FINAL

LONG TERM MONITORING REPORT

Long Term Monitoring of Site ST05

Cold Bay Long Range Radar Site, Alaska

Prepared for:
611th Civil Engineer Squadron

and

Air Force Center for Engineering and the Environment

Contract GS-10F-0533N, TO FA8903-09-F-0001
Project Number: 306

February 2010

TABLE OF CONTENTS

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

ACRONYMS AND ABBREVIATIONS

611 CES/CEAR	611th Air Support Group Civil Engineer Squadron, Asset Management Flight Restoration Element
AAC	Alaska Administrative Code
ADEC	Alaska Department of Environmental Conservation
AFCEE	Air Force Center for Engineering and the Environment
amsl	above mean sea level
AST	aboveground storage tank
bgs	below ground surface
BNCI	BNC International, Inc.
btoc	below top of casing
°C	degrees Celsius
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
DD	Declaration of Decision
DO	dissolved oxygen
DRO	diesel-range organic
DTP	depth to product
DTW	depth to water
Dup	duplicate
EPA	U.S. Environmental Protection Agency
ERPIMS	Environmental Restoration Program Information Management System
ft	feet
GAC	granular activated carbon
GW	groundwater
IRP	Installation Restoration Program
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LRRS	Long Range Radar Site
LTM	long term monitoring
mg/kg	milligram per kilogram
mg/L	milligram per liter
MNA	monitored natural attenuation
MS	matrix spike
MSD	matrix spike duplicate
mV	millivolts
ND	not detected/non-detect
NM	not measured
NTU	nephelometric turbidity unit
ORP	oxidation-reduction potential
POL	petroleum, oil, and lubricant

ACRONYMS AND ABBREVIATIONS

PQL	practical quantitation limit
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QAR	Quality Assurance Report
QC	Quality Control
RAO	remedial action objectives
RPD	relative percent difference
SGS	SGS Environnemental Services, Inc.
µg/L	micrograms per liter
USAF	U.S. Air Force
WACS	White Alice Communication System
WG	groundwater (ERPIMS format)

Executive Summary

This document presents results of the September 2009 groundwater sampling and evaluates monitored natural attenuation (MNA) as the selected remedy for addressing groundwater contamination at the Petroleum, Oil, and Lubricants (POL) Tank Area Site ST05 at Cold Bay, Alaska. As stated in the *Declaration of Decision POL Storage Area ST05, Cold Bay, Alaska* (U.S. Air Force [USAF], 2001), groundwater shall be monitored until diesel-range organics (DRO) concentrations are no greater than 1.5 milligrams per liter (mg/L) throughout the aquifer. To reach this goal, the rate of intrinsic biodegradation of DRO must be significant and demonstrable. The progress and effectiveness of MNA are evaluated through periodic monitoring of DRO concentrations in groundwater, and evaluating the data using a statistically valid trend analyses method. The progress of intrinsic biodegradation is assessed by evaluating aerobic respiration, denitrification, manganese (IV) reduction, iron (III) reduction, sulfate reduction, and methanogenesis in the groundwater data.

Six monitoring wells were sampled during this effort in September 2009 and analyzed for DRO and select MNA parameters. Groundwater contamination exceeding the 1.5 mg/L cleanup level adopted in the Declaration of Decision for ST05 (USAF, 2001) is limited to the portion of the aquifer surrounding monitoring well ST05-MW6, where DRO was detected at 2.34 mg/L in September 2009. Results from all previous sampling events at this well have also exceeded the DRO cleanup level. The source of DRO in groundwater appears to be contaminated soil that was left in place more than 15 feet below ground surface during a removal action near the former pump house. Since monitoring began at well ST05-MW6 in August 2003, DRO concentrations have varied from just above the cleanup level to just below the saturation concentration of DRO. DRO concentrations for the other five site wells have remained below the cleanup criterion for several consecutive sampling events.

Mann-Kendall statistical analyses were performed on the historical and current DRO concentration data to determine whether increasing or decreasing DRO concentration trends are present at the site across time. The analysis indicate decreasing trends in DRO concentration are present at ST05-MW5, ST05-MW7, and ST05-MW8 that are statistically significant (i.e. not random) at greater than an 85% confidence level. No significant trends were identified in the DRO data from ST05-MW3 or ST05-MW6. Well ST05-MW9 was installed in 2008 and does not yet have sufficient data to evaluate for possible DRO concentration trends.

DRO concentrations at downgradient wells have consistently been below the site cleanup criterion since the onset of regular monitoring in 2003, indicating off-site migration of the contamination is minimal. Furthermore, recently installed downgradient well ST05-MW9 has yielded DRO concentrations below the reporting limit since sampling began in 2008. Evaluation of natural attenuation parameters indicates that biodegradation is actively occurring at the site and is promoted by high levels of dissolved oxygen in upgradient groundwater. Given this limited mobility of contamination and evidence that biodegradation is occurring, future monitoring should occur at a frequency of once every five years until DRO concentrations meet the site cleanup level of 1.5 mg/L throughout the aquifer.

1.0 INTRODUCTION

The United States Air Force Center for Engineering and the Environment (AFCEE) funded BNC International, Inc. (BNCI), under Contract Number GS-10F-0533N, Task Order FA8903-09-F-0001, to perform Environmental Monitoring for Site ST05 at the Cold Bay Long Range Radar Site (LRRS) as specified in the Performance Work Statement. This project is directed and coordinated by the United States Air Force (USAF), 611th Air Support Group Civil Engineer Squadron, Asset Management Flight Restoration Element (611 CES/CEAR) on Elmendorf Air Force Base.

The purpose of the investigation was to conduct environmental monitoring of groundwater at Site ST05 in support of monitored natural attenuation (MNA) as the selected remedy stated in the *Declaration of Decision POL Storage Area ST05, Cold Bay, Alaska* (USAF, 2001). The Declaration of Decision (DD) states that groundwater shall be monitored until diesel-range organics (DRO) concentrations are no greater than 1.5 milligrams per liter (mg/L) throughout the aquifer.

This long term monitoring (LTM) Report outlines Installation Restoration Program (IRP) activities that were performed in support of LTM at Site ST05 (Petroleum, Oil, and Lubricant [POL] Tank Area) in 2009 at the Cold Bay LRRS Alaska. Under the IRP, the 611 CES/CEAR developed a LTM program in accordance with the DD.

