the five monitoring wells ranged from ND to 110 µg/L. None of the four POC well points sampled exceeded the action level of 2.7 µg/L for TCE. Results from the four well points ranged from ND to 2.4 µg/L.

2.3.1.3 1,2,4-Trimethylbenzene

The result from MW-9 was above the ADEC cleanup level of 15 µg/L for 1,2,4-Trimethylbenzene. Concentrations from all wells/well points were below the detection limit, except for ETMW-2 and MW-9, and WP0306. Their concentrations were 0.22 (0.28) µg/L, 93 µg/L and 2.5 µg/L, respectively. The results for WP036 are biased low due to the analysis occurring after the sample holding time expired.

2.3.1.4 Naphthalene

The result from MW-9 and WP0306 were above the ADEC cleanup level of 1.7 µg/L for naphthalene. Their concentrations were 220 µg/L and 4.5 µg/L, respectively. Naphthalene was detected in ETMW-2 and its duplicate at 0.76 (1.3) µg/L. Concentrations from all other wells/well points were below the detection limit.

2.3.1.5 Inorganics

Several inorganic analyses were performed to provide some analysis on whether natural attenuation of petroleum hydrocarbons is taking place in Zone 1. Please see Section 1.11 for an explanation of the methods used to evaluate natural attenuation.

Table 2-4 presents the results of natural attenuation parameter analyses for Zone 1. Also presented are field measurements of DO, oxidation reduction potential (ORP, also known as redox potential), and pH.

- DO measurements in four of the wells with DRO contamination were below 1.0 mg/L. Two of the wells with lower DRO concentrations had higher DO measurements. Depressed DO at wells containing levels of DRO above the RAO suggests that biodegradation occurring at this site.
- Ferrous iron concentrations ranged from ND in MW-6 to 10 mg/L in RP01. All of the samples with high concentrations of DRO had iron concentrations greater than 1.0 mg/L which can be used to indicate that aerobic biodegradation is occurring.
- Manganese concentrations ranged from 1.7 to 13 mg/L in wells with higher DRO results. Manganese concentrations ranged between ND to 3.9 mg/L in wells with DRO results below RAOs. In the past, wells with higher concentrations of DRO had a general tendency for higher levels of manganese. This correlation is somewhat apparent with the current sampling results.
- Methane concentrations in wells with DRO were 1.5 mg/L to 7.8 mg/L. In four wells with low DRO results, methane concentrations were 0.00025 to 1.7 mg/L. The presence of methane is evidence that intrinsic bioremediation of the fuel hydrocarbons is occurring.
- Alkalinity measurements ranged from 12 to 130 mg/L in wells with lower DRO concentrations, and 170 to 380 in wells with DRO concentrations above the RAO. Generally, elevated petroleum hydrocarbon levels correlated with increased alkalinity concentrations.

Table 2-4: Summary of Zone 1 A-Aquifer Analytical Data

Well Number	DRO (mg/L	TCE (ug/L)	Chloride (mg/L)	Sulfate (mg/L)	Alkalinity (mg/L)	Ferrous Iron (mg/L)	Manga-nese (mg/L)	Methane (mg/L)	Temp	pH	DO (mg/L)	Con	ORP (mV)
RAO	**1.5**	**2.7*/ 2.8**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
RPO-1*	**1.8**	2.3	2.9	1.9	250	10	6.9	5.4	5.95	6.49	1.29	339	10.9
GP-1A*	0.26	ND	4.2	0.69	12	1.1	0.54	0.17	8.9	5.9	1.85	42	151.5
WP03-06*	**4.4**	2.4	3.2	1.8	250	25	13	7.8	8.87	6.51	0.51	431	-48.3
WP03-11*	1.0	0.25	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
ETMW-02	0.40 (0.41)	**56 (65)**	4.3 (4.2)	8.4 (8.5)	170 (160)	0.52 (0.46)	3.9 (4.0)	3.9 (4.1)	6.6	6.16	0.75	236	149.1
MW-9	**3.4**	ND	1.8	NS	170	6.5	5.2	5.3	8.2	6.47	1.53	269	-5.7
MW89-1	**3.5**	**3.6**	18	NS	380	1.2	1.7	1.5	6.25	6.64	0.95	562	45.7
MW-6	0.062	**20**	3.8	5.2	120	ND	ND	0.00025	9.72	6.54	1.9	219	201.3
MW-23	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MW-28	0.11	**110**	2.5	NS	130	1.10	0.033	0.93	6.81	5.99	0.96	277	44.4

* TCE Action Level at POC Well Points
NS - Not Sampled/Analyzed
NA - Not Applicable
ND - Not detected above method reporting level (MRL)
RAO - Remedial action objectives
Analytical results exceeding RAOs shown in **BOLD.**
WP0306 was a substitute for WP0309
(Results) are duplicate samples

2.3.2 B-Aquifer Analytical Results

2.3.2.1 DRO

DRO was detected in all three B-aquifer wells in concentrations ranging from 0.076 mg/L to 0.92 mg/L (MW-41). All results are below the groundwater cleanup level of 1.5 mg/L.

2.3.2.2 TCE

TCE was detected in MW-41 at a concentration of 83 µg/L, and in MW13-09B at 51 (52) µg/L. These results are above the 2.8 µg/L cleanup level. MW-41 has had TCE concentrations from the previous thirteen sampling events ranging between 31 µg/L and 94 µg/L. The TCE concentration was 0.17 µg/L in MW13-13B.

2.3.2.3 Chloroform

Two of the three B-Aquifer monitoring wells had detectable chloroform concentrations above the ADEC cleanup level of 2.2 µg/L. Results for the three wells ranged from 2.3 (2.4) in MW1309B to 6.7 µg/L in MW41.

2.3.2.4 Naphthalene

The result from MW41 (4.9 µg/L) was above the ADEC cleanup level of 1.7 µg/L for naphthalene. The concentrations from the other two wells were below the detection limit.

2.3.3 DRO and TCE Concentration Trends

The statistical software ProUCL, Version 5.1 was used to assess DRO and TCE concentration trends for seven Zone 1 monitoring wells. Output from the ProUCL evaluation can be found in Appendix E. Table 2.5 and Table 2.6 summarize the concentration trends observed in the seven monitoring wells with historical concentrations of contaminants near or above RAOs. The tables list the numbers of wells exhibiting a specific concentration trend for each analyte. Well location data sets, which did not have the minimum number of four observations, or where the results were all below the reporting limit for a specific analyte, are not included in the trend summary table. Note that 36% of the concentration trends were decreasing, 14% were increasing, and 50% had no trend. Please note that one half the method detection limit for ND values was used, thus making it difficult to assess trends at or near the detection limit. Overall, since the majority of concentration trends are stable or decreasing, the trend analysis supports the conclusion that intrinsic remediation is keeping contaminant concentrations stable or decreasing at this site.

Table 2-5 Zone 1 MANN-Kendall Analysis Summary

Trend	DRO	TCE	% of Total
Decreasing	1	4	36%
Increasing	1	1	14%
No Trend	5	2	50%
Totals	7	7	14

Table 2-6 Zone 1 MANN-Kendall Trend Summary

Well	DRO	TCE
MW-41	NT	**I**
RPO1	**I**	D
GP1A	NT	D
MW89-1	**D**	**D**
MW-9	NT	NT
EKMW-2	NT	NT
WP0311	NT	**D**

D- Decreasing I - Increasing
NT – No trend

2.4 ZONE 1 CONCLUSIONS

2.4.1 A-Aquifer Monitoring

Two well points and two monitoring wells exceeded the cleanup level of 1.5 mg/L for DRO. TCE was not detected above the action level of 2.7 µg/L in any of the point of compliance (POC) well points. TCE was detected in four monitoring wells above the RAO. Monitoring well MW-9 exceeded the ADEC cleanup level for 1,2,4-trimethylbenzene and naphthalene. WP03-06 also exceeded cleanup levels for naphthalene. Inorganic parameters measured in Zone 1 groundwater provide some evidence that natural attenuation of petroleum hydrocarbons is occurring in the A-Aquifer. The Mann-Kendall statistics analysis of groundwater contaminants revealed that 36% of concentration trends are decreasing at this site, while 50% indicate no trend. Since the majority of concentration trends are decreasing or stable, this analysis provides more evidence that intrinsic remediation is attenuating contaminants, or at least keeping contaminant concentrations in check.

2.4.2 B-Aquifer Monitoring

All DRO detections in the Zone 1 B-Aquifer monitoring wells were below RAOs. MW-41 and MW13-09B exceeded the RAO of 2.8 µg/L for TCE and the RAO of 2.2 µg/L for chloroform. MW-41 also exceeded the cleanup level for naphthalene. MW-41 is at the center of an ongoing RI/FS for TCE contamination in GWZ 1, under a separate contract.

2.4.3 Product Recovery

Product probes PR-11, -12, -13, and -32 located in Seep 1 had more than the requisite 0.3 ft of product present for recovery. Approximately 0.3 liter of product was removed from the probes in June 2017.

2.4.4 Institutional Control Inspection

There were no observations of drinking water wells present, or being installed in the A-Aquifer or the B-Aquifer.

2.4.5 Condition of Wells

All wells scheduled for Zone 1 were sampled with the exception of MW-23, which didn't have enough water, and WP03-09, which was jacked out of the ground. There were no viable substitutes for MW-23. WP03-06 was sampled as a substitute for WP03-09.

WP03-11 had an extremely slow recharge rate. Sample containers were filled over the course of several hours or the next day. Methane, metals, and chloride/sulfate/alkalinity were not collected.

2.5 ZONE 1 RECOMMENDATIONS

- Monitoring should continue without any changes.
- Any recommendations are subject to change pending conversations between ADEC and AFCEC, and any comment resolution outcomes on ADEC's comments for the Five-Year Review.

Table 2-7: Zone 1 Historical Analytical Data (2000-2016)

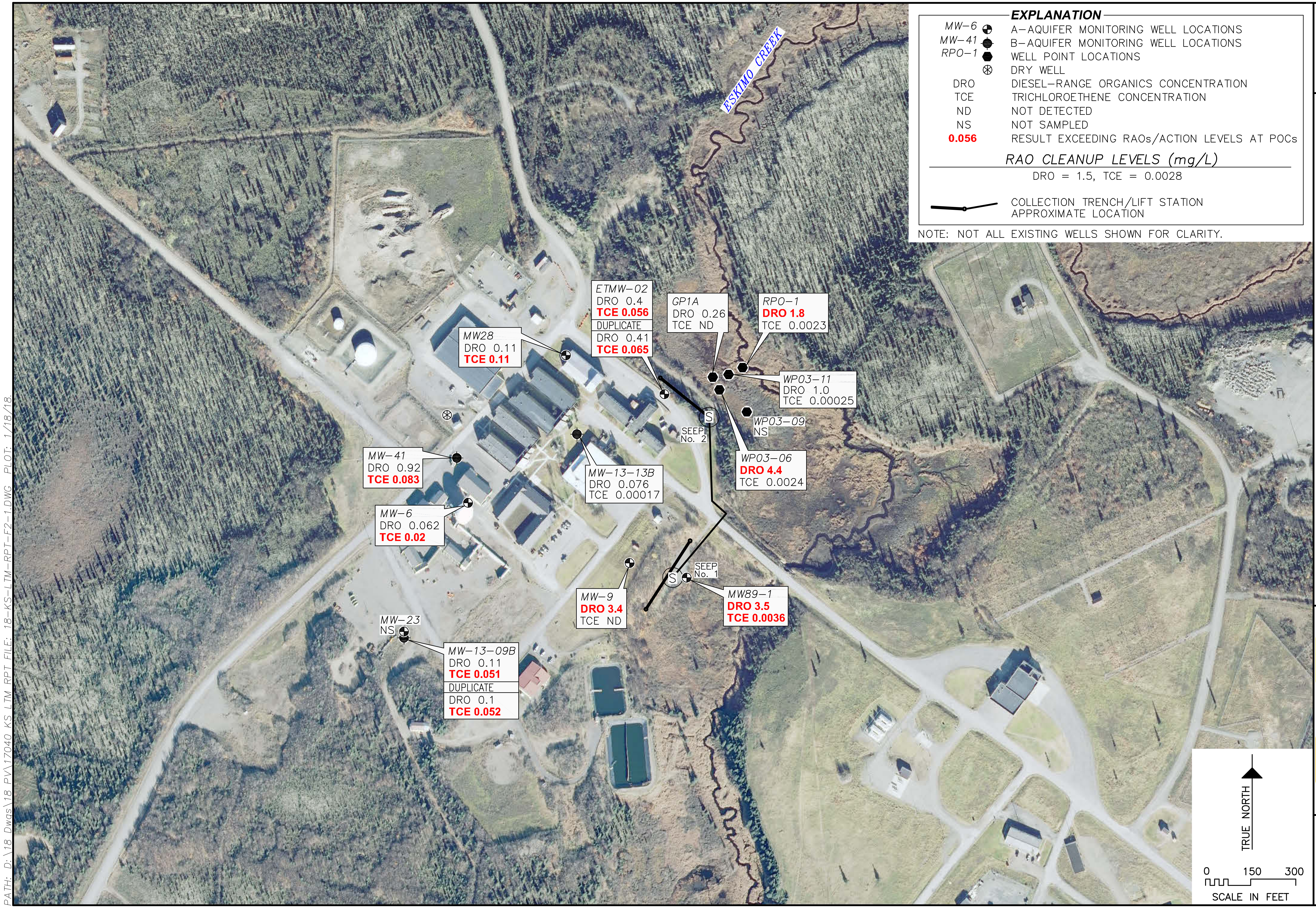
Well	Analyte (mg/L)	RAOs (mg/L)	2002	2004	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
POC-1 (RPO-1)	DRO	1.5			**1.7**	**1.5**	1.3	0.80	NS	1.3	**1.6**	**1.9**	**2.5**	**2.7**	**1.8**
	TCE	0.0027*			**0.0737**	**0.039**	**0.04**	**0.018**	NS	**0.003**	**0.005**	**0.0071**	**0.0044**	**0.0029**	0.0023
	Alkalinity	None			197	185	172	187	NS	250	270	300	230	290	250
	Iron	None			9.34	10.6	12.2	0.086	NS	22	13	9	7.8	11	10
	DO	None			5.74	0.82	0.4	2.15	NS	1.55	0.48	0.43	0.46	0.66	1.29
GP-1 *GP1A sampled in 2014 as a substitute	DRO	1.5	0.707		**2.76**	**4.2**	**4.2**	1.2	NS	0.99	**1.5**	1.2	**3.7**	**3.3**	0.26
	TCE	0.0027*	**0.616**		**0.0053**	**0.0059**	0.0012	ND	NS	ND	ND	ND	0.00032	ND	ND
	Alkalinity	None	259		272	243	235	47	NS	52	NA	100	210	310	12
	Iron	None	ND		4.22	45.9	111	40.9	NS	100	NA	66	100	100	1.1
	DO	None	NS		2.95	0.36	0.47	3.2	NS	2.92	NA	0.86	2.11	1.2	1.85
GP-2 (or alt WP03-07 in 2008, WP03-09 in 2009- 2016, WP03-06 in 2017)	DRO	1.5			0.685	**6.0**	**4.9**	**3.7**	**3.4**	**2.6**	**2.5**	**2.3**	**2.8**	**3.2**	**4.4**
	TCE	0.0027*			ND	**0.0052**	0.0024	**0.0028**	**0.0073**	ND	ND	ND	ND	ND	0.0024
	Alkalinity	None			56.2	292	287	294	149	43	99	29	97	190	250
	Iron	None			10.4	44.5	61.3	57.7	89	46	87	21	55	130	25
	DO	None			4.8	0.21	0.44	1.32	0.36	1.7	0.37	2.26	0.59	0.74	0.51
WP03-11	DRO	1.5			**3.65**	**3.7**	**4.2**	**2.0**	NS	**2.0**	**1.8**	**2.6**	**3.7**	**2.5**	1.0
	TCE	0.0027*			**0.0272**	**0.013**	**0.0088**	**0.0078**	NS	**0.0082**	**0.0049**	**0.0044**	**0.0045**	**0.0034**	0.00025
	Alkalinity	None			291	240	307	338	NS	300	270	300	300	300	NA
	Iron	None			ND	0.0705	0.047	0.30	NS	4.8	1.5	2.7	4	3.1	NA
	DO	None			4.77	0.74	0.5	1.62	NS	0.34	0.34	0.55	0.76	0.67	NA
EKMW-01 was replaced with ETMW-02 in 2012.	DRO	1.5	**29**	6.4	**3.05**	**3.9**	**1.9**	**1.7**	NS	0.73	0.56	0.5	0.61	1	0.4 (0.41)
	TCE	0.0028	0.0499	0.017	**0.0062**	**0.0058**	**0.0038**	**0.011**	NS	**0.046**	**0.073**	**0.062**	**0.089**	**0.087**	**0.056 (0.065)**
	Alkalinity	None	269	203	202	203	192	WP0	NS	170	190	160	160	140	170 (160)
	Iron	None	1.83	1.03	0.93	0.544	1.9	2.95	NS	0.71	0.52	0.2	0.49	0.029	0.52 (0.46)
	DO	None	0.22	0.29	0.64	1.10	1.02	1.52	NS	0.47	0.42	0.6	0.83	0.7	0.75
MW-9	DRO	1.5	**3.32**	**15.5**	**11.4**	**3.7**	**4.8**	**3.9**	**4.6**	**2.8**	**4.5**	**5.9**	**3.1**	**7.3**	**3.4**
	TCE	0.0028	0.0019	0.0011	ND	0.00066	ND	ND	ND	0.00025	0.0015	ND	0.00084	ND	ND
	Alkalinity	None	314	316	162	192	281	292	277	230	230	230	210	200	170
	Iron	None	1.14	1.29	1.2	1.54	3.1	4.2	6.68	6.4	7	7.4	8	7.9	6.5
	DO	None	1.27	0.82	5.23	3.61	2.55	4.05	0.77	0.88	0.48	0.76	0.68	0.98	1.53
MW89-1	DRO	1.5	**19.9**	**53.3**	**5.14**	**3.8 (3.5)**	**2.8 (3.8)**	**2.2 (2.5)**	**5.4 (5.2)**	**2.3 (2.6)**	**3.2 (3.5)**	**3.4 (3.9)**	**3.9**	**3.4**	**3.5**
	TCE	0.0028	**0.0104**	0.0003	**0.0047**	**0.0040 (0.0042)**	**0.0033**	**0.0034 (0.0035)**	**0.0038 (0.0037)**	**0.0031 (0.0035)**	**0.0034**	**0.0037 (0.0039)**	**0.0041**	**0.0037**	**0.0036**
	Alkalinity	None		18.8	315	311/313	297/291	314	333/336	350	370	390	390	370	380
	Iron	None	0.694	18.8	2.04	1.84/1.93	3.7/3.4	3.68/2.98	3.16/2.19	1.2/1.1	1.1	0.72/0.78	0.68	0.82	1.2
	DO	None	0.11	0.43	0.8	0.29	0.49	2.09	0.76	0.45	0.39	0.64	0.79	0.74	0.95
MW-6	DRO	1.5											0.2	0.096	0.062
	TCE	0.0028											**0.022**	**0.024**	**0.020**
	Alkalinity	None											110	110	120
	Iron	None											0.04	ND	ND
	DO	None											3.54	4.13	1.9
MW-23	DRO	1.5											**0.4**	0.24/0.27	NS
	TCE	0.0028											**0.026**	**0.019**	NS
	Alkalinity	None											130	110	NS
	Iron	None											0.02	ND	NS
	DO	None											6.74	8.48	NS
MW-28	DRO	1.5											**0.2**	0.12	0.11
	TCE	0.0028											**0.095 (0.12)**	**0.11**	**0.11**
	Alkalinity	None											110 (120)	120	130
	Iron	None											0.46 (0.56)	ND	1.1
	DO	None											2.66	4.17	0.96

Notes: * Action level at POCs for TCE is the ecological surface water quality criteria.
** RAO at monitoring wells for TCE (ADEC Table C)
Results shown in **BOLD** exceed ADEC Table C Cleanup Levels
DRO - Diesel Range Organics; RRO - Residual Range Organics
NS- Well Not sampled; NA - Analyte Not Analyzed; ND - Analyte Not Detected
(Results) are duplicate samples.

Table 2-8: Zone 1 Selected B-Aquifer Data (2002 - 2017)

Well	Analyte	RAOs (mg/L)	2002	2004	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
MW-41	GRO	2.2	0.112	0.046	0.0236	0.0335	0.068	0.072	0.052	0.074	0.014	NA	NA	NA	NA	NA
	DRO	1.5	1.48	0.961	**1.85**	**2.34**	1.1	0.66	0.81	1.3	0.79	0.98	1.1	1.4	1.1	0.92
	TCE	0.0028	**0.031**	**0.051**	**0.042**	**0.048**	**0.038**	**0.035**	**0.039**	**0.035**	**0.049**	**0.084**	**0.094**	**0.091**	**0.072**	**0.083**
MW13-13B	GRO	2.2												NA	NA	NA
	DRO	1.5												0.17	0.13	0.076
	TCE	0.0028												ND	ND	0.00017
MW13-09B	GRO	2.2												NA	NA	NA
	DRO	1.5												0.23 (0.15)	0.14 (0.17)	0.11 (0.10)
	TCE	0.0028												**0.043 (0.043)**	**0.048 (0.047)**	**0.051 (0.052)**
MW-42	GRO	2.2	ND	0.033	NS	ND	0.057/ND	0.012	ND	ND	ND/0.0049	NA	NA	NS	NS	NS
	DRO	1.5	ND	0.241	NS	0.97 (0.315)	0.12 (0.064)	0.056(0.059)	0.059(0.067)	0.16(0.12)	0.099(0.089)	0.086(0.082)	0.27(0.28)	NS	NS	NS
	TCE	0.0028	ND	0.0012	NS	ND(0.00207)	0.00067(0.00031)	0.00046(0.00038)	ND(0.00038)	0.0017(0.0019)	0.0023(0.0017)	0.0021(0.0022)	0.0023(0.0022)	NS	NS	NS
MW-43	GRO	2.2	ND	ND	NS	ND	0.015	0.018	ND	ND	ND	NA	NA	NS	NS	NS
	DRO	1.5	ND	0.551	NS	0.339	0.50	0.36	0.32	0.52	0.33	0.39	0.62	NS	NS	NS
	TCE	0.0028	ND	ND	NS	0.00157	ND	ND	ND	ND	ND	ND	ND	NS	NS	NS

Results in **BOLD** exceed RAOs.
ND - Not Detected
NA - Not Analyzed
NS - Not Sampled
(Result) are duplicate samples.



EXPLANATION

MW–6	◒	A–AQUIFER MONITORING WELL LOCATIONS
MW–41	⬣	B–AQUIFER MONITORING WELL LOCATIONS
RPO–1	⬢	WELL POINT LOCATIONS
	⊗	DRY WELL
DRO		DIESEL–RANGE ORGANICS CONCENTRATION
TCE		TRICHLOROETHENE CONCENTRATION
ND		NOT DETECTED
NS		NOT SAMPLED
0.056		RESULT EXCEEDING RAOs/ACTION LEVELS AT POCs

RAO CLEANUP LEVELS (mg/L)

DRO = 1.5, TCE = 0.0028

COLLECTION TRENCH/LIFT STATION
APPROXIMATE LOCATION

NOTE: NOT ALL EXISTING WELLS SHOWN FOR CLARITY.

FIGURE
2-1

DRO AND TCE ANALYTICAL RESULTS GROUNDWATER ZONE 1

GROUNDWATER ZONE 1 (OT–027)
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE
JAN. 2018
CHKD
H.L.H.
DRAWN
C.E.H.
PROJ. NO
17040

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT\RPT FILE: 18–KS–LTM–RPT–F2–1.DWG PLOT: 1/18/18.

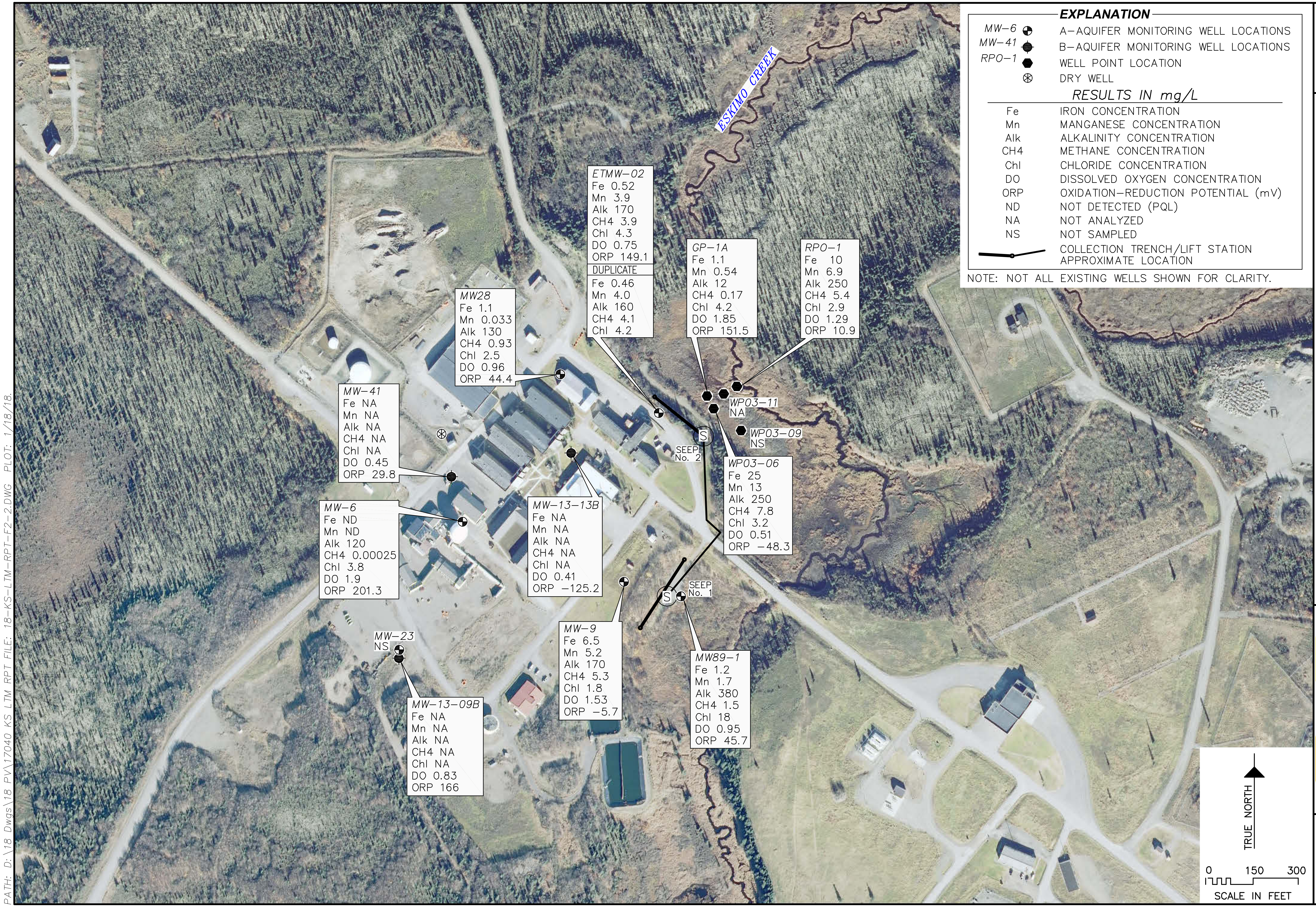


FIGURE 2-2

MONITORED NATURAL ATTENUATION RESULTS GROUNDWATER ZONE 1

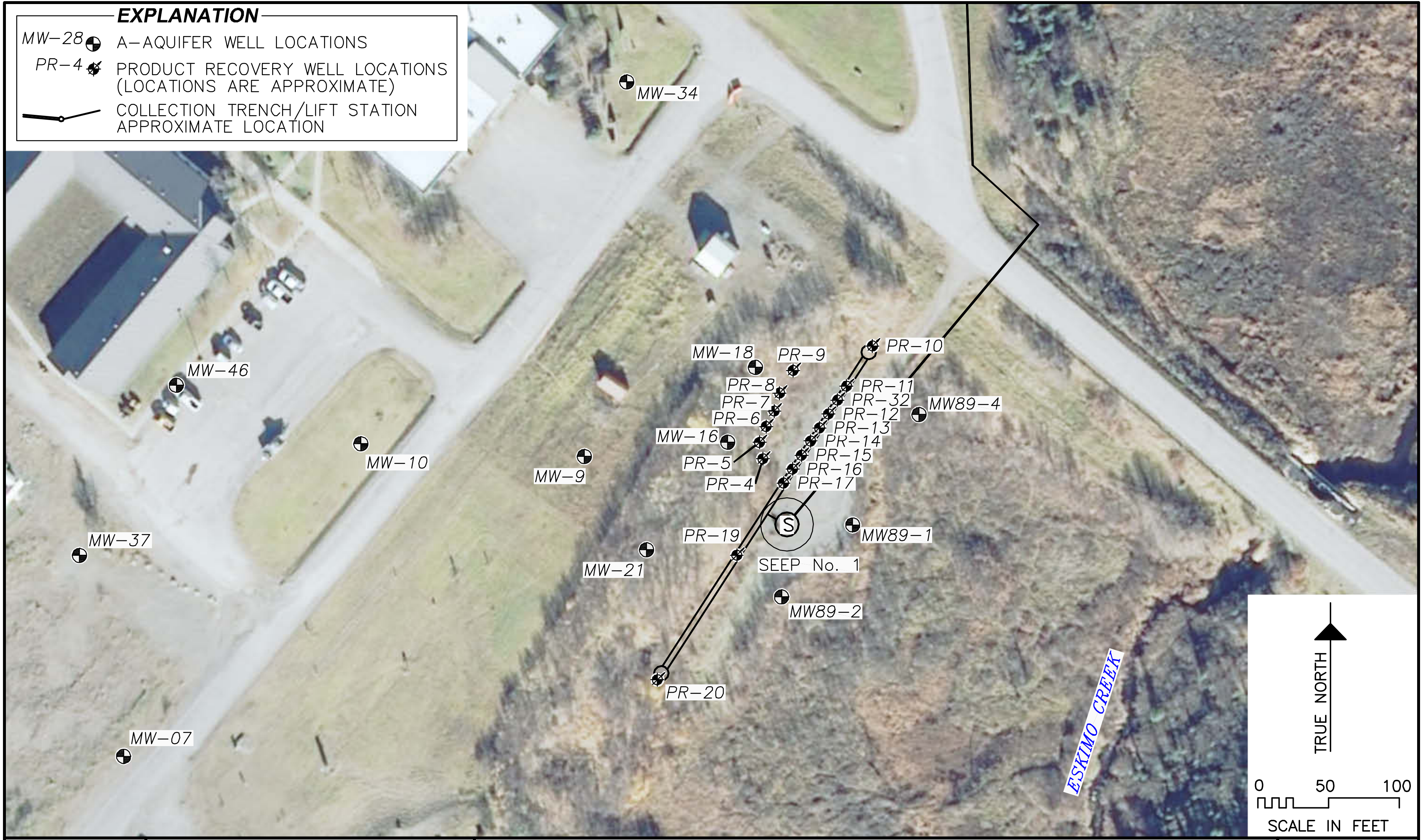
GROUNDWATER ZONE 1 (OT-027)
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE
JAN. 2018
CHKD
H.L.H.
DRAWN
C.E.H.
PROJ. NO
17040

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18-KS-LTM-RPT-F2-2.DWG PLOT: 1/18/18.

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18-KS-LTM-RPT-F2-3_4.DWG PLOT: 1/10/18.



DATE
JAN. 2018
CHKD.
H.L.H.
DRAWN
C.E.H.
PROJ. NO
17040

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

PRODUCT PROBES NEAR SEEP No. 1

GROUNDWATER ZONE 1 (OT-027)
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

FIGURE
2-3

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18-KS-LTM-RPT-F2-3_4.DWG PLOT: 1/10/18.

DATE JAN. 2018 CHKD. H.L.H. DRAWN C.E.H. PROJ. NO 17040	PACIFIC AIR FORCES REGIONAL SUPPORT CENTER & AIR FORCE CIVIL ENGINEERING CENTER JBER, ALASKA	**PRODUCT PROBES NEAR SEEP No. 2** GROUNDWATER ZONE 1 (OT-027) 2017 LONG TERM MANAGEMENT King Salmon Divert, Alaska	FIGURE **2-4**

3 ZONE 2 - BASE INDUSTRIAL AREA & ESKIMO CREEK DUMP

This section describes the results of sampling at the KSD Base Industrial Area (Groundwater Zone 2 – OT028) and Eskimo Creek Dump (LF022, formerly SS022). Historical spills and operational practices at Zone 2 resulted in contamination of the water table with petroleum-based products and chlorinated solvents, specifically DRO, GRO, BTEX, and TCE dissolved in the groundwater.

The primary objective of the monitoring program at the Base Industrial Area is to determine if MNA is occurring. The primary objective of the Eskimo Creek Dump monitoring project is to determine whether there is any contamination above cleanup levels emanating from Eskimo Creek Dump toward Eskimo Creek. TCE dissolved in groundwater is the COC at Eskimo Creek Dump.

Details regarding the site history, previous investigation results, existing remedial actions, and other information relevant to Groundwater Zone 2 are provided in the final ROD located in the electronic version of this report.

