FINAL 2018

REMEDIAL ACTION OPERATIONS &

LAND USE CONTROL INSPECTIONS

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

KING SALMON DIVERT, ALASKA

MAY 2019

CONTRACT NO. W911KB18C0029

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KING SALMON DIVERT, ALASKA

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PREFACE AND DISCLAIMER

Paug-Vik Contractors, LLC (Paug-Vik) prepared this report through a contract with the United States Army Corps of Engineers (USACE), contract number W911KB18C0029. This report presents long-term environmental management activities conducted in 2018, at six King Salmon Divert (KSD) groundwater zones.

This report provides a description of work and results performed by 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 Government 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.

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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
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
ESD	Explanation of Significant Difference
FS	Feasibility Study
FSP	Field Sampling Plan
GRO	Gasoline-Range Organics
IDW	Investigation-Derived Waste
KSD	King Salmon Divert
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
PVC	Paug-Vik Contractors, LLC
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
TOC	Total Organic Carbon
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 report presents analytical and field data collected during the 2018 field season from six 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 collected during the field activities are presented in Appendix C. A Quality Assurance Report of the analytical results from samples collected and Alaska Department of Environmental Conservation (ADEC) 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.

There are signed RODs for Zone 1, Zone 2, Zone 3, Zone 4, and Zone 6. The 2017 Five Year Review recommends using current ADEC cleanup levels, which tend to be more restrictive than those found in the final RODs. An impending new ROD for Zone 1 will use current ADEC cleanup levels, and the Air Force is developing an Explanation for Significant Differences (ESDs) for Zones 2, 3, and 4. Zones 5 and 7 do not have final RODs; therefore, the cleanup objectives are current ADEC cleanup levels.

For the purpose of this report, in Zones with final RODs, RAO tables will include both ROD and current ADEC cleanup levels for comparison. Data tables will use current cleanup levels and recommendations to reduce monitoring will be based on meeting current ADEC levels.

It should be noted that this contract was awarded late in the fall of 2018, and the field season did not commence until the end of November. By then, freezing conditions along with intermittent snow fall hampered sampling and inspection opportunities, and all tasks could not be completed during the November-December field season. Those tasks discussed below will be performed in the fall of 2019 and results will be included in the 2019 RAO/LUC report:

- IC/LUC inspections for all Zones will take place in the fall of 2019. Snow covering prevented thorough inspections.
- Zone 1 Product Probes: Product recovery typically takes place in June. Product will be removed in June 2019 under the 2018 contract and again in the September 2019 under the 2019 contract.
- Purge water will be sampled and filtered in the spring of 2019 under the 2018 contract and results will be included in the 2019 report. The water was not filtered in December because of concern for the GAC freezing. The purge water was stored in covered, labelled containers inside the fenced biocell area.

- Zone 2 surface water samples were not collected because the surface water locations were frozen. These samples will be collected in the fall of 2019.

- Zone 3 South Bluff Treatment Inspection and Landfill Caps inspections will be conducted in the fall of 2019. Snow cover prevented thorough inspections in 2018.

- Zone 4 residential wells were not sampled because of the unavailability of the homeowners or winterized outdoor spigots. Surface water/sediment samples were not collected due to freezing conditions. These samples will be collected in the fall of 2019.

- Zone 4 MW-57 will be redeveloped in the spring of 2019, sit over the summer and then sampled in the fall if no product is present.

- One Zone 4 product pillow was frozen in place during the 2018 field season and will be replaced in the spring of 2019.

- Zone 5 surface water/sediment samples were not collected due to frozen conditions. These samples will be collected in the fall of 2019.

- Zone 4 and Zone 6 landfill inspections will be conducted in the fall of 2019. Snow cover prevented thorough inspections.

GROUNDWATER ZONE 1 – BASE LIVING AREA

Groundwater samples were collected from ten Zone 1 A-Aquifer monitoring wells in December, 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.

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. Three well points and two monitoring wells exceeded the cleanup level of DRO. TCE was observed above the cleanup level of 2.8 μg/L at ETMW-02 (65/60 μg/L), MW89-1 (2.9 μg/L), MW-6 (11 μg/L), MW-23 (11 μg/L), and MW-28 (32 μg/L). TCE was detected equal to the action level of 2.7 μg/L in point-of-compliance (POC) well point POC-1. POC results ranged from 0.093 to 2.7 μg/L. Inorganic parameters provide some evidence that natural attenuation of petroleum hydrocarbons is occurring in the A-Aquifer. Most concentration trends are stable or decreasing. This indicates that intrinsic remediation is keeping contaminant concentrations stable or decreasing at this site.

TCE was found in two B-Aquifer wells at a concentration of 83 μg/L in MW-41, and 46 μg/L in MW13-09B. These results exceed the cleanup level of 2.8 μg/L.

Monitoring and recovering product at Seeps 1 and 2 will be done in the spring of 2019, and again in the fall. The IC/LUC inspection will be done in the fall of 2019. Freezing temperatures precluded filtering purge water. All of these activities will be reported in the 2019 RAO/LUC report.

GROUNDWATER ZONE 2 - BASE INDUSTRIAL AREA & ESKIMO CREEK DUMP

Groundwater samples were collected from six Zone 2 A-Aquifer monitoring wells in late November and early December 2018, and analyzed for VOCs, DRO, gasoline-range organics (GRO), geochemical indicators of intrinsic remediation, and other inorganic analytes.

Two wells exceeded the ADEC cleanup level for GRO and one exceeded the ADEC cleanup level for DRO. B-02 had the highest concentration of GRO (12 mg/L) and DRO (6 mg/L). The GRO concentration in monitoring well 629 was 4.8 mg/L.

Three wells exceeded the cleanup level of 2.8 µg/L for TCE. Those concentrations ranged between 6.1 µg/L in monitoring well 629, to 16 µg/L in B0-2. The TCE result in a fourth well was 0.31 µg/L, while the remaining two wells were non-detect.

Monitoring well 629 exceeded the cleanup level of 4.6 µg/L for benzene at 16 µg/L. Benzene was also detected in MW00-03 at 1.9 µg/L.

B-02, MW-629, and MW00-03 exceeded the cleanup level of 15 µg/L for ethylbenzene. Those results ranged between 100 µg/L to 520 µg/L.

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 suggest that intrinsic remediation of the petroleum hydrocarbons is occurring 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.

Surface water samples were not collected from three locations along Eskimo Creek due to frozen conditions in December. These samples will be collected in the fall of 2019 along with the IC/LUC inspection, and reported in the 2019 RAO/LUC report.

GROUNDWATER ZONE 3 – SOUTH BLUFF

One sample was collected from the South Bluff Treatment System lift station in November. Three more quarterly sampling events are scheduled, and those results will be discussed in the 2019 report. GRO, DRO, tetrachloroethene, TCE, heptachlor, chromium, and iron were detected in the November influent sample at levels below the effluent limitations. Arsenic was detected above the effluent limitation. Similar results were found in the March, June, and July 2018 samples which are included in this report.

Slopes, vegetation, erosion-control features, culverts, downdrains, toe roads, access roads at the North and South Bluffs, and the South Bluff Treatment System will be inspected in the fall of 2019, and results will be included in the 2019 RAO/LUC report.

GROUNDWATER ZONE 4 – NAKNEK RIVER STORAGE

Samples were collected from three A-Aquifer wells and two B-Aquifer wells in early December. Product recovery system maintenance was also performed by replacing one product recovery pillow and disposing the used one. The second pillow was frozen in place and will be replaced in the spring after breakup.

MW-51 exceeded the cleanup levels for 1,2,4-Trimethylbenzene, ethylbenzene, naphthalene, and total xylenes. The other two monitoring wells sampled also exceeded cleanup levels for ethylbenzene and naphthalene. GRO and DRO were detected below the cleanup levels.

MW-57 was not sampled due to the appearance of product while purging. This well will be redeveloped in the spring and then sampled in the fall of 2019 if there is no product present.

Low levels of GRO were detected in two B-Aquifer monitoring wells with a comparable concentration found in the trip blank and equipment blank. DRO was not detected.

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

Surface water, and sediment sampling was not conducted due to the frozen conditions in December. Residential wells were not sampled due the unavailability of homeowners. The landfill and institutional control inspections, surface water and sediment sampling, and residential well sampling will take place in the fall of 2019 and will be reported in the 2019 RAO/LUC report.

GROUNDWATER ZONE 5 – RAPCON & RED FOX CREEK

Samples were collected from six A-Aquifer wells in early December. 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; two exceeded the cleanup level of 2.2 mg/L. Three wells were analyzed for VOCs. All three exceeded cleanup levels for 1,2,4-trimethylbenzene, ethylbenzene, total xylenes, and naphthalene.

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.

One surface water/sediment location and a second sediment only location near Red Fox Creek were not sampled due to frozen conditions. These samples will be collected in the fall of 2019, and reported in the 2019 report along with the IC inspection results.

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. The IC inspection did not take place during the 2018 field season due to snow cover. The former landfill will be inspected, along with institutional controls, in the fall of 2019, and results will be reported in the 2019 report.

GROUNDWATER ZONE 7 – LAKE CAMP

Groundwater samples were collected from three monitoring wells at Lake Camp on December 3, and analyzed for DRO and MNA parameters. Monitoring wells GP01 and MW22 exceeded the RAO of 1.5 mg/L for DRO at 3.7 mg/L and 2.3 mg/L, respectively.

The IC/LUC inspection will take place in the fall of 2019, and results will be reported in the 2019 RAO/LUC report.

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 727 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 (OT027) – 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 2018 field activities and results are located in Section 2: *Zone 1 - Base Living Area.*

1.2 GROUNDWATER ZONE 2 (OT028) – 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 2018 field activities and results are located in Section 3: *Zone 2 - Base Industrial Area and Eskimo Creek Dump*.

1.3 GROUNDWATER ZONE 3 (OT029) – 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 2018 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 (OT030) – 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 2018 field activities and results are located in Section 5: *Zone 4 – Naknek River Storage*.

1.5 GROUNDWATER ZONE 5 (OT031) – 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 2018 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 2018 field activities and results are located in Section 6: *RAPCON and Red Fox Creek*.

1.6 GROUNDWATER ZONE 6 (OT032) – 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. Source areas include:

- Beach/Dock Area - AST, refueling and servicing boats (SS005)
- Former Generator Pad (SS004)
- Former Landfill Area (LF003)
- Fuel storage site that included waste oils, fuels, and PCBs

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 2018 field activities is located in Section 8: *Zone 6 – Rapids Camp*.

1.7 GROUNDWATER ZONE 7 (OT033) – 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 2018 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: *2018 Remedial Action Operations & Land Use Control Inspections Work Plans* (Paug-Vik, 2018a). 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 (Appendix B). 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 sampling was scheduled for Zone 2, and surface water and sediment sampling was scheduled for Zones 4 and 5. All the surface water/sediment locations were frozen during the December field effort. These analyses will be performed in the fall of 2019 during the normal field effort and discussed in 2019 RAO/LUC report.

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 required 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)	8260C, 8260C SIM	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)–125 mL Amber
RCRA 8 + Iron Metals	6010B	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)–125 mL Amber
1,2-Dibromomethane (EDB) & 123 TCP	8011	Glass TLC	Cool, 4°C	$Na_2S_2O_3$, Cool, 4°C	28 days (soil and water)	(1)-4oz Amber	(3)-40 mL VOAs

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. Because of the late 2018 field season, IC inspections will be conducted in the fall of 2019, along with the annual land fill inspections at the North and South Bluffs in Zone 3 and at the former landfills in Zone 4 and Zone 6. The findings will be included in the 2019 RAO/LUC report.

1.12 WASTE HANDLING

Purge water and decontamination liquids are treated using an on-site filtration system as specified in Section 8.2.2 of the FSP. Due to frozen conditions during the 2018 field effort, the purge water was stored in covered labelled containers inside the fenced biocell area. The purge water will be filtered through a drum of granulated activated carbon (GAC) in the spring of 2019. Samples of purge water will be collected before and after treatment, and analyzed for GRO, DRO, PAHs, and VOCs. Results will be shown in Table 1-1. Treated purge water will be 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 (mg/L)	After Tx Result (mg/L)
GRO	2.2		
DRO	1.5		
Benzene	0.0046		
Toluene	1.1		
Ethylbenzene	0.015		
Total Xylenes	0.19		
Trichloroethylene	0.0028		

1. Cleanup level based on ADEC 18 AAC 75 Table C, Groundwater Cleanup Levels (as revised October 2018)
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, 2018).

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 100 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).

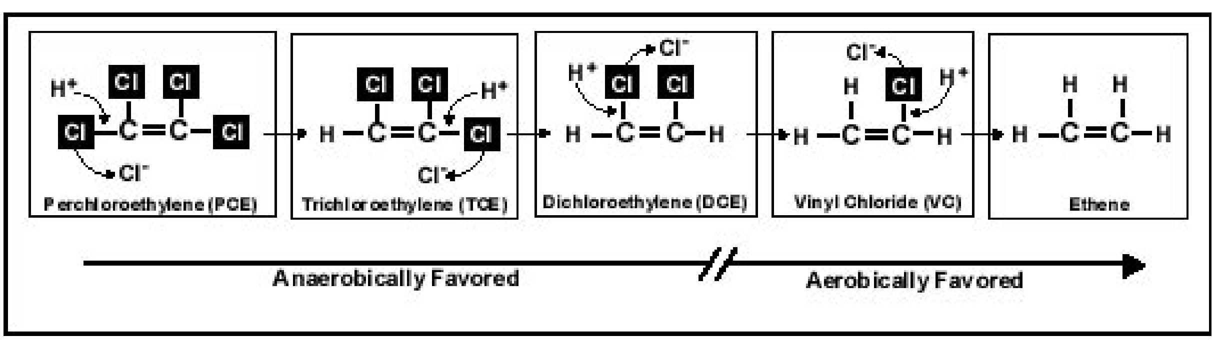
1.14.7 Alkalinity

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.

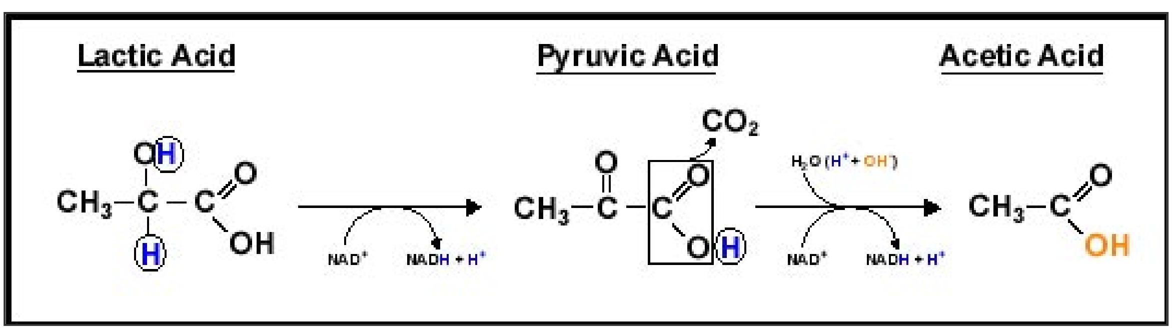


Source: www.regenesis.com/HRCtech/hrctb113.htm

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

Parameter	Description	Threshold Level (Wiedemeier et al., 1996)	Significance of Threshold Level
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	
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 5.1 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.

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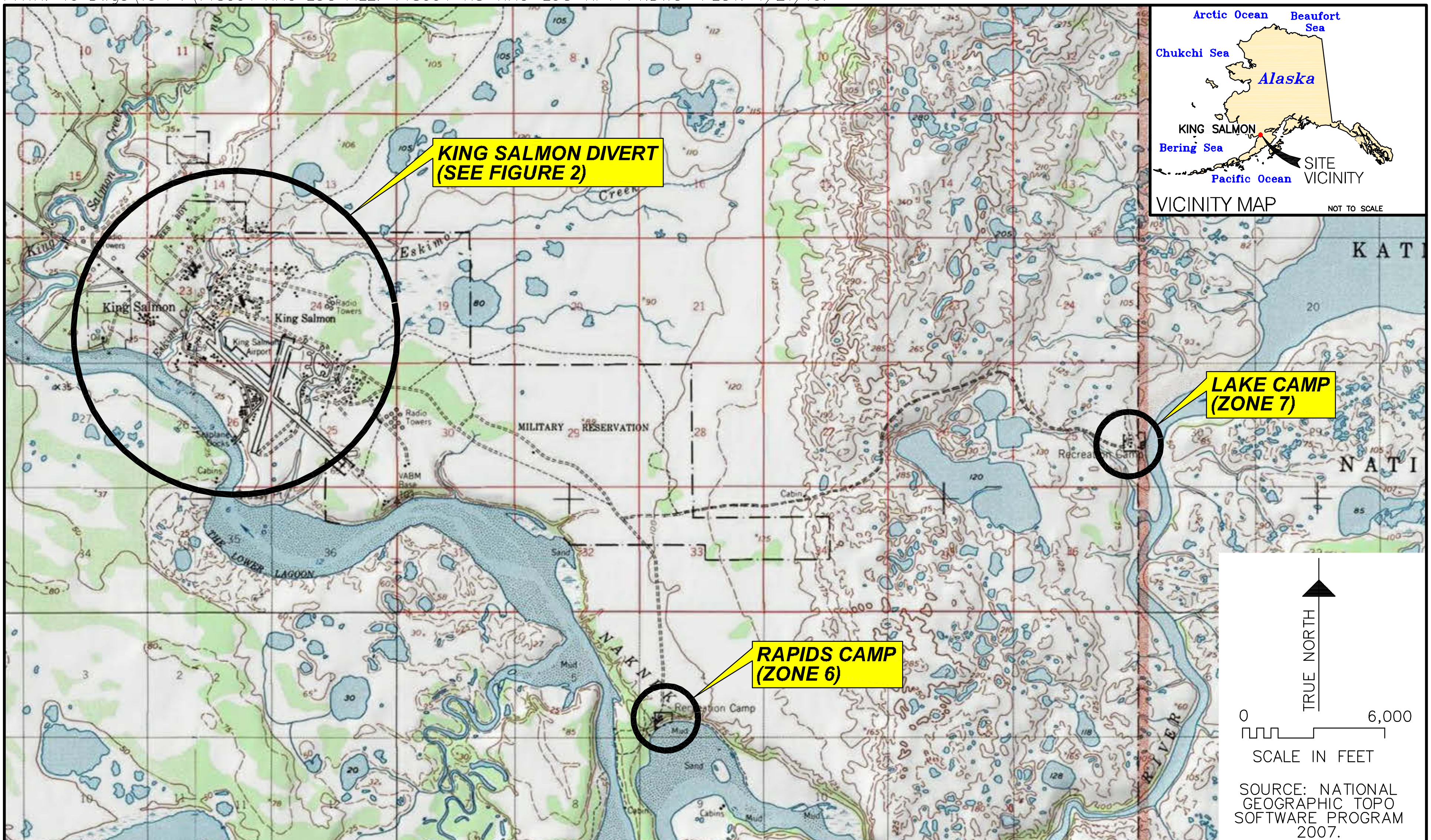