The purpose of the LTM program is to insure that the selected remedies presented in the DD are implemented properly and remain effective. The LTM program was developed to meet the requirements of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) and the National Contingency Plan. The USAF is the lead agency for the program.

1.1 ST05 SITE HISTORY

Cold Bay is located approximately 30 miles from the west end of the Alaska Peninsula, about 640 miles southwest of Anchorage, Alaska (Figure 1-1). The USAF operated the site in support of the White Alice Communication System (WACS). The site was constructed in 1958 and 1959 as the Cold Bay communications link in the extension of the Distant Early Warning Line into the Aleutians. The WACS operated from 1959 until it was deactivated in 1978.

Two aboveground storage tanks (AST) were present at ST05, each holding up to 70,000 gallons of diesel fuel. These ASTs were removed in 1994. Investigations in 1993 and 1997 indicated soil contaminated with diesel fuel existed at the former POL storage area and near the former pump house. In 1994, groundwater monitoring wells were installed and sampled at the POL storage area to monitor groundwater contamination. Analytical results indicated that surface soil, subsurface soil, and groundwater at the site were contaminated with DRO (USAF, 2001).

The following remedial action goals were developed and documented in the DD for ST05 (USAF, 2001):

- Soil from the surface to 10 feet below ground surface (bgs) – Soil containing more than 250 milligrams per kilogram (mg/kg) DRO was to be excavated and thermally treated to meet the cleanup levels stated in the DD for ST05. This action is complete.

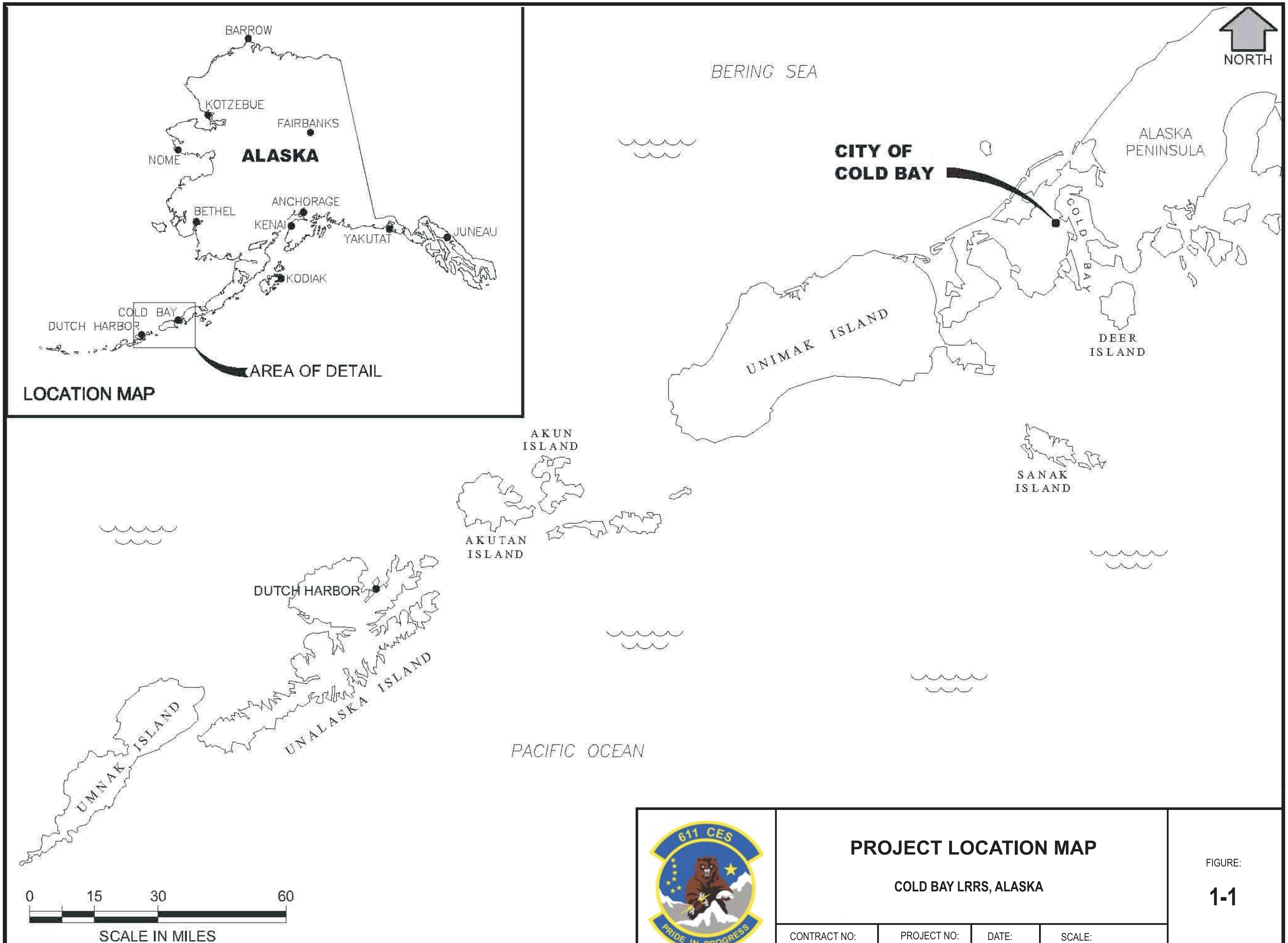


Figure modified from Jacobs Engineering 2008 MNA Evaluation Report

PROJECT LOCATION MAP

COLD BAY LRRS, ALASKA

FIGURE:

1-1

CONTRACT NO:	PROJECT NO:	DATE:	SCALE:
GS-10F-0533N	306	2/8/2010	APPROX 1" = 30 MILES

- Soil between 10 and 15 feet bgs – Removal and treatment of soil containing more than 1,000 mg/kg DRO was to be performed to ensure that inhalation and ingestion standards were met and to reduce the time needed for natural attenuation to meet cleanup levels. This action is complete.
- Fuel-contaminated groundwater – MNA was to be performed until concentrations of DRO no greater than 1.5 mg/L were achieved throughout the aquifer (Alaska Administrative Code [AAC], Title 18, Section 75.345, Table C) and surface water quality standards (AAC Title 18, Section 70) were met at the point where groundwater discharges to surface water. This action is ongoing and is the impetus for the 2009 monitoring described in this report.