3.1 REMEDIAL ACTION OBJECTIVES FOR ZONE 2

RAOs are specific cleanup levels and related requirements to be met at Groundwater Zone 2 and Eskimo Creek Dump. Groundwater and soil RAOs listed in the final Zone 2 ROD were developed using the “10 times rule” which is no longer used by ADEC. Current regulatory cleanup levels are now used for GRO. Surface water RAOs were developed in accordance with the AWQS, 18 AAC 70.

Final RAOs presented in the ROD and current ADEC cleanup levels are displayed on Table 3-1.

In addition to the regulation-based cleanup levels, action levels were defined for TCE and its degradation products to guide remedial efforts. Action levels are ecological surface water quality screening criteria.

According to the ROD, sampling may be discontinued at a sampling point once two consecutive sampling events are below RAOs. There was only one RAO exceedance in the last nine years of sampling the seven Eskimo Creek well points (ECWP04-06 exceeded the RAO for TCE in 2004). Sampling of the well points was discontinued in 2013, and the well points were decommissioned in September, 2014. Collecting surface water samples at three locations along Eskimo Creek has continued.

Table 3-1 RAOs for ERP Sites in the KSD Base Industrial Area (Zone 2)

Media	Contaminants of Concern	Maximum Conc.	Maximum Conc. Location (Date)	Maximum Conc. 2000 data	Screening and Regulatory Criteria				RAOs		
					Ecological Criteria	Basis	2002 ADEC Criteria	Basis	Action Level at POC*	Cleanup Level/ ARAR Final ROD [b]	Current ADEC Cleanup Levels
Groundwater (mg/L) (A- Aquifer)	TCE	0.750	B-02 (1988)[a]	0.062 (MW00-05)	--	--	0.005	18AAC75	0.35	0.05[b]	0.0028
	cis-1,2-DCE	0.13	145 (1996)	0.053 (MW00-02)	--	--	0.07	18AAC75	0.59	0.7[b]	0.036
	Benzene	2.0	(1988)[a]	0.48 (MW-00-04)	--	--	0.005	18AAC75	0.046[c]	0.05[b]	0.0046
	Ethylbenzene	2.3 AX	MW-708 (1997)	1.700 (MW00-04)	--	--	0.7	18AAC75	0.29[c]	7[b]	0.015
	Toluene	7.8	AP-12 (1994)	3.4 (MW00-04)	--	--	1.0	18AAC75	0.13[c]	10[b]	1.1
	DRO	26.1	B-06 (1993)	13.0 (MW00-03)	--	--	1.5	18AAC75	na	15[b]	1.5
	GRO	30	MW00-04 (2000)	30 (MW00-04)	--	--	1.3	18AAC75	na	13[b]	2.2
Surface Water (mg/L)	TCE	0.013[d]	SS-7 (1997)	NS	0.35	Ecotox	0.005	18AAC70	--	0.005	0.005
	cis-1,2-DCE	0.0014	138 (1993)	NS	0.59	ORNL	0.07	18AAC70	--	0.07	0.07
Soil (mg/Kg)[e]	DRO	12,100	VP-9 at 19 ft bgs (1988)	28 (MW00-03 at 9 ft bgs)	--	--	250	18AAC75	--	2,500[b]	230
	Benzene	1.8	(1988)[a]	ND	--	--	0.022	18AAC75	--	0.22[b]	0.022
	Ethylbenzene	94	629 (1994)	0.25 (MW00-04 at 13 ft bgs)	--	--	0.13	18AAC75	--	1.3[b]	0.13
	Toluene	97	629 (1994)	ND	--	--	6.7	18AAC75	--	6.7[b]	6.7
	TCE	1.7	(1988)[a]	0.066 (MW00-05 at 15 ft bgs)	--	--	0.011	18AAC75	--	0.11[b]	0.011

***Action levels at the POC (point of compliance) refer to groundwater concentration detected in monitoring wells adjacent to Eskimo Creek that would signal the need for active groundwater cleanup for protection of the creek. The action levels are equal to the surface water ecological screening criteria. Note that there have been no exceedance of the action levels at the POC; the maximum groundwater concentrations shown in Table 1 were not detected at locations adjacent to Eskimo Creek. The seven Eskimo Creek wellpoints were decommissioned in 2014.**

[a] This information was obtained from the EMCON, 1995 KSD Remedial Investigation (RI) (EMCON, 1995a), which did not provide specific sample locations. The RI stated that the results were obtained from 1988 sampling by the Corps of Engineers at the Refueler Shop site.

[b] Basis for the soil and groundwater cleanup levels was 18 AAC 75 using the tabulated cleanup levels (Table B1 and B2 for soil and Table C for groundwater) adjusted (x10) for the situation where groundwater is determined to not be a drinking water source. The 10x rule is no longer used by ADEC.

[c] These action levels correspond to the USEPA Ecotox (defined below in "Definitions") thresholds for surface water.

[d] The reported TCE concentration was detected in a sample from Eskimo Creek Dump surface water (not from Eskimo Creek itself). TCE has been detected in only one sample from Eskimo Creek adjacent to Groundwater Zone 2 (0.00055 mg/L in 1999). TCE was also detected in 1997 surface water sample collected from Eskimo Creek upgradient of Zone 2; the detection is considered to be unrelated to Zone 2 impacts.

[e] Sediment has been investigated and is not considered a medium of concern because no criteria were exceeded.

Definitions

18 AAC 75 Oil and Hazardous Substances Pollution Control Regulations (ADEC, 2017)
18 AAC 70 Alaska Water Quality Standards (ADEC, 2017)
Ecotox – USEPA Office of Solid Waste and Emergency Response (OSWER) Ecotox Threshold benchmark values for freshwater (ECP Update, Publication 9345.0-12FSI; EPA 540/F-05/038, January 1996)
ORNL PRG – Oak Ridge National Laboratory Preliminary Remediation Goals for Ecological Receptors (RAIS database at http://risk.lsd.ornl.gov/rap_hp.shtml, 2002)

ARAR – Applicable or Relevant and Appropriate Requirement	**RAO – Remedial Action Objective**
POC – Point of Compliance	**FPP – Floating Petroleum Product**
SQB – Sediment Quality Benchmark	**ND – Not detected**
TCE – Trichloroethene	**NE – Not evaluated**

DCE – Dichloroethene
— Not applicable
mg/Kg – milligrams per kilogram
NA – Not analyzed
mg/L – milligrams per liter
bgs – below ground surface

3.2 PROJECT TASKS

3.2.1 Groundwater Sampling Program

Groundwater samples were collected in September 16 – 17, 2017 from the eleven A-Aquifer groundwater monitoring wells identified in Table 3-2 and shown on Figure 3-1. Data collected from each monitoring well were documented on the Zone 2 Groundwater Sample Data Sheets provided in Appendix A.

3.2.2 Surface Water Sample Collection

On September 18, 2017, surface water samples were collected from three locations along Eskimo Creek (SS022/LF022) as shown on Figure 3-3. Table 3-2 has a complete list of analyses. Data collected from each sampling point were documented on the Surface Water/Sediment Sample Data Sheets provided in Appendix A.

3.2.3 Institutional Control Inspection

Institutional controls, which are land use restrictions, are part of the selected remedy. Only water from the C-Aquifer, the current source of water for KSD, will be used for drinking. Drinking water wells will not be installed in the A and B Aquifers in Zone 2 or Eskimo Creek Dump (SS022). Excavations and other subsurface activities will be restricted from sites SS020 (Old Power Plant Building), SS021 (Refueler Shop), and SS022 (Eskimo Creek Dump).

A visual inspection was performed to verify that no water wells have been installed or that no soil excavation has been conducted at the above mentioned sites.

3.2.4 Deviations from the Work Plan

The water column in AP-11 was 0.48 feet which was too small to use the water level meter to monitor drawdown. Low level flow was maintained without the well purging dry.

The depth of water at surface water locations OT28-01 and OT28-02 was insufficient to collect readings with the YSI.

Table 3-2: Groundwater Zone 2 Sample Analyses Summary

				Analytical Methods									
Location ID	Comment	Matrix	Location Type	8260C VOCs	8260C SIM VOCs	8011 EDB & 1,2,3-TCP AK2016	Alaska Method AK101/GRO	AK102 & 103 DRO	SM 2320B Alkalinity	300.0 Chloride	353.2 Nitrate + Nitrite	6010B Dissolved Fe+Mn	Sample ID
B-02		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	17KS2ZB02-107WG
MW00-05		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	17KS2ZMW0005-108WG
MW-446		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	17KS2Z446-109WG
MW-447		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	17KS2Z447-110WG
AP-11		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	17KS2ZAP11-111WG
MW-708		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	17KS2Z708-112WG
MW-629	MS/MSD	Groundwater	Monitoring Well	3	3	3	3	3	3	3	3	3	17KS2Z629-113WG
MW00-03		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	17KS2ZMW0003-114WG
MW-628		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	17KS2Z628-115WG
MW00-02		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	17KS2ZMW0002-117WG
MW-202		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	17KS2Z202-117WG
Duplicate Sample	MW-628	Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	17KS2Z626-118WG
Duplicate Sample	B-02	Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	17KS2Z627-119WG
Trip Blanks		Water	QA/QC	4	4	4	4						17KS2ZTB-MMDD
Total Samples - A-Aquifer				19		19	19	15	15	15	15	15	
Location ID		Matrix	Location Type	8260C VOCs	8260C SIM VOCs	8011 EDB & 1,2,3-TCP AK2016							**Surface Water**
OT28-01		Surface Water	Surface Water	1	1	1							17KS2ZOT281-301WS
OT28-02		Surface Water	Surface Water	1	1	1							17KS2ZOT282-302WS
OT28-03	MS/MSD	Surface Water	Surface Water	3	3	3							17KS2ZOT283-303WS
Duplicate Sample	OT28-01	Surface Water	Surface Water	1	1	1							17KS2ZOT284-304WS
Trip Blanks		Water	QA/QC	1	1	1							17KS2ZTB-MMDD
Total Samples - Surface Water				7	7	7							

3.3 ZONE 2 FINDINGS

Historical and current analytical data results are shown on Tables 3-3, 3-4, and 3-5. The RAOs for A-Aquifer groundwater in Zone 2 are ADEC Table C groundwater cleanup levels (18 AAC 75). Analytical results are provided in Appendix C, Zone 2 Tables. Photographs of field activities are located in Appendix F.

3.3.1 Groundwater Analytical Results

3.3.1.1 GRO and DRO

B-02, AP-11, MW-708, MW00-03, and MW-629 exceeded the cleanup level of 2.2 mg/L for GRO. GRO concentrations for these wells are estimated due to the analytical results exceeding the instrument calibration range. GRO levels ranged between 0.017 (MW-202) and 30 mg/L (MW-708). B-02 and MW-629 exceeded the cleanup level of 1.5 mg/kg for DRO. DRO levels ranged from 0.054 (MW 628) to 3.9 mg/L (B-02). The reported GRO result for MW-708 has been biased low due to exceeding the sample holding time by 2X.

GRO and DRO levels detected in Zone 2 groundwater are shown on Figure 3-1.

3.3.1.2 BTEX

Three wells exceeded the ADEC cleanup level for benzene, five for ethylbenzene, and five for total xylenes. There was one exceedance for toluene. BTEX detections are summarized below and shown on Figure 3-1.

- Benzene was detected at concentrations above the 0.0046 mg/L cleanup level in monitoring wells 708 (0.052 mg/L) and MW-629 (0.082 mg/L), and MW00-03 (0.0053 mg/L). Results for 708 and MW-629 are biased low due to the analyses occurring after the sample holding times expired.
- Toluene was detected above the 1.1 mg/L cleanup level in MW-708 (2.8 mg/L). Toluene was detected in B-02, AP-11, MW-628, MW-629, and MW00-03 in concentrations ranging between 0.00029 mg/L to 0.34 mg/L. Results for AP-11 and MW-629 are estimated due to the analytical results exceeding the instrument calibration range. All results listed, except MW-628 and MW00-03, have been biased low due to exceeding the sample holding time by 2X.
- Ethylbenzene concentrations in B-02, AP-11, MW-708, MW-629, and MW00-03 were above the cleanup level of 0.015 mg/L. Concentrations in those wells ranged between 0.34 mg/L to 2.4 mg/L. The reported results have been biased low due to exceeding the sample holding time by 2X.
- Total xylene concentrations in B-02, AP-11, MW-708, MW-629, and MW00-03 were above the cleanup level 0.19 mg/L. Concentrations in those wells were between 0.40 and 6.1 mg/L. Those

reported results have been biased low due to exceeding the sample holding time by 2X. Total xylenes in the remaining six Zone 2 wells had concentrations between 0.00021 and 0.0021 mg/L.

3.3.1.3 TCE

TCE was detected above the cleanup level of 2.8 µg/L in six monitoring wells. TCE levels in those wells ranged between 3 µg/L to 15 µg/L (B-02). Four wells were non-detect for TCE.

The TCE concentrations detected in Zone 2 groundwater are shown on Figure 3-2 which also depicts the inferred plume where A-Aquifer TCE concentrations exceed 2.8 µg/L.

3.3.1.4 Naphthalene

Six of the monitoring wells exceeded the ADEC groundwater cleanup level of 1.7 µg/L for naphthalene. Those results ranged between 1.7 µg/L to 150 µg/L. The 150 µg/L results from the field duplicate of monitoring well B-02 is biased low due to the analysis occurring after the sample holding time expired.

3.3.1.5 1,2,4-Trimethylbenzene

The results from three of the eleven A-Aquifer monitoring wells sampled were above the ADEC groundwater cleanup level of 15 µg/L for 1,2,4-Trimethylbenzene. The sample result from B-02 was 500 (510) µg/L, MW-708 was 91 µg/L, and MW-629 was 54 µg/L. The result for 708 is estimated due to the analytical results exceeding the instrument calibration range. The results for B-02 and the field duplicate have been biased low due to exceeding the holding time by 2X.

3.3.1.6 1,3,5-Trimethylbenzene

Monitoring well B-02 had a concentration of 150 µg/L for 1,3,5-Trimethylbenzene, which is above the ADEC groundwater cleanup level of 120 µg/L. The result for B-02 is estimated due to the analytical result exceeding the instrument calibration range. Concentrations from the other wells ranged from non-detect to 35 µg/L.

3.3.1.7 Inorganics

The monitoring well samples were analyzed for several inorganic parameters to evaluate the progress of MNA. The MNA assessment is discussed in Section 3.4.

3.3.2 Surface Water Analytical Results

Surface water contaminant levels are compared to regulatory criteria and benchmark screening levels. As discussed in Section 3.1, 18 AAC 70 provides regulatory criteria for surface water. Analytical results are provided in Appendix C, Zone 2 Tables. Table 3-4 presents historical analytical results for the COCs (BTEX and TCE) along with the appropriate water quality criteria for comparison.

3.3.2.1 BTEX & TCE

BTEX constituents and TCE were not detected in any of the samples.

3.3.2.2 Hexachlorobutadiene

Hexachlorobutadiene was detected in OT28-03 (2.2 µg/L) above the water quality criteria of 0.053 µg/L.

3.3.2.3 Naphthalene

Naphthalene was detected in OT28-01 (1.3 µg/L) and OT28-02 (40 µg/L) above quality criteria of 1.1 µg/L.

Table 3-3: Historical Zone 2 Groundwater Results

Site Area	Well Location	Analyte	RAO	1988 Analytical Results	1992 Analytical Results	1993 Analytical Results	1994 Analytical Results	1996 Analytical Results	1997 Analytical Results	1998 Analytical Results	2000 Analytical Results	2004 Analytical Results	2005 Analytical Results	2006 Analytical Results	2007 Analytical Results	2008 Analytical Results	2009 Analytical Results	2010 Analytical Results	2011 Analytical Results	2012 Analytical Results	2013 Analytical Results	2014 Analytical Results	2015 Analytical Results	2016 Analytical Results	2017 Analytical Results
Near Eskimo Creek	628	GRO	2.2 mg/L	NI	NI	NI	NS	NS	NS	NS	ND	0.0223	ND	ND	0.0168	NS	NS	0.014	ND	0.005	0.027	0.023	0.044	0.025/ND	0.042/0.032
		DRO	1.5 mg/L	NI	NI	NI	NS	ND	0.12	0.138	0.11	0.293	ND	0.0835	0.201	NS	NS	ND	ND	0.025	0.017	0.15	0.074	0.033	0.058/0.054
		BTEX	mg/L	NI	NI	NI	ND	ND	ND	ND	ND	ND	ND	ND	0.00033	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00148/0.000225
		Benzene	4.6 µg/L	NI	NI	NI	ND	ND	ND	ND	ND	ND	ND	ND	0.33	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.033/0.015
		TCE	2.8 µg/L	NI	NI	NI	**13.0**	**6.6**	**8.4/6.1**	**7.9**	**8.2**	**11.8**	**10.8**	**10.8**	**6.63**	**10.0/11.0**	**8.6/11**	**9.3**	**8.6**	**9.0**	**9.4**	**9.8**	**9.2**	**11/8.2**	**8.3/8.7**
		PFOA	0.40 µg/L																					0.033	NA
		PFOS	0.40 µg/L																					0.31	NA
Near Eskimo Creek	202	GRO	2.2 mg/L	NI	NI	NI	NI	NS	NS	NS	ND	0.0319	ND	0.0137/0.0276	0.0101/0.0101	NS	NS	ND	ND	ND	ND	ND	0.03	ND	0.017
		DRO	1.5 mg/L	NI	NI	NI	NI	0.2	ND	NS	0.86	0.215	0.0942	0.287/0.278	0.495/0.151	NS	NS	0.074	0.070	0.073	0.056	0.230	0.120	0.13	0.11
		BTEX	mg/L	NI	NI	NI	NI	ND	ND	NS	ND	ND	0.00123	ND/ND	ND/ND	NS	NS	ND	ND	ND	ND	ND	ND	ND	0.00028
		Benzene	4.6 µg/L	NI	NI	NI	NI	ND	ND	NS	ND	ND	ND	ND/ND	ND/ND	NS	NS	ND	ND	ND	ND	ND	ND	ND	0.052
		TCE	2.8 µg/L	NI	NI	NI	NI	ND	**19**	NS	ND	0.3	ND	0.18/0.16	ND/ND	NS	NS	0.13	0.14	0.16	ND	ND	ND	ND	ND
Building 149	B-02	GRO	2.2 mg/L	NS	NS	2.48	NS	NS	NS	NS	NS	**14.5**	**6.13**	**7.09/7.30**	**4.95**	NS	NS	**9.2**	**13.0**	**13.0**	**9.2**	**13.0**	**15.0**	**9.5/9.5**	**13/14**
		DRO	1.5 mg/L	25*	ND*	10.50	NS	NS	3.0	NS	NS	**7.41**	**16.5**	**7.25/6.29**	**7.29**	NS	NS	**2.8**	**6.6**	**4.3**	**3.8**	**4.3**	**3.1/3.0**	**8.9/8.6**	**3.8/3.9**
		Total BTEX	mg/L	8.679	5.34	1.148	NS	NS	1.6	NS	NS	2.03461	2.7773	3.264/3.22	4.11	NS	NS	3.35	3.3	3.4	2.9	3.4	3.2/3.4	2.96/2.79	3.9/4.3
		Benzene	4.6 µg/L	**140**	ND	**7.6**	NS	NS	3.7	NS	NS	**4.61**	2.6	**5.18/5.21**	**9.82**	NS	NS	**5.2**	ND	ND	ND	ND	ND	ND	ND
		TCE	2.8 µg/L	**750**	**390**	**56**	NS	NS	**35**	NS	NS	**54.4**	**37.2**	**37.06/39.36**	ND	NS	NS	**28**	**28**	**28**	**20**	**23**	**16/20**	**15/12**	**15/13**
Building 149	MW00-05	GRO	2.2 mg/L	NI	NI	NI	NI	NI	NI	NI	0.46	0.844/0.773	0.209/0.198	0.174	0.537	NS	NS	0.39/0.43	0.88	0.16	0.26	0.35	0.088	0.27	1.2
		DRO	1.5 mg/L	NI	NI	NI	NI	NI	NI	NI	1.9	1.02/0.995	0.677/0.720	0.658	0.633	NS	NS	0.54/0.49	0.53	0.25	0.43	0.64	0.25	0.37	1.1
		BTEX	mg/L	NI	NI	NI	NI	NI	NI	NI	0.0063	0.00431/0.00386	0.00758/0.00275	0.12	ND	NS	NS	ND	ND	ND	ND	ND	ND	ND	0.00244
		Benzene	4.6 µg/L	NI	NI	NI	NI	NI	NI	NI	ND	ND/ND	ND/ND	ND	ND	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND
		TCE	2.8 µg/L	NI	NI	NI	NI	NI	NI	NI	**62**	**18.8/17.2**	**17.8/22.2**	**13.46**	ND	NS	NS	**4.7/5.1**	**4.1**	**7.4**	**6.5**	**7.1**	**6.6**	**6.0**	**3.8**
Building 149	446	GRO	2.2 mg/L	NI	NI	ND	NS	NS	NS	NS	0.15/0.14/0.157	0.0228	ND	ND	0.0123	NS	NS	0.015	0.021	0.006	0.011	ND	0.044	ND	0.028
		DRO	1.5 mg/L	NI	NI	0.206	NS	NS	0.47	NS	0.49/0.44/ND	0.269	0.132	0.558	0.0984	NS	NS	0.11	0.035	0.1	0.1	0.22	0.17	0.13	0.063
		BTEX	mg/L	NI	NI	0.006	NS	NS	ND	NS	ND/ND/ND	ND	ND	ND	0.00057	NS	NS	ND	ND	ND	0.0003	ND	ND	ND	0.00051
		Benzene	4.6 µg/L	NI	NI	ND	NS	NS	ND	NS	ND/ND/ND	ND	ND	ND	ND	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND
		TCE	2.8 µg/L	NI	NI	**16**	NS	NS	**33**	NS	**23/20/16.9**	**12.2**	**13.8**	**12.44**	**8.16**	NS	NS	**7.7**	**4.6**	**4.4**	**5.4**	**4.1**	**6.3**	**5.7**	**3.2**
Building 157 & 159	447	GRO	2.2 mg/L	NI	NI	NS	NS	NS	NS	NS	NS	0.0264	ND	ND	0.0119	NS	NS	ND	0.017	ND	0.017	0.02	0.035	ND	0.04
		DRO	1.5 mg/L	NI	NI	0.672	0.2	NS	0.52	NS	NS	0.206	0.0809	0.173	0.177	NS	NS	0.032	0.040	0.062	0.054	0.110	0.130	0.340	0.2
		BTEX	mg/L	NI	NI	0.009	ND	NS	ND	NS	NS	2.66159	0.00242	ND	0.0030	NS	NS	0.00042	ND	ND	ND	ND	ND	ND	0.002
		Benzene	4.6 µg/L	NI	NI	ND	ND	NS	ND	NS	NS	ND	ND	ND	ND	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND
		TCE	2.8 µg/L	NI	NI	0.8	**7.2**	NS	1.6	NS	NS	**3.8**	**3.25**	**3.49**	**4.12**	NS	NS	**4.4**	**4.9**	**4.3**	**3.9**	**5.8**	**4.4**	**3.1**	**4.3**
Building 157 & 159	629	GRO	2.2 mg/L	NI	NI	NI	NS	NS	NS	NS	**10/9.5/8.03**	**25.9**	**18.9**	**6.48**	0.0789	NS	NS	2.6	0.86	**2.9**	**2.6**	**6.1**	**3.1**	**8.8**	**4.7**
		DRO	1.5 mg/L	NI	NI	NI	1.7	NS	3.1	NS	4.0/4.9/4.83	7.12	3.47	1.93	0.0999	NS	NS	0.40	0.30	0.60	1.10	0.77	0.31	0.58	**2.4**
		BTEX	mg/L	NI	NI	NI	6.20	NS	2.8	NS	4.91/5.52/3.98	11.288	9.148	2.747	0.0256	3.69 /9.06	2.08/7.54	0.95	0.20	0.92	0.88	2.2	0.66	3.0	1.04
		Benzene	4.6 µg/L	NI	NI	NI	**700**	NS	**400**	NS	**370/390/325**	**642**	**449**	**185.4**	3.41	**130/310**	**110/360**	**50.00**	**25**	**40**	**35**	**40**	**15**	**47**	**82**
		TCE	2.8 µg/L	NI	NI	NI	**10**	NS	**19**	NS	**ND/13/10.9**	**6.8**	**8.33**	**7.97**	1.19	**13/4.8**	**6.6/7.8**	**6.2**	**3.1**	**8.4**	**8.8**	**7.7**	**9**	**9.7**	**3**
Building 157 & 159	MW00-04 (AP11 sampled 2014-17 as substitute)	GRO	2.2 mg/L	NI	NI	NI	NI	NI	NI	NI	**30**	**32.3**	**14.9**	2.05	**21.3**	NS	NS	**30**	NS-DAM	NS	NS	1.2	1.7	0.4	**13**
		DRO	1.5 mg/L	NI	NI	NI	NI	NI	NI	NI	8.6	3.94	4.21	0.741	1.28	NS	NS	6.2	NS-DAM	NS	NS	0.33	0.34	0.14	0.6
		BTEX	mg/L	NI	NI	NI	NI	NI	NI	NI	12.08	11.67	6.967	1.127	16.56	NS	NS	12.53	NS-DAM	NS	NS	0.016	0.228	0.0052	4.9
		Benzene	4.6 µg/L	NI	NI	NI	NI	NI	NI	NI	**480**	**260**	**116**	**15.86**	**95**	NS	NS	**25**	NS-DAM	NS	NS	0.63	0.56	ND	1.9
		TCE	2.8 µg/L	NI	NI	NI	NI	NI	NI	NI	ND	ND	ND	ND	ND	NS	NS	ND	NS-DAM	NS	NS	ND	ND	ND	ND
Building 157 & 159	MW00-03	GRO	2.2 mg/L	NI	NI	NI	NI	NI	NI	NI	3.5	1.76	0.421	0.245	0.869	NS	NS	2.0	**8.5**	0.45	0.78	**3.2**	**4.6**	1.3	**4.3**
		DRO	1.5 mg/L	NI	NI	NI	NI	NI	NI	NI	13	1.87	0.457	0.604	0.789	NS	NS	0.43	1.3	0.27	0.48	1.5	0.58	0.39	0.29
		BTEX	mg/L	NI	NI	NI	NI	NI	NI	NI	ND	4.02268	0.02309	0.02797	0.17	NS	NS	0.412	1.32	0.127	0.16	0.664	0.78	0.32	0.76
		Benzene	4.6 µg/L	NI	NI	NI	NI	NI	NI	NI	ND	3.92	0.77	1.31	**7.56**	NS	NS	**11**	**28**	3.4	**5.4**	**19**	**7.2**	2.7	**5.3**
		TCE	2.8 µg/L	NI	NI	NI	NI	NI	NI	NI	ND	0.68	1.16	0.58	0.47	NS	NS	0.19	ND	0.27	ND	ND	ND	ND	ND
		PFOA	0.40 µg/L																					**0.41**	NA
		PFOS	0.4 µg/L																					**0.56**	NA
Downgradient of Bldg 157 & 159 (betwn MW-202 & MW-628)	MW00-02	GRO	2.2 mg/L	NI	NI	NI	NI	NI	NI	NI	ND	0.482	0.252	0.112	0.348	NS	NS	0.33/0.31	0.57/0.54	0.5/0.37	0.17/0.19	0.2/0.18	0.16	0.18	0.33
		DRO	1.5 mg/L	NI	NI	NI	NI	NI	NI	NI	0.96	0.325	0.202	0.464	0.561	NS	NS	0.10/0.14	0.20/0.21	0.16/0.2	0.19/0.18	0.35/0.41	0.22	0.24	0.18
		BTEX	mg/L	NI	NI	NI	NI	NI	NI	NI	ND	0.00034	0.00023	0.00024	0.00058	0.00024/0.00047	0.00025/0.00087	0.00027/0.00023	0.00018/0.0002	0.0002/ND	ND	ND	ND	ND	0.00083
		Benzene	4.6 µg/L	NI	NI	NI	NI	NI	NI	NI	ND	0.34	0.23	0.24	0.58	0.24/0.47	0.25/0.87	0.27/0.23	0.18/0.2	0.2/ND	ND	ND	ND	ND	0.25
		TCE	2.8 µg/L	NI	NI	NI	NI	NI	NI	NI	**25**	**12.8**	**8.68**	**5.21**	**4.05**	**3.4/4.1**	2.7/**4.1**	2.5	2.2/2.4	1.3/1.1	1.1/1.2	1.5	2	ND	1.6
Building 157 & 159	708	GRO	2.2	NI	NI	NI	NS	NS	NS	NS	NS	**30.8/30.3**	**3.54/3.14**	0.103	6.32	NS	NS	**15**	**34**	NS	0.028	0.13/0.034	0.48/0.42	ND	**30**
		DRO	1.5	NI	NI	NI	**2.8**	NS	**4.5**	NS	NS	3.54/3.71	0.428/0.388	0.0796	0.509	NS	NS	0.52	**1.6**	NS	0.024	0.16/0.15	0.067/0.092	0.05	0.95
		BTEX	mg/L	NI	NI	NI	3.29	NS	8.8	NS	NS	13.64/11.52	1.682/1.863	0.01408	3.291	NS	NS	6.32	11.7	NS	0.00274	0.0011/0.0084	0.124/0.106	ND	11.4
		Benzene	4.6 µg/L	NI	NI	NI	**680**	NS	**860**	NS	NS	**527/612**	**103/108**	0.3	**93**	NS	NS	**110**	**180**	NS	0.49	1.1/0.39	1.5/1.3	ND	**52**
		TCE	2.8 µg/L	NI	NI	NI	ND	NS	ND	NS	NS	ND/ND	ND/ND	ND	ND	NS	NS	ND	ND (0.25)	NS	ND	ND	ND	ND	ND

Notes:

ND - not detected above method dete PROD - product in well
NS - not sampled for specified analyte NI - well not yet installed
DRO - diesel-range organics TCE - trichloroethene
GRO - gasoline range organics DAM - Damaged Well
* Result of Total Petroleum Hydrocarbon (TPH) analysis, not DRO analysis
mg/L - milligrams per liter
BTEX - benzene, toluene, ethylbenzene, and xylene
Multiple results have been reported at locations with field duplicates and lab split replicates.

Information Sources
1988 Results are from COE sampling at the Refueler Shop (Thomas, 1988)
1992 Results are from the SAIC RI (SAIC, 1993).
1993 results for B-02, B-06, 446, 447 are from the KSA RI/FS (EMCON, 1995a); Nov 1993 results for 135 are from the KSA LFI (EMCON, 1995b)
May 1994 Results for 628, 629 and 708 are from the KSA RI/FS (EMCON, 1995a); July 1994 Results for B-06, 135 and 447 are from the Final Trip Report for Groundwater Monitoring (EMCON, 1995c)
1996 results are from the Eskimo Creek Dump RI/FS (EMCON, 1996)
Aug 1997 results for 202, 135 and 628 are from the Zone 1 Monitoring Report (Bristol/OASIS, 1999c)
Sept 1997 results for B-02, B-06, 446, 447, 628, 629, and 708 are from the Zone 2 and 4 Intrinsic Remediation Study (Bristol/OASIS, 2000)
In 1997, MW-628 was sampled for both the Zone 2 and the Zone 1 investigation: results are reported as Zone 2/Zone 1
July 1998 results for 135 and 628 are from the Zone 1 Monitoring Report (Bristol/OASIS, 2000)
2000 Results are from the Final Report Groundwater Zone 2 2000 Sampling and Feasibility Study (Paug-Vik/OASIS, 2001)
2004 results are from the Final Report for Long-term Monitoring for Groundwater Zone 2 (OT022 and Eskimo Creek Dump - LF022) (Paug-Vik/OASIS, 2005)
2005 results are from the Final Report for Long-term Monitoring for Groundwater Zone 2 (OT022 and Eskimo Creek Dump - LF022) (Paug-Vik/OASIS, 2007)

Table 3-4: Historical Surface Water Results for Zone 2

Location ID	Analyte	Water Quality Criteria (mg/L)	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
OT28-01	Benzene	0.005	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Ethylbenzene	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Toluene	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0002	ND	ND	ND	ND
	Xylenes	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	TCE	0.005	0.00175	0.00123	ND	ND	0.0027/0.0037	0.0018/0.0030	0.0017	0.00044	0.00094	0.00089	0.0021	0.0014	ND	ND
OT28-02	Benzene	0.005	ND	ND	ND	ND	ND	ND	0.00014	ND	ND	ND	ND	ND	ND	ND
	Ethylbenzene	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Toluene	1	ND	ND	ND	ND	ND	ND	ND	ND	0.00019	ND	ND	ND	ND	ND
	Xylenes	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	TCE	0.005	ND	ND	0.00031	**0.0118**	0.00037	0.00069	0.00072	0.00093	0.00055	0.00017	0.00062	ND	ND	ND
OT28-03	Benzene	0.005	ND	ND	ND	ND	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND
	Ethylbenzene	1	ND	ND	ND	ND	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND
	Toluene	1	ND	ND	ND	ND	NS	NS	ND	0.00034/0.00035	0.00034/0.00035	0.0021/0.0022	0.0004	0.00035	ND	ND
	Xylenes	10	ND	ND	ND	ND	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND
	TCE	0.005	ND	ND	ND	ND	NS	NS	ND/0.00014	0.0025/0.0029	0.0045/0.0041	0.002/0.0017	ND	0.0017	ND	ND

Notes: Results shown in **BOLD** indicate criteria exceedence.