DATE JAN. 2019 CHKD H.L.H. DRAWN C.E.H. PROJ. NO 718004	AIR FORCE CIVIL ENGINEERING CENTER JBER, ALASKA	**SITE LOCATION MAP** 2018 RAO/LUC King Salmon Divert, Alaska	FIGURE **1**

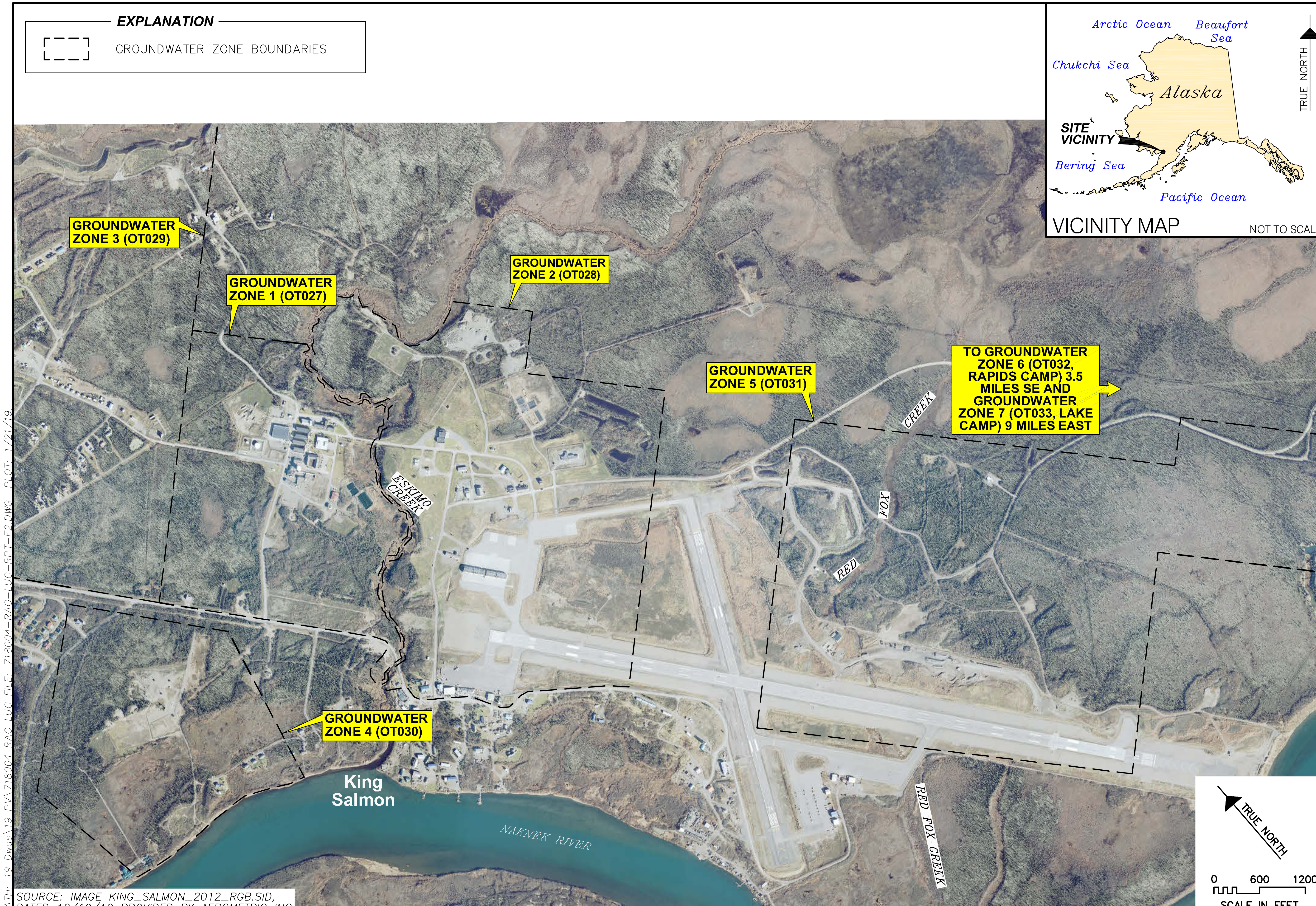


FIGURE 2

SITE LOCATION MAP

2018 RAO/LUC
King Salmon Divert, Alaska

AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE JAN. 2019
CHKD H.L.H.
DRAWN C.E.H.
PROJ. NO 718004

PATH: 19 Dwgs\19 PV\718004 RAO LUC FILE: 718004-RAO-LUC-RPT-F2.DWG PLOT: 1/21/19.

2 ZONE 1 - BASE LIVING AREA (OT027)

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 Zone 1 ROD is finalized, the RAOs for Zone 1 are the ADEC groundwater cleanup levels listed in AAC 75.345 Table C (ADEC, October 2018) and are displayed on Table 2-1 along with the ROD RAOs for comparison. 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, RPO-3, WP03-06, and GP-1A, were the only Seep No. 2 sentry wells included in the 2018 sampling program. RPO-3 was sampled as a substitute for WP03-11.

Table 2-1 Groundwater Zone 1 RAOs

					ARARs				FINAL ROD RAOs		
Media	**Contaminants of Concern**	**Maximum Conc.**	**Maximum Conc. Location (Date)**	**Maximum Conc. 1997/98/99 data**	**Ecological Criteria**	**Basis**	**Human Health/ADEC Criteria**	**Basis**	**Action Level at POC***	**Cleanup Level**	**Current ADEC Cleanup Levels****
Floating Petroleum Product	--	--	--	--	—	—	No FPP	18AAC75	NA	No FPP	No FPP
Groundwater (mg/L) (A- Aquifer)[e]	TCE	7.4	MW-28 (1994)	1.65 (MW-28)	NE	NE	0.05[a]	18AAC75	0.35	0.05	0.0027*/0.0028
	cis-1,2-DCE	0.0011	MW-402 (1993)	0.0032 (MW-27)	NE	NE	0.7[a]	18AAC75	0.59	0.07	0.036
	trans-1,2-DCE	ND	ND	ND	NE	NE	1[a]	18AAC75	0.59	1	0.36
	1,1-DCE	ND	ND	ND	NE	NE	0.07[a]	18AAC75	0.025	0.07	0.28
	Vinyl Chloride	ND	ND	ND	NE	NE	0.02[a]	18AAC75	0.782	0. 02	0.00019
Groundwater (mg/L) (B-Aquifer)	TCE	0.099	MW-41 (1992)	0.041 (MW-41)	NE	NE	0.005	18AAC75	NA	0.005	0.0028
	cis-1,2-DCE	ND	ND	ND	NE	NE	0.07	18AAC75	NA	0.07	0.036
	trans-1,2-DCE	ND	ND	ND	NE	NE	0.1	18AAC75	NA	0.1	0.36
	1,1-DCE	ND	ND	ND	NE	NE	0.007	18AAC75	NA	0.007	0.28
	Vinyl Chloride	ND	ND	ND	NE	NE	0.002	18AAC75	NA	0.002	0.00019
Surface Water (mg/L)	TCE	0.0153	SW-1 (1997)[b]	0.0153	0.35	Ecotox	0.0027[c]	18AAC70	--	0.0027	0.0027
	cis-1,2-DCE	ND	ND	ND	0.59	ORNL PRGs	0.07	18AAC70	--	0.07	0.07
	trans-1,2-DCE	ND	ND	ND	0.59	ORNL PRGs	0.1	18AAC70	--	0.1	0.1
	1,1-DCE	ND	ND	ND	0.025	ORNL PRGs	3.3E-05[c]	18AAC70	--	3.3E-05	3.3E-05
	Vinyl Chloride	ND	ND	ND	0.782	ORNL PRGs	0.002[c]	18AAC70	--	0.002	0.002
Sediment (mg/Kg)	TCE	0.0018	SWF-15 (1999)	0.0018	0.041[d]	NOAA SQuiRTs	—	—	--	0.04	0.04
	cis-1,2-DCE	0.2	SS011-37 (1996)	NA	0.4[e]	SQB	—	—	--	0.4	0.4
	trans-1,2-DCE	ND	ND	NA	0.4[e]	SQB	—	—	--	0.4	0.4
	1,1-DCE	ND	ND	NA	0.031[e]	SQB	—	—	--	0.031	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.
**18 AAC 75 Oil and Hazardous Substances Pollution Control Regulations (October 2018)
[a] 1999 ADEC Table C Groundwater Cleanup Levels with the “10 times rule” applied for A-Aquifer. This rule is no longer included in ADEC regulations; default cleanup levels are used.
[b] 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 exceedances in 1999 surface water samples collected from Eskimo Creek.
[c] Based on the consumption of water and organisms, and 10^{-6} carcinogenic risk.
[d] 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.
[e] 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
18 AAC 70 Alaska Water Quality Standards (April 2018)
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 – Trichloroethene
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)		Sediments (mg/Kg)	
	Criteria	Basis	Criteria (Freshwater Sediment)	Basis
Benzene	0.0046	18AAC75	0.057	OSWER
Ethylbenzene	0.015	18AAC75	0.089	SQB
Toluene	1.1	18AAC75	0.05	SQB
Xylenes	0.19	18AAC75	0.025	OSWER
Benzo(a)pyrene	0.00025	18AAC75	0.0324	SQuiRTs
Benzo(a)anthracene	0.00030	18AAC75	0.01572	SQuiRTs
Benzo(b)fluoranthene	0.0025	18AAC75	1.8[b]	SQuiRTs
Benzo(k)fluoranthene	0.025	18AAC75	0.0272	SQuiRTs
Dibenzo(a,h)anthracene	0.00025	18AAC75	0.01	SQuiRTs
Indeno(1,2,3-cd)pyrene	0.00019	18AAC75	0.0173	SQuiRTs
Naphthalene	0.0017	18AAC75	0.01465	SQuiRTs
GRO	2.2	18AAC75	NA	
DRO	1.5	18AAC75	NA	
TAH	NA		NA	
TAqH	NA		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, October 2018)
18 AAC 70 Alaska Water Quality Standards (ADEC, April 2018)
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

Ten 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 in 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.

An IC Inspection will be conducted in the fall of 2019 and reported in the 2019 RAO/LUC report.

2.2.3 Product Monitoring at Seeps 1 & 2

Product monitoring and recovery will occur in the spring of 2019, after breakup and again in the fall. Results will be reported in the 2019 RAO/LUC report.

2.2.4 Work Plan Deviations

- During the 2017 sampling effort, WP03-11 had an extremely slow recharge. In 2018, POC-3 was sampled as a substitute.

- Dissolved oxygen and ORP results were not collected due to the rapid drawdown and slow recharge rate at GP1A.

- Due to freezing conditions, the purge water was not sampled or filtered. The purge water is stored in the biocell area and will be sampled and filtered in the spring of 2019. Results will be included in the 2019 RAO/LUC report.

- The IC Inspection was not done due to snow covered ground conditions. The inspection will be done in the fall of 2019 and results will be included in the 2019 RAO/LUC report.

Table 2-3: Groundwater Zone 1 Sample Analyses Summary

A-Aquifer Wells Location ID	Comment	Matrix	Location Type	Analytical Methods 8260C VOCs	8260C SIM VOCs	8011 EDB & 1,2,3-TCP	AK101 GRO	AK102 DRO	8270D SIM PAHs	SM 2320B Alkalinity	300.0 Chloride/ Sulfate	353.2 Nitrate/ Nitrite	RSK-185 Methane	6010B Dissolved Fe & Mn	Sample ID
RPO-1		Groundwater	Well Point	1	1	1		1		1	1	1	1	1	18KS1ZMWRPO1-110WG
RPO-3		Groundwater	Well Point	1	1	1		1		1	1	1	1	1	18KS1ZMWRP03-112WG
WP03-06		Groundwater	Well Point	1	1	1		1		1	1	1	1	1	18KS1ZWP0309-111WG
GP-1A		Groundwater	Well Point	1	1	1		1		1	1	1	1	1	18KS1ZGP1A-113WG
ETMW-2		Groundwater	Monitoring Well	1	1	1		1		1	1	1	1	1	18KS1ZETMW2-114WG
MW-9		Groundwater	Monitoring Well	1	1	1		1		1	1	1	1	1	18KS1ZMW9-115WG
MW89-1		Groundwater	Monitoring Well	1	1	1		1		1	1	1	1	1	18KS1ZMW891-116WG
MW-6		Groundwater	Monitoring Well	1	1	1		1		1	1	1	1	1	18KS1ZMW06-117WG
MW-23		Groundwater	Monitoring Well	1	1	1		1		1	1	1	1	1	18KS1ZMW23-118WG
MW-28	MS/MSD	Groundwater	Monitoring Well	3	3	3		3		3	3	3	3	3	18KS1ZMW28-119WG
Duplicate Sample		Groundwater	Monitoring Well	1	1	1		1		1	1	1	1	1	18KS1ZMW99-120WG
Trip Blanks		Water	QA/QC	4	4	4									18KS1ZTB-MMDD
A-Aquifer Sample Totals				17	17	17	0	13	0	13	13	13	13	13	
B-Aquifer Wells Location ID		Matrix	Location Type	EPA Method 524.2 VOCs	8260C SIM VOCs	8011 EDB & 1,2,3-TCP	AK101 GRO	AK102 DRO	8270 SIM PAHs	SM 2320B Alkalinity	300.0 Chloride	353.2 Nitrate/ Nitrite	RSK-185 Methane	6010B Dissolved Fe & Mn	Sample ID
MW-41	MS/MSD	Groundwater	Monitoring Well	3				3							18KS1ZMW41-201WG
MW-13-13B		Groundwater	Monitoring Well	1				1							18KS1ZMW1313B-202WG
MW-13-09B		Groundwater	Monitoring Well	1				1							18KS1ZMW1309B-203WG
Duplicate Sample		Groundwater	Monitoring Well	1				1							18KS1ZMW44-204WG
Purge Water Inf		Groundwater	GAC Pre-treatment	1*			1*	1*	1*						18KS1ZPURGEINFMMDD
Purge Water Eff		Groundwater	GAC Post treatment	1*			1*	1*	1*						18KS1ZPURGEEFFMMDD
Equipment Blank		Water	QA/QC-Grundfos	1				1							18KS1ZEBMMDD
Trip Blanks		Water	QA/QC	2			2								18KS1ZTB-MMDD
B-Aquifer Sample Totals				9	0	0	2	7	2	0	0	0	0	0	

1* Purge water will be filtered and sampled in the spring of 2019.

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 2018 Zone 1 sampling. Results for MNA parameters are depicted on Figure 2-2 and Table 2-4. Sampling for BTEX constituents was continued in 2018, 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 in Appendix F.

2.3.1 A-Aquifer Analytical Results

2.3.1.1 DRO

Results from five of the ten A-Aquifer monitoring wells/well points sampled were above the ADEC cleanup level of 1.5 mg/L for DRO. DRO concentrations above cleanup levels ranged from 1.7 to 3.8 mg/L. On average, these results are slightly higher than last year's results.

2.3.1.2 TCE

Five of the six A-Aquifer monitoring wells had detectable TCE concentrations above the cleanup level of 2.8 µg/L. Results for the four monitoring wells ranged from 2.9 to 65 µg/L.

One of the four POC well points (POC-1) sampled equaled the action level of 2.7 µg/L for TCE. Results from the four well points ranged from 0.093 to 2.7 µg/L.

2.3.1.3 1,2,4-Trimethylbenzene

The result from MW-9 (110 µg/L) was above the ADEC cleanup level of 56 µg/L for 1,2,4-Trimethylbenzene. Low levels were also detected in ETMW-02 (0.62/0.67 µg/L), WP03-06 (3.5 µg/L), and GP1A (0.15 µg/L).

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 340 µg/L and 5.2 µg/L, respectively. Naphthalene was detected in ETMW-2 and its duplicate at 1.4/1.2 µg/L, MW-23 at 0.18 µg/L, and MW89-1 at 0.093 µg/L.

2.3.1.5 EDB and TCP

When ADEC changed the cleanup levels, method 8260 did not have low enough detection limits for EDB and TCP. In 2017 and 2018, A-Aquifer groundwater samples were analyzed for EDB and TCP using

EPA method 8011 which has a detection limit below the regulatory criteria for EDB. The detection limit for TCP is 0.0081 µg/L while the ADEC cleanup level is 0.0075 µg/L. Sample results from both years were non-detect for both analytes. However, the non-detect for TCP does not verify that TCP is below ADEC cleanup levels.

2.3.1.6 Inorganics

Several inorganic analyses were performed to help determine 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 temperature, pH, DO, conductivity, and oxidation reduction potential (ORP, also known as redox potential).

- DO measurements ranged between 3.96 and 13.4 mg/L. We believe that there was a problem measuring DO in some wells this year. DO measured at MW89-1 and ETMW-02 was much higher than in previous years and is at or above the theoretical maximum concentration of DO at the temperatures observed. MW89-1 also has DRO that exceeds cleanup levels and thus should have low DO. Problems with this year's DO data confound the normally observed inverse correlation between DRO and DO seen at this site in past years.
- Ferrous iron concentrations ranged from ND in MW-6 to 69 mg/L in GP-1A. All of the samples with high concentrations of DRO had iron concentrations equal to or greater than 1.0 mg/L. These data suggest that intrinsic biodegradation is occurring.
- Manganese concentrations ranged from 1.6 to 22 mg/L in wells with higher DRO results. Manganese concentrations ranged between ND to 4.8 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 higher concentrations of DRO were 0.83 mg/L to 4.9 mg/L. In five wells with low DRO results, methane concentrations were ND to 4 mg/L. The presence of methane is evidence that intrinsic bioremediation of the fuel hydrocarbons is occurring.
- Alkalinity measurements ranged from 64 to 150 mg/L in wells with lower DRO concentrations, and 170 to 370 in wells with DRO concentrations above the RAO. Generally, elevated petroleum hydrocarbon levels correlated with increased alkalinity concentrations.
- Temperatures at the well points ranged between 2.99 and 4.1°C and between 4.97 and 6.4°C at the monitoring wells. Temperatures less than 4.4°C tend to inhibit the rate of biodegradation.