The remedial action objectives (RAOs) for soil and groundwater specified in the DD for Site ST05 (USAF, 2001) are:

- Soil (0-10 feet bgs) 250 mg/kg DRO
- Soil (10-15 feet bgs) 1,000 mg/kg DRO
- Groundwater 1.5 mg/L DRO

1.1.1 Previous Soil Investigations and Removal Actions

An overview of previous investigations and removal actions, as stated in the 2008 MNA evaluation report (USAF, 2008), is summarized below:

- 1997 - a bioventing system was installed to study the effectiveness in addressing the petroleum-contaminated soil. Subsequent data indicated that the system was not achieving project cleanup goals.

- 2000 - the bioventing system was removed, and approximately 2,000 cubic yards of diesel fuel-contaminated soil was excavated up to 10 feet bgs near the former pump house and placed in two long-term stockpiles. Contaminated soil remained at the excavation limits and the excavation was then backfilled with clean fill material.

- 2002 and 2003 - USAF continued cleanup activities at the POL Storage Area at ST05 including the relocation of an existing soil stockpile (containing contaminated soil from the nearby Site OT01; investigation, removal, and treatment of petroleum-contaminated soil; and installation and sampling of monitoring wells. Additional test pitting and contaminated soil removal were conducted in the area of the previous excavation near the former facilities at the pump house, fuel stand, and valve vault. Contaminated soil was excavated from these areas, added to the contaminated soil stockpile, and thermally treated. In accordance with the DD, excavations did not exceed 15 feet bgs. DRO-contaminated soil remaining below 15 feet bgs appears to be the source of groundwater contamination at the site. Excavation floor samples reported DRO concentrations up to 9,720 mg/kg. Laboratory analyses confirmed that the soil left in place between the ground surface and 15 feet bgs met site cleanup standards. Approximately 10,200 tons of contaminated soil from the ST05 site were treated and all excavations were backfilled with treated soil. After backfilling was complete, the site was regraded and reseeded.

Figure 1-2 depicts the current monitoring well network in relation to former AST locations, approximate water table, DRO excavation floor concentrations, and topography into both plan and cross-section views of ST05 (adapted from USAF, 2008).

1.1.2 Previous Groundwater Investigations

Table 1-2 presents the historic DRO groundwater sampling results for Site ST05. Results from 2009 sampling are discussed in Sections 3 and 4.

In 1994, four groundwater monitoring wells were installed and sampled at the POL storage area (ST05-MW1 through ST05-MW4) to assess groundwater contamination. Results from one of the wells (ST05-MW2) adjacent to the former AST location exceeded the DRO cleanup criterion of 1.5 mg/L with a concentration of 14 mg/L.

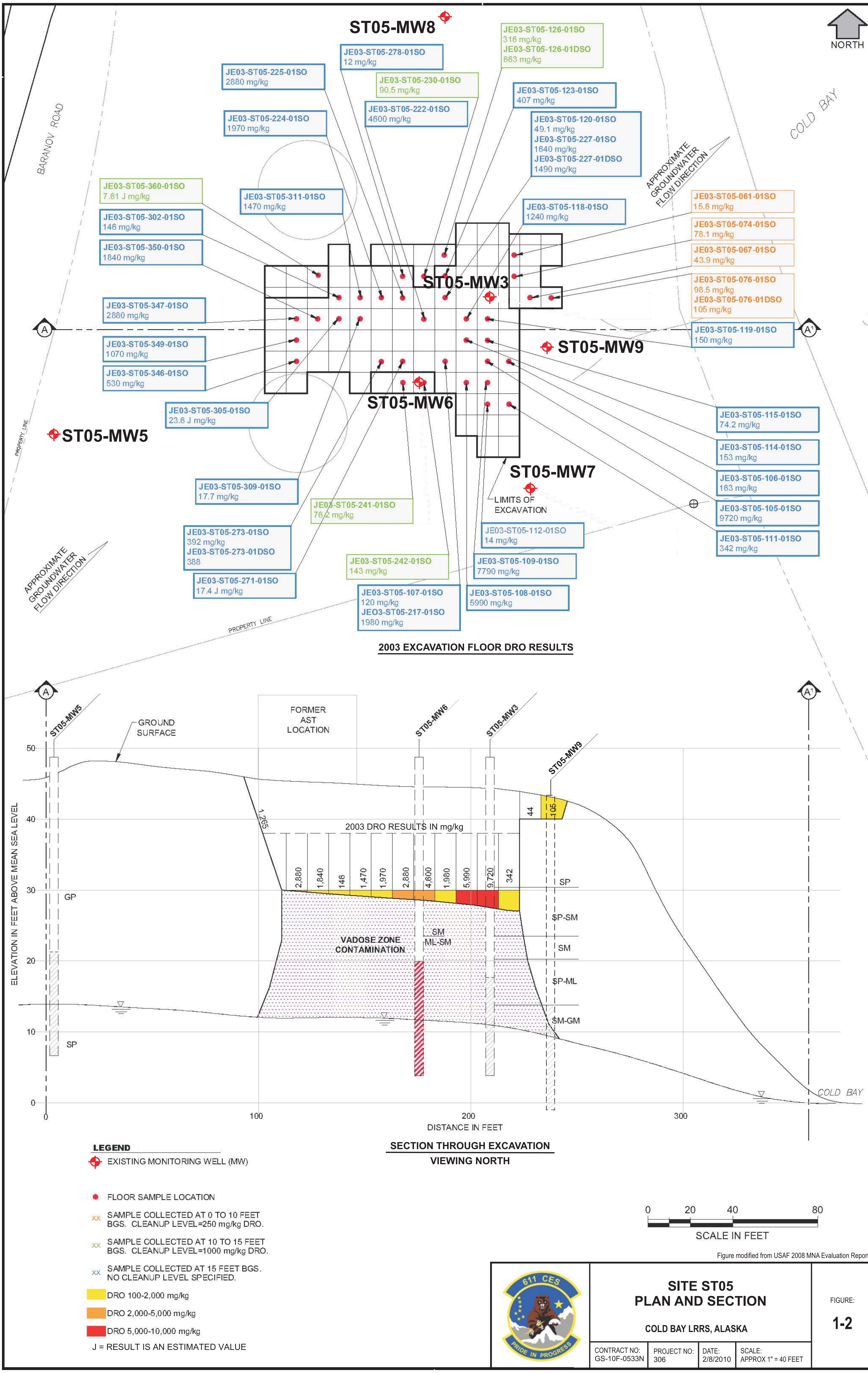
In 2000, only ST05-MW2 was sampled. Two of the three remaining wells (ST05-MW1 and ST05-MW4) were previously decommissioned, and one was erroneously assumed to have been decommissioned (ST05-MW3). Sampling results for ST05-MW2 indicated a DRO concentration of 23 mg/L and a residual-range organics concentration of 4.5 mg/L (USAF, 2001).