ND - Not detected above method reporting limit.

3.4 ZONE 2 MNA EVALUATION

The COCs for Groundwater Zone 2, petroleum hydrocarbons and TCE, are both biologically degradable, but the biodegradation mechanisms are different. Petroleum hydrocarbons degrade both aerobically and anaerobically, whereas anaerobic conditions are generally considered a prerequisite for significant biodegradation of TCE.

3.4.1 Petroleum Hydrocarbon MNA

Two lines of evidence were evaluated for the Zone 2 A-Aquifer groundwater to determine whether intrinsic bioremediation of petroleum hydrocarbons is occurring: 1) decreasing or stable contaminant concentration trends and plume size and 2) groundwater geochemistry data.

3.4.1.1 2017 DRO/GRO/Benzene Plume Behavior

Table 3-3 presents a summary of historical and current DRO, GRO, BTEX, and TCE results from selected Zone 2 monitoring wells. Figure 3-1 shows DRO/GRO/BTEX results. A statistical analysis of petroleum analyte concentration trends can be found in section 3.4.3.

- In 2011-2012, detectable dissolved GRO encompassing monitoring well B-02 returned to levels last seen in 2004. The GRO concentration in 2013 decreased to 9.2 mg/L which is what it was in 2010. In 2014 and 2015, GRO again increased to 13 mg/L and 15 mg/L respectively. In 2016, GRO had once again decreased to 9.5 mg/L, but increased to 12 mg/L in 2017.
- After a decrease in 2011, GRO monitoring well MW-629 has fluctuated between 2.6-8.8 mg/L.
- Benzene levels at MW-629 have been above cleanup levels since 2008. The 2017 benzene concentration of 82 µg/L is the highest since 2010.
- In 2010 and 2011, monitoring well 708 exceeded the cleanup level for benzene. Benzene was well below the cleanup level of 4.6 µg/L from 2013-2015, and non-detect in 2016. In 2017, benzene was above the cleanup level at 52 µg/L.
- Historically, GRO has been detected above the cleanup level of 2.2 mg/L in the following monitoring wells: MW-629, B-02, and MW-708. MW-629 has shown an almost steady increasing GRO concentration since 2011, with a recent high of 8.8 mg/L in 2016, and decreasing to 4.7 mg/L in 2017. Monitoring well 708 had more than twice the concentration of GRO in 2011 (34 mg/L) compared to 2010. From 2013-2016, the GRO concentration was between 0.028 mg/L to ND. In 2017, GRO results for 708 were 24 mg/L.
- Benzene levels in B-02 were above the 0.0046 mg/L cleanup level between 2004 and 2010. B-02 and MW00-05, located near B-02 were both non-detect for benzene in 2001-2017.

3.4.1.2 Geochemical Parameters

DO levels measured using the low flow sampling protocol in the Zone 2 A-Aquifer monitoring wells ranged from 0.28 mg/L (in 708) to 9.19 mg/L (in 446) (Figure 3-3). The area of depressed DO concentrations includes the area of detectable dissolved hydrocarbons shown in Figure 3-1. The area of depressed DO has decreased from what has been found previously. The overall pattern suggests that biodegradation of petroleum hydrocarbons in Groundwater Zone 2 is occurring.

A parameter closely associated with DO concentrations is redox potential. The Zone 2 redox potentials ranged from -85.5 mV in monitoring well 629 to 211.9 mV in MW00-02. A correlation between reduced redox potentials and petroleum-contaminated areas was observed, especially at B-02, 629, and 708. The redox data somewhat correlates with the DO data (i.e. wells with high DO also have positive redox potential, and vice versa).

Several inorganic analyses were performed to evaluate MNA of petroleum hydrocarbons at Groundwater Zone 2. A summary of Zone 2 A-Aquifer analytical data can be found in Table 3-5.

- Nitrate-nitrite was detected in all the sampled wells at concentrations between 0.013 mg/L (202) and 0.67 mg/L (447). Wells that had nitrate-nitrite concentrations less than 1 mg/L also exhibited detectable dissolved hydrocarbons (Figure 3-1). This pattern suggests that nitrate reduction may be an important biodegradation mechanism for petroleum hydrocarbon contamination in Zone 2.
- Previous sulfate results suggested that sulfate reduction does not appear to be an important biodegradation mechanism for petroleum hydrocarbon contamination in Zone 2. Sampling for sulfate was discontinued in 2015.
- Manganese was detected in ten of the monitoring wells sampled in 2017, at concentrations ranging from 0.013 mg/L to 8.7 mg/L (Figure 3-3). The inferred area where manganese concentrations exceed 1 mg/L is generally similar to the areas of increased hydrocarbon detections (Figure 3-1). This pattern suggests that petroleum hydrocarbons are being naturally attenuated in Zone 2.
- Ferrous iron was detected in nine of the monitoring wells at concentrations between 0.046 and 60 mg/L (Figure 3-3). The inferred area where ferrous iron concentrations exceed 1 mg/L generally correlates with the area of detectable dissolved hydrocarbons. This pattern suggests that petroleum hydrocarbons are being naturally attenuated in Zone 2.
- The absence of methane from previous sampling results indicated that methanogenesis is not a significant biodegration mechanism in Zone 2. Sampling for methane was discontinued in 2015.
- Alkalinity measurements ranged from 38 mg/L at MW-446 to 190 mg/L at MW-629. Generally, elevated petroleum hydrocarbon levels correlated with higher alkalinity concentrations.
- Conductivity ranged between 74 µS/cm and 241 µS/cm. Groundwater temperature ranged between 5.02 (MW-202) and 8.05 (MW00-05) degrees Celsius. Groundwater pH ranged between 6.15 (MW00-02) and 6.94 (MW-628). These groundwater environmental conditions (pH and temperature) are suitable for biodegradation to occur.

Table 3-5: Summary of Zone 2 A-Aquifer Analytical Data

Well Number	GRO (mg/L)	DRO (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Total BTEX (µg/L)	TCE (µg/L)	Choride (mg/L)	Nitrate-Nitrite (mg/L)	Alkalinity (mg/L)	Fe (mg/L)	Mn (mg/L)	DO (mg/L)	ORP (mV)	pH
RAO	**2.2**	**1.5**	**4.6**	**1,100**	**NA**	**0.0028**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
628	0.042/0.032	0.058/0.054	0.033/0.015	0.29/ND	1.48/0.225	**8.3/8.7**	3.3	0.042	95	0.38	1.9	0.34	99.8	6.94
202	0.017	0.11	0.052	ND	0.28	ND	3.2	0.013	110	60	2.8	0.94	-39.9	6.26
B-02	**13/14**	**3.8/3.9**	ND	22/23	3,872/4,253	**15/13**	2.7	0.02	87	11	1.8	0.57	-31.7	6.5
MW00-05	1.2	1.1	ND	ND	2.44	**3.8**	5	0.13	84	0.8	0.34	0.99	199.8	6.42
446	0.028	0.063	ND	ND	0.51	**3.2**	4.1	0.32	38	0.046	ND	9.19	191.1	6.43
447	0.04	0.2	ND	ND	1.99	**4.3**	2.4	0.67	68	ND	0.013	4.47	172.6	6.3
629	**4.7**	**2.4**	**82**	160	1,042	**3**	3.3	0.18	190	6.1	6.1	0.53	-85.5	6.9
MW00-03	**4.3**	0.29	**5.3**	1.8	760	ND	3.3	0.2	100	4.4	3.9	0.31	72.7	6.36
MW00-02	0.33	0.18	0.25	ND	0.83	1.6	2.8	0.042	80	ND	0.81	1.42	211.9	6.15
AP-11	**13**	0.60	1.9	340	4,872	ND	4.2	0.025	90	9.4	3.9	0.8	8.6	6.42
708	**30**	0.95	**52**	**2,800**	11,392	ND	2.8	0.044	130	9.3	8.7	0.28	-79.2	6.70

NA - Not Applicable
ND - Not detected above method reporting level (MRL)
RAO - Remedial Action Objectives
Primary/Duplicate Sample Result (MW00-02 and 708)
BOLD results are above RAO

3.4.2 TCE Reductive Dechlorination at Zone 2

As explained in section 1.15, the dominant TCE intermediate daughter product generated by reductive dechlorination is usually DCE. In 2017, DCE was not detected in any of the monitoring wells in Zone 2. This suggests that either reductive dechlorination is not occurring at this site or that DCE is quickly being degraded to carbon dioxide. This could occur if the redox environment varies throughout the aquifer (reductive dechlorination where the aquifer is reducing and aerobic degradation of DCE where more oxidized), or if the aquifer is just reduced enough to allow reductive dechlorination. In any case, the decreasing trend of TCE concentrations discussed in the next section suggest that TCE is degrading at this site so some reductive dechlorination or some other TCE degradation process must be occurring.

3.4.3 DRO, GRO, Benzene and TCE Concentration Trends

ProUCL software, Version 5.1 was used to assess DRO, GRO, benzene, and TCE concentration trends for eleven monitoring wells. Output from this program can be found in Appendix E.

Table 3-7 and Table 3-8 summarize the concentration trends observed in the monitoring wells. The tables list the numbers of wells exhibiting a specific concentration trend for each analyte. Well location data sets which did not have the minimum number of four observations, or where the results were all below the detection limit for a specific analyte, are not included in the trend summary table. Note that 29% of the concentration trends were decreasing and 5% were increasing. There was no trend for 66%. This analysis supports the conclusion that intrinsic remediation is keeping contaminant concentrations stable or decreasing at this site.

Table 3-6 Zone 2 Mann-Kendall Analysis Summary

Trend	Benzene	DRO	GRO	TCE	% of Total
Decreasing	3	4	0	4	29%
Increasing	0	0	2	0	5%
No Trend	3	7	9	6	66%
Totals	6	11	11	10	38

Table 3-7 Zone 2 Mann-Kendall Trend Summary

Site Area	Well	Benzene	DRO	GRO	TCE
Building 149	B-02	**D**	NT	**I**	**D**
Near Eskimo Creek	MW-628	N/A	NT	**I**	NT
Near Eskimo Creek	MW-202	N/A	NT	NT	NT
Building 149	MW00-05	N/A	**D**	NT	**D**
Building 149	MW-446	N/A	**D**	NT	**D**
Building 157 and 159	AP-11	NT	NT	NT	NT
Building 157 and 159	MW-447	N/A	NT	NT	NT
Building 157 and 159	MW-629	**D**	NT	NT	NT
Building 157 and 159	MW-708	**D**	**D**	NT	N/A
Downgradient of Building 157 and 159	MW00-03	NT	**D**	NT	NT
Downgradient of Building 157 and 159	MW00-02	NT	NT	NT	**D**

D- Decreasing
NT – No Trend
I - Increasing
N/A – Not applicable due to insufficient data or no detectable concentrations

3.5 ZONE 2 CONCLUSIONS

3.5.1 Petroleum Hydrocarbons

Five of the eleven Zone 2 monitoring well samples exceeded the ADEC cleanup level of 2.2 mg/L for GRO and three wells exceeded the cleanup level of 0.0046 mg/L for benzene. Monitoring data from 1997 through 2017 suggest the presence of a stable or decreasing benzene plume near and downgradient of Buildings 157/159.

The lines of evidence indicating that intrinsic bioremediation is occurring in Groundwater Zone 2 fuel hydrocarbon plumes include stable or decreasing contaminant concentrations over time, decreasing plume sizes, and changes in the groundwater geochemistry within the petroleum hydrocarbon impacted areas.

There were no BTEX constituents detected in the surface water samples.

3.5.2 TCE

There were six monitoring wells with TCE detections above the cleanup level of 2.8 µg/L. Detected TCE concentrations have declined or remained relatively stable since 2007.

TCE was not detected in any of the surface water samples. Naphthalene was detected in OT28-01 (1.3 µg/L) and in OT28-02 (40 µg/L). Chloroform was also detected in OT28-01 (0.42/0.33 µg/L).

Intrinsic remediation of the Groundwater Zone 2 TCE plume is suggested by the declining and stable TCE concentration trends. Potential mechanisms for the intrinsic remediation include the non-biological processes of dilution, dispersion, volatilization, or sorption and the biological processes of reductive dechlorination or cometabolic biodegradation.

The absence of daughter products (primarily DCE) in samples from the Zone 2 monitoring wells suggest that biologically-mediated reductive dechlorination is not a significant attenuation process, the intrinsic remediation may be resulting primarily from non-biological processes, or TCE may be reductively dechlorinating to DCE which is then rapidly oxidized to carbon dioxide. Cometabolic biodegradation of TCE would also be consistent with the absence of daughter products.

3.5.3 Institutional Control Inspection

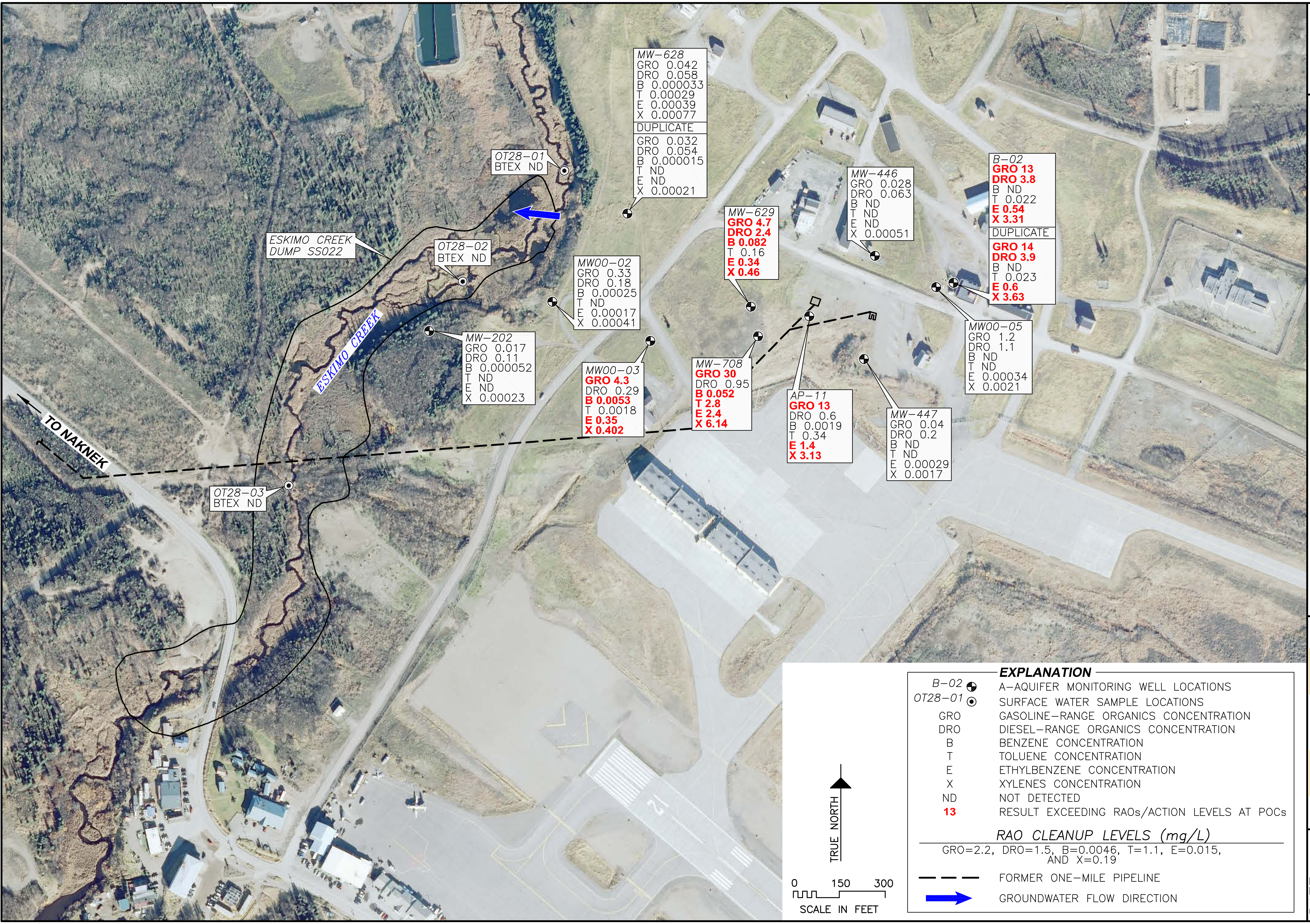
There were no observations of IC noncompliance in Zone 2.

3.5.4 Condition of Wells

All wells scheduled for sampling in Zone 2 were sampled and in good condition.

3.6 ZONE 2 RECOMMENDATIONS

- The use of the “10X Rule” used to develop cleanup levels listed in the Final Zone 2 ROD is no longer used by ADEC. The cleanup levels in the ROD should be addressed in the next 5 Year Review, to reflect current regulatory cleanup levels.
- Any recommendations are subject to change pending conversations between ADEC and AFCEC, and any comment resolution outcomes on ADEC’s comments for the Five-Year Review.



EXPLANATION

B-02 ⊕	A-AQUIFER MONITORING WELL LOCATIONS
OT28-01 ⊙	SURFACE WATER SAMPLE LOCATIONS
GRO	GASOLINE-RANGE ORGANICS CONCENTRATION
DRO	DIESEL-RANGE ORGANICS CONCENTRATION
B	BENZENE CONCENTRATION
T	TOLUENE CONCENTRATION
E	ETHYLBENZENE CONCENTRATION
X	XYLENES CONCENTRATION
ND	NOT DETECTED
13	RESULT EXCEEDING RAOs/ACTION LEVELS AT POCs

RAO CLEANUP LEVELS (mg/L)

GRO=2.2, DRO=1.5, B=0.0046, T=1.1, E=0.015, AND X=0.19

— — —	FORMER ONE-MILE PIPELINE
➡	GROUNDWATER FLOW DIRECTION

FIGURE
3-1

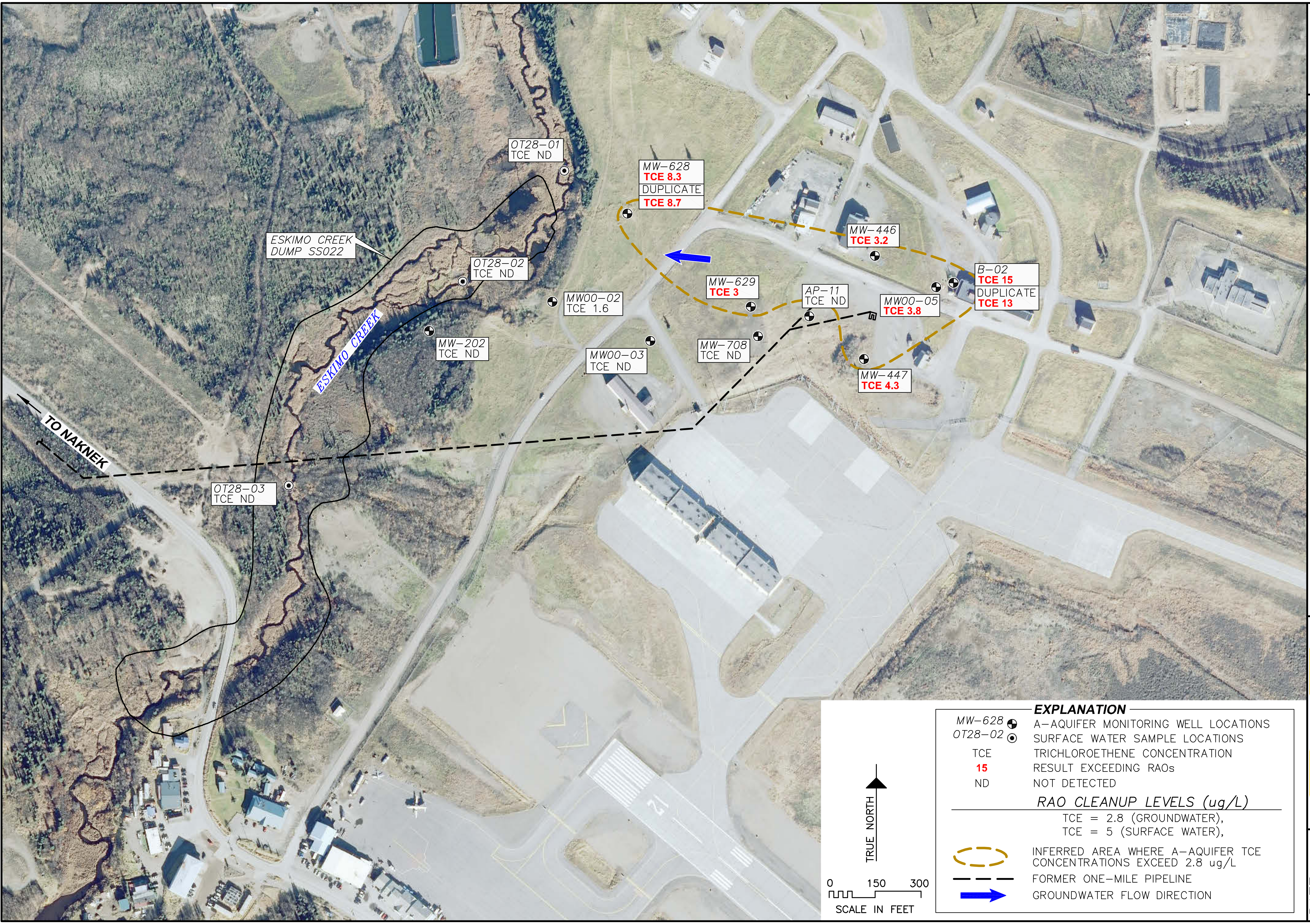
GROUNDWATER GRO, DRO, AND BTEX ANALYTICAL RESULTS GROUNDWATER ZONE 2

GROUNDWATER ZONE 2 (OT-028)
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE
SEPT. 2018
CHKD
H.L.H.
DRAWN
C.E.H.
PROJ. NO
17040

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18-KS-LTM-RPT-F3-1.DWG PLOT: 9/14/18.



EXPLANATION

MW–628 ⊕	A–AQUIFER MONITORING WELL LOCATIONS
OT28–02 ⊙	SURFACE WATER SAMPLE LOCATIONS
TCE	TRICHLOROETHENE CONCENTRATION
15	RESULT EXCEEDING RAOs
ND	NOT DETECTED

RAO CLEANUP LEVELS (ug/L)

TCE = 2.8 (GROUNDWATER),
TCE = 5 (SURFACE WATER),

⬭	INFERRED AREA WHERE A–AQUIFER TCE CONCENTRATIONS EXCEED 2.8 ug/L
– – –	FORMER ONE–MILE PIPELINE
➡	GROUNDWATER FLOW DIRECTION

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18–KS–LTM–RPT–F3–2.DWG PLOT: 5/17/18.

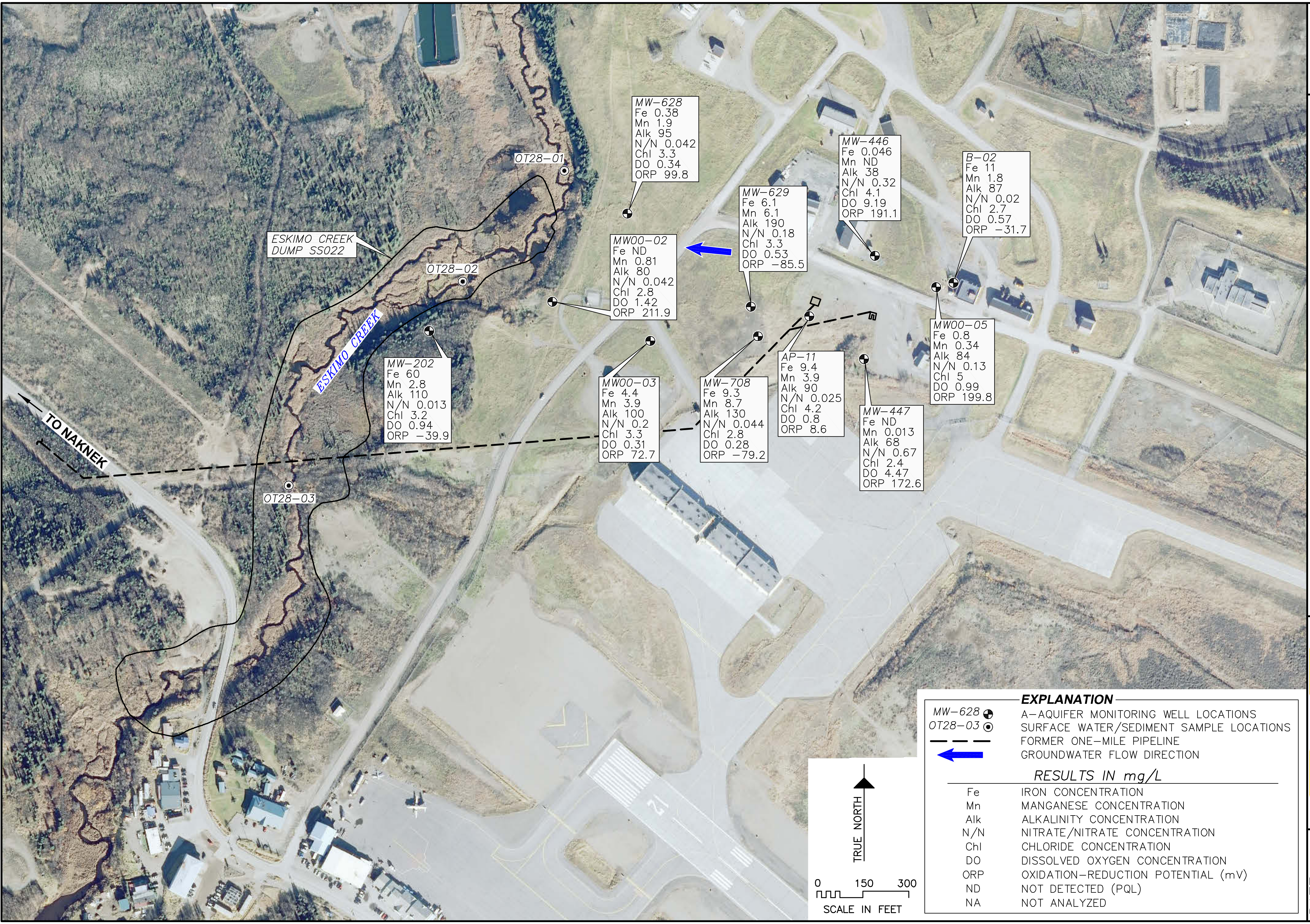
FIGURE
3-2

GROUNDWATER AND SURFACE WATER TCE ANALYTICAL RESULTS GROUNDWATER ZONE 2

GROUNDWATER ZONE 2 (OT–028)
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE
MAY 2018
CHKD
H.L.H.
DRAWN
C.E.H.
PROJ. NO
17040



PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18-KS-LTM-RPT-F3-3.DWG PLOT: 1/18/18.

FIGURE
3-3

MONITORED NATURAL ATTENUATION RESULTS GROUNDWATER ZONE 2

GROUNDWATER ZONE 2 (OT-028)
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE	CHKD	DRAWN	PROJ. NO
JAN. 2018	H.L.H.	C.E.H.	17040

4 ZONE 3 – NORTH & SOUTH BLUFFS

The North Bluff (LF005) and South Bluff (LF014) sites (Groundwater Zone 3 – OT029) are former drum disposal sites at KSD. In accordance with the ERP, the 611 CES has implemented a Post-Closure Monitoring Plan (PCMP) for these sites. The primary PCMP objectives are to evaluate the effectiveness of closure actions at the Bluff sites, provide compliance with the requirements of the *Record of Decision for Final Remedial Action North Bluff (LF005) and South Bluff (LF014) Groundwater Zone 3 (OT029*) (Paug-Vik/OASIS, 2000b), and provide an early warning system for detecting contaminant releases from the North and South Bluff landfill sites.

This report addresses post-closure activities that include North and South Bluffs' landfill inspections and inspection, maintenance, and sampling activities for the South Bluff Treatment System (SBTS).

The revised protocol for Zone 3, North and South Bluff recommends groundwater and surface water sampling for all locations at a minimum of every 5 years. Comprehensive sampling was conducted in 2014.

Annual sampling at South Bluff well points SWP-9, -10, and -11, and four surface water locations (SS-8, -9, -10, -11) situated below the SBTS was conducted between 2008 through 2012. No contaminants exceeded the ADEC cleanup criteria. According to the *Explanation of Significant Differences for North & South Bluff, Groundwater Zone 3, King Salmon Air Station, Alaska (USAF, 2005),* if three consecutive sampling rounds show that the contaminant concentrations are below the ADEC cleanup standards, then sampling frequency should be reduced to once every three years. However, they were included in the 2014 and 2015 sampling events, and again in 2016.

The inspection and maintenance program of the Bluffs is performed in accordance with the Final Operation, Monitoring, and Maintenance Manual, North and South Barrel Bluffs (Hart Crowser, 2000), except as specified in the 2017 work plan. In 2005, the EPA, ADEC, and the Air Force agreed to modify the inspection and monitoring frequency to quarterly instead of monthly and to reconfigure the SBTS to bypass the treatment system and discharge water directly to the leach field. Based on past monitoring results, recommendations from the 2013 Comprehensive Monitoring Report (Paug-Vik, 2014c), and Explanation of Significant Difference, sampling was not conducted at the South Bluff Treatment System in 2014. Sampling at the South Bluff Treatment System was resumed in 2015.

Details of the history of this site can be found in the North and South Bluffs Final Monitoring Report (PDC, 2006). The most recent results for the Bluffs can be found in Final 2014 Long Term Monitoring Report (Paug-Vik, 2015c) and Final 2015 Long Term Monitoring Report (Paug-Vik, 2016) for the South Bluff only.

The Air Force has contracted through the Corps of Engineers to complete an Explanation of Significant Difference for Zone 3.

4.1 REMEDIAL ACTION OBJECTIVES FOR SOUTH BLUFF

The RAOs for the Bluffs are set "to restore groundwater to drinking water quality standards, restore surface water to water quality standards, protect human and ecological receptors from unacceptable exposure to contaminated water..." A table of chemical-specific RAOs is not provided in the ROD.

In the *Statistical Analysis of Sampling Events, Revision of Post-Closure Monitoring Plan* (Bristol/OASIS, 1999b), COPCs were defined as all compounds detected above either regulatory criteria or ecological (non-regulatory) screening criteria. Compounds for which no screening criteria were available were also retained as COPCs. The COPCs are listed as Tables 1 and 2 in the ROD (provided on the attached DVD). Cleanup criteria were defined as either primary or secondary criteria. Primary criteria are regulatory criteria, and secondary criteria are non-regulatory screening criteria. Secondary criteria were only employed if primary criteria were not available for a specific analyte.

The primary criteria for evaluating analyte concentrations are ADEC 18 AAC 75 for groundwater (amended through October 2017. Human-health and ecological screening criteria are also used to evaluate analytical results and are presented in Table 4-1. If an analyte is not included on the ADEC standards, then the most conservative (e.g., lowest value) U.S. Environmental Protection Agency (USEPA) current Regional Screening Level (for humans based on ADEC screening requirements of a Hazard Quotient (HQ) = 0.1 and cancer risk 1 × 10-6).

Table 4-1. Groundwater Quality Criteria

Analyte	Primary Criteria*	Screening Criteria*
	ADEC 18 AAC 75 Table C Groundwater Cleanup Levels[A] mg/L	EPA Regional Screening Levels[B] Tap Water mg/L
Bulk Hydrocarbons		
Diesel Range Organics	1.5	--
Metals		
Arsenic	0.00052	0.000052
Barium	3.8	0.38
Cadmium	0.0092	0.00092
Chromium (VI)	0.00035	0.000035
Iron	--	1.4
Lead	0.015	0.015
VOCs		
1,2-Dichloroethane	0.0017	0.00017
Methylene Chloride	0.11	0.011
Toluene	1.1	0.11
Trichloroethene	0.0028	0.00028
PAHs		
Benzo(a)anthracene	0.00012	0.000030
Benzo(a)pyrene	0.000034	0.000025
Benzo(b)fluoranthene	0.00034	0.00025
Benzo(g,h,i)perylene	0.00026	--
Benzo(k)fluoranthene	0.00080	0.0025
Chrysene	0.0020	0.025
Dibenzo(a,h)anthracene	0.000034	0.000025
Indeno(1,2,3-cd)pyrene	0.00019	0.00025
Pyrene	0.12	0.012
Pesticides		
Endrin	0.0023	0.00023
Endrin Aldehyde	--	--
Methoxychlor	0.037	0.0037
Other		
Nitrogen, Nitrate-Nitrite	10	NO_3 = 3.2, NO_2 = 0.20

NOTES:

A = ADEC 18 AAC 75 Table C Groundwater Cleanup Levels (as amended through November 6, 2016), except for nitrate-nitrite which are ADEC 18 AAC 80 Drinking Water MCLs (as amended through May 20, 2011).

B = USEPA Regional Screening Levels for Chemical Contaminants at Superfund Sites (TR=1E-06 ,THQ=0.1)(June 2017).

* Remedial Action Objectives are from the ROD. See text for further explanation.