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)	Nitrate/ Nitrite (mg/L)	Alkalinity (mg/L)	Ferrous Iron (mg/L)	Manga-nese (mg/L)	Methane (mg/L)	Temp	pH	DO (mg/L)	Con	ORP (mV)
ADEC Cleanup Levels	**1.5**	**2.7*/ 2.8**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
POC-1*	**2.8**	2.7	3.0	0.76	0.015	310	12	11	2.9	3.12	6.55	3.96	459	38.8
GP-1A*	0.99	0.093	4.0	0.70	0.028	64	69	4.8	4.0	NA	NA	NA	NA	NA
WP03-06*	**3.8**	1.5	2.8	0.99	0.018	270	25	22	4.9	4.1	6.68	4.67	433	-19.9
POC-3*	**1.7**	0.50	4.0	0.34	0.013	260	7.4	3.1	2.4	2.99	6.6	9.51	375	72.9
ETMW-02	0.76 (0.90)	**65 (60)**	3.2	12	2.0	130	0.34 (0.37)	1.9 (1.8)	0.0087 (0.0088)	5.7	6.26	12.77	243	162.9
MW-9	**3.5**	ND	2.7	0.21	0.025	170	9.4	3.7	1.6	6.4	6.48	4.15	284	46.9
MW89-1	**2.8**	**2.9**	18	3.1	0.013	370	1.0	1.6	0.83	5.2	6.69	13.4	588	109.9
MW-6	0.084	**11**	6.9	5.2	0.78	120	ND	ND	ND	NA	NA	NA	NA	NA
MW-23	0.21	**11**	2.3	12	3.5	150	ND	ND	ND	4.97	6.34	9.51	292	178.6
MW-28	0.14	**32**	2.1	11	3.2	130	0.64	0.026	0.26	5.99	5.76	5.04	244	220.9

ADEC Cleanup Levels - 18 AAC 75 Table C (October 2018)
* TCE Action Level at POC Well Points
NS - Not Sampled/Analyzed
NA - Not Applicable
ND - Not detected above method reporting level (MRL)
Analytical results exceeding cleanup levels shown in **BOLD**.
WP0306 was a substitute for WP0309
POC-3 was a substitute for WP03-11
(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 0.067 mg/L to 0.76 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 46 (45) µg/L. These results are above the 2.8 µg/L cleanup level. MW-41 has had TCE concentrations from the previous fourteen sampling events ranging between 31 µg/L and 94 µg/L. TCE was not detected in MW13-13B.

2.3.2.3 Chloroform

One 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 2.0 (2.1) in MW1309B to 5.4 µg/L in MW41.

2.3.2.4 Naphthalene

The result from MW41 (7.2 µg/L) was above the ADEC cleanup level of 1.7 µg/L for naphthalene and non-detect for the other two B-Aquifer wells.

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 nine Zone 1 monitoring wells. Output from the ProUCL evaluation can be found in Appendix E. Tables 2.5 and 2.6 summarize the concentration trends observed in the nine 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 22% of the concentration trends were decreasing, 11% were increasing, and 67% had no trend. 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	3	22%
Increasing	1	1	11%
No Trend	7	5	67%
Totals	9	9	18

Table 2-6 Zone 1 MANN-Kendall Trend Summary

Well	DRO	TCE
MW-41	NT	**I**
MW13-09B	NT	NT
POC-1	**I**	**D**
GP1A	NT	**D**
MW89-1	**D**	**D**
MW-9	NT	NT
EKMW-2	NT	NT
MW-06	NT	NT
MW-28	NT	NT

D- Decreasing I - Increasing
NT – No trend

2.4 ZONE 1 CONCLUSIONS

2.4.1 A-Aquifer Monitoring

Three well points and two monitoring wells exceeded the cleanup level of 1.5 mg/L for DRO. TCE was detected equal to the action level of 2.7 µg/L at one of the point of compliance (POC) well points. TCE was detected in five 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 22% of concentration trends are decreasing at this site, while 67% indicate no trend. Since most concentration trends are decreasing or stable, this analysis provides evidence that intrinsic remediation is occurring at this site.

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. MW-41 also exceeded the RAO for chloroform and naphthalene.

2.4.3 Product Recovery

Product recovery at Zone 1 Seep 1 and Seep 2 is scheduled to occur in the spring of 2019, after breakup and again in the fall. Both results will be reported in the 2019 RAO/LUC report.

2.4.4 Institutional Control Inspection

The IC Inspection will be done in the fall of 2019 and findings will be included in the 2019 RAO/LUC report.

2.4.5 Condition of Wells

In 2017, WP03-11 had an extremely slow recharge rate. POC-3 was substituted for WP03-11. Well points GP1, GP1A, WP03-06, and WP03-11 are jacked.

2.5 ZONE 1 RECOMMENDATIONS

- Well points GP1, GP1A, WP03-06, and WP03-11 are extremely jacked out of the ground. At least three of these well points should be replaced and the fourth decommissioned.

- A-Aquifer samples were analyzed using EPA Method 8011 for EDB and TCP in 2017 and 2018. Results for all wells were non-detect for both years. EPA Method 8011 should be eliminated from the Zone 1 sampling program.

- MW13-13B has been sampled for four years without any exceedances for any analytes. Sampling at this well should discontinue.

- Reduce MNA sampling to every five years in coordination with the five-year review.

- Four Zone 1 surface water samples and sediment samples have not been collected since 2012. The recommendation in the 2012 final report approved by ADEC was to sampled surface water and sediment every three years. These samples should be collected in 2019.

Table 2-7: Zone 1 Historical Analytical Data (2002-2018)

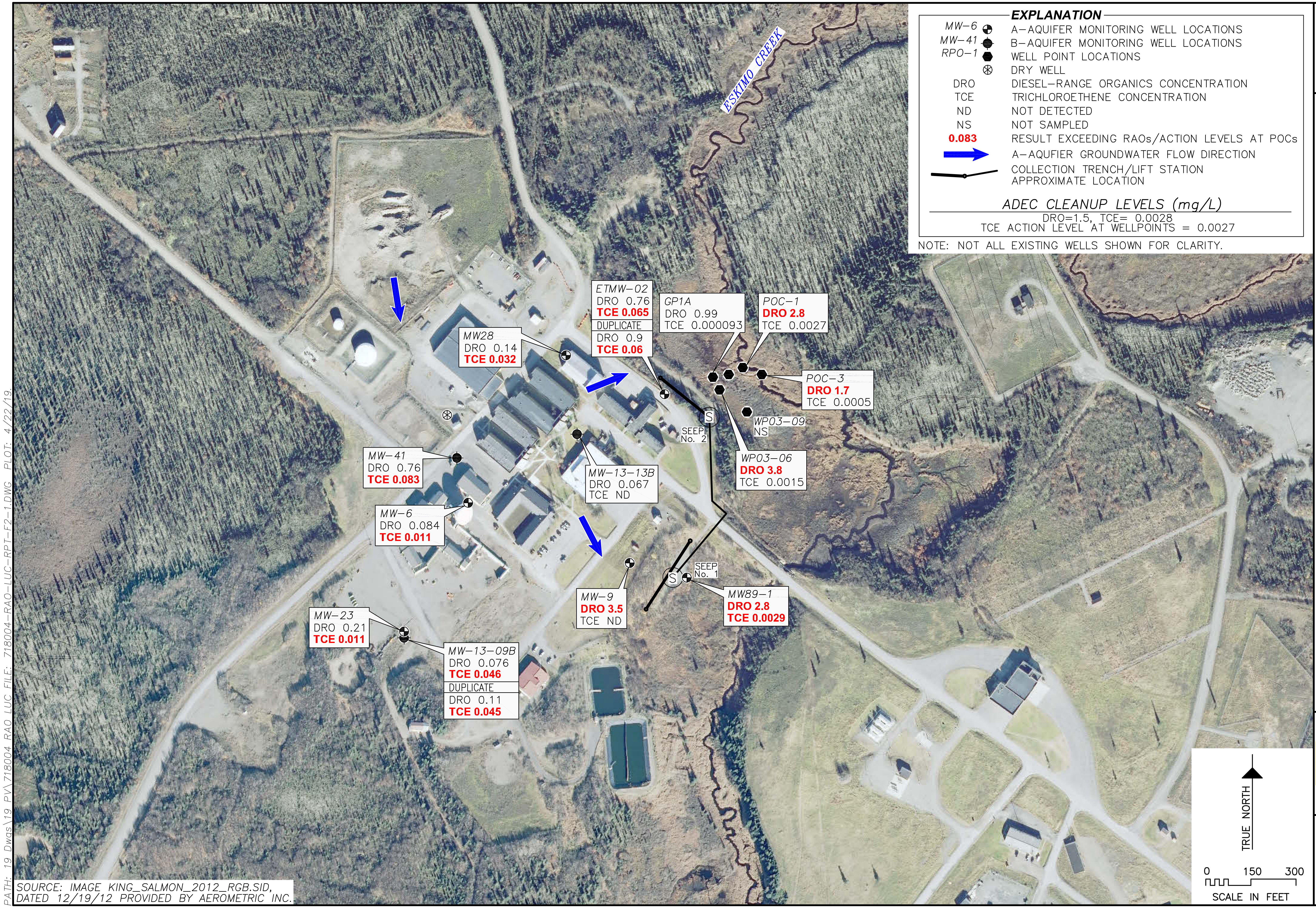
Well	Analyte (mg/L)	ADEC Cleanup Levels (mg/L)	2002	2004	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
POC-1 (RPO-1)	DRO	1.5			**1.7**	**1.5**	1.3	0.80	NS	1.3	**1.6**	**1.9**	**2.5**	**2.7**	**1.8**	**2.8**
	TCE	0.0027*			**0.0737**	**0.039**	**0.04**	**0.018**	NS	**0.003**	**0.005**	**0.0071**	**0.0044**	**0.0029**	0.0023	0.0027
	Alkalinity	None			197	185	172	187	NS	250	270	300	230	290	250	310
	Iron	None			9.34	10.6	12.2	0.086	NS	22	13	9	7.8	11	10	12
	DO	None			5.74	0.82	0.4	2.15	NS	1.55	0.48	0.43	0.46	0.66	1.29	3.96
GP-1 *GP1A sampled in 2014-2018 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	0.99
	TCE	0.0027*	**0.616**		**0.0053**	**0.0059**	0.0012	ND	NS	ND	ND	ND	0.00032	ND	ND	0.000093
	Alkalinity	None	259		272	243	235	47	NS	52	NA	100	210	310	12	64
	Iron	None	ND		4.22	45.9	111	40.9	NS	100	NA	66	100	100	1.1	69
	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 (alt WP03-07 in 2008, WP03-09 in 2009-16, WP03-06 in 2017-18)	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**	**3.8**
	TCE	0.0027*			ND	**0.0052**	0.0024	**0.0028**	**0.0073**	ND	ND	ND	ND	ND	0.0024	0.0015
	Alkalinity	None			56.2	292	287	294	149	43	99	29	97	190	250	270
	Iron	None			10.4	44.5	61.3	57.7	89	46	87	21	55	130	25	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	4.67
WP03-11 (POC-3 used as a substitute in 2018)	DRO	1.5			**3.65**	**3.7**	**4.2**	**2.0**	NS	**2.0**	**1.8**	**2.6**	**3.7**	**2.5**	1.0	**1.7**
	TCE	0.0027*			**0.0272**	**0.013**	**0.0088**	**0.0078**	NS	**0.0082**	**0.0049**	**0.0044**	**0.0045**	**0.0034**	0.00025	0.0005
	Alkalinity	None			291	240	307	338	NS	300	270	300	300	300	NA	260
	Iron	None			ND	0.0705	0.047	0.30	NS	4.8	1.5	2.7	4	3.1	NA	7.4
	DO	None			4.77	0.74	0.5	1.62	NS	0.34	0.34	0.55	0.76	0.67	NA	9.51
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)	0.76 (0.90)
	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)**	**0.065 (0.060)**
	Alkalinity	None	269	203	202	203	192	WP0	NS	170	190	160	160	140	170 (160)	130
	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)	0.34 (0.37)
	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	12.77
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**	**3.5**
	TCE	0.0028**	0.0019	0.0011	ND	0.00066	ND	ND	ND	0.00025	0.0015	ND	0.00084	ND	ND	ND
	Alkalinity	None	314	316	162	192	281	292	277	230	230	230	210	200	170	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	9.4
	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	4.15
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**	**2.8**
	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**	**0.0029**
	Alkalinity	None		18.8	315	311/313	297/291	314	333/336	350	370	390	390	370	380	370
	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	1.0
	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	13.4
MW-6	DRO	1.5											0.2	0.096	0.062	0.084
	TCE	0.0028**											**0.022**	**0.024**	**0.020**	**0.011**
	Alkalinity	None											110	110	120	120
	Iron	None											0.04	ND	ND	ND
	DO	None											3.54	4.13	1.9	NA
MW-23	DRO	1.5											**0.4**	0.24/0.27	NS	0.21
	TCE	0.0028**											**0.026**	**0.019**	NS	**0.011**
	Alkalinity	None											130	110	NS	150
	Iron	None											0.02	ND	NS	ND
	DO	None											6.74	8.48	NS	9.51
MW-28	DRO	1.5											**0.2**	0.12	0.11	0.14
	TCE	0.0028**											**0.095 (0.12)**	**0.11**	**0.11**	**0.032**
	Alkalinity	None											110 (120)	120	130	130
	Iron	None											0.46 (0.56)	ND	1.1	0.64
	DO	None											2.66	4.17	0.96	5.04

Notes: * Action level at POCs for TCE is the ecological surface water quality criteria.
** Cleanup Levels at monitoring wells for TCE (ADEC Table C, Oct. 2018)
Results shown in **BOLD** exceed ADEC Table C Cleanup Levels
DRO - Diesel 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 - 2018)

Well	Analyte	ADEC Cleanup Levels (mg/L)	2002	2004	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
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	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	0.76
	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**	**0.083**
MW13-13B	GRO	2.2												NA	NA	NA	NA
	DRO	1.5												0.17	0.13	0.076	0.067
	TCE	0.0028												ND	ND	0.00017	ND
MW13-09B	GRO	2.2												NA	NA	NA	NA
	DRO	1.5												0.23 (0.15)	0.14 (0.17)	0.11 (0.10)	0.076 (0.11)
	TCE	0.0028												**0.043 (0.043)**	**0.048 (0.047)**	**0.051 (0.052)**	**0.046 (0.045)**
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	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	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	NS
MW-43	GRO	2.2	ND	ND	NS	ND	0.015	0.018	ND	ND	ND	NA	NA	NS	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	NS
	TCE	0.0028	ND	ND	NS	0.00157	ND	ND	ND	ND	ND	ND	ND	NS	NS	NS	NS

ADEC Cleanup Levels from 18 AAC 75 Table C (October 2018)
Results in **BOLD** exceed cleanup levels.
ND - Not Detected
NA - Not Analyzed
NS - Not Sampled
(Result) are duplicate samples.



PATH: 19 Dwgs\19 PV\718004 RAO LUC FILE: 718004-RAO-LUC-RPT-F2-1.DWG PLOT: 4/22/19.

FIGURE 2-1

DRO AND TCE ANALYTICAL RESULTS GROUNDWATER ZONE 1

GROUNDWATER ZONE 1 (OT-027)
2018 RAO/LUC
King Salmon Divert, Alaska

AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE APRIL 2019
CHKD H.L.H.
DRAWN C.E.H.
PROJ. NO 718004