In 2003, four monitoring wells were installed (ST05-MW5 through ST05-MW8), ST05-MW3 was located and returned to service, and groundwater samples were obtained from each of these five wells. ST05-MW5 was installed upgradient of the site adjacent to Baranov Road. Wells ST05-MW7 and ST05-MW8 were installed downgradient of the Main Excavation Area. The fourth well, ST05-MW6, was installed in the area of highest DRO contamination in the floor of the 2003 excavation.

Analytical results from the 2003 sampling event provided the basis for subsequent groundwater sampling events in 2004, 2005, 2007, and 2009. In 2003, DRO exceeded the cleanup level in well ST05-MW6 and has continued to exceed the cleanup level in the subsequent rounds of sampling.

Two rounds of sampling were conducted in 2004 (May and September) at the same five wells sampled in 2003. Results from ST05-MW6 exceeded the DRO cleanup level for both events. The September DRO results from ST05-MW3 exceeded the cleanup level for the only time in the project's history with 1.56 mg/L. ST05-MW6 is the only well to exceed the DRO cleanup level since September 2004, and has done so consistently. DRO concentrations for all other wells tested have been below the cleanup level since August 2003.

In order to better monitor the migration of contaminants and natural attenuation at Site ST05, monitoring well ST05-MW9 was installed and sampled in July 2008. The well was installed directly downgradient of where the highest DRO results were obtained in the excavation floor as identified during the 2003 excavation. The current configuration of monitoring wells and their relation to the former AST and soil excavation sample results is shown in Figure 1-2 (adapted from USAF, 2008).



NORTH
ST05-MW8
JE03-ST05-126-01SO 316 mg/kg JE03-ST05-126-01DSO 663 mg/kg
JE03-ST05-278-01SO 12 mg/kg
JE03-ST05-225-01SO 2880 mg/kg
JE03-ST05-230-01SO 90.5 mg/kg
JE03-ST05-123-01SO 407 mg/kg
JE03-ST05-222-01SO 4600 mg/kg
JE03-ST05-224-01SO 1970 mg/kg
JE03-ST05-120-01SO 49.1 mg/kg JE03-ST05-227-01SO 1640 mg/kg JE03-ST05-227-01DSO 1490 mg/kg
COLD BAY
BARANOV ROAD
APPROXIMATE GROUNDWATER FLOW DIRECTION
JE03-ST05-360-01SO 7.61 J mg/kg
JE03-ST05-311-01SO 1470 mg/kg
JE03-ST05-302-01SO 146 mg/kg
JE03-ST05-118-01SO 1240 mg/kg
JE03-ST05-061-01SO 15.6 mg/kg
JE03-ST05-074-01SO 78.1 mg/kg
JE03-ST05-350-01SO 1840 mg/kg
JE03-ST05-067-01SO 43.9 mg/kg
ST05-MW3
JE03-ST05-076-01SO 98.5 mg/kg JE03-ST05-076-01DSO 105 mg/kg
JE03-ST05-347-01SO 2880 mg/kg
A
A'
JE03-ST05-119-01SO 150 mg/kg
ST05-MW9
JE03-ST05-349-01SO 1070 mg/kg
JE03-ST05-346-01SO 530 mg/kg
ST05-MW6
JE03-ST05-305-01SO 23.6 J mg/kg
JE03-ST05-115-01SO 74.2 mg/kg
ST05-MW5
PROPERTY LINE
JE03-ST05-114-01SO 153 mg/kg
ST05-MW7
JE03-ST05-106-01SO 163 mg/kg
JE03-ST05-309-01SO 17.7 mg/kg
LIMITS OF EXCAVATION
JE03-ST05-241-01SO 76.2 mg/kg
JE03-ST05-105-01SO 9720 mg/kg
JE03-ST05-273-01SO 392 mg/kg JE03-ST05-273-01DSO 388
JE03-ST05-112-01SO 14 mg/kg
JE03-ST05-111-01SO 342 mg/kg
JE03-ST05-242-01SO 143 mg/kg
JE03-ST05-109-01SO 7790 mg/kg
JE03-ST05-271-01SO 17.4 J mg/kg
JE03-ST05-107-01SO 120 mg/kg JEO3-ST05-217-01SO 1980 mg/kg
JE03-ST05-108-01SO 5990 mg/kg
PROPERTY LINE
2003 EXCAVATION FLOOR DRO RESULTS
GROUND SURFACE
FORMER AST LOCATION
ST05-MW5
ST05-MW6
ST05-MW3
ST05-MW9
ELEVATION IN FEET ABOVE MEAN SEA LEVEL
50
40
30
20
10
0
1,265
2003 DRO RESULTS IN mg/kg
44
105
2,880
1,840
146
1,470
1,970
2,880
4,600
1,980
5,990
9,720
342
GP
SP
SP
SP-SM
SM
SP-ML
SM-GM
SM
ML-SM
VADOSE ZONE CONTAMINATION
COLD BAY
0
100
200
300
DISTANCE IN FEET
SECTION THROUGH EXCAVATION
VIEWING NORTH
LEGEND
EXISTING MONITORING WELL (MW)
FLOOR SAMPLE LOCATION
xx SAMPLE COLLECTED AT 0 TO 10 FEET BGS. CLEANUP LEVEL=250 mg/kg DRO.
xx SAMPLE COLLECTED AT 10 TO 15 FEET BGS. CLEANUP LEVEL=1000 mg/kg DRO.
xx SAMPLE COLLECTED AT 15 FEET BGS. NO CLEANUP LEVEL SPECIFIED.
DRO 100-2,000 mg/kg
DRO 2,000-5,000 mg/kg
DRO 5,000-10,000 mg/kg
J = RESULT IS AN ESTIMATED VALUE
0 20 40 80
SCALE IN FEET
Figure modified from USAF 2008 MNA Evaluation Report
611 CES
PRIDE IN PROGRESS
SITE ST05
PLAN AND SECTION
COLD BAY LRRS, ALASKA
FIGURE:
1-2
CONTRACT NO: GS-10F-0533N
PROJECT NO: 306
DATE: 2/8/2010
SCALE: APPROX 1" = 40 FEET