-- No criteria exist for the analyte specified

mg/L = milligrams per liter or parts per million

4.2 PROJECT TASKS

4.2.1 South Bluff Treatment System Sampling Program and Inspection

An annual inspection was done at the SBTS and Lift Station on September 15, 2017. Inspections activities are summarized on the Inspection Form in Appendix B.

One quarterly influent sample was collected from the lift station on September 28, 2017, and a second sample was collected March 16, 2018. Two more sampling events are scheduled and those results will be discussed in separate letter reports. Table 4-4 includes a complete list of analytical methods.

4.2.2 Annual Inspection

Slopes, vegetation, erosion-control features, culverts, downdrains, toe roads, and access roads at the North and South Bluffs are inspected on an annual basis. The last inspection occurred on September 15, 2017.

- There were no observations of rill or channel erosion or sliding of the cap and/or underlying materials.
- All the downdrains and culverts were inspected. The wetland sides of many of the North Bluff culverts are being overgrown by grass. Three culverts required work to remove root mats to allow drainage.
- Gabions were placed along King Salmon Creek at the South Bluff site to provide stability and erosion protection to the stream bank. Approximately six gabions are out of alignment, and the stream bank beneath the gabions has been undercut due to high water levels in King Salmon Creek. A gabion near the lift station appears to have slid further toward King Salmon Creek, but it is not yet in the creek.
- Toe roads and access roads were designed to provide vehicle access to both the North Bluff and South Bluff for maintenance purposes. Vegetation (mainly alder) along toe and access roads needs to be trimmed to improve visibility and access, and to prevent vegetation growth in the roadbed. Alder is beginning to grow on the South Bluff road. Some was trimmed to allow access by truck. Most of the North Bluff roads are now impassable by truck and difficult to walk in a few sections due to overgrown alder.
- The heat terrace control box for downdrain 2 was destroyed. A few control box posts at culverts are becoming jacked out of the ground and leaning.

4.2.3 Institutional Control Inspection

The goals of ICs are to restrict site access, prevent the installation of drinking-water wells, and minimize direct exposure to subsurface debris. Specifically, excavation into or construction within 50 feet of the landfill boundaries will be restricted and the installation of drinking water wells will be prohibited within 100 feet of the landfill boundary.

A visual inspection was performed to verify that no water wells have been installed or that no soil excavation has been conducted within the specified boundaries.

The barrier fence and snow fence were inspected for unauthorized access to the North and South Bluffs. While the barrier fence is adequate in preventing access, the snow fence needs repairs most years. Approximately 100 feet of snow fencing is down at the North Bluff, and 50 feet of the fencing has been destroyed by ATV accessing the area.

4.2.4 Work Plan Deviations

There were no deviations from the work plan.

Table 4-2: South Bluff Treatment System Sample Analyses Summary

						Analytical Methods						
Month/Year	Sample Point	Comment	8260C VOC	8260C SIM VOC	8011 EDB & 1,2,3 TCP AK2016	GRO Method AK 101	DRO Method AK 102	PAHs + 1&2-Methylnaphthalene 8011	Pesticides Standard List 8081A	PCBs Standard List 8082	6020A Low Levels: As, Ba, Cd, Cr, Pb, Fe	Sample Number
September 2017	Influent	Primary Sample	1	1	1	1	1	1	1	1	1	17KSSBTS0917IN
March 2018	Influent	Primary Sample	1	1	1	1	1	1	1	1	1	17KSSBTSINF-0316
June 2018	Influent	Primary Sample	1	1	1	1	1	1	1	1	1	17KSSBTSINF-0606
July 2018	Influent	Primary Sample	1	1	1	1	1	1	1	1	1	17KSSBTSINF-0731
-	-	Trip Blank	4	4	4	4						17KSSBTS-TBMMDD
WATER ANALYSES TOTALS			**8**	**8**	**8**	**8**	**4**	**4**	**4**	**4**	**4**	

Metals: As, Ba, Cd, Cr, Pb, Fe Low Level

4.3 ZONE 3 FINDINGS

The complete analytical results of the SBTS sampling are presented in Appendix C, Zone 3 Tables. Laboratory analytical reports can be found on the attached DVD-R. Sampling results are summarized below.

4.3.1 South Bluff Treatment System

Quarterly samples were collected from the South Bluff Treatment System lift station. The samples were submitted to Test America in Sacramento for analyses by methods listed in Table 4-4.

Tables 4-7 and 4-8 present a summary of the September 2017 and March 2018 quarterly SBTS sampling results. Chromium was detected above the effluent limitation of 0.35 µg/L in September 2017. All results for the March 2018 sample were below the effluent limitations.

A comprehensive list of all analytical results is included in Appendix C, Table C-31.

Table 4-3
Laboratory Analytical Results for September 2017
South Bluff Treatment System, King Salmon Alaska

Sample Identification				
Analytical Parameters	EPA Method	Units	Effluent Limitation (Note 1)	Influent Sample 17KSSBTS0917IN
VOCs	8260B	ug/L	14,000 2.8	Acetone - 2.3 TCE - 0.11
GRO	AK 101	mg/L	2.2	ND
DRO	AK 102	mg/L	1.5	0.040
PAH	8270 SIM	mg/L		ND
Metals	6020A	ug/L	0.52 3,800 9.2 0.35 300 (Note 2) 15	Arsenic - 0.41 Barium - 3.1 Cadmium - ND Chromium - **0.53** Iron - ND Lead - ND
PCBs/Pesticides	8081/8082	ug/L	Varies	ND

Sampling was performed September 28, 2017

Legend:
VOC's - Volatile Organic Compounds
GRO - Gasoline Range Organics
DRO - Diesel Range Organics
PAH - Polynuclear Aromatic Hydrocarbons
PCBs - Polychlorinated Biphenyls
TCE - Trichloroethene
ND - None Detected
mg/L - milligrams per liter
ug/L - micrograms per liter

Notes:
1. Effluent limitations are based on Table C, Groundwater Cleanup Levels, 18 AAC 75
2. Effluent limitations for iron based on secondary MCL, 18 AAC 80.

Table 4-4
Laboratory Analytical Results for March 2018
South Bluff Treatment System, King Salmon Alaska

Sample Identification			Effluent Limitation (Note 1)	Influent Sample 18KSSBTSINF-0316
Analytical Parameters	EPA Method	Units		
VOCs	8260B	ug/L	5 2.8	Benzene - 0.017 TCE - 0.098
GRO	AK 101	mg/L	2.2	ND
DRO	AK 102	mg/L	1.5	ND
PAH	8270 SIM	mg/L		ND
Metals	6020A	ug/L	0.52 3,800 9.2 0.35 300 (Note 2) 15	Arsenic - 0.52 Barium - 3.7 Cadmium - ND Chromium - 0.2 Iron - 0.037 Lead - ND
PCBs/Pesticides	8081/8082	ug/L	Varies	ND

Sampling was performed March 16, 2018.

Legend:
VOC's - Volatile Organic Compounds
GRO - Gasoline Range Organics
DRO - Diesel Range Organics
PAH - Polynuclear Aromatic Hydrocarbons
PCBs - Polychlorinated Biphenyls
TCE - Trichloroethene
ND - None Detected
mg/L - milligrams per liter
ug/L - micrograms per liter

Notes:
1. Effluent limitations are based on Table C, Groundwater Cleanup Levels, 18 AAC 75
2. Effluent limitations for iron based on secondary MCL, 18 AAC 80.

4.4 ZONE 3 CONCLUSIONS

Low levels, below effluent limitations, of DRO, acetone, and TCE were detected in the SBTS September 2017 sample collected at the lift station. Chromium was also detected at a level above the effluent limitation.

Low levels of TCE and benzene were detected in the March 2018 SBTS sample.

There were no observations of drinking water wells or excavations out of compliance with institutional controls listed in the ROD.

4.5 ZONE 3 RECOMMENDATIONS

- Sampling at the North and South Bluffs should be reduced to once every five years in coordination with the Five Year Review. The next complete sampling event for the North and South Bluffs should be planned for 2019.

- Recent high water levels in King Salmon Creek have caused bank erosion below approximately eight gabions pulling them out of alignment and towards the creek. This section of gabions should be monitored for any erosion. The location is several hundred feet downstream from the South Bluff lift station.

- Overgrown alder should be cleared from the access roads at the North and South Bluffs.

- The Air Force should discuss security options at the North Bluff site with ADEC and the public at the next RAB meeting.

- Any recommendations are subject to change pending conversations between ADEC and AFCEC, and any comment resolution outcomes on ADEC’s comments for the Five-Year Review.

EXPLANATION

C−2	CULVERT LOCATION AND NUMBER
DD−2	DOWNDRAIN LOCATION AND NUMBER

NOTE: SOURCE OF CULVERT AND DOWNDRAIN LOCATIONS TAKEN FROM FINAL OPERATION, MONITORING, AND MAINTENANCE MANUAL, NORTH AND SOUTH BLUFFS, HART CROWSER, 2000.

FIGURE
4-1

NORTH BLUFF
CULVERT AND DOWNDRAIN LOCATIONS

GROUNDWATER ZONE 3 (OT-029)
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE
JAN. 2018
CHKD
H.L.H.
DRAWN
C.E.H.
PROJ. NO
17040

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18−KS−LTM−RPT−F4−1.DWG PLOT: 1/10/18.

EXPLANATION

C−2	CULVERT LOCATION AND NUMBER
DD−2	DOWNDRAIN LOCATION AND NUMBER

NOTE: SOURCE OF CULVERT AND DOWNDRAIN LOCATIONS TAKEN FROM FINAL OPERATION, MONITORING, AND MAINTENANCE MANUAL, NORTH AND SOUTH BLUFFS, HART CROWSER, 2000.

FIGURE **4-2**

SOUTH BLUFF CULVERT AND DOWNDRAIN LOCATIONS

GROUNDWATER ZONE 3 (OT−029)
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE JAN. 2018
CHKD H.L.H.
DRAWN C.E.H.
PROJ. NO 17040

PATH: D:\18_Dwgs\18_PV\17040_KS_LTM_RPT FILE: 18−KS−LTM−RPT−F4−2.DWG PLOT: 1/10/18.

5 ZONE 4 – NAKNEK RIVER STORAGE

Long-term monitoring at Zone 4 is performed in accordance with the *Record of Decision for Final Remedial Action at Naknek River Storage Site, Landfill No. 5, and Zone 4 Groundwater* (USAF, 1999). The purpose of this long-term monitoring program is to ensure that the selected remedies presented in the ROD are implemented properly and are effective.

5.1 DESCRIPTION OF CURRENT STUDY

The primary objective of this project is to determine the status of the groundwater contaminant plumes and to ensure that intrinsic remediation is addressing the groundwater, surface water, sediment, and soil contamination. B-Aquifer sampling was also performed in Groundwater Zone 4 to determine if this drinking water aquifer has suffered any negative impacts.

Petroleum hydrocarbon and VOC concentrations are monitored to evaluate the groundwater, surface water, and sediment contaminant plumes for possible trends and changes in the size of the contaminant plumes. The loss of contaminant plume mass may also be used as evidence for intrinsic remediation by biodegradation. Additionally, groundwater geochemical data are collected as a second line of evidence in the evaluation of intrinsic remediation by biodegradation.

Additional project objectives included the completion of annual landfill inspection for visual monitoring of Landfill No. 5 and maintenance of the product recovery system.

5.2 REMEDIAL ACTION OBJECTIVES FOR ZONE 4

Groundwater Zone 4 cleanup levels were developed in accordance with the ADEC contaminated site regulations found in 18 AAC 75. Direct application of the ADEC Table C cleanup levels was used for all groundwater cleanup levels. The B-Aquifer groundwater is assessed using the Alaska Drinking Water Standards (18 AAC 80). Groundwater and surface water cleanup levels for contaminants specified in the ROD are presented in Table 5-1.

Because sediment cleanup levels are not provided in the AWQS (18 AAC 70), ORNL sediment quality benchmarks, EPA (OSWER) Sediment Screening Benchmarks, and NOAA SQuiRTs Sediment Screening Values were used to provide screening levels for analytical results. The ORNL sediment quality benchmarks were taken from *Toxicological Benchmarks for Screening for Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1997 Revision*. Please note that these screening values are not meant to represent cleanup levels, but instead provide guidance for data quality objectives and provide a basis on which to evaluate the analytical results. Sediment sampling began after the ROD was signed, and thus no sediment COCs are specified by the ROD. The compounds listed in Table 5-2 were chosen for their common appearance at fuel spill sites and knowledge of site activities.

Table 5-1 Remedial Action Objectives (RAOs) for Zone 4

		Screening Concentrations					
Media	Contaminants of Concern	Ecological Risk-Based RG	Human Health Risk-Based RG[a]	ARARs RG	ARARs Basis	Cleanup Levels from Final ROD	Current ADEC Cleanup Levels
A-Aquifer and	Benzene	NC	NC	0.005	ADWS	0.005	0.0046
B-Aquifer	Toluene	NC	NC	1.0	ADWS	1.0	1.1
Groundwater	TCE	NC	NC	0.005	ADWS	0.005	0.0028
(mg/L)	GRO	NC	NC	1.3	18 AAC 75	1.3[d]	2.2
	DRO	NC	NC	1.5	18 AAC 75	1.5[d]	1.5
Free Product				No Free Product	18 AAC 75		No Free Product
Surface Water	TAH (BTEX)[b]	NC	NC	0.01	AWQS	0.01	
(mg/L)	TAqH (BTEX+PAH)[c]	NC	NC	0.015	AWQS	0.015	
	DRO	NC	NC	NONE	N/A	N/A	

[a] Concentrations based on 10^{-5} risk

[b] TAH are defined as the sum of BTEX compounds

[c] TAqH are defined as the sum of TAH plus PAHs, as detected by EPA Method 610. The list of PAHs includes: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,I)perylene.

[d] Basis for the GRO and DRO cleanup levels is ADEC Table C.

Definitions:

ADWS - Alaska Drinking Water Standards (18 AAC 80)
TCE – Trichloroethene
DRO - Diesel-range organics
TAqH - Total aqueous hydrocarbons (BTEX + PAH)
PAH - Polynuclear aromatic hydrocarbons
AWQS - Alaska Water Quality Criteria (18 AAC 70)
RG - Remediation goal
FP – Free product indicated
TAH - Total aromatic hydrocarbons (BTEX)
BTEX - Sum of benzene, toluene, ethylbenzene, and xylene isomers
NC - Not calculated. Either not a primary risk contributing chemical for this pathway or the chemical was not detected

Table 5-2 Sediment Benchmark Screening Levels for Groundwater Zone 4

		Screening Criteria	
Media	Contaminants of Concern	Ecological Risk-Based RG	Basis
	Benzene	0.057	OSWER
	Toluene	0.050	ORNL
	Ethylbenzene	0.004*	NOAA
Sediment	Xylene	0.025	OSWER
(mg/Kg)	TCE	0.041*	NOAA
	Benzo(a)anthracene	0.01572	NOAA
	Benzo(a)pyrene	0.0324	NOAA
	Benzo(b)fluoranthene	NA	
	Benzo(k)fluoranthene	0.0272	NOAA
	Indeno(1,2,3-cd)pyrene	0.01732	NOAA
	Naphthalene	0.01465	NOAA

The list of PAHs includes: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,I)perylene.

Also note: DRO detections in surface water and sediments are not addressed in this table, because there are no cleanup levels applicable for bulk hydrocarbons in surface water or sediments.

*Apparent Effects Threshold level for exposure in marine environments. Freshwater values are not available.

Definitions:

OSWER – EPA OSWER Sediment Screening Benchmark
NOAA – NOAA SQuiRT Sediment Screening Value
ORNL – Oak Ridge National Laboratory Toxicological Benchmarks for screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota

5.3 PROJECT TASKS

5.3.1 Zone 4 Groundwater Sampling

Groundwater samples were collected from three A-Aquifer monitoring wells and two B-Aquifer monitoring wells (Figure 5-1) in September 2017. A list of the sample identification numbers and analytical parameters for each A-Aquifer sample location is provided in Table 5-3. A list of sample identification numbers and analytical parameters for each B-Aquifer sample is provided in Table 5-4. Data collected from each monitoring well, including field measurement information, were documented on the Groundwater Sample Data Sheets, which are provided in Appendix A.

5.3.2 Residential Well Sample Collection

Three residential well samples were collected from the kitchen faucet (King) or outdoor hose bib (Bowers, and King Apartments). Data collected from each residential well were documented on Groundwater Sample Data Sheets (Appendix A). A list of the sample identification numbers and analytical parameters for each residential well sample is shown in Table 5-4.

5.3.3 Surface Water/Sediment Sample Collection

Surface water/sediment sample pairs were collected from three locations in Groundwater Zone 4 as shown on Zone 4 Figure 5-3. Table 5-5 includes a complete list of surface water/sediment pair locations and analytical methods. Data collected at each sample location were documented on Surface Water and Sediment Data Sheets, which are provided in Appendix A.

Table 5-3: Zone 4, A-Aquifer Sample Analyses Summary

				Analytical Methods										
Location ID Sample Point	Comment	Matrix	Location Type	8260C VOCs	8260C SIM VOCs	8011 EDB & 1,2,3 TCP AK2016	Alaska Method AK 101 GRO	Alaska Method AK 102 & 103 DRO	SM 2320B Alkalinity	300.0 Chloride & Sulfate	353.2 Nitrate + Nitrite	6010B Fe and Mn (dissolved)	RSK-175 Methane	Sample Number
MW-57	Product	Groundwater	Monitoring Well	-	-	-	-	-	-	-	-	-	-	PRODUCT - Not Sampled
MW-51	MS/MSD	Groundwater	Monitoring Well	3	3	3	3	3	3	3	3	3	3	17KS4ZMW51-110WG
502		Groundwater	Well Point	1	1	1	1	1	1	1	1	1	1	17KS4ZWP502-112WG
MW-62		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	1	17KS4ZMW62-113WG
Duplicate Sample	MW-62	Groundwater	Well Point	1	1	1	1	1	1	1	1	1	1	17KS4ZWP801-114WG
Project Trip Blanks		Water	QA/QC	2	2	2	2	-	-	-	-	-	-	17KS4ZTB-MMDD
WATER ANALYSES TOTALS				**8**	**8**	**8**	**8**	**6**	**6**	**6**	**6**	**6**	**6**	

Table 5-4: Zone 4, B-Aquifer and Residential Well Sample Analyses Summary

Location ID Sample Point	Comments	Matrix	Location Type	EPA Method 524.2 VOCs	Alaska Method AK 101 GRO	Alaska Method AK 102&103 DRO	Sample Number
B-Aquifer Sample Locations							
506	MS/MSD	Groundwater	B-Aquifer	3	3	3	17KS4Z506-101WG
MW97-9		Groundwater	B-Aquifer	1	1	1	17KS4ZMW979-102WG
MW97-9(D)	Duplicate	Groundwater	B-Aquifer	1	1	1	17KS4ZFARLEY-103WG
Residential Wells							
SMITH		Groundwater	Residential Well	1	1	1	17KS4ZSMITH-104WG
KING		Groundwater	Residential Well	1	1	1	17KS4ZKING-105WG
BOWERS		Groundwater	Residential Well	1	1	1	17KS4ZBOWERS-106WG
KING APARTMENTS		Groundwater	Residential Well	1	1	1	17KS4ZKINGAPTS-107WG
MARSH		Groundwater	Residential Well	1	1	1	17KS4ZMARSH-108WG
Trip Blank		Water	QA/QC	2	2		17KS4ZTB-MMDD
Water Analyses Totals				**12**	**12**	**10**	

Table 5-5: Zone 4, Surface Water/Sediment Sample Analysis Summary

Location ID Sample Point	Comments	Matrix	Location Type	8260C VOCs	8260C SIM VOCs	8011 EDB & 1,2,3 TCP AK2016	Alaska Method AK 101 GRO	Alaska Method AK 102&103 DRO	8270D SIM/DoD PAHs + 1 & 2-Methylnaphthalene	Sample Number
OT30-01	MS/MSD	Surface Water	Surface Water	3	3	3	3	3	3	17KS4ZOT301-101WS
OT30-03		Surface Water	Surface Water	1	1	1	1	1	1	17KS4ZOT303-102WS
OT30-04		Surface Water	Surface Water	1	1	1	1	1	1	17KS4ZOT304-103WS
OT30-05 (D)	OT30-01	Surface Water	Surface Water	1	1	1	1	1	1	17KS4ZOT305-104WS
Trip Blank		Water	QA/QC	1	1	1	1			17KS4ZTB-MMDD
Surface Water Sample Totals				**7**	**7**	**7**	**7**	**6**	**6**	
Location ID Sample Point	Comments	Matrix	Location Type	8260C VOCs & LL	8260C SIM VOCs & LL	8011 EDB & 1,2,3 TCP AK2016 & LL	Alaska Method AK 101 GRO	Alaska Method AK 102&103 DRO	8270C SIM/DoD PAHs + 1 & 2-Methylnaphthalene	Sample Number
OT30-01	MS/MSD	Sediment	Sediment	6	6	6	3	3	3	17KS4ZOT301-201SE
OT30-03		Sediment	Sediment	2	2	2	1	1	1	17KS4ZOT303-202SE
OT30-04		Sediment	Sediment	2	2	2	1	1	1	17KS4ZOT304-203SE
OT30-05 (D)	OT30-01	Sediment	Sediment	2	2	2	1	1	1	17KS4ZOT305-204SE
LL Trip Blank		Water	QA/QC	1	1	1				17KS4ZTB-MMDD
Sed Trip Blank		MeOH & Sand	QA/QC	1	1	1	1			17KS4ZTB-MMDD
Sediment Sample Totals				**14**	**14**	**14**	**7**	**6**	**6**	

Notes:

MS/MSD - Additional sample volume for matrix spike and matix spike duplicate analyses

(D) - Duplicate sample taken from same location as a project sample

LL-Low Level for sediment samples will be analyzed using a low level technique requiring samples be frozen for preservation.

5.3.4 Landfill Cap Inspection Activities

Slopes, vegetation, and erosion-control features at Zone 4 sites LF008 and SS012 were inspected on September 15, 2017. The document entitled *Final Operation, Monitoring, and Maintenance Manual, North and South Barrel Bluffs, King Salmon, Alaska* (Hart Crowser, 2000) was used as a guide for the inspection activities performed at the landfill.

5.3.5 Product Recovery System

The Zone 4 product recovery system is located at a seep down gradient of the former bulk fuel storage area (Figure 5-2). It consists of an impermeable fabric barrier that directs groundwater flow to a manhole containing absorbent pillows. As the water passes through the manhole, the absorbent pillows remove product. The product recovery system replaced a French drain system, which was located upgradient of the present system.

On September 15, 2017, two absorbent pillows in the product recovery system were replaced. There was some petroleum odor present and the pillows were slightly brown from product.

5.3.6 Work Plan Deviations

MW-57 was not sampled due to 0.09 feet of product present in the well. Two residential wells (Smith and Marsh) have not been sampled because the homeowners were out of town and could not be contacted.

5.4 ZONE 4 FINDINGS

5.4.1 Field-Measured Parameters

While collecting groundwater samples from monitoring wells, several water-quality parameters were recorded to determine groundwater consistency and characteristics relevant to assessing intrinsic remediation. Field measurements can be found on the sample data sheets for Zone 4 in Appendix A and in Table 5-6.

Free Product: Free product found was found only in MW-57. Free product had been found in MW-57 in 2011-2013, and 2015-2017.

Temperature: Groundwater temperatures measured in the A-Aquifer wells at the end of September were between 5.24 and 7.79˚C. These temperatures are suitable for biodegradation processes.

pH: Measurements were between 6.16 and 7.08 pH units. These levels are suitable for biodegradation processes.

Conductivity: The conductivity measurements for Zone 4 wells and wells points ranged from 126 to 196 micro Siemens per centimeter (µS/cm).

Dissolved Oxygen: DO levels ranged from 0.71 mg/L to 1.04 mg/L (Figure 5-4). Comparison of previous DO concentrations indicate that areas with elevated petroleum hydrocarbons in Groundwater Zone 4 generally have depressed DO levels (<2.0 mg/L).

The depression of DO levels in relation to the known areas of contamination suggests that microbiological activity is consuming the available DO as a terminal electron acceptor during the metabolism of fuel hydrocarbon compounds. The correlation between depleted DO levels and elevated petroleum hydrocarbon concentrations is a strong indication that aerobic biodegradation of the dissolved hydrocarbons has occurred and continues to occur at this site.

5.4.2 A-Aquifer Analytical Results

Table 5-6 presents a summary of 2017 analytical results. Table 5-7 presents the historical and current sample analytical results with the appropriate RAOs for comparison. Appendix C, Zone 4 Tables, provides a complete list of the Zone 4 A-Aquifer analytical results and all detected analytes for the Zone 4 A-Aquifer analyses.

5.4.2.1 GRO and DRO

The petroleum hydrocarbon levels (GRO and DRO) detected in Zone 4 groundwater are shown on Figure 5-1. None of the three A-Aquifer wells sampled exceeded the current ADEC cleanup level of 2.2 mg/L for GRO. Monitoring wells 502 and MW-51 exceeded the cleanup level of 1.5 for DRO. Overall, GRO concentrations ranged from 1.5 to 1.9 mg/L, and DRO concentrations ranged from 0.26 to 1.8 mg/L.

5.4.2.2 BTEX and TCE

The benzene, toluene, ethylbenzene, total xylenes, total BTEX, and TCE levels detected in groundwater are shown on Figure 5-2. The results from all three of the A-Aquifer monitoring wells sampled were above the RAO of 15 µg/L for ethylbenzene. Ethylbenzene concentrations ranged from 24 to 72 µg/L. Total xylene concentrations exceed the RAO of 190 µg/L in monitoring well MW-51 (370 µg/L). The RAOs for benzene, and toluene were not exceeded in any of the sampled Zone 4 wells. Total BTEX concentrations ranged from 124 µg/L (MW-62) to 455 µg/L (MW-51). TCE was not detected in any of the wells sampled.

5.4.2.3 1,2,4-Trimethylbenzene

The results from all three of the A-Aquifer monitoring wells sampled were above the RAO of 15 µg/L for 1,2,4-Trimethylbenzene. Concentrations for MW-51, MW-62, and 502 were 180, 28 (27), and 25 µg/L, respectively.

5.4.2.4 Naphthalene

The results from all three of the A-Aquifer monitoring wells sampled were above the RAO of 1.7 µg/L for naphthalene. Concentrations ranged from 3.9 to 90 µg/L.

5.4.2.5 Inorganics

Various geochemical indicators important for assessing aerobic biodegradation of fuel hydrocarbons were measured to evaluate if intrinsic remediation is taking place.

- Nitrate-nitrite as nitrogen was detected at low levels in all three wells sampled, at concentrations ranging from 0.01 to 0.017 mg/L. These results are similar to past results which have not shown a correlation between contamination levels and nitrate-nitrite concentrations. Current and past nitrate-nitrite results would suggest nitrate reduction is not a significant biodegradation mechanism for petroleum hydrocarbon contamination in Zone 4.
- Sulfate concentrations were 0.19 to 1.2 mg/L. Sulfate reduction does not seem to be a significant biodegradation mechanism in Zone 4.
- Ferrous iron concentrations ranged from 5.7 mg/L in MW-62 to 40 mg/L in 502. Generally, ferrous iron concentrations greater than 1.0 mg/L can be used as an indicator that aerobic biodegradation is occurring.
- Manganese concentrations ranged from 2.3 mg/L in MW-51 to 2.8 mg/L in MW-62. Manganese concentrations are generally higher in wells with increased levels of DRO and GRO.
- Methane concentrations ranged from 0.62 mg/L in MW-51 to 14 mg/L in 502. The presence of methane is evidence that intrinsic bioremediation of the fuel hydrocarbons is occurring.
- Alkalinity measurements ranged between 72-8 mg/L, and generally, elevated petroleum hydrocarbon levels correlate with increased alkalinity concentrations.

Table 5-6: Summary of Zone 4 A-Aquifer Analytical Results

Well	GRO (mg/L)	DRO (mg/L)	Benzene (mg/L)	Toluene (mg/L)	Total BTEX (mg/L)	TCE (mg/L)	Chloride (mg/L)	Nitrate-Nitrite (mg/L)	Sulfate (mg/L)	Alkalinity (mg/L)	Ferrous Iron (mg/L)	Manga-nese (mg/L)	Methane (mg/L)	DO (mg/L)	ORP (mV)	Temp (°C)	pH	Conduc-tivity (µs/cm)
RAO	**2.2**	**1.5**	**0.005***	**1***	**NA**	**0.005***	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**			**NA**		
502	1.5	**1.6**	0.0022	ND	0.210	ND	1.4	0.014	0.24	82	40	2.7	14.0	0.61	-14.8	7.8	6.39	196
MW-51	1.8	**1.8**	ND	0.013	0.455	ND	2	0.017	1.20	75	6.4	2.3	0.62	1.04	12.6	5.24	6.16	141
MW-57	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**
MW-62	1.9 (1.8)	0.26 (0.29)	0.0003 (ND)	ND (0.00098)	0.1238 (0.128)	ND	2.2	0.01	0.19	72	5.7 (5.9)	2.8	3.3 (3.0)	0.71	-78.6	6.96	7.08	126

NA - Not Applicable
NS - Not sampled
ND - Not detected above method reporting level (MRL)
PROD - Product Present in well
*RAO - Remedial action objectives listed in Final ROD
Analytical results exceeding RAOs shown in **BOLD**
Results in parentheses are Duplicate samples.

Table 5-7: Historical Results for Groundwater Zone 4 A-Aquifer

Well	Analyte	Cleanup Levels (mg/L)	1992 Analytical Results	1993 Analytical Results	1994 Analytical Results	1997 Analytical Results	2000 Analytical Results	2001 Analytical Results	2002 Analytical Results	2003 Analytical Results	2004 Analytical Results	2005 Analytical Results	2006 Analytical Results	2007 Analytical Results	2008 Analytical Results	2009 Analytical Results	2010 Analytical Results	2011 Analytical Results	2012 Analytical Results	2013 Analytical Results	2014 Analytical Results	2015 Analytical Results	2016 Analytical Results	2017 Analytical Results
MW-51	GRO	2.2	NS	1.4	NS	NS	**2.38**	1.98	0.788	1.4/1.7	1.76 (1.19)	1.16 (1.71)	NS	1.42	0.79	**2.1**	0.62	1.9	0.63	1.7 (1.6)	1.2	1.2	**2.8**	1.8
	DRO	1.5	NS	**6.23**	**5.0**	**3.96**	**9.77**	**6.8**	**2.39**	**4.2/3.4**	**9.09 (7.32)**	**5.3 (2.42)**	NS	**5.29**	**1.9**	**2.9**	0.92	**3.1**	**1.6**	**5.9 (5.6)**	1.3 (1.4)	1.4	**2.5**	**1.8**
	Benzene	0.005*	**0.048**	**0.016**	**0.012**	0.0010	0.0037	0.0042	0.0007	0.0011	0.00115	0.0006	NS	0.00026	0.00016	ND	0.00018	ND	ND	ND	ND	ND	0.00014	ND
	Toluene	1*	0.640	0.180	0.39	0.0063	0.187	0.257	0.0098	0.081	0.138	0.133	NS	0.150	0.039	0.15	0.019	0.064	0.032	0.067 (0.060)	0.034	0.037	0.066	0.013
	BTEX	NA	1.36	0.338	0.921	0.301	0.666	0.787	0.0778	0.418	0.537	0.393	NS	0.596	0.218	0.632	0.158	0.289	0.197	0.435 (0.53)	0.272 (0.281)	0.404	0.822	0.455
	TCE	0.005*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS	0.00034	0.00014	0.00026	ND	ND	ND	0.00015 (ND)	ND	0.00078	ND	ND
MW-62	GRO	2.2	NS	NS	NS	NS	**2.88**	1.98	2.07	1.8	1.87	1.15	NS	2.05	**2.5**	**2.4**	**2.2**	**4.2**	2	1.9	**2.3**	**2.5 (2.7)**	**2.2** (2.0)	1.9 (1.8)
	DRO	1.5	NS	NS	**2.3**	0.984	**3.16**	**1.62**	1.19	1.4	1.38	1.14	NS	0.762	0.54	0.59	0.65	**1.5**	0.6	0.47	0.32	0.36 (0.29)	0.35 (0.38)	0.26 (0.29)
	Benzene	0.005*	NS	NS	**0.2**	**0.086**	**0.0171**	**0.0082**	**0.0051**	0.0042	0.00346	0.00186	NS	0.00146	0.0015	0.00098	0.00056	0.00052	ND	0.001	ND	0.00042 (0.00048)	0.00045(0.00041)	0.0003 (ND)
	Toluene	1*	NS	NS	0.0049	0.041	0.0010	ND	ND	ND	0.00101	0.00092	NS	0.00297	0.0014	0.0015	0.0010	0.00072	0.00076	0.00064	0.00067	0.0011 (0.0012)	0.00066(0.00062)	ND (0.00098)
	BTEX	NA	NS	NS	0.815	0.692	0.702	0.659	0.282	0.382	0.367	0.188	NS	0.342	0.381	0.273	0.287	0.215	0.173	0.1	0.0996	0.136 (0.147)	0.09/0.085	0.1238 (0.1273)
	TCE	0.005*	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
502	GRO	2.2	NS	NS	NS	NS	1.87	**2.13**	**3.42**	1.8	**2.44**	1.91	NS	1.29	2.1	1.7	**2.7**	**2.5**	0.52	1.5	**2.5**	**2.4**	1.7	1.5
	DRO	1.5	NS	**3.8**	NS	**13.5**	**2.44**	**16.7**	**7.86**	**3.2**	**6.48 D**	**2.13**	NS	**3.89**	1.4	**5.3**	**5.2**	**4.2**	0.61	**2.4**	**1.5**	**1.6**	**1.6**	**1.6**
	Benzene	0.005*	NS	**0.21**	NS	**0.073**	**0.0174**	**0.0207**	**0.0102**	0.004	**0.00805**	**0.00685**	NS	0.0013	0.0014	0.0024	**0.0078**	0.0023	0.0011	0.0025	0.0031	0.0043	0.0036	0.0022
	Toluene	1*	NS	0.011	NS	0.047	0.0087	0.0964	0.0067	0.002	0.00375	0.00153	NS	0.00361	0.0083	0.0051	0.036	0.0022	0.00054	0.0055	0.0016	0.0015	ND	ND
	BTEX	NA	NS	2.90	NS	2.30	0.740	1.33	1.522	0.691	1.027	0.851	NS	0.0769	0.420	0.288	0.639	0.083	0.11	0.271	0.375	0.335	0.287	0.299
	TCE	0.005*	NS	ND	NS	ND	ND	ND	ND	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	0.0021	ND	ND
MW-57	GRO	2.2	NS	NS	NS	NS	0.94	0.909	1.02	0.99	0.72	0.384	NS	0.531	0.71	0.54	0.19	**PROD**	**PROD**	**PROD**	0.54	**PROD**	**PROD**	**PROD**
	DRO	1.5	NS	**13.4**	**4.3**	**5.62**	**5.64**	**6.97**	**13.4**	**6.3**	**5.99**	**3.71**	NS	**12.8**	**6.1**	**11**	**6.4**	**PROD**	**PROD**	**PROD**	**8.7**	**PROD**	**PROD**	**PROD**
	Benzene	0.005*	NA	ND	**0.034**	ND	ND	ND	ND	ND	ND	ND	NS	ND	ND	ND	ND	**PROD**	**PROD**	**PROD**	ND	**PROD**	**PROD**	**PROD**
	Toluene	1*	NA	0.0027	0.039	0.0017	0.0014	0.0012	0.0012	0.0013	0.00126	0.00102	NS	0.00191	0.0023	0.0011	0.00033	**PROD**	**PROD**	**PROD**	0.0012	**PROD**	**PROD**	**PROD**
	BTEX	NA	NA	0.0256	0.161	0.075	0.114	0.102	0.104	0.174	0.190	0.0464	NS	0.0881	0.110	0.634	0.0087	**PROD**	**PROD**	**PROD**	0.0789	**PROD**	**PROD**	**PROD**
	TCE	0.005*	**0.0766**	**0.0089**	NA	0.0011	0.0014	ND	ND	ND	0.00106	0.00144	NS	0.00082	0.0011	0.0007	0.0003	**PROD**	**PROD**	**PROD**	0.00092	**PROD**	**PROD**	**PROD**

NOTES:

ND - Not detected above the method reporting limit

NS - Not sampled for this analyte

Analytical results exceeding the RAOs are shown in **BOLD**

DRO - Diesel-range organics

GRO - Gasoline range organics

TCE - Trichloroethene

BTEX - Benzene, Toluene, Ethylbenzene, Xylenes

PROD - Product Present in well

(Results) are duplicate samples.