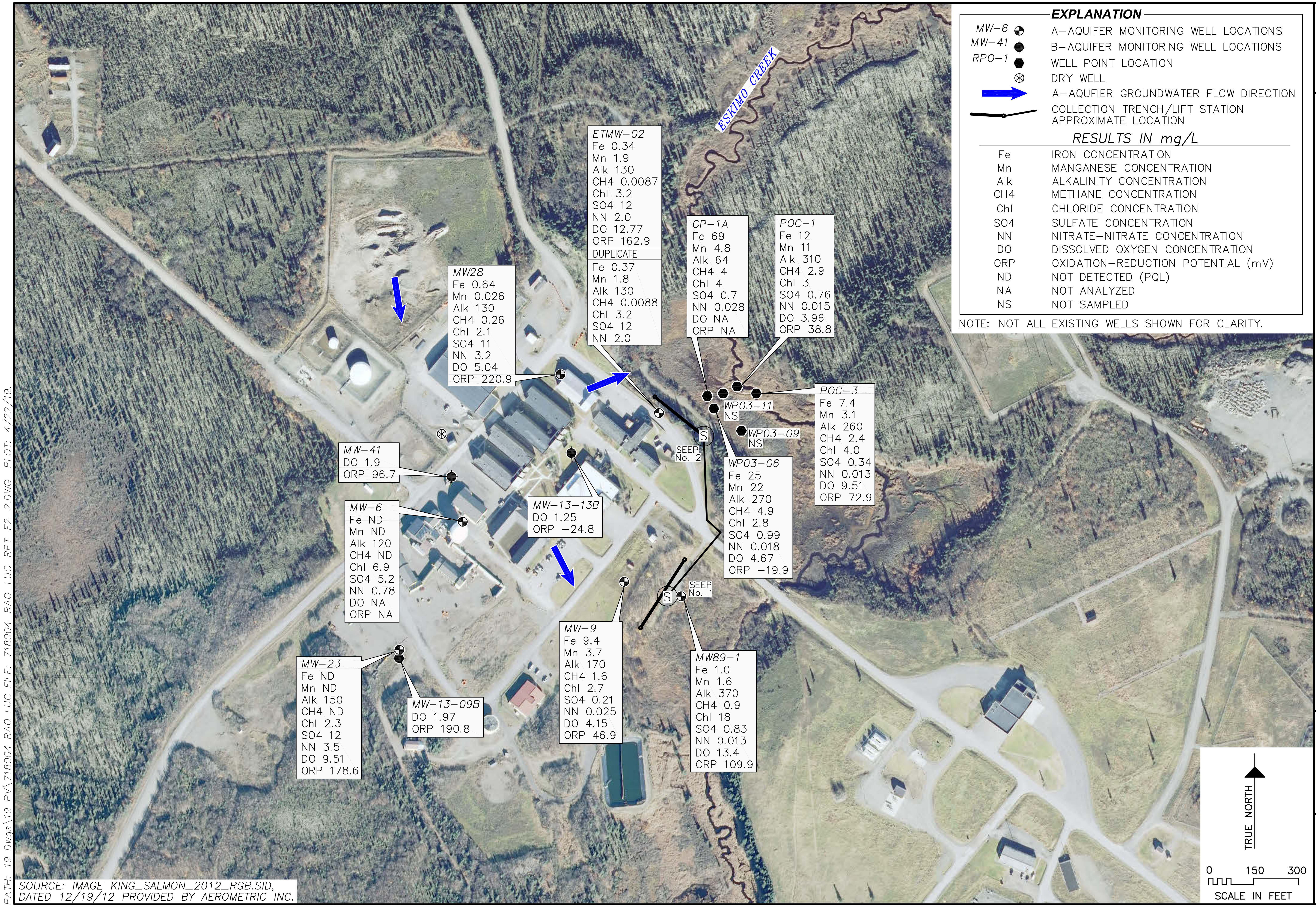


FIGURE 2-2

MONITORED NATURAL ATTENUATION RESULTS GROUNDWATER ZONE 1

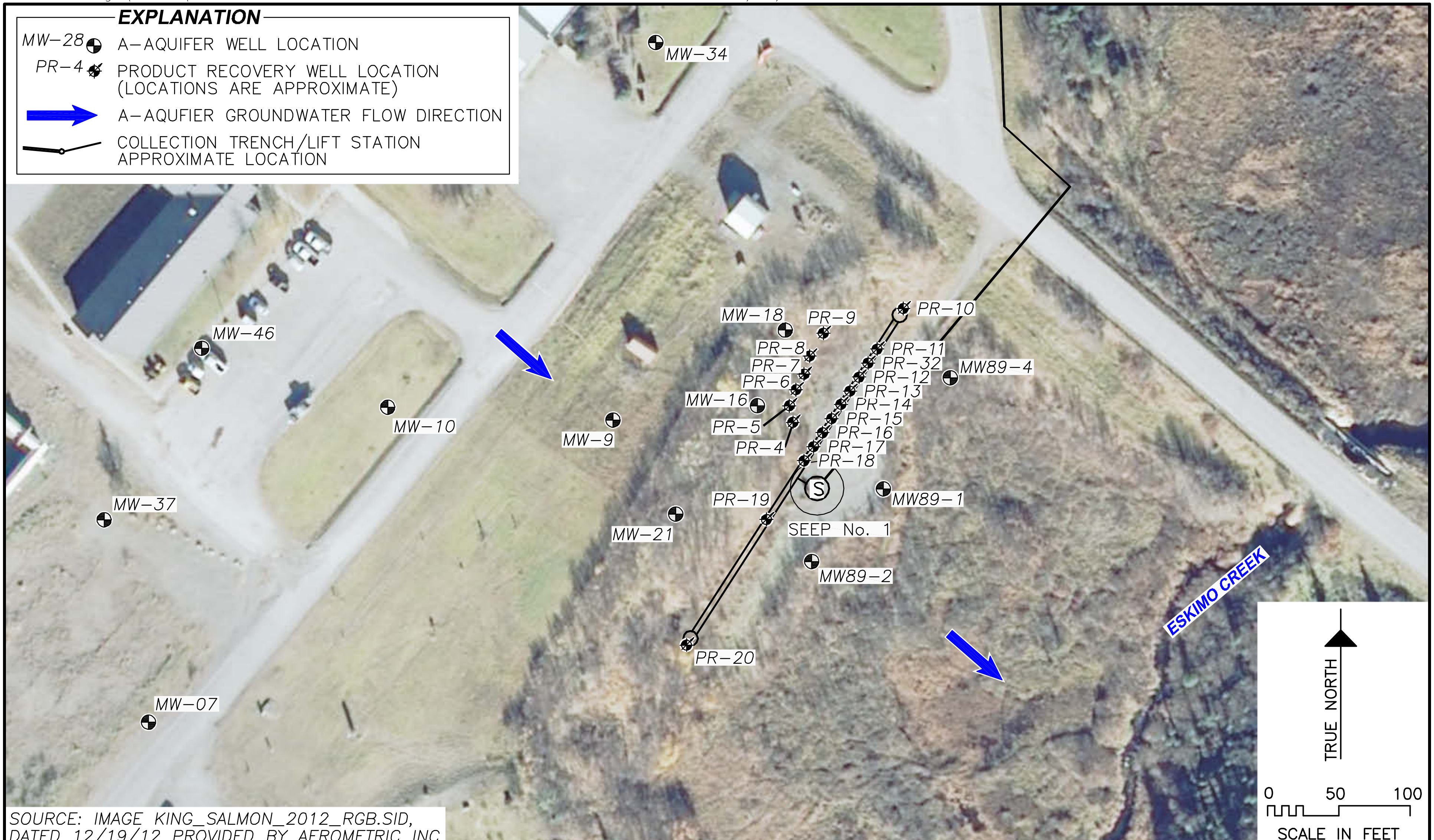
GROUNDWATER ZONE 1 (OT-027)
2018 RAO/LUC
King Salmon Divert, Alaska

AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE APRIL 2019
CHKD H.L.H.
DRAWN C.E.H.
PROJ. NO 718004

PATH: 19 Dwgs\19 PV\718004 RAO LUC FILE: 718004-RAO-LUC-RPT-F2-2.DWG PLOT: 4/22/19.

PATH: 19 Dwgs\19 PV\718004 RAO LUC FILE: 718004-RAO-LUC-RPT-F2-3_4.DWG PLOT: 4/22/19.



SOURCE: IMAGE KING_SALMON_2012_RGB.SID, DATED 12/19/12 PROVIDED BY AEROMETRIC INC.

DATE	APRIL 2019
CHKD.	H.L.H.
DRAWN	C.E.H.
PROJ. NO	718004

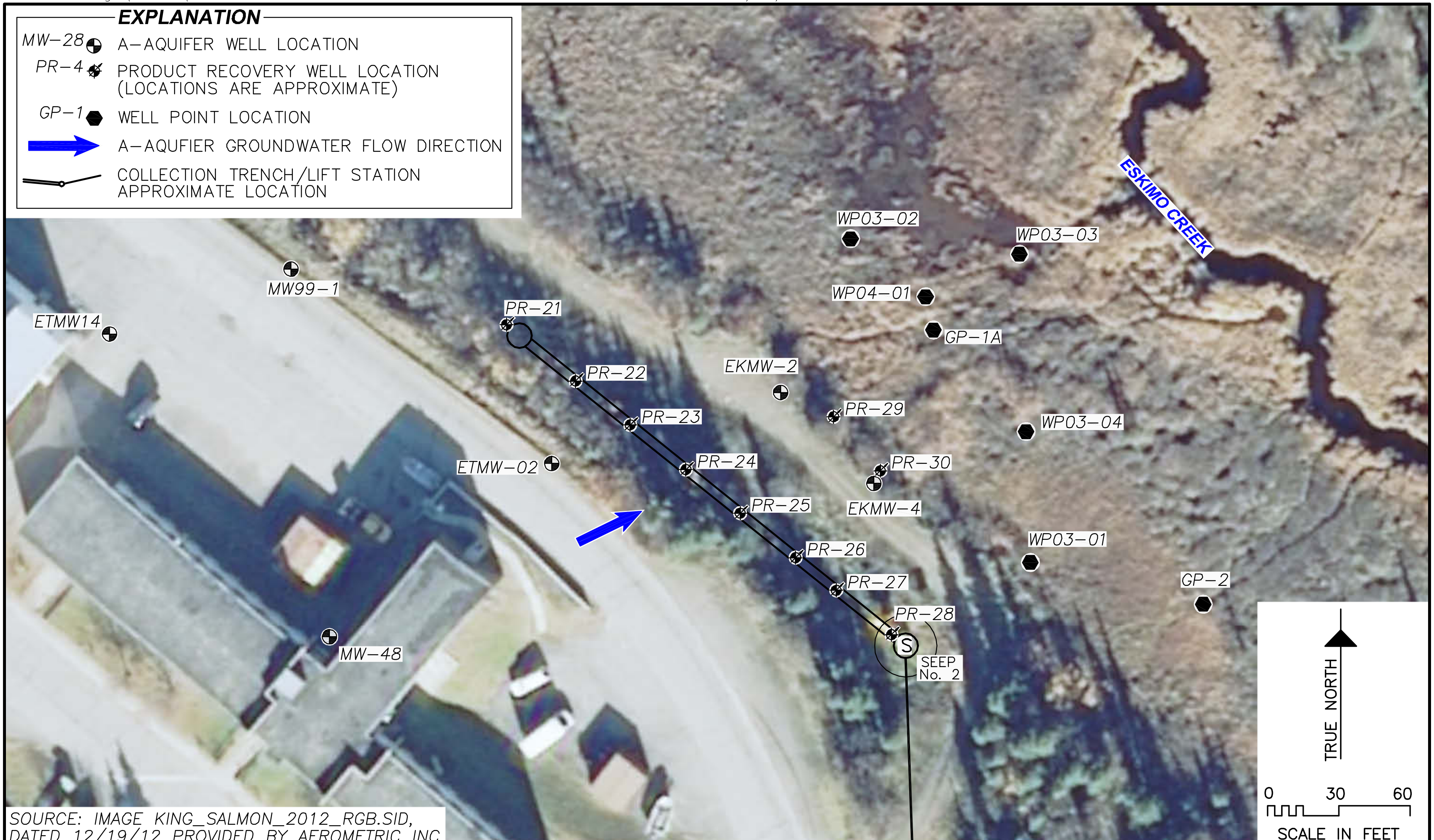
AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

PRODUCT PROBES NEAR SEEP No. 1 (OT027)

GROUNDWATER ZONE 1
2018 RAO/LUC
King Salmon Divert, Alaska

FIGURE
2-3

PATH: 19 Dwgs\19 PV\718004 RAO LUC FILE: 718004-RAO-LUC-RPT-F2-3_4.DWG PLOT: 4/22/19.



DATE APRIL 2019 CHKD. H.L.H. DRAWN C.E.H. PROJ. NO 718004	AIR FORCE CIVIL ENGINEERING CENTER JBER, ALASKA	**PRODUCT PROBES NEAR SEEP No. 2 (OT027)** GROUNDWATER ZONE 1 2018 RAO/LUC King Salmon Divert, Alaska	FIGURE **2-4**

3 ZONE 2 - BASE INDUSTRIAL AREA & ESKIMO CREEK DUMP (OT028)

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 groundwater 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. Surface water RAOs were developed in accordance with the AWQS, 18 AAC 70.

The 2017 Five Year Review recommends using current promulgated ADEC cleanup levels, and an ESD for Zone 2 is being developed using those cleanup levels. Final RAOs presented in the Zone 2 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 SS022 sampling point once two consecutive sampling events are below RAOs. 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, but these samples were not collected during this past field season due to frozen conditions.

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 [f]
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	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 recognized 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.

[f]18AAC 75 Table C (October 2018)

Definitions

18 AAC 75 Oil and Hazardous Substances Pollution Control Regulations (ADEC, 2002)
18 AAC 70 Alaska Water Quality Standards (ADEC, 1999)
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
POC – Point of Compliance
SQB – Sediment Quality Benchmark
TCE – Trichloroethene
DCE – Dichloroethene
— Not applicable
mg/kg – milligrams per kilogram
RAO – Remedial Action Objective
FPP – Floating Petroleum Product
ND – Not detected
NE – Not evaluated
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 between November 2 and December 2, 2018 from six 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

Surface water locations were frozen during the late November, early December field effort. These samples will be collected in the fall of 2019 and reported in the 2019 LUC/RAO report.

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).

The IC Inspection will occur in the fall of 2019 and findings will be included in the 2019 RAO/LUC report.

3.2.4 Work Plan Deviations

The LUC inspection and surface water samples were not collected due to frozen and snow-covered conditions during the November-December field effort.

Table 3-2: Groundwater Zone 2 Sample Analyses Summary

Location ID	Comment	Matrix	Location Type	Analytical Methods									Sample ID
				8260C VOCs	8260C SIM VOCs	8011 EDB & 1,2,3-TCP	AK101 GRO	AK102 DRO	SM 2320B Alkalinity	300.0 Chloride/ Sulfate	353.2 Nitrate + Nitrite	6010B Dissolved Fe+Mn	
B-02		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	18KS2ZB02-107WG
AP-11		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	18KS2ZAP11-111WG
MW-708		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	18KS2Z708-112WG
MW-629	MS/MSD	Groundwater	Monitoring Well	3	3	3	3	3	3	3	3	3	18KS2Z629-113WG
MW00-03		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	18KS2ZMW0003-114WG
MW-628		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	18KS2Z628-115WG
Duplicate Sample		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	1	18KS2Z627-119WG
Trip Blanks		Water	QA/QC	4	4	4	4						18KS2ZTB-MMDD
Total Samples - A-Aquifer				13	13	13	13	9	9	9	9	9	

Location ID	Comment	Matrix	Location Type	8260C VOCs	8260C SIM VOCs	8011 EDB & 1,2,3-TCP		Sample ID
OT28-01		Surface Water	Surface Water					18KS2ZOT281-301WS
OT28-02		Surface Water	Surface Water					18KS2ZOT282-302WS
OT28-03	MS/MSD	Surface Water	Surface Water					18KS2ZOT283-303WS
Duplicate Sample		Surface Water	Surface Water					18KS2ZOT284-304WS
Trip Blanks		Water	QA/QC					18KS2ZTB-MMDD
Total Samples - Surface Water				0	0	0		

3.3 ZONE 2 FINDINGS

Historical and current analytical data results are shown on Tables 3-3 and 3-4. 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 and MW-629 exceeded the cleanup level of 2.2 mg/L for GRO. GRO results were 12 mg/L and 4.8 mg/L respectively. GRO levels for the other four monitoring wells ranged between 0.017 mg/L (708) and 0.85 mg/L (MW00-03). B-02 exceeded the cleanup level of 1.5 mg/kg for DRO. DRO levels ranged from 0.065 (MW-628) to 6.0 mg/L (B-02).

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

3.3.1.2 BTEX

Monitoring well 629 exceeded the ADEC cleanup level for benzene, ethylbenzene, and total xylenes. B-02 exceeded cleanup levels for ethylbenzene and total xylenes. There were no exceedances 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 well MW-629 (0.016 mg/L). Benzene was also detected in MW00-03 at 0.0019 mg/L.
- Toluene was detected in B-02 and MW-629 below the cleanup level of 1.0 mg/L. Results were 0.080 and 0.14 mg/L, respectively.
- Ethylbenzene concentrations in B-02, MW-629, and MW00-03 were above the cleanup level of 0.015 mg/L. Concentrations in those wells ranged between 0.10 mg/L to 0.52 mg/L.
- Total xylene concentrations in B-02, and MW-629 were above the cleanup level 0.19 mg/L. Concentrations in those wells were 2.94 and 1.04 mg/L respectively. MW00-03 was the only other monitoring well with any xylene detection (0.070 mg/L.)

3.3.1.3 TCE

TCE was detected above the cleanup level of 2.8 µg/L in three monitoring wells (628, B-02, 629). TCE levels in those wells ranged between 6.1 µg/L to 16 µg/L (B-02). Two 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 the current ADEC cleanup level of 2.8 µg/L.

3.3.1.4 Naphthalene

Monitoring wells B-02 and 629 exceeded the ADEC groundwater cleanup level of 1.7 µg/L for naphthalene. Those results were 120 µg/L and 19 µg/L respectively.

3.3.1.5 1,2,4-Trimethylbenzene

The results from two of the six A-Aquifer monitoring wells sampled were above the ADEC groundwater cleanup level of 56 µg/L for 1,2,4-Trimethylbenzene. The sample result from B-02 was 520 µg/L and 110 µg/L for 629. The result from MW00-03 was 1.2 µg/L.

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 60 µg/L. The result from 629 was 19 µg/L and 1.1 µg/L for MW00-03.

3.3.1.7 EDB and 1,2,3-TCP

1,2-Dibromomethane was detected in four monitoring wells below the cleanup level of 0.075 µg/L. Concentrations ranged between 0.0068 to 0.015 µg/L.

Monitoring wells B-02 and 629 exceeded the cleanup level of 0.0075 µg/L for 1,2,3-Trichloropropane. The results were 0.021 and 0.0091, respectively.

3.3.1.8 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.

Table 3-3: Historical Zone 2 Groundwater Results

Site Area	Well Location	Analyte	ADEC Cleanup Levels	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	2018 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	0.028/0.031
		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	0.065/0.064
		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	ND
		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	ND
		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	9.7/9.0
		PFOA	0.40 µg/L																					0.033	NA	NA
		PFOS	0.40 µg/L																					0.31	NA	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	NS
		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	NS
		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	NS
		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	NS
		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	NS
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	12
		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	6.0
		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	3.5
		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	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	16
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	NS
		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	NS
		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	NS
		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	NS
		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	NS
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	NS
		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	NS
		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	NS
		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	NS
		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	NS
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	NS
		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	NS
		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	NS
		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	NS
		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	NS
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	4.8
		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	0.50
		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	1.6
		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	16
		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	6.1
Building 157 & 159	MW00-04 (AP11 sampled 2014-18 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	0.020
		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	0.067
		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	ND
		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	ND
		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	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	0.85
		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	0.24
		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	0.17
		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	1.9
		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	0.31
		PFOA	0.40 µg/L																					0.41	NA	NA
		PFOS	0.40 µg/L																					0.56	NA	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	NS
		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	NS
		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	NS
		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	NS
		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	NS
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	0.017
		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	ND
		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	ND
		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	ND
		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	ND

Notes:

ADEC Cleanup Levels from 18 AAC 75 Table C (October 2018)

ND - not detected above method detection limit | 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 TPH analysis, not DRO analysis

mg/L - milligrams per liter

BTEX - benzene, toluene, ethylbenzene, and xylene

Multiple results have been reported at locations w/ field duplicates and lab split replicates.

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 2018 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.

3.4.1.2 Geochemical Parameters

DO measurements ranged between 2.13 mg/L (in 629) to 13.22 mg/L (in 628) (Figure 3-3). We believe that there was a problem measuring DO in some wells this year. DO measured at all wells besides MW-629 was over 10 mg/L which is high for groundwater. B-02 has DRO and GRO concentrations above cleanup levels, but the DO measured in this well in 2018 was high (12.99 mg/L), at or above DO solubility, and much higher than in previous years. DO measured at MW-629 was low (2.13 mg/L) as one would expect in an aquifer with naturally degrading hydrocarbons.

A parameter closely associated with DO concentrations is redox potential. The redox potentials ranged from -32.2 mV (629) to 269.5 mV (AP-11). A correlation between reduced redox potentials and petroleum-contaminated areas was observed, especially at B-02 and 629.

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 3-4.

- Nitrate-nitrite was detected in all the wells at concentrations between 0.023 mg/L (628) and 0.65 mg/L (708). 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.
- Sulfate results ranged between 1.2 mg/L in monitoring well B-02 to 3.8 mg/L in AP-11. Previous sulfate results suggested that sulfate reduction does not appear to be an important biodegradation mechanism for petroleum hydrocarbon contamination in Zone 2.

- Manganese was detected in all of the monitoring wells sampled in 2018, at concentrations ranging from 0.0054 mg/L to 4.1 mg/L (Figure 3-3). The wells where manganese concentrations are highest (B-02 and 629) also have the high DRO and GRO. This pattern suggests that petroleum hydrocarbons are being naturally attenuated in Zone 2.
- Ferrous iron was detected in all of the monitoring wells at concentrations between 0.031 and 17 mg/L (Figure 3-3). The wells where ferrous iron concentrations are highest (B-02 and 629) also have the high DRO and GRO. This pattern suggests that petroleum hydrocarbons are being naturally attenuated in Zone 2.
- Alkalinity measurements ranged from 17 mg/L at 708 to 130 mg/L at MW-629. Generally, elevated petroleum hydrocarbon levels correlated with higher alkalinity concentrations.
- Conductivity ranged between 51µS/cm and 235µS/cm. Groundwater temperature ranged between 4.76 (629) and 6.06 (AP-11) degrees Celsius. Groundwater pH ranged between 5.61 (708) and 6.06 (AP-11). These groundwater environmental conditions (pH and temperature) are suitable for biodegradation to occur.