Table 1-2
ST05 Historic Groundwater Diesel-Range Organics Analytical Results

Date	Monitoirng Well								
	ST05-MW1	ST05-MW2	ST05-MW3	ST05-MW4	ST05-MW5	ST05-MW6	ST05-MW7	ST05-MW8	ST05-MW9
September 2009	-	-	1.44 M	-	ND M [0.941]	2.34 M	ND M [0.842]	ND M [0.833]	ND M [0.800]
July 2008	-	-	-	-	-	-	-	-	0.250 J B
October 2007	-	-	0.95	-	0.051 J	3.4	0.083 J	0.12	-
October 2005	-	-	1.23	-	0.155 J	4.24	1.211 J	0.198 J	-
May 2005	-	-	1.06	-	0.0853 J	1.6	0.147 J	0.101 J	-
September 2004[1]	-	-	1.56	-	0.217	3.88	0.492	0.292 J	-
May 2004[1]	-	-	0.997	-	0.182	4.2	0.275	0.409	-
August 2003[1]	-	-	0.844	-	0.26	2.6	0.744	0.3	-
2000	-	23	-	-	-	-	-	-	-
1994	0.33	14	1.1	0.13	-	-	-	-	-

Notes:
The cleanup level for DRO in groundwater is 1.5 mg/L.
1 = Groundwater was also tested for benzene, toluene, ethylbenzene, and xylenes compounds, which were then eliminated as contaminants of concern; see previous reports.
J = result is an estimated value; B = analyte detected in associated blank as well as in the sample.
M = potential matrix interference.
Bolded results indicate values above the cleanup level.
All units are mg/L. Analytical method AK102 used for all samples.

2.0 SEPTEMBER 2009 FIELDWORK METHODS

The September 2009 groundwater monitoring was conducted in fulfillment of requirements set forth in the DD for Site ST05 (USAF, 2001). The *Final Environmental Cleanup Plan, Cold Bay Long-Range Radar Site,* October 2002 (USAF, 2002) was the workplan and sampling and analyses plan used for this project. Modifications to this plan are included in the September 2009 letter workplan produced by BNCI and approved by AFCEE and the Alaska Department of Environmental Conservation (ADEC). The primary modification from the 2002 plan is the inclusion of the new monitoring well (ST05-MW9) installed in 2008.

A deviation from the September 2009 letter workplan was required when the submersible pump and controller were damaged in transit. Because the pump failed to work properly, five of the six wells were sampled using bailers rather than the submersible pump and low-flow method.

2.1 INSPECTION OF SITE WELLS

Prior to purging and sampling the site wells, the condition of each well's casing, protective cap, and monument components were inspected and documented in the field log book. Several wells had damaged monuments and/or were not secured with adequate locks. Efforts were made to repair damaged monuments and a new set of like-keyed locks were installed, however two of the locks could not be latched due to well damage. A brief description of each well's condition is noted below.

ST05-MW3 (Stickup)
No well identification marker was present and the monument cover and lock were found on ground adjacent to the well upon arrival. The well casing was observed to have frost-jacked and projected above top of monument. A new lock was installed on the well cap, but the monument cover could not be secured because the frost-jacked casing prevented the cover from closing.

ST05-MW5 (Flush-mount)
The well was marked with bollards but had no identification marker. The bolts were missing from the monument cover upon arrival and were not replaced. A new well cap and lock were installed on the casing.

ST05-MW6 (Stickup)
No well identification marker was found. A lock was present upon arrival, but not latched. The monument cover was drilled out to accommodate the new lock.

ST05-MW7 (Stickup)
The well was identified with a metal tag. A lock was present upon arrival, but not engaged. The monument cover was drilled out to accommodate a new lock.

ST05-MW8 (Stickup)
The well was identified with a metal tag. The well monument was missing its cover upon arrival. A new lock was installed on the casing cap, but monument could not be secured due to the missing cover.

ST05-MW9 (Flush-mount)
The well identified with a plastic tag. The monument cover was present upon arrival but not secured because the casing had frost-jacked. A well cap and new lock were installed on the casing.

Additional details of the well inspection are included in the Field Notes in Appendix A.

2.2 WATER LEVEL MEASUREMENTS

A down-hole, depth-to-water meter was used to measure water levels in the six wells at Site ST05. Although not measured with an oil/water interface probe, evidence of free product was not observed on the tip of the probe or in the purge bucket during sampling. Section 3.1 presents and discusses the water-level measurement data.

2.3 GROUNDWATER SAMPLING

Sampling was conducted on 25 and 26 September 2009. Purging and sampling was first attempted using the low-flow technique with a Proactive Monsoon submersible pump, however the pump and controller were found to have been damaged during shipping and did not operate properly. A replacement controller was sent to the site but did not rectify the problem and low-flow sampling was abandoned after completing one well (ST05-MW5). The remaining five wells were purged and sampled using new, disposable, polyethylene bailers, as approved by 611th Remedial Project Manager while fieldwork was in progress.

Before sampling, a minimum of three well volumes from each of the bailed monitoring wells was purged, and water quality parameters were collected after each 2-liter volume was removed. Groundwater samples were then collected for the following laboratory analyses:

- DRO by method AK102
- Alkalinity by SM20 2320B
- Total iron and manganese by SW6020
- Dissolved iron and manganese (field filtered) by SW6020
- Methane by RSK-175
- Sulfate by U.S. Environmental Protection Agency (EPA) 300.0
- Sulfide by SM 4500 S
- Total nitrate/nitrite-N by SM 4500 NO3-F

Quality Control (QC)/Quality Assurance (QA) samples included one field duplicate and one matrix spike/matrix spike duplicate (MS/MSD) pair. Details from sampling activities can be found in the Sampling Data Sheets and Field Notes included in Appendix A. Analytical results are presented and discussed in Section 3.

Purged groundwater and water from decontamination of equipment (depth-to-water meter) was treated using granular activated carbon (GAC) and discharged on site adjacent to each respective monitoring well. No free product or sheen was noted on the purge water prior to treating with the GAC unit.