* - RAOs in Final ROD

5.4.3 Benzene, DRO, GRO and TCE Concentration Trends

The ProUCL software, Version 5.1 was used to assess benzene, ethylbenzene, DRO, GRO, and TCE concentration trends for three Zone 4 monitoring wells. Output from the ProUCL evaluation can be found in Appendix E.

Table 5-8 and Table 5-9 summarize the concentration trends observed in the three key monitoring wells (MW-51, MW-62, MW-502) with historical concentrations of contaminants near or above RAOs. The tables list the numbers of wells exhibiting a specific concentration trend for each analyte. Well location data sets, which did not have the minimum number of four observations, or where the results were all below the reporting limit for a specific analyte, are not included in the trend summary table. Note that 57% of the concentration trends were decreasing, 0% were increasing, and 43% had no trend. Please note that one half the method detection limit was used for ND values, thus making it difficult to assess trends at or near the detection limit. Overall, since the majority of concentration trends are decreasing, the trend analysis supports the conclusion that intrinsic remediation is keeping contaminant concentrations stable or decreasing at this site.

Table 5-8 Zone 4 Mann-Kendall Analysis Summary

Trend	Benzene	Ethyl-benzene	GRO	DRO	TCE	% of Total
Decreasing	3	2	0	3	0	57%
Increasing	0	0	0	0	0	0%
No Trend	0	1	3	0	2	43%
Totals	3	3	3	3	2	14

Table 5-9 Zone 4 Mann-Kendall Trend Summary

Well	Benzene	Ethyl-benzene	GRO	DRO	TCE
MW-51	**D**	NT	NT	**D**	NT
MW-62	**D**	**D**	NT	**D**	NT
MW-502	**D**	**D**	NT	**D**	N/A

D- Decreasing
NT – No trend
N/A Not applicable due to insufficient data or no detectable concentrations

5.4.4 B-Aquifer & Residential Well Analytical Results

Groundwater samples were collected from two B-Aquifer monitoring wells and three residential wells within Zone 4 to determine if contaminants present in the A-Aquifer have impacted the underlying B-Aquifer. Table 5-10 presents the historical and current sample analytical results for the contaminants of concern and the appropriate RAO or cleanup levels for comparison. Appendix C, Zone 4 Tables provide a complete list of the Zone 4 B-Aquifer analytical results.

Both B-Aquifer monitoring wells and the duplicate had low level detections of GRO (0.024-0.025 mg/L) and DRO (0.048 - 0.088 mg/L). Due to a laboratory QC error, the DRO results from the monitoring wells are biased low. DRO was detected in one residential well (Bowers) at 0.022 mg/L. Toluene was detected in monitoring well 506 (0.18 µg/L). TCE (0.2 µg/L) and naphthalene (0.81 µg/L) were detected in the primary sample from MW-979.

Table 5-10: Historical Results for Zone 4 B-Aquifer

Well Number	Analyte	RAO mg/L	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
506	GRO	2.2	ND	0.0178	0.0477	ND	0.0101	ND	0.018(0.015)	ND	ND	ND	ND	0.024	ND	ND	0.025
	DRO	1.5	0.032	0.0509	0.112	ND	ND	ND	ND	ND	ND	0.017 (0.016)	0.016(ND)	0.056 (0.062)	0.055	0.049	0.088
	Benzene	0.005*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Toluene	1*	0.00013	ND	ND	ND	ND	ND	ND	ND	ND	ND (0.00028)	0.00025(0.00027)B	ND	ND	ND	0.00018
	BTEX	NA	0.00013	ND	ND	ND	ND	0.00023	ND	ND	ND	ND (0.00028)	0.00025(0.00027)B	ND	ND	ND	0.00018
	TCE	0.005*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW97-9	GRO	2.2	ND	0.00955	ND	ND	ND	ND	ND	ND	ND	0.009 B	ND	0.026	ND	ND	0.025 (0.024)
	DRO	1.5	0.085	0.04665	0.184	ND	ND	ND	ND	ND	ND	0.017	ND	0.036	0.037/0.044	0.042/0.044	ND (0.048)
	Benzene	0.005*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Toluene	1*	ND	ND	ND	ND	ND	ND	0.00028	ND	ND	ND	ND	ND	ND	ND	ND
	BTEX	NA	ND	ND	ND	ND	ND	ND	0.00028	ND	ND	ND	ND	ND	ND	ND	ND
	TCE	0.005*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0002 (ND)
Residential Wells			**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Smith	GRO	2.2	NS	ND	ND	ND	ND	0.024 F	ND	ND	ND	ND	0.024	ND	ND	ND	NS
	DRO	1.5	NS	ND	0.177	0.0859	ND	ND	ND	ND	ND	0.018	ND	0.059	0.049	0.036	NS
	Benzene	0.005*	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS
	Toluene	1*	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS
	BTEX	NA	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS
	TCE	0.005*	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS
King	GRO	2.2	NS	ND	ND	ND	ND	0.029 F	ND	ND	ND	ND	ND	ND	ND	ND	ND
	DRO	1.5	NS	ND	0.193	ND	ND	ND	ND	ND	ND	0.017	ND	0.048	0.04	0.047	ND
	Benzene	0.005*	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Toluene	1*	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	BTEX	NA	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	TCE	0.005*	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bowers	GRO	2.2	NS	NS	NS	NS	NS	NS	0.012 F VB	ND	ND	ND	0.03	ND	ND	ND	ND
	DRO	1.5	NS	NS	NS	NS	NS	NS	ND	ND	ND	0.02	ND	0.086	0.067	0.034	0.022
	Benzene	0.005*	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Toluene	1*	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND
	BTEX	NA	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND
	TCE	0.005*	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND
King Apt	GRO	2.2	NS	NS	NS	NS	NS	NS	0.012 F VB	ND	ND	ND	ND	0.016	ND	ND	ND
	DRO	1.5	NS	NS	NS	NS	NS	NS	ND	ND	ND	0.018	ND	0.05	0.05	0.028	ND
	Benzene	0.005*	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Toluene	1*	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND
	BTEX	NA	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND
	TCE	0.005*	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND
Marsh	GRO	2.2	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	0.015	NS
	DRO	1.5	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.041	0.052	NS
	Benzene	0.005*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	NS
	Toluene	1*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	NS
	BTEX	NA	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	NS
	TCE	0.005*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	NS

ND - Not detected above method reporting level.
RAO - Remedial action objectives.
NS - Not Sampled.
F- The analyte was positively identified but the associated numerical value is below the Reporting Limit (RL).
V - The flag was assigned during the A/E's data review process.
B - The analyte was found in an associated blank, as well as in the sample.
Results in parentheses indicate duplicate sample.
* - RAOs found in final ROD

5.4.5 Surface Water/Sediment Analytical Results

Surface water and sediment contaminant concentrations were compared to RAOs and benchmark screening levels. RAOs are available for surface water only, and are developed in accordance with AWQS 18 AAC 70. Analytical results for the sediment samples were evaluated using the screening criteria shown in Table 5-2. In accordance with the ADEC *Sediment Quality Guidelines* technical memorandum (ADEC, 2013), analytes detected in the 2017 Zone 4 sediment samples that did not have criteria listed in Table 5-2 were compared to criteria found in the NOAA SQuiRTs (NOAA, 2008). Table 5-11 presents the historical and current sample analytical results for the contaminants of concern and the appropriate cleanup levels for comparison. Appendix C, Zone 4 Tables provide a complete list of the Zone 4 detected analytes and analytical results, along with the appropriate cleanup levels or benchmark screening levels. Sample locations and analytical results are shown on Figure 5-3.

Topography and vegetation of the wetland just down-gradient of Landfill No. 5 suggests that surface water flows south and east to a culvert, running under the road, about 150 feet south of monitoring well 502. Samples from OT30-01 and OT30-03 were taken to assess the change in contaminant levels in water as it flows along this likely surface water drainage pattern. The sample from OT30-01 was collected about ten feet south of the Upper Naknek Area product recovery system. The OT30-03 sample was collected from just up-gradient of the culvert draining the wetland west of the road. A sample was also collected from OT30-04 which is located below the edge of the river bank and MW-57. MW-57 had product present during six of seven sampling events since 2011. A strong fuel odor was observed at OT30-01 and OT30-04. Sheen was observed on the sample from OT30-04, but not on the other two surface water samples.

5.4.5.1 Surface Water GRO and DRO

GRO and DRO concentrations detected at three surface water locations are shown on Figure 5-3. GRO was detected in all three surface water locations in concentrations ranging from 0.022 mg/L in OT30-03 to 0.83 mg/L in OT30-04. DRO was detected in all three surface water samples ranging from 0.13 mg/L in OT30-03 to 6.3 mg/L in OT30-04. There are no criteria for bulk hydrocarbons in surface water. There was sheen observed on the surface water at OT30-04.

5.4.5.2 Surface Water TAH and TAqH

TAH are determined by adding together all of the BTEX concentrations. The AWQS cleanup level for TAH in surface water (10 µg/L) was not exceeded in any of the surface water samples. TAH results were 1.7 (2.1) µg/L for OT30-01, and ND for OT30-03, and 0.17 µg/L for OT0-04. TAqH are determined by adding together the TAH and PAH concentrations. The AWQS cleanup level for TAqH (15 µg/L) was not exceeded in the samples from OT30-01 (1.99/2.24 µg/L) and OT30-03 (0.035 µg/L). TAqH results of 15.57 µg/L at OT30-04 exceeded the water quality criteria of 15 µg/L.

5.4.5.3 Sediment GRO and DRO

The petroleum hydrocarbon levels detected in the Zone 4 sediment samples are depicted in Figure 5-3. GRO and DRO were detected in the primary/duplicate sample from OT30-01 (3.5/5.6 mg/kg and 110/120 mg/kg respectively). GRO and DRO were detected in the sample from OT30-03 (0.57 mg/kg and 3 mg/kg, respectively). GRO and DRO were also detected in the sample from OT30-04 at 88 mg/kg and 1,700 mg/kg, respectively. There are no criteria for GRO and DRO in sediments.

5.4.5.4 Sediment TCE, VOCs, and PAHs

Benzene, ethylbenzene, and TCE were not detected in any of the sediment samples. O-xylene (0.0069/ND mg/kg) was detected in the primary sample at OT30-01. All of the Method 8260C VOC results are biased low due to the analyses being performed after the sample holding times expired. Naphthalene (0.480/0.31 mg/kg) concentrations in OT30-01 exceeded the ecological risk-based remediation goal listed in Table 5-2 (NOAA SQuiRTs, NOAA, 2008). Naphthalene (0.17 mg/kg), benzo[a]anthracene (0.055 mg/kg), and benzo[a]pyrene (0.039 mg/kg) exceeded the screening criteria at OT30-04. There are no sediment cleanup levels listed in the Zone 4 ROD.

Table 5-11: Zone 4 Historical Surface Water and Sediment Results

Surface Water

Location ID	Analyte	Screening Levels (mg/L)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
OT30-01	GRO	NA	0.100	0.234	0.768	NS	0.0304	0.080	0.021	0.10 (0.11)	ND	ND (0.0096)	0.051 (0.050)	0.039 (0.047)	0.018	ND	0.038 (0.035)
	DRO	NA	8.50	4.38	3.81	NS	1.61	2.8	2.6	2.7 (2.9)	1.9(2.2)	0.4	2.0 (2.1)	1.1 (1.0)	1.4	0.93 (1.0)	1.2 (1.1)
	TAH	0.01	0.00789	**0.0130**	**0.1560**	NS	ND	0.0023	0.00012	0.00240	ND	0.00077(ND)	0.0051 (0.0052)	0.00132 (0.00156)	0.00144(0.00103)	0.0048 (0.0043)	0.0017 (0.0021)
	TAqH	0.015	0.0115	0.0149	**0.1664**	NS	0.00014	0.0033	0.00028	0.0034 (0.0026)	ND (0.00061)	0.00085(0.00013)	0.0079 (0.0085)	0.00217(0.00245)	0.00205(0.00169)	0.00717 (0.00693)	0.00199 (0.0.00224)
OT30-03	GRO	NA	0.024	0.0361	ND		ND	0.020(0.057)	ND	ND	ND	ND	0.0095	ND	0.019	ND	0.022
	DRO	NA	0.64	0.588	0.404	NS	0.178	0.28(0.28)	0.22(0.23)	0.18	0.25	0.082	0.16	0.19	0.15	0.17	0.13
	TAH	0.01	ND	0.00088	ND	NS	0.00071	ND(0.00041)	ND	ND	ND	ND	0.00054	ND	ND	ND	ND
	TAqH	0.015	0.00245	0.00238	ND	NS	0.00078	0.000138 (0.00055)	0.000124 (0.000108)	0.000073	0.000032	0.000031	0.00073	0.000042	0.000017	ND	0.000035
OT30-04	GRO	NA	0.077	0.26	0.0701	NS	NS	NS	NS	NS	NS	NS	4.4	2.6	0.47	0.72	0.83
	DRO	NA	0.016	0.014	ND	NS	NS	NS	NS	NS	NS	NS	42 - Sheen	16 - Sheen	11 - Sheen	2.7 -Sheen	6.3 - Sheen
	TAH	0.01	ND	ND	ND	NS	NS	NS	NS	NS	NS	NS	ND	ND	0.00023	ND	0.00017
	TAqH	0.015	0.00179	0.00159	ND	NS	NS	NS	NS	NS	NS	NS	**0.048**	**0.03741**	0.00985	0.014	**0.01557**

Sediment

Location ID	Analyte	Screening Levels (mg/Kg)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
OT30-01	GRO	NA	7.15	2.75	15.5	NS	6.51	16	7.1	13 (33)	28 (46)	58 (17)	8.1 (9.6)	37 (46)	8.3/5.8	ND	3.5 (5.6)
	DRO	NA	157	1,190	185	NS	213	250	150	380 (350)	240 (320)	480 (240)	220 (170)	470 (670)	200/270	500 (510)	110 (120)
	Benzene	0.01	0.0044	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Toluene	0.05	0.0069	ND	ND	NS	ND	0.0036	0.011	0.010 (0.012)	0.017 (0.037)	0.0028 (0.0035)	ND	ND	ND	ND	ND
	Ethylbenzene	0.004	**0.339**	ND	**0.123**	NS	ND	**0.013**	**0.012**	**0.055 (0.052)**	**0.058 (0.076)**	ND(0.0026)	**0.084 (0.081)**	ND **(0.023)**	**0.01**	**0.012**	ND
	Naphthalene	0.01465											**1.1 (0.9)**	**1.2**	**0.36 (0.38)**	**0.26**	**0.48 (0.31)**
	Xylenes	0.025	**1.217**	**0.0842**	**0.881**	NS	**0.0698**	**0.149**	**0.166**	**0.70 (0.64)**	**0.84 (1.05)**	**0.043 (0.035)**	**1.2 (1.16)**	**0.163 (0.206)**	**0.139 (0.194)**	**0.108**	0.0069 (ND)
OT30-03	GRO	NA	ND	0.396	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	3.2	0.86	0.57
	DRO	NA	75.2	220	35.8	NS	ND	ND	17 (14)	21	18	3.1	3.4	7.4	6.1	7.0	3.0
	Benzene	0.01	0.0009	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Toluene	0.05	ND	ND	ND	NS	ND	ND	ND (0.0066)	ND	ND	ND	0.00052 (LL)	ND	ND	0.0013	ND
	Ethylbenzene	0.004	ND	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Naphthalene	0.01465								**0.023**	0.0033	0.0079	0.0054	0.002	0.012	ND	0.00084
	Benzo (1)	0.01572								**0.17**	**0.059**	0.011	0.0021	0.0016	0.0021	0.0042	**0.016**
	Benzo(2)	0.0324								**0.17**	**0.058**	0.0093	0.0025	0.0022	0.0023	ND	0.015
	Benzo(3)	0.0272								**0.2**	**0.073**	0.0081	0.0038	0.0026	0.0032	ND	0.019
	Xylenes	0.025	0.0025	ND	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
OT30-04	GRO	NA	45	102	186	NS	NS	NS	NS	NS	NS	NS	120	84	19	35	88
	DRO	NA	ND	0.673	13	NS	NS	NS	NS	NS	NS	NS	7,500	3,300	980	4,000	1,700
	Benzene	0.01	0.0009	ND	ND	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND
	Toluene	0.05	0.0027	ND	ND	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND
	Ethylbenzene	0.004	ND	ND	0.0022	NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND
	Naphthalene	0.01465				NS	NS	NS	NS	NS	NS	NS	**0.44**	**0.66**	**0.17**	**0.78**	**0.17**
	Benzo (1)	0.01572			**0.126**	NS	NS	NS	NS	NS	NS	NS	**0.083**	**0.076**	**0.069**	**0.2**	**0.055**
	Benzo(2)	0.0324			**0.127**	NS	NS	NS	NS	NS	NS	NS	**0.04**	**0.05**	**0.039**	**0.12**	**0.039**
	Benzo(3)	0.0272			**0.0492**	NS	NS	NS	NS	NS	NS	NS	**0.048**	**0.049**	0.02	**0.061**	**0.059**
	Xylenes	0.025	ND	ND		NS	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND

NOTES:

Analytical results exceeding screening levels shown in **BOLD**

TAH (BTEX)

TAqH (BTEX + PAH)

(Results) are duplicate samples.

Benzo(1): Benzo[a]anthracene

Benzo(2): Benzo[a]pyrene

Benzo(3): Benzo[b]fluoranthene

5.4.6 Landfill Inspection Results

Slopes, vegetation, and erosion-control features at Landfill No. 5 (LF008) and SS012 were inspected on September 15, 2017. The inspections were documented on the Landfill Inspection Form, which has been included in Appendix A. During this inspection, Landfill No. 5 had no evidence of erosion of the landfill cap. No sinkholes were observed. Vegetation cover was estimated at 60-100% and the vegetation was in good condition with increasing growth of alder and grass. The eastern side had very little vegetation, while the western side had some grass and alder. Any willow and spruce trees growing are small.

Upper Naknek Area of SS012 is located between the Alaska Peninsula Highway and LF008. It is comprised of mostly bare sand and is frequently used by ATVs, which have probably prevented any vegetation from taking hold.

Lower Naknek Area (SS012) located on the southern edge of Zone 4 and near the bank of the Naknek River, is overgrown with alder and other indigenous vegetation. There is a path just wide enough to drive a vehicle around the perimeter of SS012.

5.4.7 Institutional Control Inspection

Institutional Controls (ICs) are part of the selected remedy necessary to meet the RAOs. The goals of the ICs are to prevent the drinking of groundwater contaminated above 18 AAC 75.345 Table C groundwater cleanup levels and to help ensure the proper management of soil contaminated above Method Two cleanup levels in order to comply with State regulations (18 AAC 75.375). ICs within the site boundaries consist of prohibiting the installation of water supply wells as long as the aquifer fails ADEC Table C cleanup levels. A visual inspection was performed to verify that no drinking water wells have been installed.

5.4.8 Condition of Wells

The wells and well points scheduled for Zone 4 were sampled and in good condition, with the exception of MW57, which had product present.

5.5 ZONE 4 CONCLUSIONS

5.5.1 General Conclusions

Intrinsic bioremediation has been evident from previous sampling events at the Zone 4 A-Aquifer monitoring wells. The combined lines of evidence of a stable benzene plume, as well as changes in the groundwater chemistry strongly support the occurrence of intrinsic bioremediation in the hydrocarbon-impacted areas of this groundwater system. Intrinsic bioremediation of fuel-impacted groundwater is expected to continue in Zone 4.

Free-phase hydrocarbons were observed in MW-57 for the sixth time in seven years. Sampling results from OT30-04 suggest that the DRO plume at MW-57 is having an impact on the river bank at that location. POL contaminated soil removal is planned under a separate contract.

5.5.2 A-Aquifer Monitoring Wells

Analytical data showed GRO above ROD cleanup levels, but below current ADEC cleanup levels in all three wells sampled. DRO was above cleanup levels in the samples from monitoring well 502 and MW-51. MW-57 had detectable product this year and was not sampled.

There were no RAO exceedances for benzene, and toluene. Ethylbenzene and naphthalene exceeded the ADEC groundwater cleanup levels in all three of the A-Aquifer monitoring wells sampled. MW51 also had an exceedance of total xylenes. TCE was not detected in any of the wells sampled.

5.5.3 B-Aquifer Monitoring Wells and Residential Wells

DRO and GRO were detected in B-Aquifer monitoring wells at levels well below the cleanup levels. One residential well also had similar detections of DRO (0.02 mg/L).

5.5.4 Surface Water and Sediment

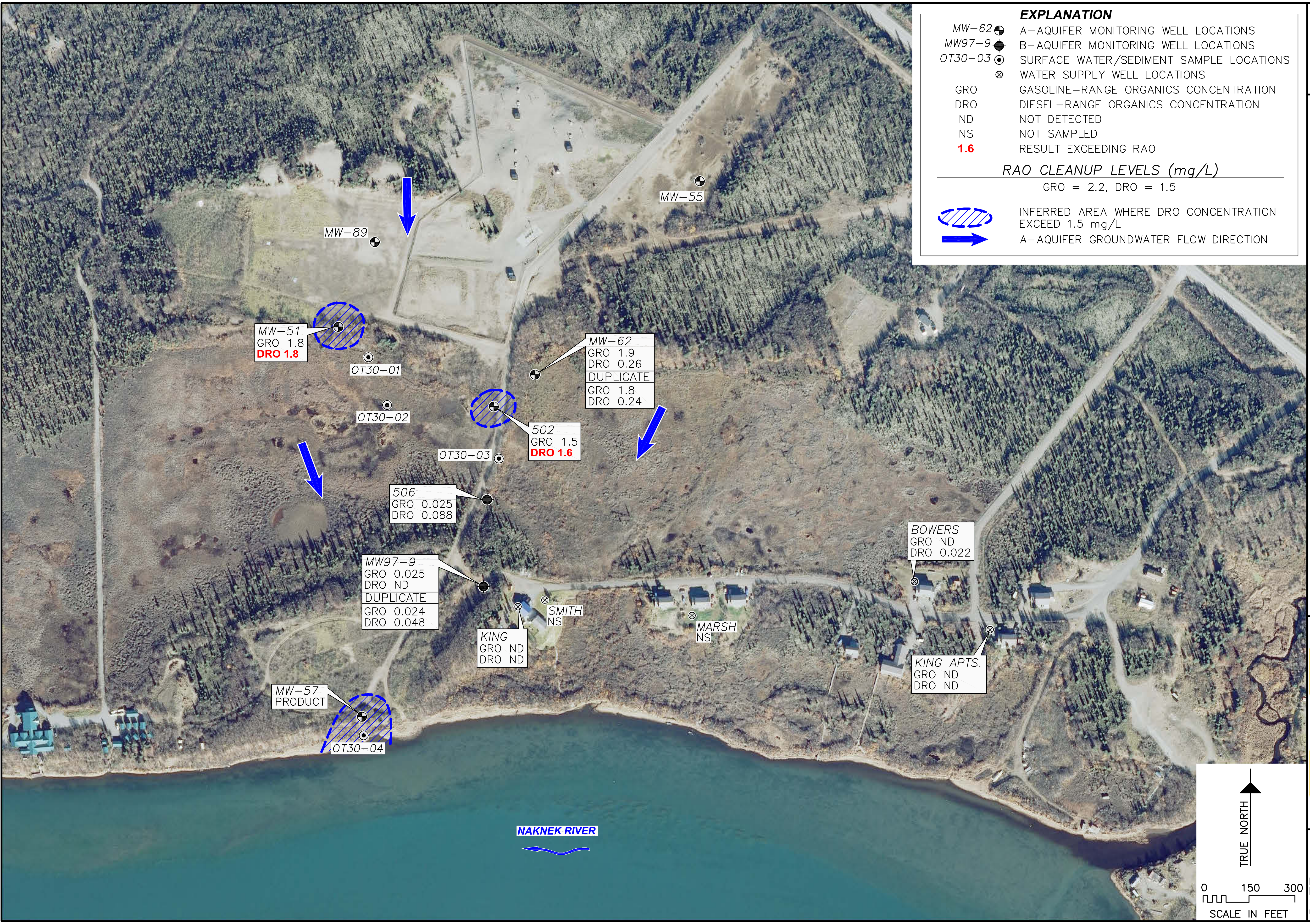
As in previous years, petroleum hydrocarbons decreased from the outlet of the product recovery system at OT30-01 downstream to the outfall of the culvert at OT30-03, indicating that the wetlands are degrading petroleum hydrocarbons at this site. GRO and DRO were detected in all three surface water/sediment pairs. Concentrations of naphthalene were above sediment criteria in the sample collected at OT30-1 and benzo[a]anthracene exceeded criteria at OT30-03.

OT30-04 surface water GRO and DRO results were 0.83 and 6.3 mg/L (sheen), respectively. Sediment GRO and DRO results were 88 and 1,700 mg/Kg, respectively. The PAHs benzo[a]anthracene, benzo(a)pyrene, and naphthalene exceeded criteria.

5.6 ZONE 4 RECOMMENDATIONS

- Monitoring should continue because drinking water wells and other sensitive receptors lie downgradient of this site.
- Chloride, sulfate, and alkalinity results are not providing any useful information, and should be eliminated from the sampling program.
- Any recommendations are subject to change pending conversations between ADEC and AFCEC, and any comment resolution outcomes on ADEC's comments for the Five-Year Review.

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18-KS-LTM-RPT-F5-1.DWG PLOT: 5/17/18.