Table 3-4: 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)	Sulfate (mg/L)	Nitrate-Nitrite (mg/L)	Alkalinity (mg/L)	Fe (mg/L)	Mn (mg/L)	Temp	DO (mg/L)	ORP (mV)	pH
ADEC Cleanup Level	**2.2**	**1.5**	**4.6**	**1,100**	**NA**	**2.8**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
628	0.028 (0.031)	0.065 (0.064)	ND	ND	ND	**9.7 (9.0)**	3.7	2.4	0.023 (0.025)	82 (74)	0.37 (0.56)	1.9	5.21	13.22	138.4	6.68
B-02	**12**	**6.0**	ND	80	3,540	**16**	14	1.2	0.029	110	17	2.7	5.83	12.99	-31.7	6.5
629	**4.8**	0.50	**16**	140	1,576	**6.1**	2.8	2.3	0.13	130	4.7	4.1	4.76	2.13	-32.2	6.85
MW00-03	0.85	0.24	1.9	ND	171.9	0.31	2.7	3.6	0.7	80	2.6	2.3	6.03	10.09	72.7	6.36
AP-11	0.020	0.067	ND	ND	ND	ND	3.2	3.8	0.46	41	0.047	0.12	6.06	10.5	269.5	5.7
708	0.017	ND	ND	ND	ND	ND	2.4	2.6	0.65	17	0.031	0.0054	5.83	11.01	219.8	5.61

ADEC Cleanup Levels from 18 AAC 75 Table C (October 2018)
NA - Not Applicable
ND - Not detected above method reporting level (MRL)
RAO - Remedial Action Objectives
Primary (Duplicate) Sample Result
BOLD results are above RAO

3.4.2 TCE Reductive Dechlorination in Zone 2

As explained in section 1.15, the dominant TCE intermediate daughter product generated by reductive dechlorination is usually DCE. In 2018, DCE was detected only in monitoring well 629. 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 occurring where the aquifer is reducing and aerobic degradation of DCE occurring 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 six monitoring wells. Output from this program can be found in Appendix E.

Table 3-5 and Table 3-6 summarize the concentration trends observed in the monitoring wells. The tables list the numbers of wells exhibiting a specific concentration trend for each analyte. Wells 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 27% of the concentration trends were decreasing and 9% were increasing. There was no trend for 63%. This analysis supports the conclusion that intrinsic remediation is keeping contaminant concentrations stable or decreasing at this site.

Table 3-5 Zone 2 Mann-Kendall Analysis Summary

Trend	Benzene	DRO	GRO	TCE	% of Total
Decreasing	3	2	0	1	27%
Increasing	0	0	2	0	9%
No Trend	2	4	4	4	63%
Totals	5	6	6	5	22

Table 3-6 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
Building 157 and 159	AP-11	NT	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

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 & Benzene

Two of the six Zone 2 monitoring well samples exceeded the ADEC cleanup level of 2.2 mg/L for GRO, one well exceeded the cleanup level of 1.5 mg/L for DRO, and one well exceeded the cleanup level of 0.0046 mg/L for benzene. Monitoring data from 1997 through 2018 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.

3.5.2 TCE

Three of the six monitoring wells sampled had TCE detections above the cleanup level. Detected TCE concentrations have declined or remained relatively stable since 2007.

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 all but one sample 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

The IC Inspection will take place in the fall of 2019 and findings will be included in the 2019 RAO/LUC report.

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 ROD states that “annual sampling may be modified to less frequent sampling when sufficient data to establish trends have been establish.” Upon reviewing past sampling results, the following are recommended for Zone 2:

- B02, 629, 202, and MW00-03 should be sampled for GRO, DRO, and VOCs. B02 and 629 both had an exceedance for 1,2,3-TCP in 2018, and therefore Method 8011 should continue to be used at these two wells.
- AP11 and 708 should be sampled for GRO and VOCs. Method 8011 should also be used at 708 since there was an exceedance for EDB in 2017 at this well.
- 628, MW00-05, 446, 447, and MW00-02 should be sampled for VOCs only.
- 202 is considered a surface water protection well, and should be sampled in 2019, and then sampled every other year.
- MW00-04 should be decommissioned because it is damaged.
- Add total aromatic hydrocarbons (TAH) and total aqueous hydrocarbon (TAqH) analyses for surface water as recommended in the 2017 Five Year Review Report.
- Reduce MNA sampling to every five years in coordination with the five-year review.

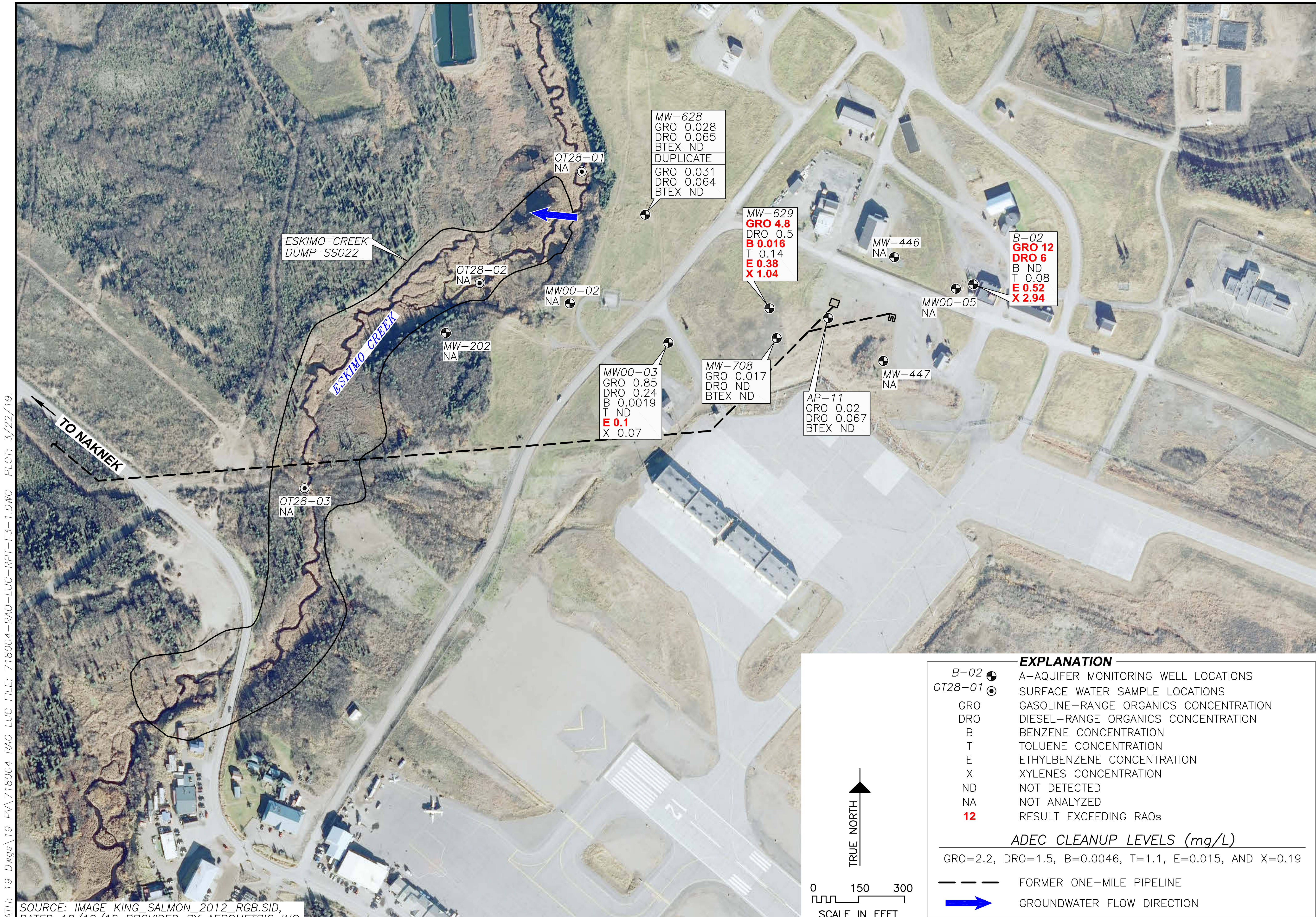


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FIGURE 3-1

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

GROUNDWATER ZONE 2 (OT-028)
2018 RAO/LUC
King Salmon Divert, Alaska

AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE MARCH 2019
CHKD H.L.H.
DRAWN C.E.H.
PROJ. NO 718004

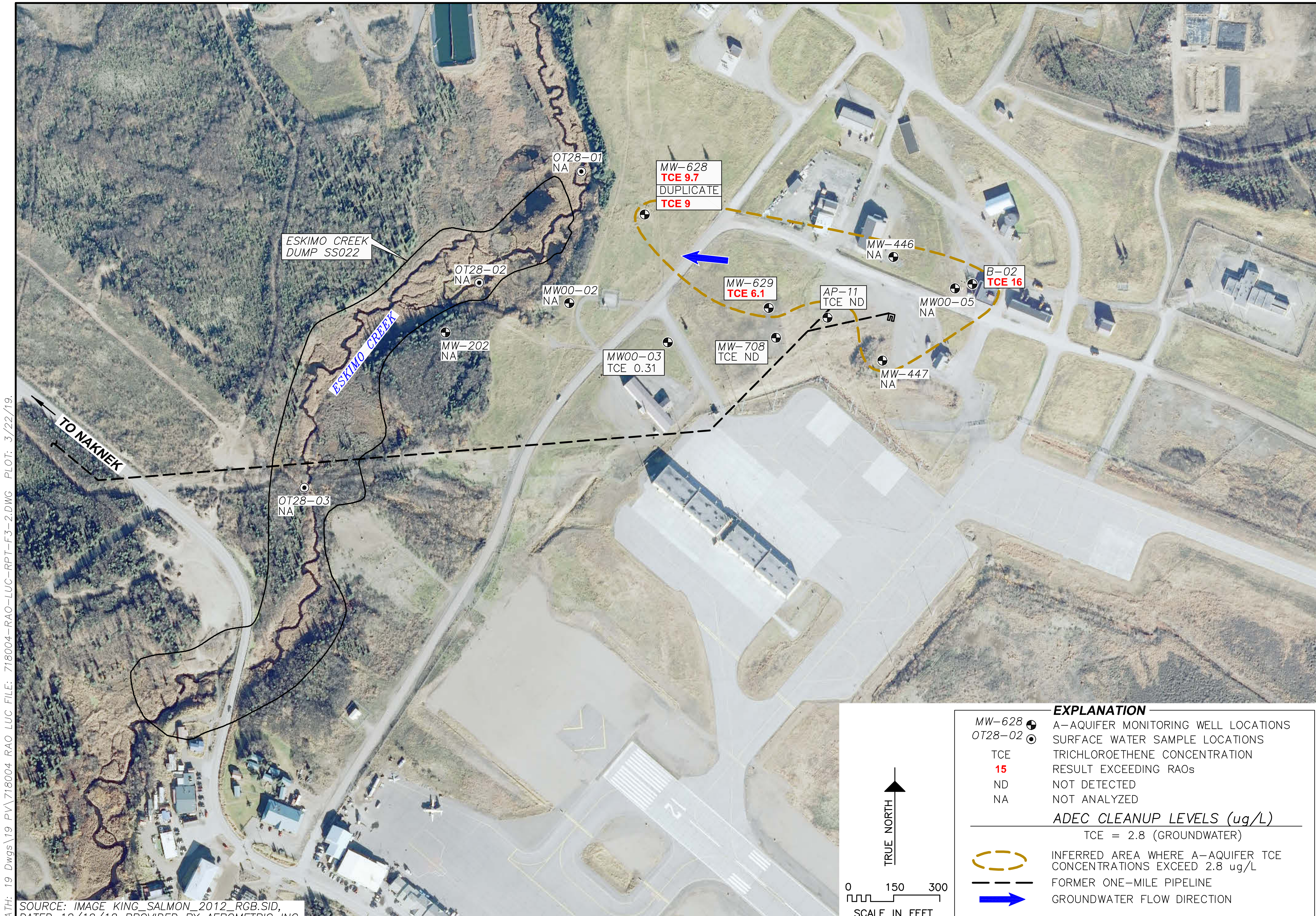

FIGURE 3-2

GROUNDWATER TCE ANALYTICAL RESULTS GROUNDWATER ZONE 2

GROUNDWATER ZONE 2 (OT-028)
2018 RAO/LUC
King Salmon Divert, Alaska

AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE MARCH 2019
CHKD H.L.H.
DRAWN C.E.H.
PROJ. NO 718004

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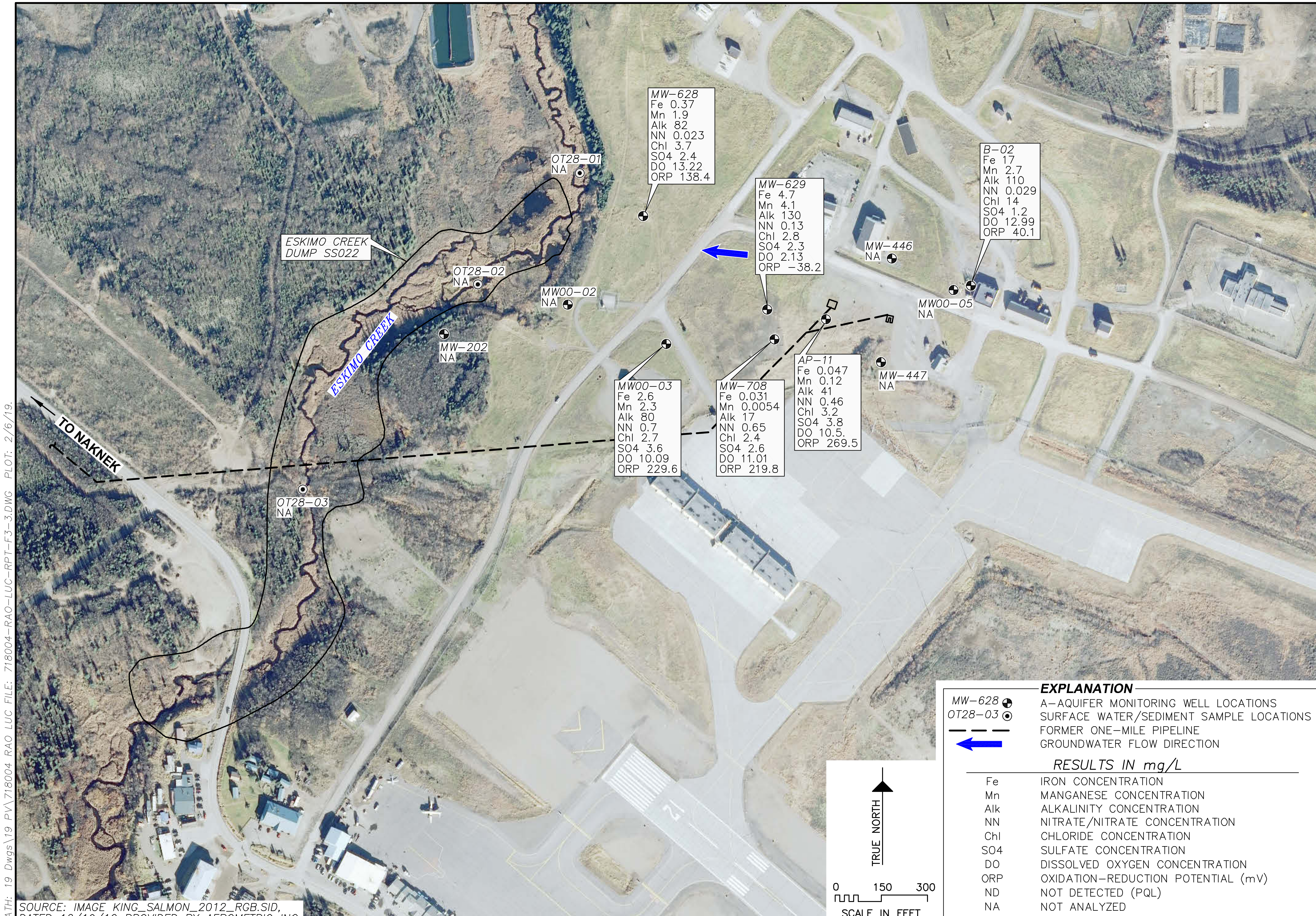


FIGURE 3-3

MONITORED NATURAL ATTENUATION RESULTS GROUNDWATER ZONE 2

GROUNDWATER ZONE 2 (OT-028)
2018 RAO/LUC
King Salmon Divert, Alaska

AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE FEB. 2019
CHKD H.L.H.
DRAWN C.E.H.
PROJ. NO 718004

PATH: 19 Dwgs\19 PV\718004 RAO LUC FILE: 718004-RAO-LUC-RPT-F3-3.DWG PLOT: 2/6/19.

4 ZONE 3 – NORTH & SOUTH BLUFFS (OT029)

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).

Comprehensive sampling was conducted in 2014. The revised protocol for Zone 3, North and South Bluffs recommends groundwater and surface water sampling for all locations at a minimum of every 5 years and should be in coordination with the Five Year Review. The next Five Year Review is due in 2022, and comprehensive sampling is planned for 2019.

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, 2015, and 2016 sampling events.

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 2018 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 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), Final 2015 Long Term Monitoring Report (Paug-Vik, 2016) for the South Bluff only, and Final 2016 Long Term Monitoring Report (Paug-Vik, 2017).

It has been observed and reported as recently as 2017, that fencing around the North Bluff has been knocked down to allow unauthorized use of ATVs on the landfill caps and toe roads. Snow fencing has been replaced, but it doesn't prevent access.

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 2018). 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* ADEC 18 AAC 75 Table C Groundwater Cleanup Levels[A] mg/L
Bulk Hydrocarbons	
Diesel Range Organics	1.5
Metals	
Arsenic	0.00052
Barium	3.8
Cadmium	0.0092
Chromium (VI)	0.00035
Iron	--
Lead	0.015
VOCs	
1,2-Dichloroethane	0.0017
Methylene Chloride	0.11
Toluene	1.1
Trichloroethene	0.0028
PAHs	
Benzo(a)anthracene	0.0003
Benzo(a)pyrene	0.00025
Benzo(b)fluoranthene	0.0025
Benzo(g,h,i)perylene	0.00026
Benzo(k)fluoranthene	0.00080
Chrysene	0.0020
Dibenzo(a,h)anthracene	0.00025
Indeno(1,2,3-cd)pyrene	0.00019
Pyrene	0.12
Pesticides	
Endrin	0.0023
Endrin Aldehyde	--
Methoxychlor	0.037
Other	
Nitrogen, Nitrate-Nitrite	10

NOTES:

A = ADEC 18 AAC 75 Table C Groundwater Cleanup Levels (as amended through October 2018), 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 will be done at the SBTS and Lift Station in the fall of 2019. Inspections activities will be summarized on the Inspection Form in Appendix B and reported in the 2019 RAO/LUC report.

While neither lift station pump was working, one quarterly influent sample was collected from the lift station on November 28, 2018. Three more sampling events are scheduled, and those results will be discussed in the 2019 report. Table 4-2 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 next inspection will occur in the fall of 2019 and findings will be included in the 2019 RAO/LUC report.

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.

An IC Inspection will be performed to verify that no water wells have been installed or that no soil excavation has been conducted within the specified boundaries in the fall of 2019 and findings will be included in the 2019 RAO//LUC report.

4.2.4 Work Plan Deviations

Due to the late field season with freezing and snowy conditions, the SBTS, IC, and North and South Bluffs' inspections were not conducted. These inspections will take place in the fall of 2019 and findings will be included in the 2019 RAO/LUC report.