2.4 FIELD PARAMETERS

Groundwater field parameters (pH, conductivity, dissolved oxygen [DO], temperature, and oxidation-reduction potential [ORP]) were measured using a YSI 556 water quality meter. Turbidity was measured separately using a Hach 2100P Portable Turbidimeter (Method EPA 180.1). Field parameters were measured with YSI 556 as water was pumped through a flow-through cell for well ST05-MW5, and by submerging the sensor probe in purge water poured into an open container for remaining wells. The latter method was required because these wells were purged and sampled using bailers.

3.0 GROUNDWATER MONITORING RESULTS

This section presents results from the September 2009 groundwater sampling event at Site ST05. A data quality assessment is presented in Section 3.4 and Level II analytical results are included in Appendix C.

3.1 WATER-LEVEL MEASUREMENTS

Water levels were measured in the six wells at Site ST05 (Table 3-1) prior to purging and sampling. There is evidence that frost heaving has affected top of casing elevations at the site. Therefore, the 2009 groundwater elevations and flow direction interpretation should be considered approximate. The data does suggest that groundwater elevations decline from west to east, indicating that groundwater from Site ST05 flows easterly toward Cold Bay (Figure 3-1). This is consistent with previous surveys.

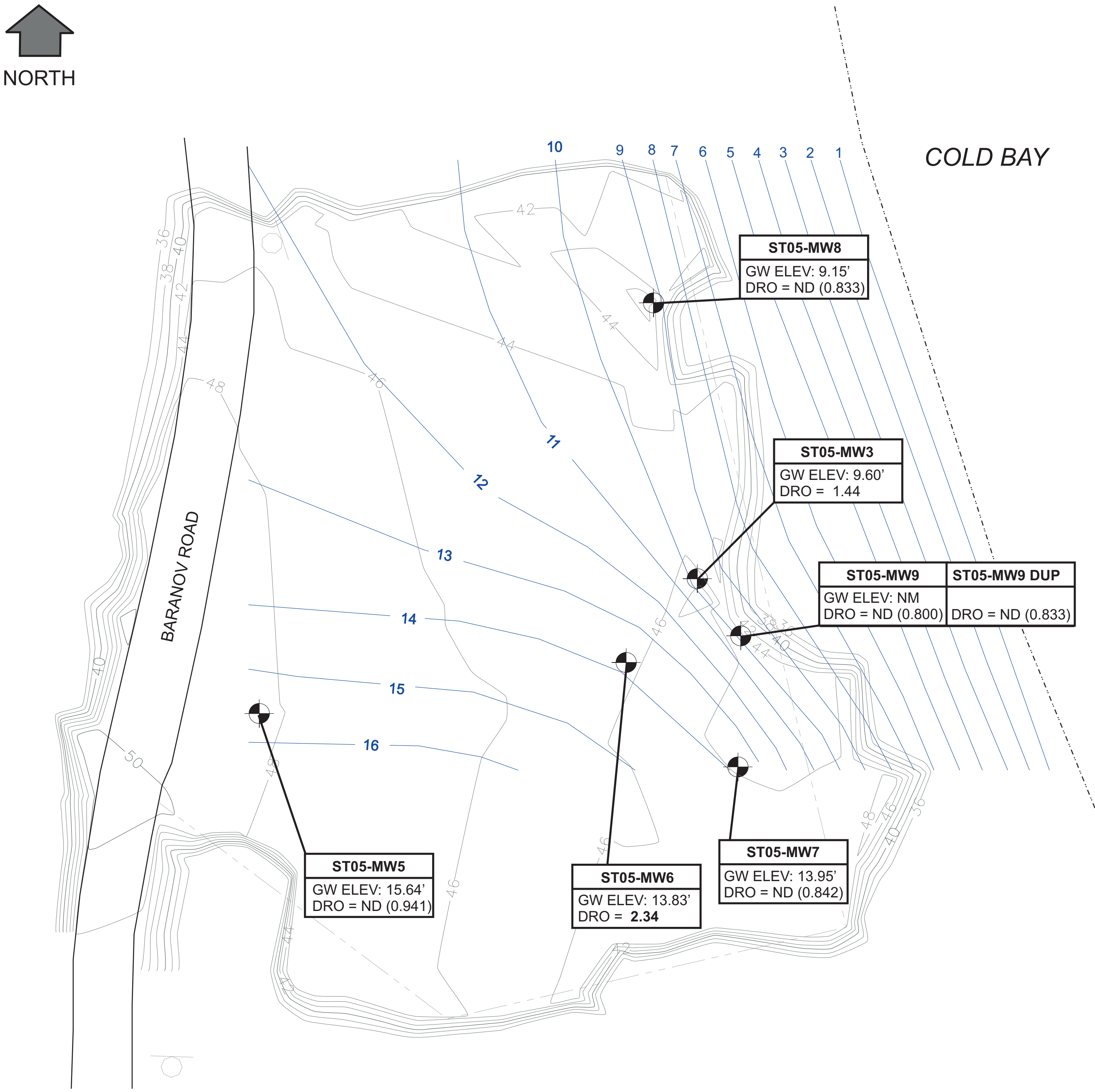
Table 3-1
Static Water Level Measurements, 25 September 2009

Well ID	Time	Well Depth (ft btoc)	DTW (ft btoc)	TOC elev.* (ft amsl)	GW Elev. (ft amsl)	DTP (ft btoc)	Product Thickness (ft)
ST05-MW3	1208	44.6	38.74	48.34	9.60	NM	NM
ST05-MW5	1136	44.1	32.61	48.25	15.64	NM	NM
ST05-MW6	1216	45.1	33.71	47.54	13.83	NM	NM
ST05-MW7	1152	45.0	33.74	47.69	13.95	NM	NM
ST05-MW8	1144	53.1	37.54	46.69	9.15	NM	NM
ST05-MW9	1200	44.6	33.02	NM	NM	NM	NM

DTW = depth to water
NM = not measured
DTP = depth to product
GW = groundwater
* = Evidence of frost heaving indicates top of casing elevations may be inaccurate
ft = feet
btoc = below top of casing
amsl = above mean sea level

3.2 DIESEL-RANGE ORGANICS RESULTS

DRO was detected in two of the six site wells during the September 2009 monitoring event. The concentration of DRO from well ST05-MW6, from within the contaminant plume, was 2.34 mg/L, which exceeds the 1.5 mg/L cleanup level. DRO was also detected below the cleanup level in the sample from well ST05-MW3 at a concentration of 1.44 mg/L. DRO results for wells ST05-MW5, ST05-MW7, ST05-MW8, and ST05-MW9 were each below the detection limit (i.e. non-detect) (Figure 3-1 and Table 3-2).