EXPLANATION

MW-62 ◐	A-AQUIFER MONITORING WELL LOCATIONS
MW97-9 ●	B-AQUIFER MONITORING WELL LOCATIONS
OT30-03 ⊙	SURFACE WATER/SEDIMENT SAMPLE LOCATIONS
⊗	WATER SUPPLY WELL LOCATIONS
GRO	GASOLINE-RANGE ORGANICS CONCENTRATION
DRO	DIESEL-RANGE ORGANICS CONCENTRATION
ND	NOT DETECTED
NS	NOT SAMPLED
1.6	RESULT EXCEEDING RAO

RAO CLEANUP LEVELS (mg/L)

GRO = 2.2, DRO = 1.5

▨	INFERRED AREA WHERE DRO CONCENTRATION EXCEED 1.5 mg/L
➡	A-AQUIFER GROUNDWATER FLOW DIRECTION

FIGURE

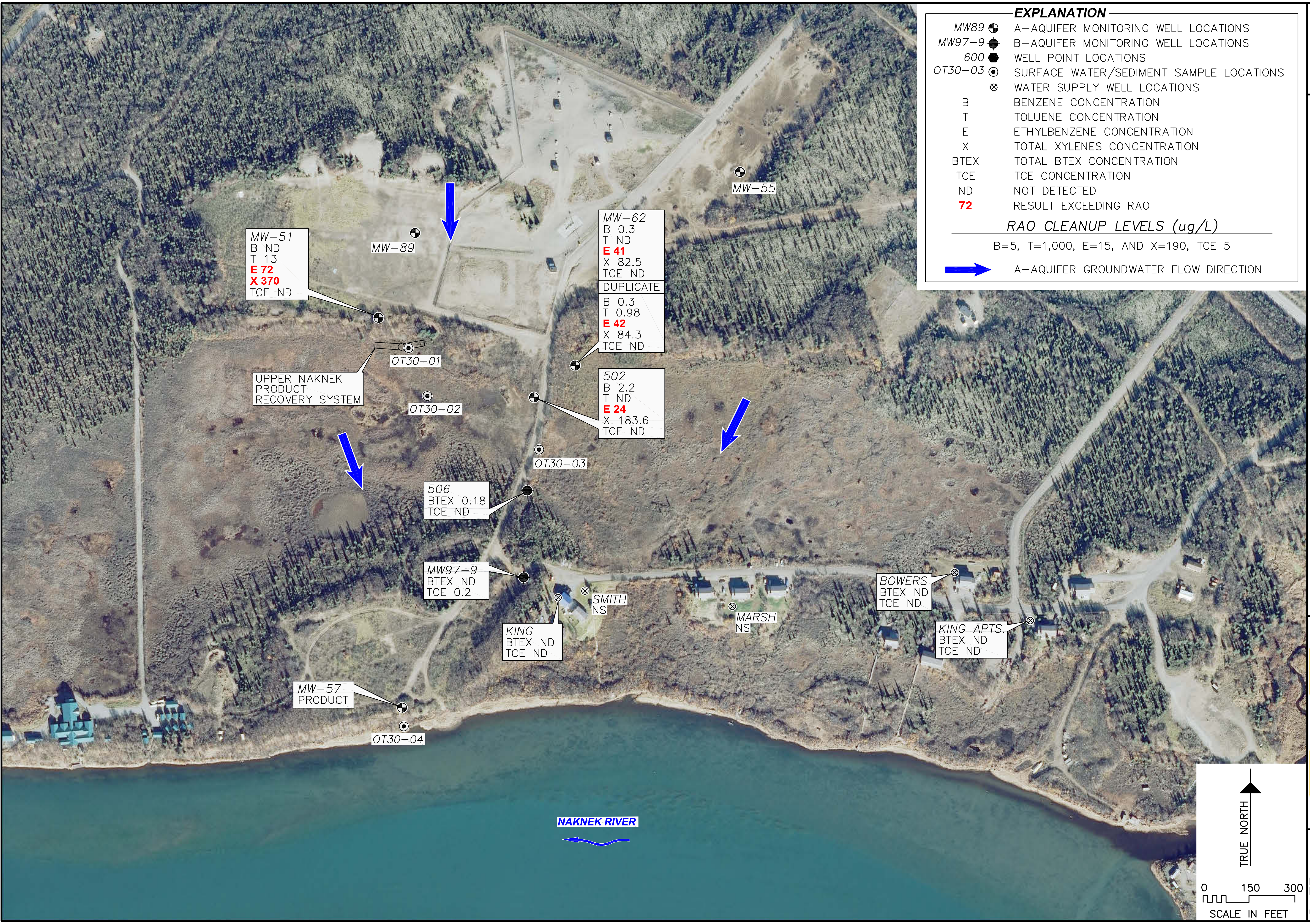
5-1

GROUNDWATER DRO AND GRO PLUME EXTENT AND ANALYTICAL RESULTS GROUNDWATER ZONE 4

NAKNEK RIVER STORAGE (GWZ4, OT-030)
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE
MAY 2018
CHKD
H.L.H.
DRAWN
C.E.H.
PROJ. NO
17040



EXPLANATION

MW89 ◐	A-AQUIFER MONITORING WELL LOCATIONS
MW97-9 ◐	B-AQUIFER MONITORING WELL LOCATIONS
600 ⬢	WELL POINT LOCATIONS
OT30-03 ⊙	SURFACE WATER/SEDIMENT SAMPLE LOCATIONS
⊗	WATER SUPPLY WELL LOCATIONS
B	BENZENE CONCENTRATION
T	TOLUENE CONCENTRATION
E	ETHYLBENZENE CONCENTRATION
X	TOTAL XYLENES CONCENTRATION
BTEX	TOTAL BTEX CONCENTRATION
TCE	TCE CONCENTRATION
ND	NOT DETECTED
72	RESULT EXCEEDING RAO

RAO CLEANUP LEVELS (ug/L)

B=5, T=1,000, E=15, AND X=190, TCE 5

➡	A-AQUIFER GROUNDWATER FLOW DIRECTION

FIGURE

5-2

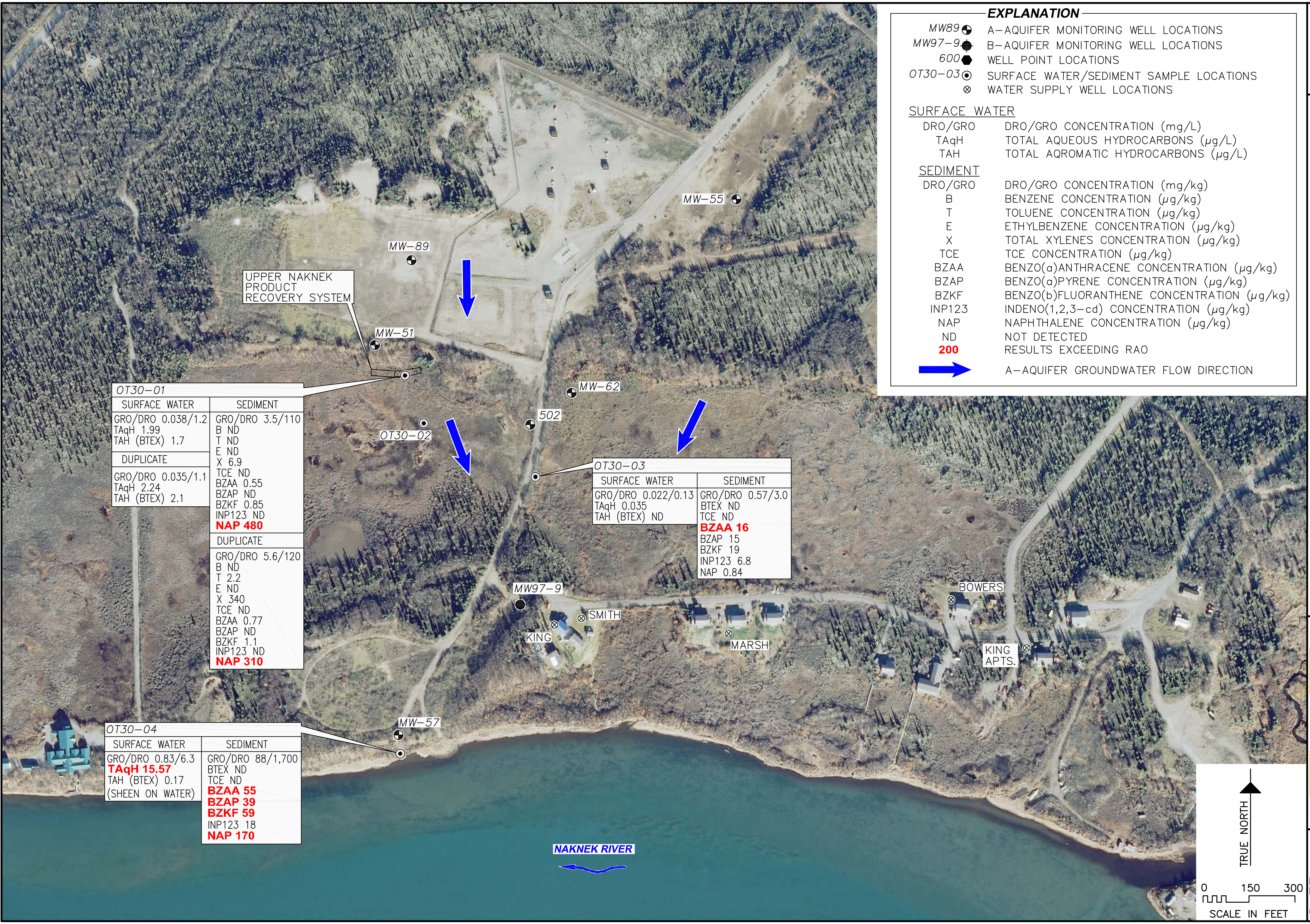
BTEX AND TCE ANALYTICAL RESULTS GROUNDWATER ZONE 4

NAKNEK RIVER STORAGE (GWZ4, OT-030)
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE
JAN. 2018
CHKD
H.L.H.
DRAWN
C.E.H.
PROJ. NO
17040

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18-KS-LTM-RPT-F5-2.DWG PLOT: 1/18/18.



OT30–01

SURFACE WATER	SEDIMENT
GRO/DRO 0.038/1.2 TAqH 1.99 TAH (BTEX) 1.7	GRO/DRO 3.5/110 B ND T ND E ND X 6.9 TCE ND BZAA 0.55 BZAP ND BZKF 0.85 INP123 ND **NAP 480**
DUPLICATE	DUPLICATE
GRO/DRO 0.035/1.1 TAqH 2.24 TAH (BTEX) 2.1	GRO/DRO 5.6/120 B ND T 2.2 E ND X 340 TCE ND BZAA 0.77 BZAP ND BZKF 1.1 INP123 ND **NAP 310**

OT30–03

SURFACE WATER	SEDIMENT
GRO/DRO 0.022/0.13 TAqH 0.035 TAH (BTEX) ND	GRO/DRO 0.57/3.0 BTEX ND TCE ND **BZAA 16** BZAP 15 BZKF 19 INP123 6.8 NAP 0.84

OT30–04

SURFACE WATER	SEDIMENT
GRO/DRO 0.83/6.3 **TAqH 15.57** TAH (BTEX) 0.17 (SHEEN ON WATER)	GRO/DRO 88/1,700 BTEX ND TCE ND **BZAA 55** **BZAP 39** **BZKF 59** INP123 18 **NAP 170**

EXPLANATION

MW89 ⊕	A–AQUIFER MONITORING WELL LOCATIONS
MW97–9 ⊕	B–AQUIFER MONITORING WELL LOCATIONS
600 ●	WELL POINT LOCATIONS
OT30–03 ⊙	SURFACE WATER/SEDIMENT SAMPLE LOCATIONS
⊗	WATER SUPPLY WELL LOCATIONS

SURFACE WATER

DRO/GRO	DRO/GRO CONCENTRATION (mg/L)
TAqH	TOTAL AQUEOUS HYDROCARBONS (µg/L)
TAH	TOTAL AQROMATIC HYDROCARBONS (µg/L)

SEDIMENT

DRO/GRO	DRO/GRO CONCENTRATION (mg/kg)
B	BENZENE CONCENTRATION (µg/kg)
T	TOLUENE CONCENTRATION (µg/kg)
E	ETHYLBENZENE CONCENTRATION (µg/kg)
X	TOTAL XYLENES CONCENTRATION (µg/kg)
TCE	TCE CONCENTRATION (µg/kg)
BZAA	BENZO(a)ANTHRACENE CONCENTRATION (µg/kg)
BZAP	BENZO(a)PYRENE CONCENTRATION (µg/kg)
BZKF	BENZO(b)FLUORANTHENE CONCENTRATION (µg/kg)
INP123	INDENO(1,2,3–cd) CONCENTRATION (µg/kg)
NAP	NAPHTHALENE CONCENTRATION (µg/kg)
ND	NOT DETECTED
200	RESULTS EXCEEDING RAO
➡	A–AQUIFER GROUNDWATER FLOW DIRECTION

FIGURE
5-3

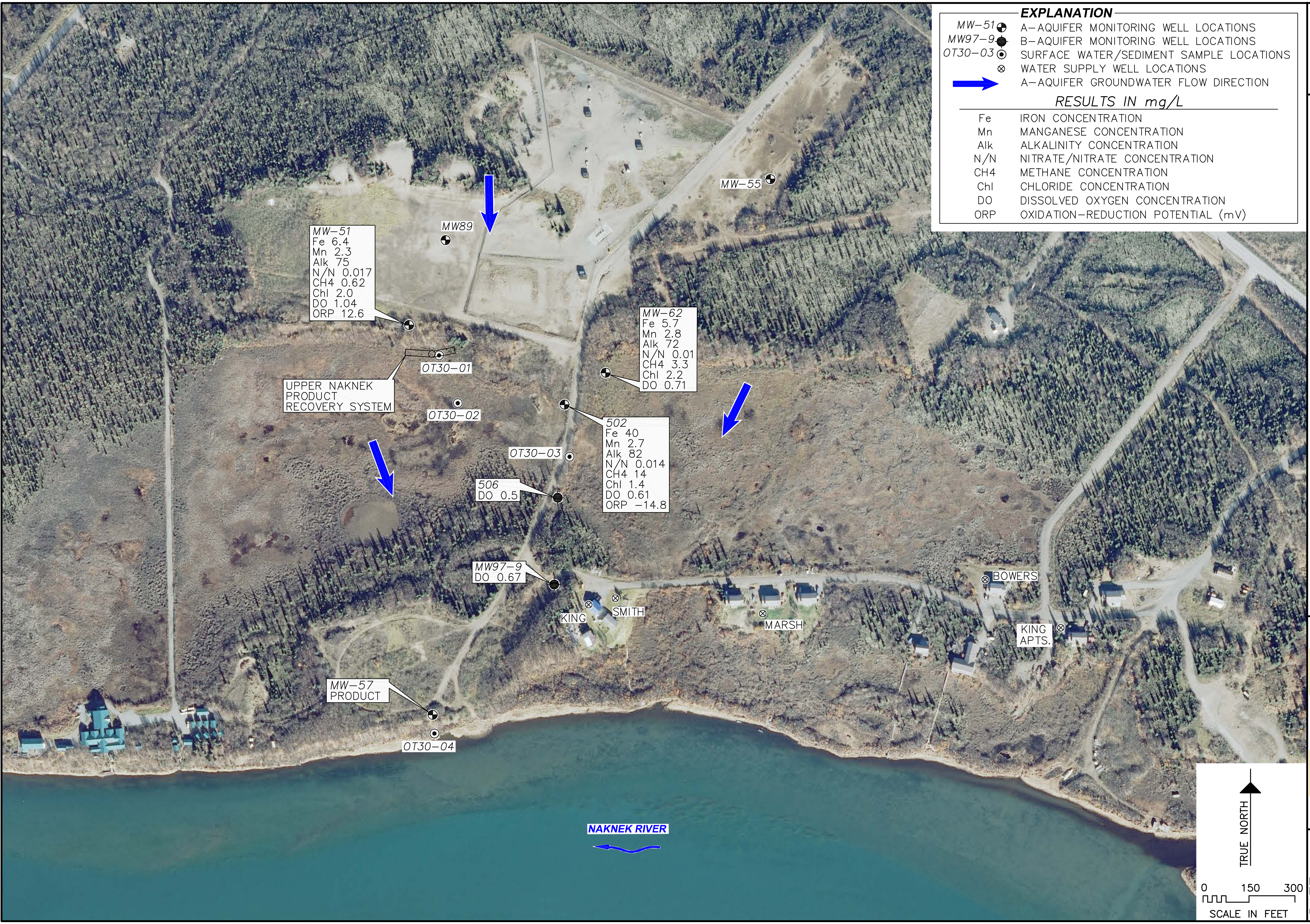
SURFACE WATER AND SEDIMENT ANALYTICAL DATA GROUNDWATER ZONE 4

NAKNEK RIVER STORAGE (GWZ4, OT–030)
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE	JAN. 2018
CHKD	H.L.H.
DRAWN	C.E.H.
PROJ. NO	17040

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18–KS–LTM–RPT–F5–3.DWG PLOT: 1/10/18.



EXPLANATION

MW-51 ◐ A-AQUIFER MONITORING WELL LOCATIONS
MW97-9 ● B-AQUIFER MONITORING WELL LOCATIONS
OT30-03 ⊙ SURFACE WATER/SEDIMENT SAMPLE LOCATIONS
⊗ WATER SUPPLY WELL LOCATIONS
➡ A-AQUIFER GROUNDWATER FLOW DIRECTION

RESULTS IN mg/L

Fe	IRON CONCENTRATION
Mn	MANGANESE CONCENTRATION
Alk	ALKALINITY CONCENTRATION
N/N	NITRATE/NITRATE CONCENTRATION
CH4	METHANE CONCENTRATION
Chl	CHLORIDE CONCENTRATION
DO	DISSOLVED OXYGEN CONCENTRATION
ORP	OXIDATION-REDUCTION POTENTIAL (mV)

FIGURE
5-4

MONITORED NATURAL ATTENUATION RESULTS GROUNDWATER ZONE 4

NAKNEK RIVER STORAGE (GWZ4, OT-030)
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE
JAN. 2018
CHKD
H.L.H.
DRAWN
C.E.H.
PROJ. NO
17040

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18-KS-LTM-RPT-F5-4.DWG PLOT: 1/18/18.

6 ZONE 5 - RAPCON AND RED FOX CREEK

Historical spills and operational practices at RAPCON have resulted in contamination of the water table with petroleum-based products and chlorinated solvents, specifically petroleum product floating on the groundwater, DRO, GRO, and VOCs, including TCE dissolved in the groundwater. Red Fox Creek and its tributary drainages have contained contaminants resulting from RAPCON and other contaminated sites.

The Air Force has contracted through the Corps of Engineers to complete a Zone 5 Record of Decision.

6.1 DESCRIPTION OF CURRENT STUDY

When two consecutive sampling events showed no groundwater contamination above the cleanup levels for specific analytes at specific monitoring locations, monitoring for those analytes at those locations was discontinued. When two consecutive sampling events showed no TAH and no TAqH surface water contamination above cleanup levels, surface water and sediment sampling was discontinued at that location. The following changes to the 2013-2016 monitoring programs were made based on recommendations from the 2012 comprehensive groundwater monitoring report (Paug-Vik, 2013c):

- Monitoring wells FT01-SVE1 and FT01-FD9 were analyzed for DRO only.
- FT01-SVE2 and FT01-MW01 were analyzed for DRO and GRO only. FT01-MW01 was also analyzed for PFOA/PFOS in 2016.
- FT01-MW02 was analyzed for VOCs, DRO, and GRO.
- MW-83, located 1,000 feet southeast of RAPCON, was analyzed for PFOA/PFOS in 2016.
- Monitoring was discontinued at RFC-1 and RFC-7 because all TAH and TAqH results have been below water quality criteria since 2005.
- VOC and PAH analyses were continued at RFC-4 and RFC-5 for surface water and sediment.
- A visual inspection of the area will be conducted to ensure that no drinking water wells have been installed and no excavations have been made.

Surface water sampling at RFC-5 was eliminated when results for TAH and TAqH in 2013 and 2014 were below cleanup levels.

In 2017, VOC analysis was added for FT01-SVE2 when the TCE cleanup level was changed from 5 to 2.8 µg/L. Two consecutive rounds of sampling did not achieve new cleanup levels for TCE (4.2 µg/L in 2012).

The purpose of the current study was to collect groundwater samples from six monitoring wells at the RAPCON site, and to collect a surface water and sediment sample pair from RFC-4 and a sediment sample only from RFC-5. The data collected during this project includes concentrations of petroleum hydrocarbons, VOC, and MNA parameters in groundwater, and VOC and PAH parameters in surface water and sediment.

6.2 REMEDIAL ACTION OBJECTIVES FOR RAPCON/RED FOX CREEK

The cleanup levels presented in Table 6-1 are based on the ADEC 18 AAC 75 Method 2 cleanup levels and ecological benchmark screening levels. Surface water screening criteria found in 18 AAC 70 and relevant EPA and ORNL screening criteria were used to establish RAOs for surface water at Red Fox Creek. Because sediment cleanup levels are not provided in the AWQS (18 AAC 70), ORNL ecological benchmarks, EPA (OSWER) Sediment Screening Benchmarks, and NOAA SQuiRT Sediment Screening Values were used to provide screening levels for analytical results. The ORNL ecological benchmarks were taken from the *Tier II Secondary Chronic Surface Water Benchmarks*.

Table 6-1 Cleanup Levels for RAPCON

Chemical of Concern	Maximum Concentration	Maximum Concentration Location (Date)	Maximum Concentration (Location) in 2006	Clean Up Level	Basis
Groundwater (µg/L)					
TCE	**636**	GP-9 (1996)	**84.8** (SVE-2)	2.8	18AAC75(a)
DRO	**43.2** (mg/L)	GP-9 (1996)	**8.95** (SVE-2)	1.5 (mg/L)	18AAC75(a)
GRO	**21** (mg/L)	GP-9 (1996)	**6.26** (SVE-2)	2.2 (mg/L)	18AAC75(a)
Benzene	**1,430**Y	GP-9 (1996)	**16.3** (SVE-2)	4.6	18AAC75(a)
Toluene	**8,190Y**	GP-9 (1996)	**1,230** (SVE-2)	1,100	18AAC75(a)
Ethylbenzene	**706**	GP-9 (1995)	239 (SVE-2)	15	18AAC75(a)
EDB	**94.9**Y	GP-9 (1996)	ND (<10 or <1)	0.075	18AAC75(b)
Surface Water (µg/L)					
Benzene	**113**	(SW-1 -1996)	2.18 (RFC-04)	4.6	18AAC75
Benzo(k) fluoranthene	**18.2**	(RFC-04 – 2003)	ND (52.6)	0.012	EPAWQC
Naphthalene	**12.2**	(RFC-04 – 2003)	6.8 (RFC-04)	1.7	18AAC75
TAH	**2,026**	(SW-1 - 1996)	**51.7** (RFC-04)	10	18AAC70
TAqH	**2,026(c)**	(SW-1 -1996)	**52** (RFC-04)	15	18AAC70

Definitions:

18 AAC 75 = ADEC Oil and Hazardous Substances Pollution Control Regulations, as amended through July 1, 2017
18 AAC 70 = ADEC Alaska Water Quality Standards, as amended through February 5, 2017
ORNL = Oak Ridge National Laboratory (ORNL) Tier II Secondary Chronic Surface Water Benchmark; from https://rais.ornl.gov/tools/eco_search.php
EPAWQC = EPA National Recommended Water Quality Criteria – Human Health Criteria Table: 2015; from https://epa.gov/wqc

RAO = remedial action objectives
GRO = gasoline-range organics
TAH = total aromatic hydrocarbons
mg/L = milligrams per liter
bgs = below ground surface
TCE = trichloroethene
EDB = 1,2-dibromoethane (ethylene dibromide)
TAqH = total aqueous hydrocarbons
mg/Kg = milligrams per kilogram
Y = samples received at pH>2
DRO = diesel-range organics

Results shown in **bold font** exceed the RAO.

Notes:
(a) 18 AAC 75.345 (b) (1) Table C Groundwater Cleanup Level
(b) Calculated cleanup level in accordance with 18 AAC 75.340(g); provided in ADEC Tech Memo 01-007.
(c) PAHs were not analyzed in this sample; therefore, the TAqH concentration is the same as the TAH concentration.
(d) Although petroleum hydrocarbon contamination remains in RAPCON smear zone soil and possibly under the RAPCON building foundation, soil cleanup has already been performed to the maximum extent practicable (i.e., excavation to the groundwater table followed by SVE/AS and bioventing). Therefore, no further active soil cleanup is practicable, although natural processes will continue to clean up the soil contamination over time.

6.3 PROJECT TASKS

6.3.1 RAPCON Groundwater Monitoring

Monitoring was conducted at RAPCON to document changes in contaminant concentrations in the groundwater. Groundwater monitoring was performed September 26, 2017. A list of the groundwater laboratory samples collected during this project is presented in Table 6-2. Groundwater sampling results are displayed on Figure 6-1 and in Table 6-4 and Table 6-5.

6.3.2 Red Fox Creek Sampling

To evaluate potential impacts to Red Fox Creek resulting from contamination at RAPCON, one surface water and two sediment samples were collected September 28, 2017, from two locations in a drainage ditch that flows by the RAPCON site into Red Fox Creek. A list of the surface water and sediment samples collected is presented in Table 6-3. The surface water and sediment sampling results are shown on Figure 6-2, Table 6-8, and Table 6-9.

Table 6-2: RAPCON Groundwater Sample Analyses Summary

Location ID Sample Point	Comments	Matrix	Location Type	Analytical Methods						
				8260C VOCs	8260C SIM	8011 EDB and 1,2,3-TCP AK2016	Alaska Method AK 102 DRO	Alaska Method AK 101 GRO	EPA Method 6010B Fe & Mn (dissolved)	Sample Number
FT01-FD9		Groundwater	Monitoring Well				1		1	17KS5ZFD9-101WG
MW-01		Groundwater	Monitoring Well				1	1	1	17KS5ZMW1-102WG
MW-02	MS/MSD	Groundwater	Monitoring Well	3	3	3	3	3	3	17KS5ZMW2-103WG
SVE-1	Upgradient	Groundwater	Monitoring Well				1		1	17KS5ZSV1-104WG
SVE-2	Upgradient	Groundwater	Monitoring Well	1	1	1	1	1	1	17KS5ZSV2-105WG
BV-17		Groundwater	Monitoring Well	1	1	1	1	1	1	17KS5ZBV17-106WG
Duplicate Sample	BV-17	Groundwater	Monitoring Well	1	1	1	1	1	1	17KS5ZMW3-107WG
Project Trip Blanks		Water	QA/QC	1	1	1		1		17KS5ZTB-MMDD
Water Analyses Totals				**7**	**7**	**7**	**9**	**8**	**9**	

Table 6-3: Red Fox Creek Surface Water/Sediment Sample Analyses Summary

Location ID Sample Point	Comments	Matrix	Location Type	8260C VOCs & LL	8260C SIM VOCs & LL	Method 8270D SIM PAHs+1&2-MethNap	Method SW3550 Percent Moisture	Sample Number
RFC-04	MS/MSD	Surface Water	Stream	3	3	3		17KS5ZRFC4-502WS
Duplicate Sample		Surface Water	Stream	1	1	1		17KS5ZRFC9-505WS
Surface Water Trip Blank		Water	QA/QC	1	1			17KS5ZTB-MMDD
Surface Water Analyses Total				**5**	**5**	**4**		
RFC-04	MS/MSD	Sediment	Stream Bed	6	6	3	3	17KS5ZRFC4-602SE
RFC-05		Sediment	Stream Bed	2	2	1	1	17KS5ZRFC5-603SE
Duplicate Sample		Sediment	Stream Bed	2	2	1	1	17KS5ZRFC9-605SE
Low-Level Trip Blank	Low Level Blank	Sediment	QA/QC	1	1			17KS5ZTB-MMDD
Sediment Trip Blank	Methanol and Silica	Sediment	QA/QC	1	1			17KS5ZTB-MMDD
Sediment Sample Analyses Totals				**12**	**12**	**5**	**5**	

LL - Low Level for sediment samples will be analyzed using a low level technique requiring samples be frozen for preservation.

1&2-MethNap - 1&2-Methylnaphthalene

6.4 RAPCON/RED FOX CREEK FINDINGS

6.4.1 RAPCON Groundwater Analytical Results

Analytical results are provided in Appendix C, Zone 5 Tables. Table 6-4 presents current and historical sample analytical results for the contaminants of potential concern at this site (benzene, total BTEX, DRO, GRO, and TCE). Table 6-5 presents a summary of 2017 analytical data.

6.4.1.1 Petroleum Hydrocarbons

One of the wells sampled for GRO exceeded the RAO of 2.2 mg/L. GRO concentrations ranged from 0.54 mg/L to 3.0 mg/L. Four of the six wells sampled for DRO exceeded the RAO of 1.5 mg/L. DRO concentrations ranged between 0.6 mg/L to 4.5 mg/L.

6.4.1.2 BTEX

VOCs samples were collected from FT01-MW02, SVE-2, and FT01-BV17. Benzene was detected in FT01-MW02 above the cleanup level and in FT01-BV17 below the cleanup level. Toluene was detected in all three of the wells at concentrations below cleanup levels. Ethylbenzene was detected in all three wells above cleanup levels. Total xylenes were detected in SVE-2 at above the cleanup level.

6.4.1.3 TCE

The concentration of TCE in FT01-MW02 and SVE-2 were ND, while the TCE concentration in FT01-BV17 was 0.56 µg/L, which is below the cleanup level of 2.8 µg/L.

6.4.1.4 Cis-1,2-Dichloroethene (Cis- DCE)

Cis-DCE was detected above the cleanup level in FT01-MW02 and below the cleanup level in SVE-2. Cis-DCE is an indicator of anaerobic degradation of TCE.

6.4.1.5 Iron

Iron concentrations detected in RAPCON groundwater ranged from 0.99 mg/L (FT01-MW01) to 14 mg/L (SVE-2). Higher iron concentrations correspond to the wells with the greatest petroleum hydrocarbon contamination, suggesting that natural biodegradation of the petroleum hydrocarbons is occurring.

6.4.1.6 Other VOC Results

FT01-MW02 and SVE-2 exceeded the cleanup levels for 1,2,4-trimethylbenzene and naphthalene. Appendix C presents a listing of all the detected analytes from the 2017 groundwater-monitoring event.

Table 6-4: Historical RAPCON Groundwater Analytical Data

Well	Analyte (RAO in mg/L)	8/16/01 (Paug-Vik)	10/21/01 (Paug-Vik)	9/26/02 (Paug-Vik)	5/13/2003 (Paug-Vik)	9/16/2003 (Paug-Vik)	9/22/04 (Paug-Vik)	9/21/2005 (Paug-Vik)	9/18/2006 (Paug-Vik)	8/2007 (Paug-Vik)	8/2008 (Paug-Vik)	9/2009 (Paug-Vik)	9/2010 (Paug-Vik)	8/2011 (Paug-Vik)	9/2012 (Paug-Vik)	9/2013 (Paug-Vik)	9/2014 (Paug-Vik)	9/2015 (Paug-Vik)	10/2016 (Paug-Vik)	10/2017 (Paug-Vik)
SVE-1	Benzene (0.0046)	**0.0083**	**0.0093**	**0.0137**	**0.0068**	**0.0089**	**0.0126**	**0.005**	0.0033	0.00279	0.00070	ND	0.00067	ND	0.00018	NS	NS	NS	NS	NS
	Total BTEX	0.319	0.285	0.7207	0.3145	0.4293	1.3446	0.587	0.553	0.578	0.392	0.399	0.816	0.302	0.81100	NS	NS	NS	NS	NS
	GRO (2.2)	1.09	0.945	**3.01**	1.65	1.23	**3.4**	1.58	1.67	1.35	1.3	1.6	**3.8**	1.2	0.78	NS	NS	NS	NS	NS
	DRO (1.5)	**2.61**	**8.74**	**3.96**	**2.7**	**3.71**	**6.88**	**4.94**	**4.35**	**3.16**	**1.5**	**1.6**	**2.0**	**1.5**	1.4	**1.5**	**1.6**	0.79	1.2	**1.9**
	TCE (0.0028)	0.0025	**0.0036**	**0.0069**	**0.0029**	**0.0042**	**0.0092**	ND	**0.0039**	ND	0.0019	0.0015	0.0019	0.00090	0.00082	NS	NS	NS	NS	NS
	EDB (0.000075)					**ND (0.001)**	**ND (0.001)**	**ND (0.001)**	**ND (0.001)**	**ND (0.001)**	**ND (0.002)**	**ND (0.01)**	ND (0.000019)	ND (0.000019)	ND	NS	NS	NS	NS	NS
	Iron	5.99	2.83	12.6	6.19	7.27	7.89	3.78	5.82	5.52	5.8	5.0	4.35	3.79	3.7	5.8	7.1	4.5	2.1	7.7
	DO	2.81	11.37	0.12	0.3	0.18	0.35	0.26	2.06	1.12	0.56	1.00	0.63	1.04	1.61	0.50	0.70	1.10	1.47	1.88
SVE-2	Benzene (0.0046)	**0.0905**	**0.0485**	**0.0865**	**0.0236**	**0.025**	**0.0172**	**0.00768**	**0.0163**	**0.00869**	**0.0063**	**0.0074**	0.0037	0.0013	0.0015	NS	NS	NS	NS	ND
	Total BTEX	1.9765	2.1025	4.3625	1.7496	1.3694	1.7422	0.511	2.909	2.69	2.86	2.05	1.10	0.156	0.461	NS	NS	NS	NS	1.07
	GRO (2.2)	**12.8**	**5.69**	**12.8**	**6.11**	**3.1**	**4.6**	**4.84**	**6.26**	**4.22**	**5.8**	**6.0**	**4.0**	0.57	2.000	**3.70**	**7.70**	2.0	**4.1**	**3.0**
	DRO (1.5)	**14.5**	**11.4**	**11.7**	**20**	**15.8**	**2.87**	**7.81**	**8.95**	**10.9**	**6.0**	**5.1**	**3.2**	1.40	**2.00**	**4.00**	**3.60**	**2.4**	**1.5**	**2.3**
	TCE (0.0028)	**0.162**	**0.0648**	**0.108**	**0.0581**	**0.060**	**0.0573**	**0.0248**	**0.0848**	**0.0478**	**0.060**	**0.017**	**0.011**	0.0027	**0.0042**	NS	NS	NS	NS	ND
	EDB (0.000075)					**0.0011**	**ND (0.001)**	**ND (0.001)**	**ND (0.001)**	**ND (0.001)**	**ND (0.002)**	**ND (0.04)**	0.0000088	0.000018	ND	NS	NS	NS	NS	ND
	Iron	22.7	17	20.6	16.5	11.2	7.44	6.77	11.1	9.05	10.5	7.2	4.7	2.26	7.5	14.00	13.00	12.00	12.00	14.00
	DO	0.91	9.82		0.25	0.22	0.54	0.23	1.77	0.94	0.57	0.67	2.19	0.61	1.32	0.65	0.63	0.71	0.63	0.84
FT01-FD9	Benzene (0.0046)	0.0016	ND (0.0003)	ND (0.0005)	**0.0139**	**0.0219**	**0.0157**	**0.021**	**0.0105**	**0.0155**	**0.0075**	0.0012	0.0031	0.0022	0.00047	NS	NS	NS	NS	NS
	Total BTEX	0.0483	0.1503	0.079	0.0846	0.0661	0.1294	0.115	0.054	0.1537	0.207	0.087	0.129	0.134	0.27	NS	NS	NS	NS	NS
	GRO (2.2)	0.533	0.571	0.479	0.531	0.435	0.93	0.807	0.41	0.965	0.43	1.1	1.1	1.0	1.1	NS	NS	NS	NS	NS
	DRO (1.5)	**41.1**	**15.1**	**5.62**	**8.74**	**11.3**	**9.09**	**6.73**	**6.85**	**5.26**	**2.6**	0.12	1.4	**2.0**	**1.7**	**1.8**	**1.9**	1.2	**1.7**	0.6
	TCE (0.0028)	**0.0145**	**0.0072**	**0.0036**	**0.0174**	**0.0374**	**0.0296**	**0.0401**	**0.0159**	**0.015**	**0.012**	**0.0042**	0.0023	0.0012	0.0022	NS	NS	NS	NS	NS
	EDB (0.000075)					**0.0007**	**ND (0.001)**	**ND (0.001)**	**ND (0.001)**	**ND (0.001)**	**ND (0.002)**	**ND (0.004)**	0.000014	ND(0.000019)	0.0000067	NS	NS	NS	NS	NS
	Iron	3.09	ND (0.062)	2.23	8.3	8.56	8.01	5.88	3.1	5.02	4.1	2.9	3.59	3.74	4.5	4.3	5.2	3.3	3.6	1.1
	DO	0.55	11.3	1.42	0.51	0.15	1.4	0.47	0.36	4.55	0.32	0.30	2.21	0.72	0.92	0.63	0.49	0.99	1.62	7.41
MW-01	Benzene (0.0046)	0.0039	ND (0.0003)	0.0006	**0.0264**	**0.0367**	**0.0162**	**0.00836**	**0.0115**	**0.00812**	**0.0073(0.0080)**	0.0023 (0.0029)	0.0024 (0.0023)	0.0025 (0.0022)	0.00049/0.00047	NS	NS	NS	NS	NS
	Total BTEX	0.3918	0.0631	0.3802	0.7986	0.3297	0.3966	0.181	0.174	0.1055	0.117(0.094)	0.263 (0.252)	0.126 (0.121)	0.214 (0.188)	0.035/0.023	NS	NS	NS	NS	NS
	GRO (2.2)	**2.95**	0.354	1.45	**2.75**	1.12	1.65	1.01	0.63	0.536	0.99(0.99)	1.5 (1.5)	1.6 (1.7)	1.6 (1.5)	0.44 (0.32)	0.57	**2.50**	1.20	**2.80**	1.4
	DRO (1.5)	**28.7**	**13.4**	**14.6**	**10.3**	**10.1**	**8.58**	**4.63**	**5.76**	**5.95**	**3.9 (3.5)**	**2.2 (2.2)**	**1.6 (1.7)**	**2.8 (2.3)**	0.37 (1.1)	1.4	0.8	1.4	1.2	**1.5**
	TCE (0.0028)	**0.0195**	**0.0051**	**0.0052**	**0.0298**	**0.0467**	**0.0295**	**0.0489**	**0.0201**	**0.0113**	**0.0082 (0.0080)**	**0.0053(0.0085)**	**0.0030(0.0028)**	0.0017 (0.0013)	0.0013/0.0014	NS	NS	NS	NS	NS
	EDB (0.000075)					**0.0006**	**ND (0.001)**	**ND (0.001)**	**ND (0.001)**	**ND (0.001)**	**ND (0.002)**	**ND (0.004)**	0.000022(0.000015)	0.000014 (0.000019)	0.000016 (0.000019)	NS	NS	NS	NS	NS
	PFOA (0.00040)																		**0.0033**	NS
	PFOS (0.00040)																		**0.0110**	NS
	Iron	7.51	ND (0.062)	6.1	10	12.8	9.94	8.47	6.33	6.86	7.2 (7.2)	5.6 (5.7)	5.6 (5.7)	3.59 (7.67)	3.3 (3.1)	3.60	15.00	10.00	2.90	0.99
	DO	0.28	10.85	0.48	0.21	0.15	0.38	0.22	0.33	4.56	0.59	0.4	0.4	0.5	0.25	0.32	0.55	0.44	0.72	0.58
MW-02	Benzene (0.0046)	ND (0.0003)	ND (0.0003)	ND (0.0005)	**0.0259**	**0.0484**	**0.0232**	**0.0124**	**0.0138**	**0.0197**	0.0042	**0.0050**	NS	**0.0071**	0.0038	0.0043 (0.0042)	0.00041 (0.00031)	0.0011	ND	**0.0048**
	Total BTEX	0.1901	0.2217	0.1957	0.2566	0.1794	0.1105	0.198	0.187	0.188	0.257	0.218	NS	0.336	0.6030	0.524 (0.6)	0.397 (0.183)	0.349	0.449	0.170
	GRO (2.2)	1.62	1.88	1.5	2.13	0.981	1.39	1.37	1.09	1.57	1.2	1.6	NS	**3.7**	**3.1**	**2.2**	1.9 (1.7)	1.4	1.9	1.3
	DRO (1.5)	**12.6**	**24.1**	**22.7**	**15.5**	**15**	**14.1**	**9.44**	**5.88**	**8.65**	**5.8**	**1.8**	NS	**5.1**	**3.8**	**3.3 (3.2)**	**2 (2.9)**	**2.7**	**2.2**	**4.5**
	TCE (0.0028)	0.0045	ND (0.005)	**0.0029**	**0.0235**	**0.0802**	**0.0842**	**0.0793**	**0.0334**	**0.0221**	**0.0097**	**0.0070**	NS	**0.011**	**0.0088**	0.0012 (0.0011)	0.00039(0.00032)	0.00093	ND	ND
	EDB (0.000075)					**ND (0.001)**	**ND (0.001)**	**ND (0.001)**	**ND (0.001)**	**ND (0.001)**	**ND (0.002)**	**ND (0.01)**	NS	ND (0.000020)	ND	NS	NS	NS	NS	ND
	Iron	6.97	13.7	6.9	11.2	14.4	6.72	10.5	7.79	4.94	9.0	6.8	NS	8.6	11.0	11	11	10	11	11
	DO	0.19	0.75	NM	0.13	0.11	0.4	0.27	0.27	4.63	0.34	0.54	NS	0.10	0.35	0.34	0.72	0.54	0.80	0.85
BV-17	Benzene (0.0046)							0.00285	ND	ND	0.0031	0.00047	0.00039	0.00020	0.0037	0.002	0.0014	0.0004(0.00035)	ND	0.0002
	Total BTEX							0.00468	ND	ND	0.0043	0.00047	0.0029	0.0026	0.265	0.21	0.9114	0.081	0.658 (0.649)	0.07
	GRO (2.2)							0.043	0.04	0.012	1.5	0.22	0.24	0.16	0.99	1.1	**3.9**	0.46 (0.45)	**2.6 (2.7)**	0.54 (0.57)
	DRO (1.5)							**2.26**	0.88	**3.72**	**4.4**	**2.0**	1.0	0.80	1.3	**2**	**2.5**	0.95 (0.85)	**1.9 (2.1)**	1.4 (0.7)
	TCE (0.0028)							**0.00737**	ND	0.00072	**0.0076**	0.0021	0.00098	0.00061	**0.0042**	**0.0033**	**0.0052**	0.0017	**0.0032 (0.0031)**	0.00055
	EDB (0.000075)							**ND (0.001)**	**ND (0.001)**	**ND (0.001)**	**ND (0.002)**	**ND (0.002)**	ND (0.000019)	0.0000097	0.00001	NS	NS	NS	NS	0.0000071
	Iron							ND	ND	ND	ND	0.0980	0.0283	0.359	1.2	1.1	1.4	0.73 (0.76)	2.1	1.3 (1.4)
	DO							1.8	10.3	12.05	0.4	0.65	0.28	0.45	0.51	0.60	1.05	0.59	0.95	0.78