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

Month/Year	Sample Point*	Comment	Analytical Methods									Sample Number
			8260C VOC	8260C SIM VOC	8011 EDB & 1,2,3 TCP	GRO Method AK 101	DRO Method AK 102	8270 SIM PAHs	Pesticides Standard List 8081A	PCBs Standard List 8082	6020A Low Levels: As, Ba, Cd, Cr, Pb, Fe	
Nov-18	Influent	Primary Sample	1	1	1	1	1	1	1	1	1	18KSSBTSIN1128
Feb-19	Influent	Primary Sample	1	1	1	1	1	1	1	1	1	18KSSBTS0219IN01
Apr-19	Influent	Primary Sample	1	1	1	1	1	1	1	1	1	18KSSBTS0419IN01
Jun-19	Influent	Primary Sample	1	1	1	1	1	1	1	1	1	18KSSBTS0619IN01
-	-	Trip Blank	4	4	4	4						18KSSBTS-TBMMDD
WATER ANALYSES TOTALS			**8**	**8**	**8**	**8**	**4**	**4**	**4**	**4**	**4**	

*Collecting an effluent sample is not necessary. See Section 3.2.

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. Also included in Appendix C are the past three years of SBTS sampling results. 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 are 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. One quarterly sample has been collected at the time this report was written. Therefore the March, June, and July 2018 quarterly reports will be included in this SBTS findings section along with the results from November 2018.

Table 4-3 summarizes the March 2018 results and all results were below the regulatory limits. Low levels of benzene, TCE, arsenic, barium, chromium, and iron were detected.

Table 4-4 summarizes the June 2018 results and all results were below the regulatory limits. Detections include GRO, TCE, chloroform, arsenic, barium, and chromium.

Table 4-5 summarizes the July 2018 results. Tetrachloroethene, TCE, and barium were detected below regulatory limits.

Table 4-6 presents a summary of the November 2018 quarterly SBTS sampling results. GRO, DRO, acetone, benzene, tetrachloroethene, TCE, and heptachlor were detected below the regulatory limits. Arsenic was detected above the effluent limitation. However, according to "Notes to Table C" (18 AAC 75, October 2018), "Due to the prevalence of naturally occurring arsenic throughout the state, arsenic at a site will be considered background arsenic unless anthropogenic contribution from a source, activity, or mobilization by means of another introduced contaminant is known or suspected."

A comprehensive list of all the November 2018 analytical results is included in Appendix C, Table C-15. A comprehensive table of 2015-2018 SBTS results has also been included in Appendix C as Table C-16.

Table 4-3
Laboratory Analytical Results for March 2018
South Bluff Treatment System, King Salmon Alaska

Sample Identification				
Analytical Parameters	EPA Method	Units	Effluent Limitation (Note 1)	Influent Sample 18KSSBTSINF-0316
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.

Table 4-4
Detected Analytes for June 2018
South Bluff Treatment System, King Salmon, Alaska

Sample Identification			Effluent Limitation (Note 1)	Influent Sample 18KSSBTSINF-0606
Analytical Parameters	EPA Method	Units		
VOCs	8260C SIM	µg/L	2.2 2.8	Chloroform - 0.032 J Trichloroethene - 0.11
GRO	AK 101	µg/L	2,200	16 J VB
DRO	AK 102	mg/L		ND
PAH	8270 SIM	mg/L		ND
Metals	6020	µg/L	0.52 3,800 0.35	Arsenic - 0.37 J Barium - 3.4 Cadmium - ND Chromium - 0.33 J Iron - ND Lead - ND
PCBs/Pesticides	8081/8082	µg/L		ND

Sampling was performed June 6, 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
µg/L - micrograms per liter

J - The quantitation is an estimation.
B - The analyte was found in an associated blank.
V- Indicates that the data qualifier was assigned during the data review process.

Notes:
1. Effluent limitations are based on Table C, Groundwater Cleanup Levels, 18 AAC 75, rev January 2018

Table 4-5
Detected Analytes for July 2018
South Bluff Treatment System, King Salmon, Alaska

Sample Identification				
Analytical Parameters	EPA Method	Units	Effluent Limitation (Note 1)	Influent Sample 18KSSBTSINF-0731
VOCs	8260C SIM	µg/L	41 2.8	Tetrachloroethene - 0.015 J Trichloroethene - 0.090
GRO	AK 101	µg/L		ND
DRO	AK 102	mg/L		ND
PAH	8270 SIM	mg/L		ND
Metals	6020	µg/L	0.52 3,800	Arsenic - ND[2] Barium - 3.4 Cadmium - ND Chromium - ND Iron - ND Lead - ND
PCBs/Pesticides	8081/8082	µg/L		ND

Sampling was performed July 31, 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
µg/L - micrograms per liter

J - The quantitation is an estimation.
B - The analyte was found in an associated blank.
V- Indicates that the data qualifier was assigned during the data review process.

Notes:
1. Effluent limitations are based on Table C, Groundwater Cleanup Levels, 18 AAC 75, rev January 2018
2. The detection limit for arsenic was 12 µg/L. All other detection limits were below ADEC cleanup levels.

Table 4-6
Laboratory Analytical Results for November 2018
South Bluff Treatment System, King Salmon Alaska

Sample Identification			Effluent Limitation (Note 1)	Influent Sample 18KSSBTSIN1128
Analytical Parameters	EPA Method	Units		
VOCs	8260B	ug/L	41 2.8	Tetrachloroethene - 0.019 TCE - 0.16
GRO	AK 101	mg/L	2.2	0.017
DRO	AK 102	mg/L	1.5	0.063
PAH	8270 SIM	mg/L		ND
Metals	6020A	ug/L	0.52 3,800 9.2 0.35 300 (Note 2) 15	Arsenic - **0.56** Barium - 4.0 Cadmium - ND Chromium - 0.19 Iron - 60 Lead - ND
PCBs/Pesticides	8081/8082	ug/L	0.14	Heptachlor - 0.0057

Sampling was performed November 28, 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 GRO, DRO, acetone, benzene, tetrachloroethene, TCE, and heptachlor were detected in the SBTS November 2018 sample collected at the lift station. Arsenic was also detected at a level above the effluent limitation, however this is likely naturally occurring arsenic.

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 is planned for 2019.

- We recommend mothballing the SBTS based on the historic sampling data. The results from 2015-2018 are included in Appendix C. This mothballing can be accomplished by simply turning off the pumps at the lift station and leaving them off (as they are now because the pumps/controls are not presently working). Under this scenario, the French drain system will continue to gather water from the toe of the South Bluffs and conduct it to the lift station, which will overflow when there is enough water. The lift station can be sampled annually to continue to confirm that no contamination is coming out of the South Bluffs.

- Discontinue sampling for arsenic and chromium. This should be accomplished through an ESD.

- 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.

- Neither lift station pump was working. A determination should be made whether to replace the pumps.

- Sections of the fencing around the North Bluff have been torn down allowing the unauthorized use of ATVs on the landfill caps. The Air Force should discuss security options at the North Bluff site with ADEC and the public at the next RAB meeting.

FIGURE 4-1

SOUTH BLUFF (OT029) CULVERT AND DOWNDRAIN LOCATIONS

GROUNDWATER ZONE 3 SOUTH BLUFF
2018 RAO/LUC
King Salmon Divert, Alaska

AIR FORCE CIVIL ENGINEERING CENTER JBER, ALASKA

DATE JAN. 2019
CHKD H.L.H.
DRAWN C.E.H.
PROJ. NO 718004

PATH: 19 Dwgs\19 PY\718004 RAO LUC FILE: 718004-RAO-LUC-RPT-F4-1.DWG PLOT: 1/21/19.

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.

SOURCE: IMAGE KING_SALMON_2012_RGB.SID, DATED 12/19/12 PROVIDED BY AEROMETRIC INC.

PATH: 19 Dwgs\19 PV\718004 RAO LUC FILE: 718004-RAO-LUC-RPT-F4-2.DWG PLOT: 1/21/19.

FIGURE 4-2

NORTH BLUFF (OT029) CULVERT AND DOWNDRAIN LOCATIONS

GROUNDWATER ZONE 3 NORTH BLUFF
2018 RAO/LUC
King Salmon Divert, Alaska

AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE	CHKD	DRAWN	PROJ. NO
JAN. 2019	H.L.H.	C.E.H.	718004

5 ZONE 4 – NAKNEK RIVER STORAGE (OT030)

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.

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 include the annual landfill inspection for visual monitoring of Landfill No. 5 and maintenance of the product recovery system.

5.1 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 along with current ADEC cleanup levels. As recommended in the 2017 Five Year Review, 2018 sampling results were compared to the current promulgated ADEC Table C Groundwater Cleanup Levels.

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 Groundwater Zone 4

Media	Contaminants of Concern	Screening Concentrations					
		Ecological Risk-Based RG	Human Health Risk-Based RG[a]	ARARs		ROD Cleanup Levels	Current ADEC Cleanup Levels[c]
				RG	Basis		
Floating Petroleum Product		—	No FPP	No FPP	18AAC75	No FPP	No FPP
A-Aquifer and B-Aquifer Groundwater (mg/L)	Benzene	NC	NC	0.005	ADWS	0.005	0.0046
	Toluene	NC	NC	1.0	ADWS	1.0	1.1
	TCE	NC	NC	0.005	ADWS	0.005	0.0028
	GRO	NC	NC	2.2	18 AAC 75	1.3[d]	2.2
	DRO	NC	NC	1.5	18 AAC 75	1.5[d]	1.5
Surface Water (mg/L)	TAH (BTEX)[b]	NC	NC	0.010	AWQS	0.010	0.010
	TAqH (BTEX+PAH)[c]	NC	NC	0.015	AWQS	0.015	0.015
	DRO	NC	NC	NONE	N/A	-	-
Soil (mg/kg)	Benzo(a)anthracene	3.52	22	NONE	N/A	3.5	0.70
	Benzo(a)pyrene	2.24	1.8	NONE	N/A	1.8	1.5 [f]
	Benzo(b)fluoranthene	2.56	16	NONE	N/A	2.6	15 [f]
	Benzo(k)fluoranthene	2.24	17.5	NONE	N/A	2.24	150 [f]
	Indeno(1,2,3-cd)pyrene	NC	4	NONE	N/A	4	15 [f]
	DRO	NC	NC	NONE	N/A	2,500[d]	250

[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. PAHs will be analyzed by EPA Method 8270 SIM.
[d]Basis for the GRO and DRO cleanup levels is 18 AAC 75, per the Zone 4 Final ROD (USAF, 1999).
[e]18 AAC 75 Table C for groundwater and Table B Migration to Groundwater for soil (October 2018)
[f] 18 AAC 75 Table B Under 40 Inch Zone/Human Health (October 2018)

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.

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
FPP – Floating Petroleum Product
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,l)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

5.2 PROJECT TASKS

5.2.1 Zone 4 Groundwater Sampling

Groundwater samples were collected from three A-Aquifer monitoring wells and two B-Aquifer monitoring wells (Figure 5-1) in December 2018. 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.

5.2.2 Residential Well Sample Collection

Residential wells were not sampled during the November-December field effort. Residents were not available and/or outdoor spigots were winterized. These samples will be collected in the fall of 2019, and results will be reported in the 2019 RAO/LUC report.

5.2.3 Surface Water/Sediment Sample Collection

Surface water/sediment samples pairs were not collected from three locations in Groundwater Zone 4 due to frozen conditions during the November-December 2018 field effort. These samples will be collected in the fall of 2019, and results will be reported in the 2019 RAO/LUC report.

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

Location ID Sample Point	Comment	Matrix	Location Type	Analytical Methods: 8260C VOCs	8260C SIM VOCs	8011 EDB & 1,2,3 TCP	AK 101 GRO	AK 102 DRO	EPA 2320B Alkalinity	6010B Fe + Mn (dissolved)	RSK-185 Methane	Sample ID
MW-57		Groundwater	Monitoring Well									18KS4ZMW57-109WG
MW-51	MS/MSD	Groundwater	Monitoring Well	3	3	3	3	3	3	3	3	18KS4ZMW51-110WG
502		Groundwater	Well Point	1	1	1	1	1	1	1	1	18KS4ZWP502-112WG
MW-62		Groundwater	Monitoring Well	1	1	1	1	1	1	1	1	18KS4ZMW62-113WG
Duplicate Sample		Groundwater	Well Point	1	1	1	1	1	1	1	1	18KS4ZWP801-114WG
Project Trip Blanks		Water	QA/QC	2	2	2	2					18KS4ZTB-MMDD
Water Analyses Totals				**8**	**8**	**8**	**8**	**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	Analytical Methods			Sample Number
				EPA Method 524.2 VOCs	AK 101 GRO	AK 102 DRO	
B-Aquifer Sample Locations							
506	MS/MSD	Groundwater	B-Aquifer	3	3	3	18KS4Z506-101WG
MW97-9		Groundwater	B-Aquifer	1	1	1	18KS4Z5MW979-102WG
MW97-9(D)	Duplicate	Groundwater	B-Aquifer	1	1	1	18KS4ZFARLEY-103WG
Equipment Blank		Water	QA/QC	1	1	1	18KS4ZEBMMDD
Residential Wells							
SMITH		Groundwater	Residential Well				18KS4ZSMITH-104WG
KING		Groundwater	Residential Well				18KS4ZKING-105WG
BOWERS		Groundwater	Residential Well				18KS4ZBOWERS-106WG
KING APARTMENTS		Groundwater	Residential Well				18KS4ZKINGAPTS-107WG
MARSH		Groundwater	Residential Well				18KS4ZMARSH-108WG
Trip Blank		Water	QA/QC				18KS4ZTB-MMDD
Water Analyses Totals				**6**	**6**	**6**	

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

Location ID Sample Point	Comments	Matrix	Location Type	Analytical Methods						Sample ID
				8260C VOCs	8260C SIM VOCs	8011 EDB & 1,2,3-TCP	AK 101 GRO	AK 102 DRO	8270D SIM/DoD PAHs	
OT30-01	MS/MSD	Surface Water	Surface Water							18KS4ZOT301-101WS
OT30-03		Surface Water	Surface Water							18KS4ZOT303-102WS
OT30-04		Surface Water	Surface Water							18KS4ZOT304-103WS
OT30-05	Duplicate	Surface Water	Surface Water							18KS4ZOT305-104WS
Trip Blank		Water	QA/QC							18KS4ZTB-MMDD
Surface Water Sample Totals				**0**	**0**	**0**	**0**	**0**	**0**	
Location ID Sample Point	Comments	Matrix	Location Type	8260C VOCs	8260C SIM VOCs	8011 EDB & 1,2,3-TCP	AK 101 GRO	AK 102 DRO	8270C SIM/DoD PAHs	Sample ID
OT30-01	MS/MSD	Sediment	Sediment							18KS4ZOT301-201SE
OT30-03		Sediment	Sediment							18KS4ZOT303-202SE
OT30-04		Sediment	Sediment							18KS4ZOT304-203SE
OT30-05	Duplicate	Sediment	Sediment							18KS4ZOT305-204SE
Sed Trip Blank		MeOH & Sand	QA/QC							18KS4ZTB-MMDD
Sediment Sample Totals				**0**	**0**	**0**	**0**	**0**	**0**	

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.

5.2.4 Landfill Cap Inspection Activities

Slopes, vegetation, and erosion-control features at Zone 4 sites LF008 and SS012 will be inspected in the fall of 2019 and findings will be included in the 2019 RAO/LUC report. The document entitled *Final Operation, Monitoring, and Maintenance Manual, North and South Barrel Bluffs, King Salmon, Alaska* (Hart Crowser, 2000) will be used as a guide for the inspection activities performed at the landfill.

5.2.5 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.

In November, one of two absorbent pillows in the product recovery system was replaced. There was petroleum odor present and the pillow was stained brown. The second pillow was encased in ice and could not be removed and replaced. It will be replaced in the spring of 2019, after breakup.

5.2.6 Work Plan Deviations

- MW-57 was not sampled due to the presence of product after purging. It will be redeveloped in the spring of 2019 and sampled in the fall of 2019 if no product is present.
- Residential samples were not collected due to homeowners being unavailable.
- Surface water and sediment samples were not collected due to frozen conditions.
- One of two product recovery pillows was encased in ice and not replaced.
- LF008 and SS012 were not inspected due to snow cover.

5.3 ZONE 4 FINDINGS

5.3.1 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 in MW-57 after purging took place. Free product had previously been found in MW-57 in 2011-2013, and 2015-2017.

Temperature: Groundwater temperatures measured in the A-Aquifer wells at the beginning of December were between 2.72 and 5.96˚C.

pH: Measurements were between 6.35 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 86 to 222 micro Siemens per centimeter (µS/cm).

Dissolved Oxygen: DO levels ranged from 1.76 mg/L to 3.63 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.

5.3.2 A-Aquifer Analytical Results

Table 5-6 presents a summary of 2018 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.

5.3.2.1 GRO and DRO

The petroleum hydrocarbon levels (GRO and DRO) detected in Zone 4 groundwater are shown on Figure 5-1. None of the A-Aquifer wells sampled exceeded the current cleanup level of 2.2 mg/L for GRO. GRO concentrations ranged from 1.7 to 2.1 mg/L. There were no exceedances for DRO. DRO concentrations ranged from 0.26 to 1.3 mg/L.

5.3.2.2 BTEX and TCE

The benzene, toluene, ethylbenzene, total xylenes, total BTEX, and TCE levels detected in groundwater are shown on Figure 5-2. The RAOs for benzene and toluene were not exceeded in any of the samples. 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 68 µg/L. Total xylene concentration exceeded the RAO of 190 µg/L in monitoring wells MW-51 (440 µg/L) and 502 (321 µg/L). Total BTEX concentrations ranged from 42 µg/L (MW-62) to 529 µg/L (MW-51). TCE was not detected in any of the wells sampled.

5.3.2.3 1,2,4-Trimethylbenzene

The result from MW-51 was above the RAO of 56 µg/L for 1,2,4-Trimethylbenzene. Concentrations for MW-51, MW-62, and 502 were 150, 28 (30), and 26 µg/L, respectively.

5.3.2.4 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 5.1 to 110 µg/L.

5.3.2.5 1,2-Dibromoethane (EDB)

EDB was detected in MW-51 at 0.0040 µg/L. The cleanup level is 0.075 µg/L.

5.3.2.6 Inorganics

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

- Ferrous iron concentrations ranged from 5.9 (5.7) mg/L in MW-62 to 33 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 2.5 (2.6) mg/L in MW-51 and MW62 to 2.6 mg/L in 502. Manganese concentrations are generally higher in wells with increased levels of DRO and GRO.
- Methane concentrations ranged from 0.25 mg/L in MW-51 to 8.8 mg/L in 502. The presence of methane is evidence that intrinsic bioremediation of the fuel hydrocarbons is occurring.
- Alkalinity measurements ranged between 60-75 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)	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)
ADEC Cleanup Levels	**2.2**	**1.5**	**0.0046**	**1.1**	**NA**	**0.0028**	**NA**	**NA**	**NA**	**NA**			**NA**		
502	2.0	1.1	0.0024	ND	0.37	ND	75	33	2.6	8.8	3.63	69.4	2.8	6.35	135
MW-51	2.1	1.3	ND	0.021	0.53	ND	73	6.1	2.5	0.25	1.76	45.6	5.96	6.69	151
MW-57	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	**PROD**	2.69	36	3.65	6.63	222
MW-62	1.7	0.26 (0.68)	ND	0.00027 (0.00028)	0.042 (0.048)	ND	61 (60)	5.9 (5.7)	2.5 (2.6)	1 (0.92)	3.6	66.3	2.72	7.08	86

NA - Not Applicable
NS - Not sampled
ND - Not detected above method reporting level (MRL)
PROD - Product Present in well
ADEC Cleanup Levels from 18 AAC 75 Table C (October 2018)
Analytical results exceeding RAOs shown in **BOLD**
Results (XX) are Duplicate samples.