0 30 60
APPROXIMATE SCALE (FEET)

LEGEND		ABBREVIATIONS	
(symbol)	MONITORING WELL	DRO	DIESEL-RANGE ORGANICS
— 10 —	SURFACE CONTOUR	NM	NOT MEASURED
— 13 —	GROUNDWATER CONTOUR		

NOTES

1. ALL RESULTS ARE IN mg/L (MILLIGRAMS PER LITER).
2. THE CLEANUP LEVEL FOR DRO IN GROUNDWATER IS 1.5 mg/L.
3. VALUES IN **BOLD** TEXT INDICATE RESULT EXCEEDED CLEANUP LEVEL.
4. SAMPLING OCCURRED IN SEPTEMBER 2009.

Figure modified from Jacobs Engineering 2008 MNA Evaluation Report

611 CES
PRIDE IN PROGRESS

SITE MAP INCLUDING DRO RESULTS AND GROUNDWATER CONTOURS

COLD BAY LRRS, ALASKA

CONTRACT NO:	PROJECT NO:	DATE:	SCALE:
GS-10F-0533N	306	2/5/10	APPROX 1" = 60 FEET

FIGURE:

3-1

Table 3-2 September 2009 Groundwater Analytical Results

Analyte	Method	Cleanup[1] Level	Unit	ST05-MW3	ST05-MW5	ST05-MW6	ST05-MW7	ST05-MW8	ST05-MW9	ST05-MW9 Dup
			Sample ID	09ST05MW03-0925-WG	09ST05MW05-0925-WG	09ST05MW06-0926-WG	09ST05MW07-0926-WG	09ST05MW08-0926-WG	09ST05MW09-0926-WG	09ST05MW19-0926-WG
			Lab ID	109529004/ 1095290013	109529001/ 1095290010	109529009/ 1095290018	109529002/ 1095290011	109529003/ 1095290012	109529007/ 1095290016	109529008/ 1095290017
			Collection Date	9/26/2009	9/25/2009	9/26/2009	9/26/2009	9/26/2009	9/26/2009	9/26/2009
			Matrix	GW	GW	GW	GW	GW	GW	GW
DRO	AK 102	1.5	mg/L	1.44	ND [0.941]	**2.34**	ND [0.842]	ND [0.833]	ND [0.800]	ND [0.833]
Alkalinity	SM20 2320B	-	mg/L	144	45.8	166	47.1	73.5	55.4	55.0
Iron, Total	SW6020	-	µg/L	3,810	616	5,340	4,690	1,940	1,830	1,760
Iron, Dissolved	SW6020 Dissolved	-	µg/L	9.67 J	12.9 J	5,690	814	16.6 J	ND [20.0]	ND [20.0]
Manganese, Total	SW6020	-	µg/L	811	56.5	1,160	91.0	65.4	71.2	71.4
Manganese, Dissolved	SW6020 Dissolved	-	µg/L	89.9	9.35	1,260	16.0	3.34	3.34	0.34
Methane	RSK-175	-	µg/L	12	ND [7.2]	ND [7.2]	ND [7.2]	ND [7.2]	ND [7.2]	ND [7.2]
Sulfate	EPA 300.0	-	mg/L	5.67	4.87	4.58	3.14	4.91	3.87	3.85
Sulfide	EPA 376.2	-	mg/L	ND [0.100]	ND [0.100]	ND [0.100]	ND [0.100]	ND [0.100]	ND [0.100]	ND [0.100]
Total Nitrate/Nitrite-N	EPA 353.2	-	mg/L	0.592	0.210	0.105	0.465	0.749	0.984	1.03

Notes:

[1] Cleanup level established by Declaration of Decision (USAF, 2001).

Bolded result indicate a value above the cleanup level.

[ ] = practical quantitation limit (PQL); µg/L = micrograms per liter.

J = Estimated value; result greater than method detection limit, but less than PQL; M = potential matrix interference; GW = groundwater.

For definitions, see the Acronyms and Abbreviations section.

3.3 MONITORED NATURAL ATTENUATION PARAMETERS

Table 3-2 presents laboratory MNA analytical results and Table 3-3 presents field-measured groundwater parameters (pH, conductivity, turbidity, DO, temperature, and ORP) recorded immediately prior to sampling. Section 5.0 presents an analysis of MNA parameters.

Table 3-3
September 2009 Field Parameters

Well ID	Temp. (°C)	pH	Conductivity (mS/cm³)	Turbidity (NTUs)	(% saturation)	DO (calc. mg/L)	ORP (mV)
ST05-MW3	5.12	6.59	0.360	218	51.1	6.9	169.4
ST05-MW5	7.68	6.69	0.169	70.9	80.6	9.8	213.5
ST05-MW6	5.00	6.57	0.394	7.48	24.6	3.2	-96.8
ST05-MW7	4.79	6.45	0.171	333	90.8	11.8	237.6
ST05-MW8	4.98	6.49	0.277	119	85.0	10.9	250.3
ST05-MW9	4.81	6.31	0.189	193	80.7	10.6	258.7

Note:
For definitions, see list of Acronyms and Abbreviations
1 = All wells except ST05-MW5 were bailed, DO readings are therefore erroneously high due to agitation
Conversion of DO from % saturation to mg/L assumes correction factor of 1.00 for sea level.

3.4 DATA QUALITY ASSESSMENT

The following laboratory performed analytical work for this project:

SGS Environmental Services, Inc. (SGS)
200 W. Potter Drive
Anchorage, AK 99518-1605

A full data validation review of the analytical data for this project was performed by:

OASIS Environmental, Inc.
825 W. 8th Ave.
Anchorage, AK 99501

The Quality Assurance Report and ADEC Laboratory Data Review Checklist prepared by OASIS Environmental are presented in Appendix C.

The data validation review performed determined that the overall quality of the September 2009 Cold Bay Site ST05 groundwater water monitoring data is acceptable and usable for the purposes of this project. The QA/QC data indicate that the quality control mechanisms were effective in ensuring measurement data reliability within the expected limits of sampling and analytical error. All project DRO results were qualified "M" to indicate a potential matrix interference as discussed in the Quality Assurance Report. No other qualifiers were assigned. The computed completeness percentage for this project is over 99 percent.