NS - Not Sampled

ND - Not detected above method reporting level (MRL)

RAO - Remedial action objectives

Analytical results exceeding RAOs shown in **BOLD**.

(Results) are duplicate samples.

Table 6-5: Summary of Zone 5 A-Aquifer Analytical Data

Well Number	DRO (mg/L)	GRO (mg/L)	TCE (ug/L)	Ferrous Iron (mg/L)	Manga-nese (mg/L)	DO (mg/L)	ORP (mV)	pH	Con. (µS/cm)
RAO	**1.5**	**2.2**	**2.8**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
FD-9	0.60	NA*	NA*	1.1	1.8	7.41	143.6	5.79	42
MW-01	**1.5**	1.4	NA*	0.99	2.9	0.58	36.2	6.51	180
MW-02	**4.5**	1.3	ND	11	4.2	0.85	45.1	6.09	135
SVE-1	**1.9**	NA*	NA*	7.7	4.6	1.88	86.2	6.1	212
SVE-2	**2.3**	**3.0**	ND	14	4.2	0.84	21	6.17	213
BV-17	1.4 (0.70)	0.54 (0.57)	0.56 (0.55)	1.3 (1.4)	6.5 (7.1)	0.78	18.1	6.5	258

NA* - Not Analyzed

NA - Not Applicable

ND - Not detected above method reporting level (MRL)

RAO - Remedial action objectives

Analytical results exceeding RAOs shown in **BOLD.**

(Results) are duplicate samples.

6.4.2 RAPCON Statistical Trend Analysis

The ProUCL software, Version 5.1 was used to assess benzene, DRO, GRO, and TCE concentration trends for six RAPCON monitoring wells. Output from this program can be found in Appendix E. Table 6-6 and Table 6-7 summarize the concentration trends observed in six key monitoring wells (FT01-BV1, FT01-FD9, FT01-MW01, FT01-SVE1, and FT01-SVE2) with historical concentrations of contaminants near or above RAOs. The tables list the numbers of wells exhibiting a specific concentration trend for benzene, DRO, GRO, and TCE. Well location data sets which did not have the minimum number of four observations, where the results were all below the reporting limit for a specific analyte, or were not sampled for a particular analyte are not included in the trend summary table. Note that 56% of the concentration trends were decreasing and 6% were increasing. Another 38% of the concentration trends showed no trend. Overall, since the majority of concentration trends are decreasing, the trend analysis supports the conclusion that intrinsic remediation is keeping contaminant concentrations stable or decreasing at this site.

Table 6-6 RAPCON Mann-Kendall Analysis Summary

Trend	Benzene	DRO	GRO	TCE	% of Total
Decreasing	1	5	1	2	56%
Increasing	0	0	1	0	6%
No Trend	2	1	2	1	38%
Totals	3	6	4	3	16

Table 6-7 RAPCON Mann-Kendall Trend Summary

Well	Benzene	DRO	GRO	TCE
FT01-BV17	NT	NT	**I**	NT
FT01-FD9	NA	**D**	NA	NA
FT01-MW01	NA	**D**	NT	NA
FT01-MW02	NT	**D**	NT	**D**
FT01-SVE1	NA	**D**	NA	NA
FT01-SVE2	**D**	**D**	**D**	**D**

D - Decreasing I – Increasing
NT – No Trend NA – Not Analyzed

6.4.3 Red Fox Creek Surface Water Analytical Results

Surface water contaminant levels detected in the RFC-04 sample were compared to regulatory criteria and benchmark screening levels. The AWQS in 18 AAC 70 provides regulatory criteria for surface water. Analytical results are shown in Appendix C, Zone 5 Tables. Table 6-8 presents current and historical surface water sample analytical results for selected COCs at Red Fox Creek.

6.4.3.1 Petroleum Hydrocarbons

RFC-04 surface water was not analyzed for DRO and GRO. Low levels of several PAHs (1-methylnaphthalene, 2-methylnaphthalene, and naphthalene) were detected the RFC-04 surface water sample.

6.4.3.2 VOCs

The m,p-Xylene concentration (28/31 µg/L) in the sample from RFC-04 exceeded the applicable water quality criteria of 1.8 µg/L. Ethylbenzene (11 µg/L) exceeded the water quality criteria of 7.3 µg/L. The TAH (BTEX) concentration of 61.75 (70.34) µg/L and TAqH (BTEX + PAH) concentration of 62.67 (70.97) µg/L detected in RFC-04 were above the water quality criteria of 10 µg/L and 15 µg/L respectively.

6.4.4 Sediment Analytical Results

There are no regulatory criteria for sediment samples; sediment analytical results are evaluated using the NOAA SQuiRT (NOAA, 2008) and benchmark screening levels found on ORNL's Risk Assessment Information System (ORNL, 2017). Table 6-8 presents current and historical sediment sample analytical results for selected contaminants of potential concern at Red Fox Creek.

6.4.4.1 Petroleum Hydrocarbons

RFC-04 and RFC-05 were not analyzed for DRO and GRO. RFC-04 exceeded the screening criteria for 2-methylnaphthalene, acenaphthylene, fluorene, and naphthalene. Pyrene was the only PAH detected in the sample from RFC-05.

6.4.4.2 VOCs

Sediment samples were collected for low level (frozen) and medium level (methanol preservation) analysis. There are no low level sample results for RFC-04 because target and non-target analytes were too highly concentrated to be analyzed by low level analysis. Acetone was detected in RFC-04 and RFC-05 above screening criteria, and naphthalene was detected above screening criteria in RFC-04. TCE was also detected in RFC-05 at 3.4 µg/Kg. The TCE and acetone results for RFC-05 are biased low due to the analysis occurring after the sample holding time expired.

6.4.5 Institutional Control Inspection

There were no indications that drinking water wells have been installed or that excavating has occurred.

6.4.6 Condition of Wells

The six wells scheduled for Zone 5 were sampled and in good condition.

Table 6-8: Historical Red Fox Creek Surface Water Analytical Data

Location	Location	Analyte	Water Quality Criteria	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
RFC-01	Located in drainage ditch upgradient of RAPCON site.	TAH	0.01	ND	0.0004	0.0048	ND	ND	ND	0.00012 (ND)	ND	ND	ND	ND	NS	NS	NS	NS	NS
		TAqH (mg/L)	0.015	ND	**0.017**	0.0048	ND	ND	ND	0.00012 (ND)	ND	0.000009(0.0000047)	ND	0.0000185 (0.0000097)	NS	NS	NS	NS	NS
		GRO (mg/L)	NA	NS	ND	0.058 F VB	ND	ND	0.0108	0.014 (0.041)	ND	ND	ND	ND	NS	NS	NS	NS	NS
		DRO (mg/L)	NA	ND	0.303 VBJM	2.19 VM	0.14 F VM	0.269 VBJM	0.434	0.17 (0.28)	0.11 (0.15)	0.12	0.16 (0.15)	0.083 (0.077)	NS	NS	NS	NS	NS
		TCE (mg/L)	0.021	ND	ND	ND	ND	ND	ND	ND	ND	0.00018	0.00020(0.00021)	ND	NS	NS	NS	NS	NS
		cis-1,2-DCE (mg/L)	0.07	ND	ND	0.00094 F	ND	ND	ND	0.0001 (ND)	ND	ND	ND	ND	NS	NS	NS	NS	NS
		Benzene (mg/L)	0.0046	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
		m,p-Xylene (mg/L)	0.0018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
		o-Xylene (mg/L)	0.013	ND	ND	ND	ND	ND	ND	0.00012 (ND)	ND	ND	ND	ND	NS	NS	NS	NS	NS
		Naphthalene (mg/L)	0.0017	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
RFC-04	Located in drainage ditch adjacent to the RAPCON site.	TAH (mg/L)	0.01		**0.071**	0.011		**0.0517**	**0.0166**	**0.0311**	**0.0521**	**0.036**	**0.159**	0.0065	**0.06 (0.065)**	**0.089 (0.0394)**	**0.099 (0.0663)**	**0.257 (0.292)**	**0.062 (0.070)**
		TAqH (mg/L)	0.015		**0.072**	0.011		**0.052**	**0.0170**	**0.0330**	**0.0526**	**0.037**	**0.162**	0.0117	**0.064 (0.069)**	**0.09217 (0.0513)**	**0.109 (0.0727)**	**0.259 (0.293)**	**0.0.063 (0.071)**
		GRO (mg/L)	NA		0.463 VM	0.13		0.352 VM	0.114	0.26	0.30	0.26	0.94	0.63	NA	NA	NA	NA	NA
		DRO (mg/L)	NA		2.49 VM	3.5 VM		1.75 VJM	4.30	2.30	0.12	1.3	2.8	0.83	NA	NA	NA	NA	NA
		TCE (mg/L)	0.021		0.0014	ND		0.00106 VJ	0.00104	0.0010	0.00055	0.0012	0.00095	0.00047	0.00054(0.00061)	0.0002 (ND)	0.00045(0.00026)	ND	0.00016 (0.00018)
		cis-1,2-DCE (mg/L)	0.07		0.0149	0.0078		0.0136 VJ	0.0032	0.0085	0.0052	0.0055	0.0058	0.00480	0.0078(0.0077)	0.0044 (0.0028)	0.0044(0.0034)	0.009 (0.0073)	0.0016 (0.0014)
		Benzene (mg/L)	0.0046		**0.0068**	0.00106		0.00218 VJ	0.00041	0.0023	0.0011	0.00066	0.00054	0.00051	0.00077(0.00085)	ND	ND	ND	0.00015 (0.00014)
		m,p-Xylene (mg/L)	0.0018		**0.0231**	**0.00313**		**0.0172 VJ**	**0.00553**	**0.014**	**0.024**	**0.012**	**0.065**	**0.069**	**0.023 (0.025)**	**0.046 (0.017)**	**0.052 (0.032)**	**0.16 (0.18)**	**0.028 (0.031)**
		o-Xylene (mg/L)	0.013		**0.0323**	0.00503		**0.0273 VJ**	0.0090	0.0094	**0.016**	**0.016**	**0.083**	**0.062**	**0.021 (0.022)**	**0.023 (0.013)**	**0.023 (0.017)**	**0.033 (0.035)**	**0.021 (0.027)**
		Naphthalene (mg/L)	0.0017		**0.0122**	0.0016		0.0068 VJ	0.00004	0.00064	**0.0042**	**0.0039**	**0.0064**	**0.014**	**0.015 (0.015)**	**0.01 (0.004)**	**0.0059 (0.0036)**	**0.051 (0.058)**	**0.0043 (0.0052)**
RFC-05	Located in drainage ditch downgradient from RAPCON site and just before confluence with Red Fox Creek.	TAH (mg/L)	0.01	ND	**0.011**	0.0027	**0.0128**	0.0015	ND	0.0012	0.00043	ND	**0.022**	**0.022**	0.0022	0.00047	NS	NS	NS
		TAqH (mg/L)	0.015	ND	0.012	0.0028	0.0132	0.0015	ND	0.0012	0.00043	ND	**0.022**	**0.023**	0.00227	0.00048	NS	NS	NS
		GRO (mg/L)	NA	NS	0.083 F VM	0.0193 F VB	0.105	0.032 F VM	ND	0.015	ND	ND	0.16	0.15	NA	NA	NS	NS	NS
		DRO (mg/L)	NA	ND	2.09 VM	0.865 VM	1.26 VM	1.47 VJM	1.6	1.0	0.79	0.36	0.99	0.36	NA	NA	NS	NS	NS
		TCE (mg/L)	0.021	ND	0.0006	0.00045 F	0.00089	0.00047 F VJ	ND	0.00053	0.00056	0.00055	0.00082	0.00031	0.00029	ND	NS	NS	NS
		cis-1,2-DCE (mg/L)	0.07	ND	0.0036	ND	0.00405	0.00224 VJ	ND	0.00080	0.00030	0.00038	0.0015	0.001	0.00044	ND	NS	NS	NS
		Benzene (mg/L)	0.0046	ND	0.0026	ND	0.00071	0.00024 VJ	ND	ND	ND	ND	0.00021	ND	ND	ND	NS	NS	NS
		m,p-Xylene (mg/L)	0.0018	ND	**0.0024**	ND	**0.00302**	ND	ND	ND	ND	ND	**0.0067**	**0.0081**	0.00062	0.0002	NS	NS	NS
		o-Xylene (mg/L)	0.013	ND	0.004	ND	0.0078	0.00122 VJ	ND	ND	ND	ND	**0.013**	0.01	0.00083	0.00027	NS	NS	NS
		Naphthalene (mg/L)	0.0017	ND	0.0019	0.000017	0.0025	0.00065 F VJ	ND	0.0000043	0.00015	ND	0.00092	**0.002**	0.001	ND	NS	NS	NS
RFC-07	Located in Red Fox Creek drainage downgradient from where RAPCON drainage ditch enters.	TAH (mg/L)	0.01				0.001	0.00056	ND	0.0012	0.00039	0.00048	ND	0.0007	NS	NS	NS	NS	NS
		TAqH (mg/L)	0.015				0.001	0.00078	ND	0.0012	0.00039	0.00048	0.0000082	0.00071	NS	NS	NS	NS	NS
		GRO (mg/L)	NA				ND	ND	ND	0.050	ND	ND	ND	0.008	NS	NS	NS	NS	NS
		DRO (mg/L)	NA				0.435 VM	0.494 VJM	1.56	0.80	0.22	0.11	0.18	0.10	NS	NS	NS	NS	NS
		TCE (mg/L)	0.021				ND	ND	ND	ND	ND	ND	0.00015	ND	NS	NS	NS	NS	NS
		cis-1,2-DCE (ug/L)	0.07				0.0004	ND	ND	0.00011	ND	ND	0.00012	ND	NS	NS	NS	NS	NS
		Benzene (ug/L)	0.0046				ND	ND	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
		m,p-Xylene (mg/L)	0.0018				ND	ND	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
		o-Xylene (mg/L)	0.013				0.00035	ND	ND	ND	ND	ND	ND	0.00029	NS	NS	NS	NS	NS
		Naphthalene (ug/L)	0.0017				ND	0.000094 F VJ	ND	0.0000084	ND	ND	ND	**0.0076**	NS	NS	NS	NS	NS

Notes:

Results shown in **BOLD** exceed ADEC 18 AAC 70 Water Quality Criteria.

TCE - Trichloroethene, cis-1,2-DCE - cis-1,2-Dichloroethene

TAH - Total Aromatic Hydrocarbons (BTEX)

TAqH - Total Aqueous Hydrocarbons (TAH + PAH)

Results in parentheses are duplicate samples.

NA - Not Analyzed

NS - Not Sampled

ND - Not Detected

Table 6-9: Historical Red Fox Creek Sediment Analytical Data

Location	Analyte	Criteria	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
RFC1	GRO (mg/Kg)	NA	NS	0.499 F VJ	1.22 F VB	0.471 F VBJ	0.638 F VJ	0.461	NS	ND	ND (2.9)	3.2 (3.5)	ND	NS	NS	NS	NS	NS
	DRO (mg/Kg)	NA	216 VJM	227 VJ	87.9	115 F	216 F VJ	54	20 (73)	330 (240)	52 (50)	100 (100)	58 (72)	NS	NS	NS	NS	NS
	Anthracene (mg/Kg)	0.01	**0.0107 VM**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
	Chrysene (mg/Kg)	0.02683	**0.0305 VJM**	ND	ND	ND	ND	0.0123	0.016 (0.012)	ND	0.016 (0.025)	0.010 (ND)	ND	NS	NS	NS	NS	NS
	Fluorene (mg/Kg)	0.01	**0.0844 VJM**	ND	ND	**0.0381 F**	ND	**0.0151**	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
	Naphthalene (mg/Kg)	0.01465	ND	**0.0318 F VM**	ND	ND	ND	0.00453	ND	ND (0.0039)	ND (0.0042)	0.0025 (0.0030)	0.001/ND	NS	NS	NS	NS	NS
	Xylenes (mg/Kg)	0.025	ND	ND	ND	ND	ND	ND	ND (0.01)	ND	ND	ND	ND	NS	NS	NS	NS	NS
	Acetone (mg/Kg)	0.0099	ND	ND	**0.0161 VJM**	**0.046 F VBJ**	**0.38**	ND	**0.023 (0.074)**	**0.051 (0.19)**	**0.12 (0.039)**	ND	0.0036 (0.0093)	NS	NS	NS	NS	NS
	TCE (mg/Kg)	0.04	ND	ND	0.00088 F VJM	ND	ND	ND	0.0012 (0.0015)	0.0054 (ND)	0.0010 (0.0011)	ND	ND	NS	NS	NS	NS	NS
	cis-1,2-DCE (mg/Kg)	0.4	ND	ND	0.00113 F VJM	ND	ND	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
RFC4	GRO (mg/Kg)	NA		3.11	1.07 F VBJ		131 VJ	8.63	NS	38	36	110	33	NA	NA	NA	NA	NA
	DRO (mg/Kg)	NA		826 VJ	492		3,100 VJ	683	140	64	120	370	240	NA	NA	NA	NA	NA
	Anthracene (mg/Kg)	0.01		ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Chrysene (mg/Kg)	0.02683		**0.0527 F VM**	ND		ND	ND	0.0053	ND	ND	ND	ND	0.019 (0.0013)	0.0029 (0.0068)	ND	ND	ND
	Fluorene (mg/Kg)	0.01		**0.049 F VM**	ND		**0.111 F VJ**	**0.0403**	**0.030**	0.004	0.016	ND	ND	**0.044 (0.017)**	**0.037 (0.059)**	**0.046 (0.050)**	**0.049 (0.058)**	**0.14 (0.045)**
	Naphthalene (mg/Kg)	0.01465		**0.391 VM**	**0.639 VM**		**0.905 VJ**	**0.212**	**0.260**	**0.470**	**0.22**	**0.84**	**0.18**	**0.16 (0.24)**	**2.4 (1.8)**	**1.2 (0.92)**	**2 (5.3)**	**3.6 (2.7)**
	Xylenes (mg/Kg)	0.025		**0.0313 VM**	**0.0965 VJM**		**0.12**	**0.0425**	**0.79**	**1.0**	**0.29**	**1.1**	**0.064**	**0.13 (0.24)**	**7.3 (4.51)**	**3.165 (2.557)**	**9.15 (17.9)**	**2.3 (1.9)**
	Acetone (mg/Kg)	0.0099		ND	**0.0257 VJM**		ND	ND	**0.18**	**0.033**	**0.032**	**0.19**	**0.15**	**0.11**	ND **(0.17)**	ND	ND	ND **(0.086)**
	TCE (mg/Kg)	0.04		0.0008 F VM	ND		ND	ND	0.0018	ND	ND	0.0024	0.00073	ND	ND	ND	ND	ND
	cis-1,2-DCE (mg/Kg)	0.4		0.0299 VM	0.0185 VJM		ND	ND	0.013	0.0042	0.0021	0.0020	0.0012	ND	0.0150	ND	ND	ND
RFC5	GRO (mg/Kg)	NA	NS	ND	0.391 F VBJ	ND VJ	1.67 F VJ	ND	NS	ND	ND	3.2	ND	NA	NA	NA	NA	NA
	DRO (mg/Kg)	NA	57.4 VJM	26.2 F VJ	89.4 F	37 F	53.1 F VJ	21.2	9.6	7.7	22	24	11	NA	NA	NA	NA	NA
	Anthracene (mg/Kg)	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Chrysene (mg/Kg)	0.02683	0.0102 VJM	ND	ND	ND	ND	ND	0.00047	ND	ND	ND	0.00085	ND	0.0018	ND	ND	ND
	Fluorene (mg/Kg)	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Naphthalene (mg/Kg)	0.01465	ND	0.0038 F VBM	ND	0.0007 F VBJ	ND	ND	0.0043	ND	0.0091	0.0098	0.00046	ND	**0.017**	**0.02**	**0.025**	ND
	Xylenes (mg/Kg)	0.025	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**0.057**	ND
	Acetone (mg/Kg)	0.0099	ND	ND	**0.0128 VJM**	**0.046 F VBJ**	**0.43**	ND	**0.14**	**0.13**	**0.32**	**0.19**	**0.36**	**0.12**	**0.14**	**0.025**	**0.02**	**0.23**
	TCE (mg/Kg)	0.04	ND	ND	ND	0.0024 F VJ	ND	ND	0.0030	0.0150	0.0018	0.0015	ND	0.0084	ND	ND	0.00076	0.0034
	cis-1,2-DCE (mg/Kg)	0.4	ND	ND	ND	0.0026 F VJ	ND	ND	0.0027	ND	ND	ND	ND	ND	ND	ND	ND	ND
RFC7	GRO (mg/Kg)	NA				1.43 F VBJ	ND VJ	ND	NS	ND	ND	5.7	ND	NS	NS	NS	NS	NS
	DRO (mg/Kg)	NA				48.7 F	626 F VJ	114	28	14	7.8	32	9.2	NS	NS	NS	NS	NS
	Anthracene (mg/Kg)	0.01						ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
	Chrysene (mg/Kg)	0.02683						ND	ND	ND	ND	ND	0.0015	NS	NS	NS	NS	NS
	Fluorene (mg/Kg)	0.01				ND	ND	**0.0166**	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
	Naphthalene (mg/Kg)	0.01465				ND	ND	ND	0.0023	ND	ND	0.011	0.00066	NS	NS	NS	NS	NS
	Xylenes (mg/Kg)	0.025						ND	0.012	ND	ND	0.010	ND	NS	NS	NS	NS	NS
	Acetone (mg/Kg)	0.0099				**0.108 VBJ**	**0.63**	ND	**0.30**	**0.52**	**0.12**	**0.47**	**0.48**	NS	NS	NS	NS	NS
	TCE (mg/Kg)	0.04				ND	ND	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS
	cis-1,2-DCE (mg/Kg)	0.4				ND	ND	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS	NS

Results shown in **BOLD** exceed Sediment Benchmark Screening Criteria.

TCE - Trichloroethene, cis-1,2-DCE - cis-1,2-Dichloroethene

Results in parentheses indicated duplicate sample.

NA - Not Analyzed

NS - Not Sampled

6.5 RAPCON/RED FOX CREEK CONCLUSIONS

6.5.1 RAPCON Groundwater

Information gained from the 2017 field activities was reviewed along with previous investigation results to draw conclusions on the progress of monitored natural attenuation at the RAPCON site. The ProUCL statistics analysis of groundwater contaminants revealed that 56% of concentration trends are decreasing. Since the majority of concentration trends are decreasing, this indicates that intrinsic remediation is attenuating contaminants, or at the very least keeping contaminant concentrations in check.

Detected groundwater contaminant concentrations in 2017 were generally lower for GRO and higher for DRO than last year’s results. High iron concentrations in groundwater continue to correlate with higher petroleum hydrocarbon concentrations in the monitoring wells, thus providing evidence for natural biodegradation of petroleum compounds. Depleted dissolved oxygen levels in all of the wells with higher DRO is another indication that aerobic biodegradation has occurred.

Concentrations of 1,2,4-trimethylbenzene, ethylbenzene, total xylenes, and naphthalene exceeded ADEC cleanup levels in monitoring wells MW-2 and SVE-2. The sample from BV-17 also had an ethylbenzene concentration of 29 µg/L, which exceeded the ADEC cleanup level of 15 µg/L.

6.5.2 Red Fox Creek Sampling

Contaminants detected in the surface water at RFC-04 in 2017 are generally similar to those detected the two previous monitoring events with TAH, TAqH, xylenes, and naphthalene above water quality criteria.

Naphthalene, fluorene, and xylenes remain above sediment screening criteria at RFC-04. Acetone was also above the screening criteria at RFC-05. TCE was detected in the low level sediment sample from RFC-05 below screening criteria.

6.6 RAPCON/RED FOX CREEK RECOMMENDATIONS

- Sampling in Zone 5 RAPCON/Red Fox Creek should continue without changes.
- Any recommendations are subject to change pending conversations between ADEC and AFCEC, and any comment resolution outcomes on ADEC’s comments for the Five-Year Review.

NOTE:
1. ONLY ANALYTES EXCEEDING A CLEANUP LEVEL IN AT LEAST ONE SAMPLING EVENT ARE SHOWN ON THIS FIGURE.

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18–KS–LTM–RPT–F6–1.DWG PLOT: 1/10/18.

FIGURE
6-1

RAPCON GROUNDWATER ANALYTICAL RESULTS

RAPCON AND RED FOX CREEK
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE	JAN. 2018
CHKD	H.L.H.
DRAWN	C.E.H.
PROJ. NO	17040

EXPLANATION

RFC–04 ⊙	SURFACE WATER/SEDIMENT SAMPLE LOCATIONS
TCE	TRICHLOROETHENE CONCENTRATION
ACE	ACETONE CONCENTRATION
FLE	FLUORENE CONCENTRATION
NAP	NAPHTHALENE CONCENTRATION
X	XYLENES CONCENTRATION
TAH	TOTAL AROMATIC HYDROCARBONS CONCENTRATION
TAqH	TOTAL AQUEOUS HYDROCARBONS CONCENTRATION
(SED)	SEDIMENT (mg/Kg)
(SW)	SURFACE WATER (mg/L)
ND	NOT DETECTED
0.14	RESULT EXCEEDING RAO AND/OR WATER QUALITY CRITERIA

RAO CLEANUP LEVELS

SEE TABLE 6–8 FOR SURFACE WATER RAOs.
SEE TABLE 6–9 FOR SEDIMENT RAOs.

➡ GROUNDWATER FLOW DIRECTION

RFC–04
TCE (SED/SW) ND/0.00016
ACE (SED/SW) ND/0.011
FLE (SED) **0.14**
NAP (SED/SW) **3.6/0.0043**
X (SED/SW) **2.29/0.049**
TAH (SW) **0.062**
TAqH (SW) **0.063**

DUPLICATE
TCE (SED/SW) ND/0.00018
ACE (SED/SW) **0.086**/0.0094
FLE (SED) **0.045**
NAP (SED/SW) **2.7/0.0052**
X (SED/SW) **1.9/0.058**
TAH (SW) **0.07**
TAqH (SW) **0.071**

RFC–05
TCE (SED) 0.0034
ACE (SED) **0.23**
FLE (SED) ND
NAP (SED) ND
X (SED) ND

FIGURE **6-2**

RED FOX CREEK SURFACE WATER AND SEDIMENT ANALYTICAL RESULTS

RAPCON AND RED FOX CREEK
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE	JULY 2018
CHKD	H.L.H.
DRAWN	C.E.H.
PROJ. NO	17040

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18-KS-LTM-RPT-F6-2.DWG PLOT: 7/30/18.

7 ZONE 6 – RAPIDS CAMP

Groundwater Zone 6 (Rapids Camp) is located on the northern bank of the Naknek River, roughly 4 miles southeast of KSD. The camp occupies about 12.5 acres of land and was established in 1952 as part of a USAF program to build facilities for "morale, recreation, and welfare." Included were boat docks, fish camps, lodging, and a fuel storage area. The camp was closed in 1977, and all structures and tanks have been removed. All groundwater contaminant concentrations in the Rapids Camp area were below the appropriate regulatory requirements, and in 2008, eight monitoring wells were decommissioned. The only remaining data needs are satisfied by long-term monitoring of the landfill site.

An inspection was conducted in the Rapids Camp Landfill (LF003) following the requirements of the ROD (USAF, 2000). The primary objective is monitoring the landfill cap to make sure it is acting as a competent cover for landfilled materials. The document entitled *Final Operation, Monitoring, and Maintenance Manual, North and South Barrel Bluffs, King Salmon, Alaska* (Hart Crowser, 2000) was used as a guide for the inspection activities performed at the landfill.

7.1 RAPIDS CAMP LANDFILL INSPECTION

Slopes, vegetation, and erosion-control features at Rapids Camp Landfill (Site LF003) were inspected on September 23, 2016. The inspection was documented on the Landfill Inspection Form, which has been included in Appendix A. Photographs can be found in Appendix F. During this inspection, there was no evidence of erosion of the landfill cap. No sinkholes were observed. Vegetation cover was estimated at 100%, and the vegetation, consisting of birch, alder, and grass, was in good conditions.