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

Well	Analyte	Cleanup Levels (mg/L)	1992	1993	1994	1997	2000	20001	2002	2003	2004	2005	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
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)	1.42	0.79	2.1	0.62	1.9	0.63	1.7 (1.6)	1.2	1.2	**2.8**	1.8	2.1
	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)**	**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**	1.3
	Benzene	0.0046	**0.048**	**0.016**	**0.012**	0.0010	0.0037	0.0042	0.0007	0.0011	0.00115	0.0006	0.00026	0.00016	ND	0.00018	ND	ND	ND	ND	ND	0.00014	ND	ND
	Toluene	1.1	0.640	0.180	0.39	0.0063	0.187	0.257	0.0098	0.081	0.138	0.133	0.150	0.039	0.15	0.019	0.064	0.032	0.067 (0.060)	0.034	0.037	0.066	0.013	0.021
	BTEX	NA	1.36	0.338	0.921	0.301	0.666	0.787	0.0778	0.418	0.537	0.393	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	0.53
	TCE	0.0028	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00034	0.00014	0.00026	ND	ND	ND	0.00015 (ND)	ND	0.00078	ND	ND	ND
MW-62	GRO	2.2	NS	NS	NS	NS	**2.88**	1.98	2.07	1.8	1.87	1.15	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)	1.7
	DRO	1.5	NS	NS	**2.3**	0.984	**3.16**	**1.62**	1.19	1.4	1.38	1.14	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)	0.26(0.068)
	Benzene	0.0046	NS	NS	**0.2**	**0.086**	**0.0171**	**0.0082**	**0.0051**	0.0042	0.00346	0.00186	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)	ND
	Toluene	1.1	NS	NS	0.0049	0.041	0.0010	ND	ND	ND	0.00101	0.00092	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)	0.00027(0.00028)
	BTEX	NA	NS	NS	0.815	0.692	0.702	0.659	0.282	0.382	0.367	0.188	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)	0.042(0.048)
	TCE	0.0028	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	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	1.29	2.1	1.7	**2.7**	**2.5**	0.52	1.5	**2.5**	**2.4**	1.7	1.5	2.0
	DRO	1.5	NS	**3.8**	NS	**13.5**	**2.44**	**16.7**	**7.86**	**3.2**	**6.48 D**	**2.13**	**3.89**	1.4	**5.3**	**5.2**	**4.2**	0.61	**2.4**	1.5	**1.6**	**1.6**	**1.6**	1.1
	Benzene	0.0046	NS	**0.21**	NS	**0.073**	**0.0174**	**0.0207**	**0.0102**	0.004	**0.00805**	**0.00685**	0.0013	0.0014	0.0024	**0.0078**	0.0023	0.0011	0.0025	0.0031	0.0043	0.0036	0.0022	0.0024
	Toluene	1.1	NS	0.011	NS	0.047	0.0087	0.0964	0.0067	0.002	0.00375	0.00153	0.00361	0.0083	0.0051	0.036	0.0022	0.00054	0.0055	0.0016	0.0015	ND	ND	ND
	BTEX	NA	NS	2.90	NS	2.30	0.740	1.33	1.522	0.691	1.027	0.851	0.0769	0.420	0.288	0.639	0.083	0.11	0.271	0.375	0.335	0.287	0.299	0.37
	TCE	0.0028	NS	ND	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0021	ND	ND	ND
MW-57	GRO	2.2	NS	NS	NS	NS	0.94	0.909	1.02	0.99	0.72	0.384	0.531	0.71	0.54	0.19	**PROD**	**PROD**	**PROD**	0.54	**PROD**	**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**	**12.8**	**6.1**	**11**	**6.4**	**PROD**	**PROD**	**PROD**	**8.7**	**PROD**	**PROD**	**PROD**	**PROD**
	Benzene	0.0046	NA	ND	**0.034**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**PROD**	**PROD**	**PROD**	ND	**PROD**	**PROD**	**PROD**	**PROD**
	Toluene	1.1	NA	0.0027	0.039	0.0017	0.0014	0.0012	0.0012	0.0013	0.00126	0.00102	0.00191	0.0023	0.0011	0.00033	**PROD**	**PROD**	**PROD**	0.0012	**PROD**	**PROD**	**PROD**	**PROD**
	BTEX	NA	NA	0.0256	0.161	0.075	0.114	0.102	0.104	0.174	0.190	0.0464	0.0881	0.110	0.634	0.0087	**PROD**	**PROD**	**PROD**	0.0789	**PROD**	**PROD**	**PROD**	**PROD**
	TCE	0.0028	**0.0766**	**0.0089**	NA	0.0011	0.0014	ND	ND	ND	0.00106	0.00144	0.00082	0.0011	0.0007	0.0003	**PROD**	**PROD**	**PROD**	0.00092	**PROD**	**PROD**	**PROD**	**PROD**

NOTES:

ND - Not detected above the method reporting limit
NS - Not sampled for this analyte
Results exceeding the Cleanup Levels are shown in **BOLD**
DRO - Diesel-range organics
Cleanup Levels from ADEC 18 AAC75 Table C (October 2018)

GRO - Gasoline range organics
TCE - Trichloroethene
BTEX - Benzene, Toluene, Ethylbenzene, Xylenes
PROD - Product Present in well

(Results) are duplicate samples.

5.3.3 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

5.3.4 B-Aquifer Analytical Results

Groundwater samples were collected from two B-Aquifer monitoring 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 had low level detections of GRO (0.015-0.016 mg/L). These results are flagged because GRO was detected in the trip blank and equipment blank at similar concentrations of 0.017 mg/L and 0.018 mg/L respectively. The results are biased high due to field contamination and a matrix effect. DRO was not detected.

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	2018
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	0.015
	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	ND
	Benzene	0.0046	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Toluene	1.1	0.00013	ND	ND	ND	ND	ND	ND	ND	ND	ND/0.00028	0.00025/0.00027	ND	ND	ND	0.00018	ND
	BTEX	NA	0.00013	ND	ND	ND	ND	0.00023	ND	ND	ND	ND/0.00028	0.00025/0.00027	ND	ND	ND	0.00018	ND
	TCE	0.0028	ND	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	0.016/ND
	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	ND
	Benzene	0.0046	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Toluene	1.1	ND	ND	ND	ND	ND	ND	0.00028	ND	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	ND
	TCE	0.0028	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0002/ND	ND
Residential Wells			**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Smith	GRO	2.2	NS	ND	ND	ND	ND	0.024	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	0.0046	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NS	
	Toluene	1.1	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	0.0028	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	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	0.0046	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	
	Toluene	1.1	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	0.0028	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	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	0.0046	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	
	Toluene	1.1	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	0.0028	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	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	0.0046	NS	NS	NS	NS	NS	NS	ND	ND	ND	ND	ND	ND	ND	ND	ND	
	Toluene	1.1	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	0.0028	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	0.0046	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	ND	ND	NS	
	Toluene	1.1	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	0.0028	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.

* - RAOs found in final ROD

5.3.5 Condition of Wells

The wells and well points scheduled for Zone 4 were sampled and in good condition, with the exception of MW-57. Initial product probe measurement indicated that no product was present. After purging, the presence of product became evident. This may be due to recent POL contaminated soil excavating that took place in the vicinity of the well earlier in 2018. The well will be redeveloped in the spring of 2019, and then sampled in the fall if there is no product present.

5.4 ZONE 4 CONCLUSIONS

5.4.1 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 decreasing 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.

5.4.2 A-Aquifer Monitoring Wells

Analytical data showed GRO and DRO below current ADEC cleanup levels in all three wells sampled. MW-57 was not sampled due to the presence of product after purging.

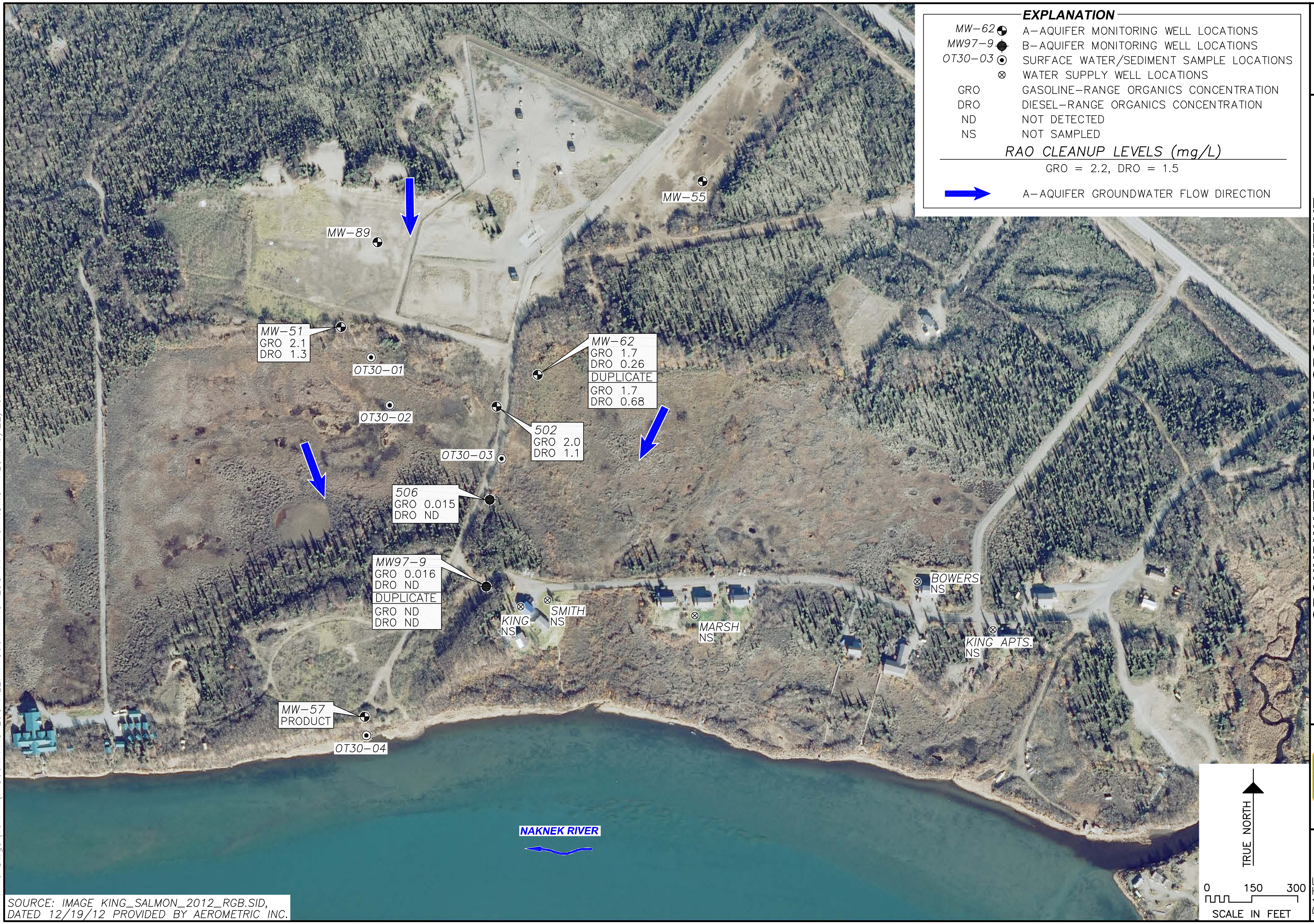
There were no detections for benzene or RAO exceedances toluene. Ethylbenzene and naphthalene exceeded cleanup levels in all three of the A-Aquifer monitoring wells sampled. MW-51 and 502 exceeded the cleanup level for total xylenes. TCE was not detected in any of the wells sampled.

5.4.3 B-Aquifer Monitoring Wells

GRO was detected in the two B-Aquifer monitoring wells, in the trip blank, and the equipment blank at similar levels, well below the cleanup level.

5.5 ZONE 4 RECOMMENDATIONS

- Monitoring should continue because drinking water wells and other sensitive receptors lie downgradient of this site.
- MW-57 should be redeveloped in 2019 and sampled if there is no product present.
- Method 8011 should be eliminated from the analyses. All results were non-detect in 2017. In 2018 the only detection was EDB well below regulatory criteria in MW-51.
- Sampling for MNA parameters should be reduced to once every five years in coordination with the next Five Year Review.



PATH: 19 Dwgs\19 PV\718004 RAO LUC FILE: 718004-RAO-LUC-RPT-F5-1.DWG PLOT: 3/22/19.

FIGURE 5-1

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

NAKNEK RIVER STORAGE (GWZ4, OT-030)
2018 RAO/LUC
King Salmon Divert, Alaska

AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE MARCH 2019
CHKD H.L.H.
DRAWN C.E.H.
PROJ. NO 718004

FIGURE 5-2

BTEX AND TCE ANALYTICAL RESULTS GROUNDWATER ZONE 4

NAKNEK RIVER STORAGE (GWZ4, OT-030)
2018 RAO/LUC
King Salmon Divert, Alaska

AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE MARCH 2019 | CHKD H.L.H. | DRAWN C.E.H. | PROJ. NO 718004

PATH: 19 Dwgs\19 PV\718004 RAO LUC FILE: 718004-RAO-LUC-RPT-F5-2.DWG PLOT: 3/22/19.

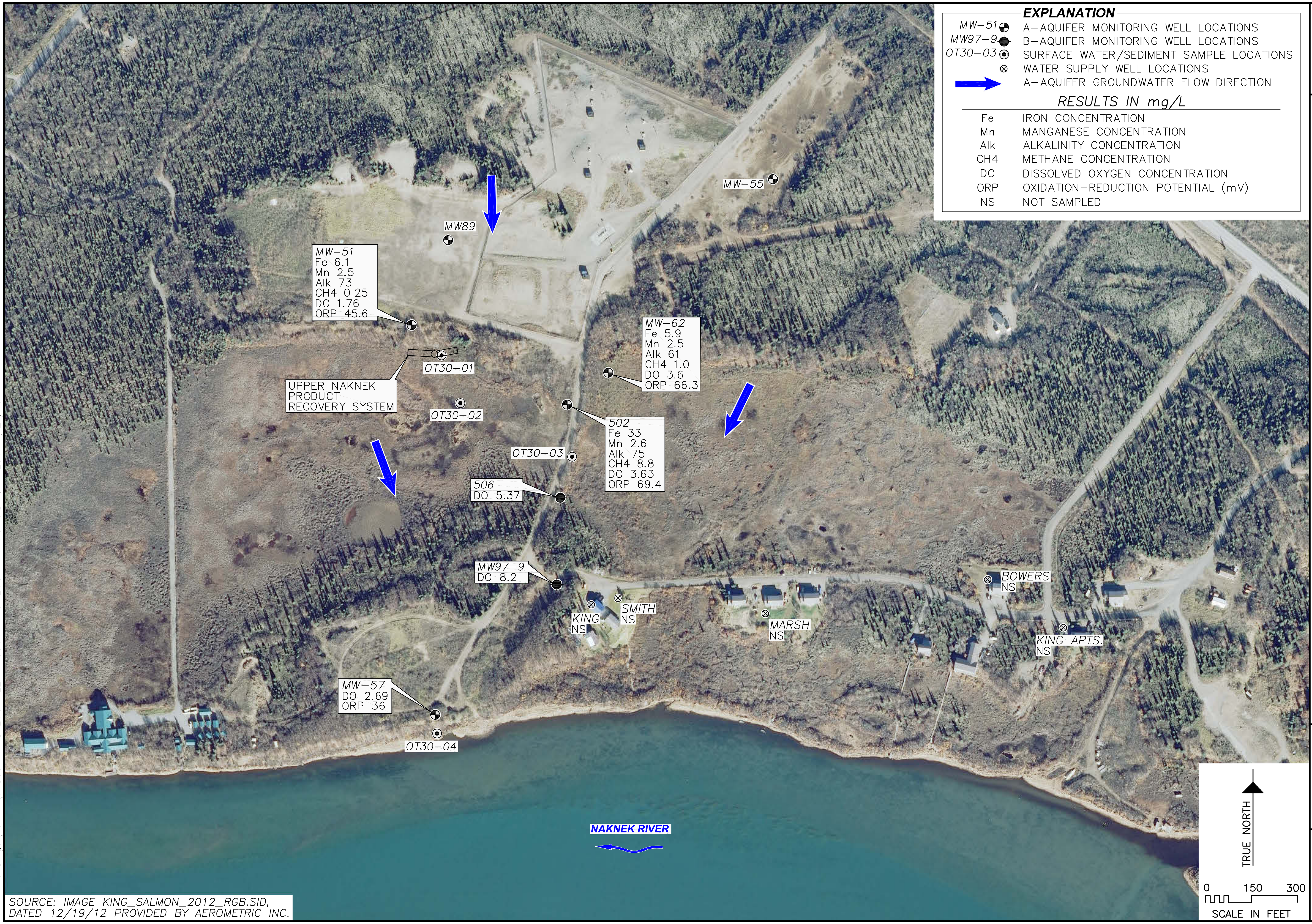


FIGURE 5-3

MONITORED NATURAL ATTENUATION RESULTS GROUNDWATER ZONE 4

NAKNEK RIVER STORAGE (GWZ4, OT-030)
2018 RAO/LUC
King Salmon Divert, Alaska

AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE JAN. 2019	CHKD H.L.H.	DRAWN C.E.H.	PROJ. NO 718004

PATH: 19 Dwgs\19 PV\718004 RAO LUC FILE: 718004-RAO-LUC-RPT-F5-3.DWG PLOT: 1/21/19.

6 ZONE 5 - RAPCON AND RED FOX CREEK (OT031)

Historical spills and operational practices at RAPCON have resulted in contamination of groundwater 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 purpose of the current field effort 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.

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. The RAPCON/Red Fox Creek monitoring wells and surface water/sediment locations are sampled as follows:

- Monitoring wells FT01-SVE1 and FT01-FD9 were analyzed for DRO only.
- FT01-MW01 was analyzed for DRO and GRO only.
- FT01-MW02, FT01-SVE2, and BV-17 were analyzed for VOCs, DRO, and GRO.
- The six wells were analyzed for dissolved iron and manganese.
- VOC and PAH analyses are continued at RFC-4 and RFC-5 for surface water and sediment.

6.1 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 Preliminary Remedial Action Objectives for RAPCON and Red Fox Creek

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
DRO	**43.2** (mg/L)	GP-9 (1996)	**8.95** (SVE-2)	1.5 (mg/L)	18AAC75
GRO	**21** (mg/L)	GP-9 (1996)	**6.26** (SVE-2)	2.2 (mg/L)	18AAC75
Benzene	**1,430**Y	GP-9 (1996)	**16.3** (SVE-2)	4.6	18AAC75
Toluene	**8,190Y**	GP-9 (1996)	**1,230** (SVE-2)	1,100	18AAC75
Ethylbenzene	**706**	GP-9 (1995)	239 (SVE-2)	15	18AAC75
EDB	**94.9**Y	GP-9 (1996)	ND (<10 or <1)(a)	0.075	18AAC75
Surface Water (µg/L)					
TAH	**2,026**	(SW-1 - 1996)	**51.7** (RFC-04)	10	18AAC70
TAqH	**2,026**(b)	(SW-1 -1996)	**52** (RFC-04)	15	18AAC70

Notes:

a – All EDB results in 2006 were ND. The reporting limits for the samples were either 1.0 or 10 µg/L, depending on the sample.
b - PAHs were not analyzed in this sample; therefore, the TAqH concentration is the same as the TAH concentration.
Results shown in **bold font** exceed the RAO.