Institutional controls listed in the Zone 6 ROD prohibit drinking water wells within 100 feet of the boundaries of the former generator pad and landfill, excavation of soils deeper than five feet bgs in the area of the former generator pad, and excavation or construction in the area of the landfill. Bristol Bay Telephone dug a trench to bury a cable. The trench was near the powerline and went through the generator pad portion of the area. They stated they encountered some debris below the surface, but they were able to leave it in place. Some metal runway material was left above ground at the bottom of the hill where they constructed a small pad. There were no other observations of noncompliance of institutional controls at the former landfill or generator pad.

7.2 ZONE 6 RECOMMENDATIONS

- ADEC should be petitioned for Site Status change to Cleanup Complete with Institutional Controls.
- Any recommendations are subject to change pending conversations between ADEC and AFCEC, and any comment resolution outcomes on ADEC's comments for the Five-Year Review.

FIGURE
7-1

LANDFILL INVESTIGATION
GROUNDWATER ZONE 6

NAKNEK RECREATIONAL CAMP (RAPIDS CAMP GWZ6)
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE
JAN. 2018
CHKD
H.L.H.
DRAWN
C.E.H.
PROJ. NO
17040

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18-KS-LTM-RPT-F7-1.DWG PLOT: 1/10/18.

8 ZONE 7 – LAKE CAMP

Historical spills and operational practices at Lake Camp have resulted in contamination of groundwater with petroleum-based products. In 2009, approximately 255 cubic yards of POL contaminated soil were excavated from SS004, a former vehicle maintenance site. Another 900 cubic yards were excavated from SS005. A fuel storage tank to supply fuel for a generator was previously located at SS005. Both excavations were to groundwater at approximately 4-5 feet below ground surface. Sheen was observed on the groundwater. No groundwater samples were collected in 2009. A complete description of excavation activities can be found in *Remedial Action Projects, King Salmon, Airport (Paug-Vik, November, 2012).*

The Air Force has contracted through the Corps of Engineers to complete a Record of Decision for Zone 7.

8.1 DESCRIPTION OF CURRENT STUDY

The purpose of the current study was to collect groundwater samples from two monitoring wells and two well points located at SS0004, two monitoring wells located at SS005, and one monitoring well located at LF001. The data collected during this project includes concentrations of DRO and MNA parameters in groundwater.

A land use control inspection was also conducted to ensure no drinking water wells have been installed or unauthorized excavating has occurred.

8.2 REMEDIAL ACTION OBJECTIVES FOR ZONE 7

RAOs for Lake Camp are ADEC cleanup levels. The RAOs are listed in Table 8.1.

Table 8-1 Cleanup Levels for Lake Camp

	Site Data			**Regulatory Criteria**	
Media	Chemical of Concern	Maximum Conc. (Location, Date)	Maximum Conc. 2000 (Location)	Regulatory Criteria for Unrestricted Use	Basis
Ground-water (mg/L)	DRO	**12** (MW-08, 2000)	**12** (MW-08)	1.5	18AAC75 Table C
Soil (mg/Kg)	DRO	**54,000** (0-2' SB-05 2000)	**54,000** (0-2' SB-05)	230	18AAC75. Method Two
	PAHs[2]	*		various	18AAC75. Method Two

Notes:

** Because polynuclear aromatic hydrocarbons (PAHs) are commonly associated with DRO contamination, they are considered to be potential COCs for these sites. There has been no PAH analysis of soil samples at SS004 and SS005 to confirm the presence or absence of PAHs in site soil. Regulated PAHs include the following compounds: acenaphthene, anthracene, benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, and pyrene.*

*Results exceeding cleanup levels are shown in **bold** font.*

Definitions:

18AAC75 = Oil and Hazardous Substances Pollution Control Regulations

Method Two refers to the 18 AAC 75.341 Method Two Table B1 or Table B2 (Under 40-inch zone) soil cleanup levels, which are protective of residential land use and migration to groundwater (unlimited use/unrestricted exposure).

Table C refers to the 18 AAC 75.345 Table C groundwater cleanup levels, which are protective of drinking water.

RAOs = remedial action objectives
DRO = diesel-range organics
bgs = below ground surface
PAH = polynuclear aromatic hydrocarbons
mg/L = milligrams per liter
mg/Kg = milligrams per kilogram

8.3 PROJECT TASKS

8.3.1 Zone 7 Groundwater Sampling

Groundwater monitoring was conducted at Lake Camp to document contaminant concentrations and MNA parameters in the groundwater. Samples were collected September 18-19, 2017. A list of the groundwater laboratory samples collected during this project is presented in Table 8-2. Groundwater sampling results are displayed on Figure 8-1 and listed in Table 8-3.

8.3.2 Institutional Control Inspection

Institutional controls are part of the selected remedy necessary to meet the RAOs. The goals of the institutional controls are to prevent the drinking of groundwater contaminated above 18 AAC 75.345 Table C groundwater cleanup levels and to help ensure the proper management of soil contaminated above Method Two cleanup levels in order to comply with State regulations (18 AAC 75.375). Institutional controls within the site boundaries consist of:

- Prohibiting the installation of water supply wells as long as the aquifer fails ADEC Table C cleanup levels.
- A restriction on excavation without a proper soil management plan.

A visual inspection was performed to verify that no water wells have been installed and no soil excavating has taken place.

8.3.3 Deviations from the Work Plan

There were no deviations from the work plan.

Table 8-2: Zone 7, A-Aquifer Sample Analyses Summary

				Analytical Methods						
Location ID Sample Point	Comments	Matrix	Location Type	AK 102 DRO	SM 2320B Alkalinity	300.0 Chloride & Sulfate	353.2 Nitrate + Nitrite	EPA Method 6010B Fe and Mn (dissolved)	RSK 175 Methane	Sample Number
LF02	(D)	Groundwater	Monitoring Well	1	1	1	1	1	1	17KS7ZLF02-107WG
GP01	MS/MSD	Groundwater	Monitoring Well	3	3	3	3	3	3	17KS7ZGP01-108WG
GP02		Groundwater	Monitoring Well	1	1	1	1	1	1	17KS7ZGP02-109WG
MW07		Groundwater	Monitoring Well	1	1	1	1	1	1	17KS7ZMW07-110WG
WP19		Groundwater	Well Point	1	1	1	1	1	1	17KS7ZWP19-111WG
WP20		Groundwater	Well Point	1	1	1	1	1	1	17KS7ZWP20-112WG
MW21		Groundwater	Monitoring Well	1	1	1	1	1	1	17KS7ZMW21-113WG
MW22		Groundwater	Monitoring Well	1	1	1	1	1	1	17KS7ZMW22-114WG
Duplicate	LF02	Groundwater	Monitoring Well	1	1	1	1	1	1	17KS7ZMW23-115WG
WATER ANALYSES TOTALS				**11**	**11**	**11**	**11**	**11**	**11**	

MS/MSD - Additional sample volume for matrix spike and matix spike duplicate analyses

(D) - Duplicate sample taken from same location as a project sample

8.4 ZONE 7 FINDINGS

8.4.1 Field Measured Parameters

While collecting groundwater samples from monitoring wells, several water-quality parameters were recorded to determine groundwater characteristics relevant to assessing intrinsic remediation. Field measurements can be found on the sample data sheets for Zone 7 in Appendix A and a summary of results can be found in Table 8-3.

Free Product: Free product was not observed in any of the wells.

Temperature: Groundwater temperatures measured in the A-Aquifer wells during September were between 4.17˚C and 8.01˚C. These temperatures are suitable for biodegradation processes.

pH: Measurements taken during September were between 5.57 and 6.3 pH units. These levels are suitable for biodegradation processes.

Conductivity: The conductivity measurements ranged from 35 to 296 micro Siemens per centimeter (µS/cm). Elevated levels of conductivity may be associated with groundwater contamination.

Dissolved Oxygen: DO levels ranged between 0.67 mg/L and 4.17 mg/L. Areas with elevated petroleum hydrocarbons generally have depressed DO levels (<2.0 mg/L). This was generally the case in Zone 7.

Redox Potential: Redox potentials were between 15.6 and 332.7 millivolts (mV). Lower redox potentials generally correlate with areas of petroleum contamination.

Table 8-3: Summary of Zone 7 A-Aquifer Analytical Data

Well	DRO (mg/L)	Chori de (mg/L	Nitrate-Nitrite (mg/L)	Sulfate (mg/L)	Ferrous Iron (mg/L)	Manganese (mg/L)	Methane (µg/L)	Alkalinity (mg/L)	Temperature	DO (mg/L)	ORP (mV)	pH	Con. (µS/cm)
RAO	**1.5**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
LF02	1.0 (0.95)	2.7	0.018 (0.024)	1.6 (1.7)	1.4 (1.3)	0.20 (0.19)	71 (62)	61 (63)	7.96	0.67	15.6	6.48	135
MW07	0.029	2.7	1.1	0.70	0.035	0.050	1.9	22	5.0	0.86	332.7	5.78	47
GP01	**2.8**	2.6	0.035	1.3	1.8	2.8	11,000	160	6.37	0.90	110.4	6.3	296
GP02	0.18	2.2	0.060	2.7	0.11	0.04	ND	13	4.17	3.0	209.4	5.57	35
MW21	0.14	3.0	0.071	0.42	0.033	0.027	0.37	55	7.2	4.17	177	5.95	101
MW22	**2.5**	2.0	0.014	1.2	0.22	0.18	1.3	30	6.38	3.65	181.1	5.74	53
WP19	0.099	1.5	0.012	1.1	6.0	0.10	220	32	8.01	0.99	94.2	5.72	74
WP20	0.27	2.0	0.017	0.23	16	0.13	1,600	40	6.73	4.6	48.8	6.12	109

NA - Not Applicable
ND - Not detected above method reporting level (MRL)
RAO - Remedial action objectiv
Analytical results exceeding RAOs shown in **BOLD.**
(Results) are duplicate samples.

8.4.2 Analytical Results

Analytical results are shown in Appendix C, Zone 7 Tables. Table 8-4 presents current and historical groundwater sample analytical results for selected Zone 7 COCs.

8.4.2.1 DRO

The petroleum hydrocarbon levels (DRO) detected in Zone 7 groundwater are shown on Figure 8-1. Monitoring wells GP01 and MW22 exceeded the RAO of 1.5 mg/L for DRO with concentrations of 2.8 mg/L and 2.5 mg/L respectively. Overall, DRO concentrations ranged from 0.029 to 2.8 mg/L. Current and historical DRO results for selected Zone 7 monitoring wells/well points can be found in Tables 8-3 and 8-6.

8.4.2.2 Inorganics

Various geochemical indicators important for assessing aerobic biodegradation of fuel hydrocarbons were measured to evaluate if intrinsic remediation is taking place. A summary of Zone 7 analytical results can be found in Table 8-3.

- Nitrate-nitrite as nitrogen was detected at low levels all of the wells sampled during 2017 at concentrations ranging from 0.012 to 1.1 mg/L. All of the wells also exhibited detectable dissolved hydrocarbons. However, the well with the lowest hydrocarbon concentration had the highest concentration of nitrate-nitrite. There does not appear to be a correlation between contamination levels and nitrate-nitrite concentrations. Current nitrate-nitrite results would suggest nitrate reduction is not a significant biodegradation mechanism for petroleum hydrocarbon contamination in Zone 7.
- Sulfate concentrations ranged between 0.23 to 2.7 mg/L, but there does not appear to be a good correlation between low sulfate concentrations and high DRO concentrations. As with nitrate-nitrite, sulfate reduction does not seem to be a significant biodegradation mechanism in Zone 7.
- Ferrous iron concentrations ranged from 0.033 in MW21 to 16 mg/L in WP20, but there does not appear to be a good correlation between high ferrous iron concentrations and high DRO concentrations. As with nitrate-nitrite, iron reduction does not seem to be a significant biodegradation mechanism in Zone 7.
- Manganese concentrations ranged from 0.027 mg/L in MW21 to 2.8 mg/L in GP01. While higher DRO did correlate with higher manganese at GP01, higher DRO did not correlate with higher manganese at MW22. It is unclear if manganese reduction is an important biodegradation mechanism at this site.
- Methane concentrations ranged from ND in GP02 to 11.0 mg/L in GP01. While higher DRO did correlate with higher methane at GP01, higher DRO did not correlate with higher methane at MW22. It is unclear if methanogenesis is an important biodegradation mechanism at this site.

- Alkalinity measurements ranged from 13 to 160 mg/L (GP01), and generally, elevated petroleum hydrocarbon levels correlated with increased alkalinity concentrations at GP-01, but not at MW22.

8.4.1 DRO and TCE Concentration Trends

The statistical software ProUCL, Version 5.1 was used to assess DRO concentration trends for three Zone 7 monitoring wells. Output from the ProUCL evaluation can be found in Appendix E.

Table 8.4 and Table 8.5 summarize the concentration trends observed in the three monitoring wells with historical concentrations of contaminants near or above RAOs. The tables list the numbers of wells exhibiting a specific concentration trend for each analyte. Well location data sets, which did not have the minimum number of four observations, or where the results were all below the reporting limit for a specific analyte, are not included in the trend summary table. Note that 100% of the wells had no trend. Overall, since the majority of concentration trends are stable, the trend analysis supports the conclusion that intrinsic remediation is keeping contaminant concentrations stable at this site.

Table 8-4 Zone 7 MANN-Kendall Analysis Summary

Trend	DRO	% of Total
Decreasing	0	0%
Increasing	0	0%
No Trend	3	100%
Totals	3	3

Table 8-5 Zone 7 MANN-Kendall Trend Summary

Well	DRO
GP-01	NT
LF02	NT
MW22	NT

NT – No trend

8.4.2 Institutional Control Inspection

There were no indications of water well installations or excavating occurring within the property boundaries of Zone 7.

8.4.3 Condition of Wells

The eight wells scheduled for Zone 7 were sampled and in good condition.

8.5 ZONE 7 CONCLUSIONS

Two of eight wells sampled in 2017 exceeded RAO for DRO.

DRO concentrations at MW22 and LF02 have increased since last year's sampling event, while there is a DRO decrease at GP01. The DRO results from the other five wells have slightly decreased since they were last sampled in 2014.

The data we have suggests that overall DRO concentrations are steady, and that some biodegradation processes may be occurring.

8.6 ZONE 7 RECOMMENDATIONS

- Sampling should continue at monitoring wells LF02, GP-01, and MW22. If the DRO concentration at LF02 remains below the cleanup level of 1.5 mg/L in 2018, sampling of the well should be discontinued.

- Sampling should be discontinued at MW07, GP02, MW21, WP19, and WP20 since sample results have decreased since they were last sampled in 2014, and remain below cleanup levels.

- Sampling for nitrate/nitrite, sulfate, and ferrous iron should be discontinued.

- 2015 soil samples collected from three LF01 locations indicated DRO contaminated soil above cleanup levels. This soil should be excavated and treated.

- Any recommendations are subject to change pending conversations between ADEC and AFCEC, and any comment resolution outcomes on ADEC's comments for the Five-Year Review.

Table 8-6: Historical Zone 7 A-Aquifer DRO Results

Well	1994 Analytical Results (mg/L)	1998 Analytical Results (mg/L)	2000 Analytical Results (mg/L)	2013 Analytical Results (mg/L)	2014 Analytical Results (mg/L)	2015 Analytical Results (mg/L)	2016 Analytical Results (mg/L)	2017 Analytical Results (mg/L)
RAO	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
LF02	0.82	**5.2**	NS	0.95 (0.83)	**2.1**	0.64(0.55)	0.47(0.43)	1.0 (0.95)
MW07	NI	NI	0.03	ND	0.061/0.055	NS	NS	0.029
GP01	0.024	ND	?	**2.6**	**4.5**	**2.9**	**4.1**	**2.8**
GP02	**5.7**	**2.4**	?	0.1	0.2	NS	NS	0.18
MW21	NI	NI	**3.23**	0.25	0.25	NS	NS	0.14
MW22	NI	NI	**2.6**	**2.7**	0.84	1.0	**2.2**	**2.5**
WP19	NI	NI	0.2	0.087	0.12	NS	NS	0.099
WP20	NI	NI	0.17	0.34	0.29	NS	NS	0.27

ND - Not Detected

NS - Not Sampled

NI - Not Installed

NF- Not Found

? - Well Removed according to ROD

(Duplicate Sample Result)

EXPLANATION

GP01 ⊕	A-AQUIFER WELL LOCATION
WP20 ⬢	WELL POINT LOCATION
DRO	DIESEL-RANGE ORGANICS CONCENTRATION
2.5	RESULT EXCEEDING RAO

RAO CLEANUP LEVEL (mg/L)

DRO = 1.5

DATE
JAN. 2018
CHKD
H.L.H.
DRAWN
C.E.H.
PROJ. NO
17040

PACIFIC AIR FORCES REGIONAL SUPPORT CENTER
& AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

GROUNDWATER DRO RESULTS
GROUNDWATER ZONE 7

NAKNEK RECREATIONAL CAMP (GWZ7)
2017 LONG TERM MANAGEMENT
King Salmon Divert, Alaska

FIGURE

8-1

PATH: D:\18 Dwgs\18 PV\17040 KS LTM RPT FILE: 18-KS-LTM-RPT-F8-1.DWG PLOT: 1/10/18.

9 REFERENCES

ADEC, 2000. *Risk Assessment Procedures Manual* (June 8, 2000).

ADEC, 2008a. *Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances*, as amended through December 12, 2008.

ADEC, 2013. *Technical Memorandum from Division of Spill Prevention and Response, Contaminated Sites Remediation Program, Sediment Quality Guidelines (SQG)*, January 2013.

ADEC, 2016. 18 AAC 75, Oil and Hazardous Substances Pollution Control Regulations, revised as of November 7, 2017.

ADEC, 2017a. *18 AAC 70, Water Quality Standards,* as amended through November 7, 2017.

ADEC, 2017b. 18 AAC 80, *Drinking Water Regulations,* as amended November 7, 2017.

Air Force Center for Environmental Excellence (AFCEE), 1993. *Handbook for the Installation Restoration Program, Remedial Investigations and Feasibility Studies (RI/FS).*

AFCEE, 2000. *Designing Monitoring Programs to Effectively Evaluate the Performance of Natural Attenuation.* January 2000.

American Petroleum Institute (API), 2001. *Methods for Determining Inputs to Environmental Petroleum Hydrocarbon Mobility and Recovery Models.* API Publication Number 4711, July 2001.

Brauner, S.J., 1997. *Nonparametric Estimation of Slope: Sen's Method in Environmental Pollution.* In: Environmental Sampling and Monitoring Primer, a set of web pages found at http://www.cee.vt.edu/program_areas/environmental/teach/smprimer/sen/sen.html.

Bristol Environmental and Engineering Services Corporation and OASIS Environmental, Inc. (Bristol/OASIS), 1999b. *Statistical Analysis of Sampling Events, Revision of Post-Closure Monitoring Plan, North and South Bluffs*, King Salmon Airport, May 1999.

Bristol/OASIS, 2000c. *Final Implementation of Long-Term Groundwater Monitoring and Intrinsic Remediation Assessment of King Salmon Airport Groundwater Zones 2 and 4.* November 2000.

Bristol/OASIS, 2000d. *Final Implementation of Long-Term Groundwater Monitoring and Intrinsic Remediation Assessment Report Zone 2(OT028) and Zone 4 (OT030).* November 2000.

Bristol/OASIS, 2000e. *Final Groundwater Monitoring Report, Groundwater Zone 1 1998 Results.* December 2000.

Buchman, M.F., 1999. *NOAA Screening Quick Reference Tables, NOAA HAZMAT Report 99-1, Seattle, WA, Coastal Protection and Restoration Division, National Oceanic and Atmospheric Administration (NOAA).*

CH2M Hill. 1989. *Installation Restoration Plan, King Salmon Airport, Stage 1, Final Technical Report.* August 29, 1989.

CH2M Hill. 1990. *Installation Restoration Plan, Stage 2, Final Draft Technical Report.* CH2M Hill, October 3, 1990.

EA Engineering, Science, and Technology, Inc. 2011. *Monitoring Well Decommissioning and Repair. King Salmon Air Station, Alaska.* August 2011.

Earth Tech, Inc., 2006. *Final Technical Report, Implementation of Remedial Process Optimization at King Salmon Air Station, Alaska.* June, 2006.

Environmental Management, Inc. (EMI), 1995. *King Salmon Airport UST 1-Mile Pipeline Field Report/Site Assessment.* January 1995.

Engineering Science (ES), 1985. *Installation Restoration Program. Phase 1: Records Search. AAC-Southern Region: King Salmon AFB, Cape Newenham AFB, Cape Romanzof AFB, Cold Bay AFB, Sparrevohn AFB, and Tatalina AFB.* September 1985.

EMCON, Alaska Inc. (EMCON), 1995a. *Installation Restoration Program (IRP) Final Post-Closure Monitoring Plan for North and South Bluff, King Salmon, Alaska*.

EMCON, 1995b. *Final Report, Limited Field Investigation, King Salmon Airport, King Salmon, Alaska.* June 1995.

EMCON, 1995c. *Final Report, Remedial Investigation/Feasibility Study (RI/FS) at Fourteen Sites. King Salmon Airport, King Salmon, Alaska: Stage 3, Part 1: Remedial Investigation*. August, 1995.

EMCON, 1995d. *Ecological Risk Assessment for King Salmon Airport.* August 1995.

EMCON. 1995e. *King Salmon Airport, Groundwater Sampling Data for Monitoring Well Sampling Program Conducted in September/October*.

EMCON, 1996. *Final Seep Sampling at Eskimo Creek and Naknek Sites, King Salmon Airport, King Salmon, Alaska.* July 1996.

EMCON, 1997a. *King Salmon Airport, King Salmon, Alaska, Installation Restoration Program, Feasibility Study Report FINAL (Revised).* March 1997.

EMCON, 1997b. *Final Eskimo Creek Dump and Landfill No. 3 Remedial Investigation,* King Salmon, Alaska, July 1997.

Finnish Meteorological Institute, 2002. *MAKESENS 1.0 Mann-Kendall Test and Sens Slope Estimates for the Trend of Annual Data*. http://www.fmi.fi/kuvat/MAKESENS_1_0.xls.

Gilbert, R.O., 1987. *Statistical Methods for Environmental Pollution Monitoring.* Van Nostrand Reinholt, New York, NY, 320pp.

Hart Crowser, Inc., 1997. *Post-Closure Monitoring Report, October 1996, North and South Bluff, King Salmon Airport, King Salmon, Alaska*.

Hart Crowser, Inc., 2000. *Operations, Monitoring and Maintenance Manual. North and South Bluffs, King Salmon, Alaska*, May 2000.

Hem, John D., 1986. *Study and Interpretation of the Chemical Characteristics of Natural Water*, U.S. Geological Survey Water-Supply Paper 2254, 263 pp.

Jones, D.S., Suter II, G.W., Hull, R.N., 1997. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1997 Revision.* Prepared for the U.S. Department of Energy, Office of Environmental Management by Oak Ridge National Laboratories (ORNL). November. ES/ER/TM-95/R4.

OASIS Environmental, Inc. (OASIS), 1998a. *Installation Restoration Program, King Salmon Airport, King Salmon Alaska: Human Food Chain, Aquatic Biota, and Wetlands Evaluations: Final Technical Report. Volume I – Report Text and Tables.* November 1998.

OASIS, 1998b. *Installation Restoration Program, King Salmon Airport, King Salmon Alaska: Human Food Chain, Aquatic Biota, and Wetlands Evaluations: Final Technical Report. Volume II – Maps, Figures, and Photographs.* November 1998.

Oak Ridge National Laboratory (ORNL), 1996. *Tier II Secondary Chronic Surface Water Benchmarks, 1996 revision*, from http://risk.lsd.ornl.gov/homepage/eco_tool.shtml

ORNL, 1996. *Sediment Preliminary Remediation Goals (PRGs) for Ecological Endpoints*, *1996 revision*, from http://risk.lsd.ornl.gov/homepage/eco_tool.shtml

ORNL, 1997. *Preliminary Remediation Goals*. August 1997.

ORNL, 2017. Risk Assessment Information System (RAIS). Ecological Benchmark Tool, Sediment Choices. Accessed August 2017. https://rais.ornl.gov/tools/eco_search.php

NOAA. 2008. *Screening Quick Reference Tables*, as amended in 2008.

Parsons Engineering Science, Inc. (Parsons), 1996. *Draft Treatability Study in Support of Intrinsic Remediation for Fire Training Area 1 (FT01), King Salmon Airport, King Salmon, Alaska. May 1996.*

Paug-Vik Development Corporation (Paug-Vik) & OASIS Environmental (Paug-Vik & OASIS), 2000. *Record of Decision for Final Remedial Action, North Bluff (LF005) and South Bluff (LF014), Groundwater Zone 3, King Salmon Air Station, King Salmon Alaska*, April 2000.

Paug-Vik & OASIS, 2001. *Final Report, Groundwater Zone 2 (OT028) 2000 Sampling and Feasibility Study, King Salmon Air Station, Alaska.* August 14, 2001.

Paug-Vik & OASIS, 2005a. *Final Technical Report, Remediation Systems, 2003 Operation, Monitoring and Maintenance Bioventing Systems at Six Remediation Sites, King Salmon Air Station, Alaska.* August 5, 2005.

Paug-Vik & OASIS, 2005b. *Final 2004 Long-Term Monitoring Report, Groundwater Zone 2 (OT028) and Eskimo Creek Dump (SS022), King Salmon Air Station, Alaska,* October 25, 2005.

Paug-Vik/OASIS, 2007a. *Final 2005 Long-Term Monitoring Report, Groundwater Zone 2 (OT028) and Eskimo Creek Dump (LF022), King Salmon Air Station, Alaska.* June 15, 2007.

Paug-Vik, 2000a. *1999 Final Monitoring Report, North and South Bluffs, King Salmon Air Station, Alaska.* June 2000.

Paug-Vik, 2001. *Final Report, Long Term Monitoring for 2000, Naknek River Storage (Groundwater Zone 4 – OT030) and Rapids Camp (Groundwater Zone 6 – OT032), King Salmon Air Station, Alaska.* October 19, 2001.

Paug-Vik, 2002. *2001 Final Monitoring Report, North and South Bluffs, King Salmon Air Station, Alaska.* July 2002.

Paug-Vik, 2002. *Final Report, Long Term Monitoring for 2001, Naknek River Storage (Groundwater Zone 4 – OT030) and Rapids Camp (Groundwater Zone 6 – OT032), King Salmon Air Station, Alaska.* September 2002.

Paug-Vik, 2003. *2002 Final Monitoring Report, North and South Bluffs, King Salmon Air Station*, August 2003.

Paug-Vik, 2003. *Final Report, Long Term Monitoring for 2002, Naknek River Storage (Groundwater Zone 4 – OT030, Sites LF008 and SS012) and Rapids Camp Landfill (Site LF003), King Salmon Air Station, Alaska.* August 15, 2003.

Paug-Vik, 2004. *2003 Final Monitoring Report, North and South Bluffs, King Salmon Air Station, Alaska.* August 2004.

Paug-Vik, 2005a. *Final Report, Long Term Monitoring for 2003, Naknek River Storage (Groundwater Zone 4 – OT030, Sites LF008 and SS012) and Rapids Camp Landfill (Site LF003), King Salmon Air Station, Alaska.* March 11, 2005.

Paug-Vik, 2005b. *Final Remedial Systems Technical Report, 2003 Operations, Monitoring, and Maintenance at Six Sites, King Salmon Air Station, Alaska*. August 2005.

Paug-Vik, 2005c. *Final Quality Assurance Project Plan, King Salmon Air Station, Alaska.* November 10, 2005.

Paug-Vik, 2006. *2004 Final Monitoring Report, North Bluff (LF014) and South Bluff (LF005), King Salmon Air Station, Alaska.* October 31, 2006.

Paug-Vik, 2007b. *Final Report, Long Term Monitoring for 2005, Naknek River Storage (Groundwater Zone 4 – OT030, Sites LF008 and SS012) and Rapids Camp Landfill (Site LF003), King Salmon Air Station, Alaska.* June 8, 2007.

Paug-Vik, 2007c. *Final Remedial Systems Technical Report, 2005 Operations, Monitoring, and Maintenance at Six Sites, King Salmon Air Station, Alaska*. June 8, 2007.

Paug-Vik, 2007d. *Final 2006 Long-Term Monitoring Report, Groundwater Zone 2 (OT028) and Eskimo Creek Dump (LF022), King Salmon Air Station, Alaska.* September 21, 2007.

Paug-Vik, 2007e. *2006 Final Monitoring Report, North Bluff (LF014) and South Bluff (LF005), King Salmon Air Station, Alaska.* September 24, 2007.

Paug-Vik, 2007f. *Final Report, Long Term Monitoring for 2006, Naknek River Storage (Groundwater Zone 4 – OT030, Sites LF008 and SS012) and Rapids Camp Landfill (Site LF003), King Salmon Air Station, Alaska.* September 25, 2007.

Paug-Vik, 2007g. *Final Report for 2006 Long-Term Monitoring, Base Living Area (Groundwater Zone 1 – OT027), King Salmon Air Station, Alaska.* September 28, 2007.

Paug-Vik, 2012, *Final Report for Remedial Action Projects, King Salmon, Airport, Alaska.* November 2012.

Paug-Vik, 2017a. *Final Work Plans, 2017 Environmental Monitoring Projects, King Salmon Air Station, Alaska.* September 2017.

Paug-Vik 2016b. *Final 2016 Long Term Monitoring Report, King Salmon Air Station, Alaska.* May 2018.

Science Applications International Corporation (SAIC), 1993a. *Subsurface Investigation, Construction of Soil Containment Cells, Construction of French Drain, and Removal of Hydrocarbon-Contaminated Soils: Naknek River Storage Site (SS12), King Salmon Airport, King Salmon, Alaska.* Draft Report. August 13, 1993.

SAIC, 1993b. *Final Report, Groundwater Monitoring Performed October 1992, King Salmon Airport, King Salmon, Alaska*. September 1993.

Thomas, Delwyn F. (CENPA-EN-G-M), 1988. *Letter Report Re: Soil and Groundwater Contamination, ADAL Refueler, King Salmon AFS, Alaska*. December 18, 1988.

U.S. Air Force (USAF), 1999. *Record of Decision for Final Remedial Action Naknek River Storage Sites, Landfill No. 5, and Zone 4 Groundwater, King Salmon Airport, Alaska.* April 1999.

USAF, 2000. *Record of Decision for Interim Remedial Action, Site: Groundwater Zone OT027 (Zone 1), King Salmon Air Station, King Salmon, Alaska.* November 2000.

USAF, 2002. *Record of Decision for Final Remedial Action at Sites: Groundwater Zone OT028 (Zone 2), Waste Accumulation Area 3 (SS017), Eskimo Creek Dump (SS022), Refueler Shop (SS021), and Old Power Plant Building (SS020), King Salmon Air Station, Alaska*.

USAF, 2005. *Explanation of Significant Differences for North & South Bluff, Groundwater Zone 3, King Salmon Air Station, Alaska.* November 2005.

USAF, 2006. *Draft First Five-Year Review for Groundwater Zones 1-4 and 6, King Salmon Air Station, Alaska, January, 2006*.

USAF, 2007. F*inal 2005 and 2006 King Salmon Air Station, Alaska, Remedial Process Optimization Field Activities Report*. April 2007.

USAF, 2008. *Draft Record of Decision RAPCON Fire Training Area No. 4 (FT004) Groundwater Zone 5, King Salmon Air Station, King Salmon, Alaska.* June 2008.

U.S. Environmental Protection Agency (USEPA), 1996. *Ecotox Thresholds*. Office of Solid Waste and Emergency Response, January 1996.

USEPA, 1996. *ECO Update, Office of Solid Waste and Emergency Response (OSWER), Publication 9345.0-12FSI, USEPA 540/F-95/038, PB95-963324*, Intermittent Bulletin, Vol. 3, No. 2.

USEPA, 2001a. *Comprehensive Five-Year Review Guidance, EPA 540-R-01-007, OSWER No. 9355.7-03B-P. USEPA, 2001b. Region IV Waste Management Division, Water Quality Standards Unit's Screening List*, as amended November 30, 2001.

USEPA, 2001b. *Region IV Waste Management Division, Sediment Screening Values*, as amended November 30, 2001. From http://risk.lsd.ornl.gov/homepage/eco_tool.shtml

USEPA, 2003. *Region V, RCRA, Ecological Screening Levels,* as amended through August 22, 2003. From http://risk.lsd.ornl.gov/homepage/eco_tool.shtml

USEPA, 2004a. *How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites, A Guide for Corrective Action Plan Reviewers*, Chapter 5, Landfarming. EPA 510-R-04-002. May 2004.

USEPA, 2004b. *National Recommended Water Quality Criteria*, as amended in 2004.

USEPA, 2005. *Region III Risk-Based Concentrations,* as amended through April 7, 2005.

USEPA, 2016a. *PFOA & PFOS Drinking Water Health Advisories*. EPA 800-F-16-003. Nov. 2016.

USEPA, 2016b. *Regional Screening Levels for Chemical Contaminants at Superfund Sites.* May 2016.

Wiedemeier, Todd H., et al., 1998. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater*. September 1998.

Wiedemeier, Todd H., John T. Wilson, Donald H. Kampbell, Ross N. Miller, and Jerry E. Hansen, 1999. *Technical Protocol for Implementing Intrinsic Remediation with Long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater*. For AFCEE. March 1999.