Definitions:

18AAC75 = Oil and Hazardous Substances Pollution Control Regulations, Table C Groundwater Cleanup Level (October 2018)
18AAC70 = Alaska Water Quality Standards (April 2018)

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

6.2 PROJECT TASKS

6.2.1 RAPCON Groundwater Monitoring

Groundwater monitoring was conducted at RAPCON to document changes in contaminant concentrations in the groundwater. Sampling was performed December 4, 2018. A sample analyses summary for groundwater is presented in Table 6-2. Groundwater sampling results are displayed on Figure 6-1 and in Table 6-3 and Table 6-4.

6.2.2 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 scheduled to be collected from two locations in a drainage ditch that flows by the RAPCON site into Red Fox Creek. These samples were not collected due to the frozen conditions during the field effort.

6.2.3 Work Plan Deviations

- Surface water and sediment samples were not collected due to the frozen conditions during the field effort.

- The IC inspection was not done due to the snow covered ground conditions.

Table 6-2: RAPCON/RFC Sample Analyses Summary

Location ID Sample Point	Comments	Matrix	Location Type	Analytical Methods: 8260C VOCs	8260C SIM VOCs	8011 EDB & 1,2,3-TCP	AK 101 GRO	AK 102 DRO	EPA Method 6010B Fe & Mn (dissolved)	Sample ID
FT01-FD9		Groundwater	Monitoring Well					1	1	18KS5ZFD9-101WG
MW-01		Groundwater	Monitoring Well				1	1	1	18KS5ZMW1-102WG
MW-02	MS/MSD	Groundwater	Monitoring Well	3	3	3	3	3	3	18KS5ZMW2-103WG
SVE-1	Upgradient	Groundwater	Monitoring Well					1	1	18KS5ZSV1-104WG
SVE-2	Upgradient	Groundwater	Monitoring Well	1	1	1	1	1	1	18KS5ZSV2-105WG
BV-17		Groundwater	Monitoring Well	1	1	1	1	1	1	18KS5ZBV17-106WG
Duplicate Sample		Groundwater	Monitoring Well	1	1	1	1	1	1	18KS5ZMW3-107WG
Project Trip Blanks		Water	QA/QC	1	1	1		1		18KS5ZTB-MMDD
Water Analyses Totals				**7**	**7**	**7**	**7**	**10**	**9**	

Location ID Sample Point	Comments	Matrix	Location Type	Analytical Method: 8260C VOCs	8260C SIM VOCs	8011 EDB & 1,2,3-TCP	8270D SIM PAHs	Sample ID
RFC-04	MS/MSD	Surface Water	Stream					18KS5ZRFC4-502WS
Duplicate Sample		Surface Water	Stream					18KS5ZRFC9-505WS
Surface Water Trip Blank		Water	QA/QC					18KS5ZTB-MMDD
Surface Water Analyses Totals				**0**	**0**	**0**	**0**	
RFC-04	MS/MSD	Sediment	Stream Bed					18KS5ZRFC4-602SE
RFC-05		Sediment	Stream Bed					18KS5ZRFC5-603SE
Duplicate Sample		Sediment	Stream Bed					18KS5ZRFC9-605SE
Sediment Trip Blank	Methanol and Silica	Sediment	QA/QC					18KS5ZTB-MMDD
Sediment Sample Analyses Totals				**0**	**0**	**0**	**0**	

6.3 RAPCON/RED FOX CREEK FINDINGS

6.3.1 RAPCON Groundwater Analytical Results

Analytical results are provided in Appendix C, Zone 5 Tables. Table 6-3 presents current and historical sample analytical results for the contaminants of potential concern at this site (benzene, total BTEX, DRO, GRO, and TCE). Table 6-4 presents a summary of 2018 analytical data.

6.3.1.1 Petroleum Hydrocarbons

Two of the wells sampled for GRO exceeded the RAO of 2.2 mg/L. GRO concentrations ranged from 1.3 mg/L to 3.1 mg/L. Four of the six wells sampled for DRO exceeded the RAO of 1.5 mg/L. DRO concentrations ranged between 1.1 mg/L to 2.2 mg/L.

6.3.1.2 BTEX

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

6.3.1.3 TCE

The concentration of TCE in FT01-MW02 was 0.73 µg/L and 1.4 (1.1) µg/L in FT01-BV17. Both results are below the cleanup level of 2.8 µg/L.

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

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

6.3.1.5 Other VOC Results

FT01-MW02, BV17, and SVE-2 exceeded the cleanup levels for 1,2,4-trimethylbenzene and naphthalene. FT01-MW02 and BV17 exceeded the cleanup level for 1,3,5-trimethylbenzene. EDB was detected in BV17 at 0.0069 µg/L which is below the cleanup level of 0.075 µg/L. Appendix C presents a listing of all the detected analytes from the 2018 groundwater-monitoring event.

6.3.1.6 Dissolved Oxygen

As discussed above, we appeared to have some difficulty measuring DO in some wells in 2018. In Zone 5, the DO reported for all wells besides MW-02 appear to be reasonable. The 17.47 mg/L DO measured at MW-02 is above the solubility of DO at these temperatures and thus this reading should be ignored.

Looking at the other wells, DO does appear to be depressed at this site, which does suggest that intrinsic remediation is occurring.

Table 6-3: Historical RAPCON Groundwater Analytical Data

Well	Analyte (ADEC Cleanup Level 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)	12/2018 (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	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	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	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**	**1.7**
	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	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	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	11
	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	2.3
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	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	0.72
	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**	1.7
	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**	1.1
	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	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	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	9.4
	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	2.5
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	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	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	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	1.4
	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	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	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	3.6
	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	4.7
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	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	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	**3.1**
	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**	**1.7**
	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	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	NS
	PFOA (0.00040)																		**0.0033**	NS	NS
	PFOS (0.00040)																		**0.0110**	NS	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	2.3
	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	2.9
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**	0.00041
	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	0.67
	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	**2.4**
	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**	**2.2**
	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	0.00073
	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	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	12
	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	17
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	ND
	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	0.37/0.29
	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)	1.5/1.3
	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)	**1.6**/1.4
	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	0.0014/0.0011
	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	0.0000069/0.0000063
	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)	3.5/3.6
	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	3.0

NS - Not Sampled
ND - Not detected above method reporting level (MRL)
ADEC Cleanup Levels from 18 AAC 75 Table C (October 2018)
Analytical exceedances shown in **BOLD**.
(Results) are duplicate samples.

Table 6-4: 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)	Temp (°C)	DO (mg/L)	ORP (mV)	pH	Con. (µS/cm)
ADEC Cleanup Levels	**1.5**	**2.2**	**2.8**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
FD-9	1.4	NA*	NA*	3.6	2.8	4.5	4.66	64.9	6.42	108
MW-01	**1.7**	**3.1**	NA*	2.3	6.0	4.6	2.89	72.4	6.8	206
MW-02	**2.2**	**2.4**	0.73	12	4.4	4.81	17.47	111.3	6.05	111.3
SVE-1	**1.7**	NA*	NA*	11	3.8	5.08	2.34	26.2	6.39	316
SVE-2	1.1	1.7	ND	9.4	2.6	5.18	2.49	4.3	6.52	221
BV-17	**1.6**/1.4	1.5/1.3	1.4/1.1	3.5/3.6	5.2/5.3	4.59	2.96	-10.8	6.81	199

NA* - Not Analyzed
NA - Not Applicable
ND - Not detected above method reporting level (MRL)
Cleanup levels from ADEC 18 AAC 75 Table C (October 2018)
Analytical results exceeding cleanup levels shown in **BOLD.**
(Results) are duplicate samples.

6.3.2 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 6-5 and Table 6-6 summarize the concentration trends observed in six key monitoring wells (FT01-BV17, 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 64% of the concentration trends were decreasing and 7% were increasing. Another 29% 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 6-5 RAPCON Mann-Kendall Analysis Summary

Trend	Benzene	DRO	GRO	TCE	% of Total
Decreasing	1	5	1	2	64%
Increasing	0	0	1	0	7%
No Trend	0	1	2	1	29%
Totals	1	6	4	3	14

Table 6-6 RAPCON Mann-Kendall Trend Summary

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

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

6.3.3 Institutional Control Inspection

The IC Inspection was not conducted due to frozen and snow covered conditions during the field effort. The inspection will take place in the fall of 2019 and findings will be included in the 2019 RAO/LUC report.

6.3.4 Condition of Wells

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

6.4 RAPCON/RED FOX CREEK CONCLUSIONS

6.4.1 RAPCON Groundwater

Information gained from the 2018 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 64% and 29% of concentration trends are decreasing or show no trend. Since the majority of concentration trends are decreasing or stable, this indicates that intrinsic remediation is attenuating contaminants, or at the very least keeping contaminant concentrations in check.

Detected groundwater contaminant concentrations in 2018 were generally lower for GRO and higher for DRO than last year's results. Depressed dissolved oxygen levels in most all of the wells with DRO contamination 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, BV17, and SVE-2. MW2 and BV17 also exceeded the cleanup level for 1,3,5-trimethylbenzene.

6.4.2 Red Fox Creek Sampling

Surface water and sediment locations were frozen during the December field effort. These samples will be collected in the fall and reported in the 2019 RAO/LUC report.

6.5 RAPCON/RED FOX CREEK RECOMMENDATIONS

- Sampling in Zone 5 RAPCON/Red Fox Creek should continue without changes, except to discontinue EPA Method 8011. EDB was detected well below the cleanup level in BV17 in 2017 and 2018. There were no other detections using this method.
- Reduce sampling for iron and manganese to every five years in coordination with the Five Year Review.
- The Zone 5 ROD should be finalized.

PATH: 19 Dwgs\19 PV\718004 RAO LUC FILE: 718004-RAO-LUC-RPT-F6-1.DWG PLOT: 2/6/19.

FIGURE 6-1

RAPCON GROUNDWATER ANALYTICAL RESULTS

RAPCON AND RED FOX CREEK
2018 RAO/LUC
King Salmon Divert, Alaska

AIR FORCE CIVIL ENGINEERING CENTER
JBER, ALASKA

DATE FEB. 2019
CHKD H.L.H.
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PROJ. NO 718004

7 ZONE 6 – RAPIDS CAMP (OT032)

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 will be 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) will be used as a guide for the inspection activities performed at the landfill in the fall of 2019 and reported in the 2019 RAO/LUC report. The 2018 inspection was not conducted during the 2018 field season due to snow covered ground.

FIGURE 7-1

LANDFILL INVESTIGATION GROUNDWATER ZONE 6

NAKNEK RECREATIONAL CAMP (RAPIDS CAMP GWZ6)
2018 RAO/LUC
King Salmon Divert, Alaska

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DATE	JAN. 2019
CHKD	H.L.H.
DRAWN	C.E.H.
PROJ. NO	718004

PATH: 19 Dwgs\19 PV\718004 RAO LUC FILE: 718004-RAO-LUC-RPT-F7-1.DWG PLOT: 1/21/19

8 ZONE 7 – LAKE CAMP (OT033)

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. Seventy-five drums were removed from the former landfill LF001 in 2009. POL contamination remains at this site. A complete description of excavation and drum removal activities can be found in *Remedial Action Projects, King Salmon, Airport (Paug-Vik, November, 2012)*.

The purpose of the current field effort was to collect groundwater samples from one monitoring well located at SS0004, one monitoring well 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.

8.1 GROUNDWATER CLEANUP LEVELS FOR ZONE 7

The Lake Camp objective is the ADEC cleanup level for DRO listed in Table 8.1.

Table 8-1 Groundwater 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

Definitions:

18AAC75 Table C = Oil and Hazardous Substances Pollution Control Regulations (October 2018)
RAOs = remedial action objectives
DRO = diesel-range organics
mg/L = milligrams per liter

8.2 PROJECT TASKS

8.2.1 Zone 7 Groundwater Sampling

Groundwater monitoring was conducted at Lake Camp to document contaminant concentrations and MNA parameters in the groundwater. Samples were collected December 3, 2018. 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.

8.2.2 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 (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 restriction on excavation without a proper soil management plan.

A visual inspection will be performed in the fall of 2019, to verify that no water wells have been installed and no soil excavating has taken place. The results will be reported in the 2019 RAO-LUC Report.

8.2.3 Work Plan Deviations

- The Institutional Control Inspection was not conducted due to snow cover.

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

Location ID Sample Point	Comments	Matrix	Location Type	Analytical Methods						Sample ID
				AK 102 DRO	SM 2320B Alkalinity*	300.0 Chloride & Sulfate	353.2 Nitrate + Nitrite	EPA Method 6010B Fe + Mn (dissolved)	RSK 185 Methane	
LF02		Groundwater	Monitoring Well	1	1	1	1	1	1	18KS7ZLF02-107WG
GP01	MS/MSD	Groundwater	Monitoring Well	3	3	3	3	3	3	18KS7ZGP01-108WG
MW22		Groundwater	Monitoring Well	1	1	1	1	1	1	18KS7ZMW22-114WG
Duplicate		Groundwater	Monitoring Well	1	1	1	1	1	1	18KS7ZMW23-115WG
Water Analyses Totals				**6**	**6**	**6**	**6**	**6**	**6**	

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

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

*No Head Space

8.3 ZONE 7 FINDINGS

8.3.1 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 December were between 2.76˚C and 4.52˚C. Temperatures less than 4.4˚C tend to inhibit the rate of biodegradation.

pH: Measurements were between 5.81 and 6.26 pH units. These levels are suitable for biodegradation processes.

Conductivity: The conductivity measurements ranged from 83 to 223 micro Siemens per centimeter (µS/cm). Elevated levels of conductivity may be associated with groundwater contamination.

Dissolved Oxygen: DO levels ranged between 2.09 mg/L and 3.99 mg/L. Areas with elevated petroleum hydrocarbons generally have depressed DO levels.

Redox Potential: Redox potentials were between 68.4 and 135.7 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)	Choride (mg/L)	Nitrate-Nitrite (mg/L)	Sulfate (mg/L)	Ferrous Iron (mg/L)	Manga-nese (mg/L)	Methane (µg/L)	Alkalinity (mg/L)	Tempera-ture	DO (mg/L)	ORP (mV)	pH	Con. (µS/cm)
ADEC Cleanup Level	**1.5**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
LF02	0.56 (0.54)	3.6	0.38 (0.34)	1.1 (1.2)	0.33 (0.31)	0.15 (0.17)	0.22 (0.081)	53 (52)	3.72	3.99	97	6.25	114
GP01	**3.7**	2.3	0.019	0.63	4.2	2.2	7.7	120	4.52	2.09	68.4	6.26	223
MW22	**2.3**	2.0	ND	1	9.2	0.43	0.11	51	2.76	3.48	135.7	5.81	83

NA - Not Applicable
ND - Not detected above method reporting level (MRL)
Cleanup Level from ADEC 18 AAC 75 Table C (October 2018)
Analytical results exceeding cleanup levels shown in **BOLD.**
(Results) are duplicate samples.

8.3.2 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.

8.3.2.1 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 3.7 mg/L and 2.3 mg/L, respectively. Overall, DRO concentrations ranged from 0.54 to 3.7 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.

8.3.2.2 Inorganics

Various geochemical indicators important for assessing aerobic biodegradation of fuel hydrocarbons were measured to evaluate if intrinsic remediation is taking place. Sampling for these geochemical indicators has taken place annually since 2013 and have yet to provide any useful information regarding intrinsic remediation. A summary of Zone 7 analytical results can be found in Table 8-3.

- Nitrate-nitrite as nitrogen was detected at low levels in two of the wells sampled during 2018 at concentrations ranging from 0.019 to 0.38 mg/L. All of the wells 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 0.63 to 1.2 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 0.33 in LF02 to 9.2 mg/L in MW22, 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 0.15 mg/L in LF02 to 2.2 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 0.11 in MW22 to 7.7 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 51 to 120 mg/L (GP01), and generally, elevated petroleum hydrocarbon levels correlated with increased alkalinity concentrations at GP-01, but not at MW22.

8.3.1 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 groundwater cleanup levels. 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
GP01	NT
LF02	NT
MW22	NT

NT – No trend

8.3.2 Institutional Control Inspection

The IC inspection will be conducted in the fall of 2019, and results will be included in the 2019 RAO/LUC report.

8.3.3 Condition of Wells

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

8.4 ZONE 7 CONCLUSIONS

Two of three wells sampled in 2018 exceeded the cleanup level for DRO.

DRO concentrations at MW22 and LF02 have decreased since last year's sampling event, while there is a DRO increase at GP01.

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

8.5 ZONE 7 RECOMMENDATIONS

- Sampling should continue at monitoring wells GP01 and MW22. The DRO concentration at LF02 has remained below the cleanup level of 1.5 mg/L for four consecutive years, therefore sampling of the well should be discontinued.
- As discussed in section 8.4.2.2, sampling for various geochemical indicators has not provided any useful data for assessing aerobic biodegradation of fuel hydrocarbons. Sampling for nitrate/nitrite, chloride/sulfate, alkalinity, methane, ferrous iron, and manganese should be discontinued.
- 2015 soil samples collected from three LF01 locations indicated DRO contaminated soil above cleanup levels. AFCEC should consider a future removal action at LF01.
- The Zone 7 ROD should be finalized.

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)	2018 Analytical Results (mg/L)
ADEC Cleanup Level	1.5	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)	0.56 (0.54)
MW07	NI	NI	0.03	ND	0.061/0.055	NS	NS	0.029	NS
GP01	0.024	ND	?	**2.6**	**4.5**	**2.9**	**4.1**	**2.8**	**3.7**
GP02	**5.7**	**2.4**	?	0.1	0.2	NS	NS	0.18	NS
MW21	NI	NI	**3.23**	0.25	0.25	NS	NS	0.14	NS
MW22	NI	NI	**2.6**	**2.7**	0.84	1.0	**2.2**	**2.5**	**2.3**
WP19	NI	NI	0.2	0.087	0.12	NS	NS	0.099	NS
WP20	NI	NI	0.17	0.34	0.29	NS	NS	0.27	NS

ND - Not Detected

NS - Not Sampled

NI - Not Installed

NF- Not Found

? - Well Removed according to ROD

(Duplicate Sample Result)

Cleanup Level from ADEC 18 AAC 75 Table C (October 2018)

Analytical results exceeding cleanup levels shown in **BOLD**.

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GROUNDWATER DRO RESULTS
GROUNDWATER ZONE 7

NAKNEK RECREATIONAL CAMP (GWZ7)
2018 RAO/LUC
King Salmon Divert, Alaska

FIGURE
8-1

PATH: 19 Dwgs\19 PV\718004 RAO LUC FILE: 718004-RAO-LUC-RPT-F8-1.DWG PLOT: 4/24/19.

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