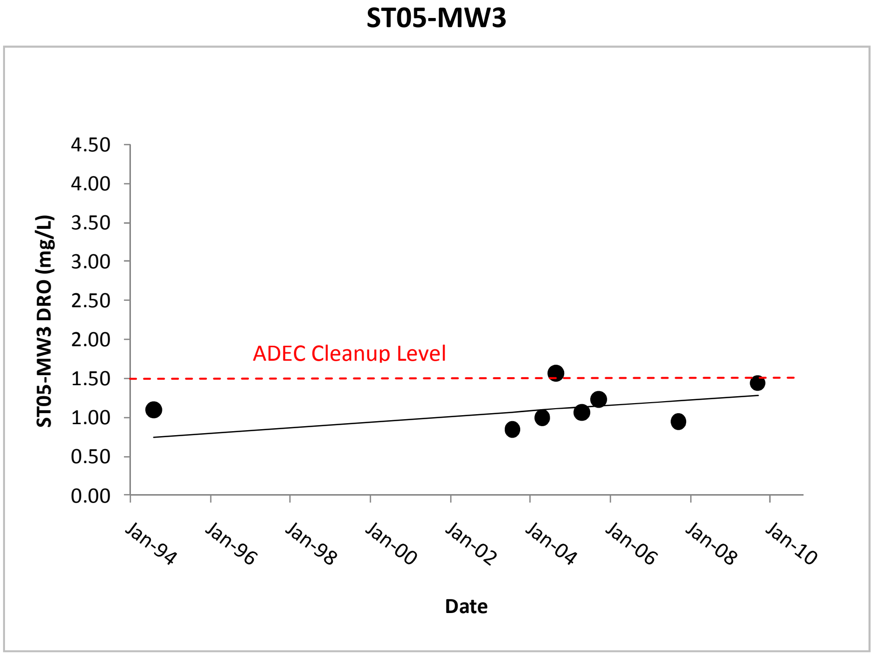
4.0 DIESEL-RANGE ORGANICS TREND ANALYSIS

Statistical analysis of DRO concentrations for Site ST05 wells was performed to evaluate potential concentration trends. Analytical data from 1994 to September 2009 were used in the statistical evaluation. Analytical results from each sampling event are included in Table 1-2. DRO results were analyzed for monotonic trends using the non-parametric, assigned rank, Mann-Kendall statistical analysis and Sen's non-parametric, linear trend, slope estimation method using the Excel MAKESENS template developed by Salmi et al. (2002). The methods require at least four data points for statistical significance at a 90 percent confidence level. Well ST05-MW9 was not analyzed using the Mann-Kendall test because its dataset consists of only two data points. Positive Test S values indicate statistically increasing values with time, and negative values indicate statistically decreasing values with time. The methods are distribution independent and insensitive to outliers and missing data. Non-detect values are treated as ½ the value of the method detection limit (Boyacioglu and Boyacioglu, 2006). The probability that the Mann-Kendall S value represents a valid trend, and is not from a random distribution, is evaluated by looking up the probability using *n* (the number of observations) and the *S value* on the tabulated probability table from Kendall (1975). For the purposes of this report a trend will not be considered valid unless it has a significance level ≤ 0.15, which corresponds to a probability of 85% (i.e. 85% confidence level) or greater that the numbers are not from a random distribution.

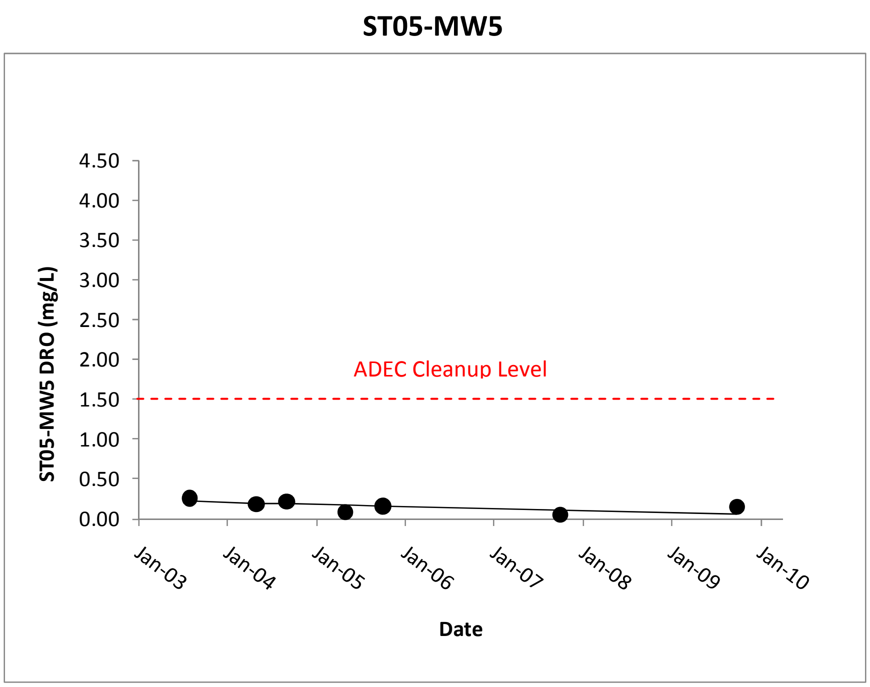
Mann-Kendall analysis indicates decreasing DRO trends are present in the data from ST05-MW5, ST05-MW7 and ST05-MW8 that are statistically significant at a confidence level greater than 85%. The trend at ST05-MW5 is significant and >95% (97%), the trend at ST05-MW8 is statistically significant at >90% (93%), and the trend from ST05-MW7 is significant at >85% (88%). There are no statistically significant trends in the data from ST05-MW3 or ST05-MW6. Scatter plots of DRO concentrations over time for wells ST05-MW3, ST05-MW5, ST05-MW6, ST05-MW7, and ST05-MW8 are shown on Figure 4-1 below. Sen's slope estimations are included as solid black lines on each plot. Red dashed lines represent RAO of 1.5 mg/L DRO.

As shown on the graphs below, each of the wells with the exception of well ST05-MW3 have decreasing trends according to Sen's slope estimations (solid black lines). It should be noted, however, that DRO concentrations for wells ST05-MW5, ST05-MW7, and ST05-MW8 had non-detect results for the September 2008 sampling round. The plotted data points for these wells are only estimates, and may range between zero and twice the plotted values (i.e. one-half detection limit plotted).

Figure 4-1 Site ST05 Groundwater Monitoring DRO Concentration Trends



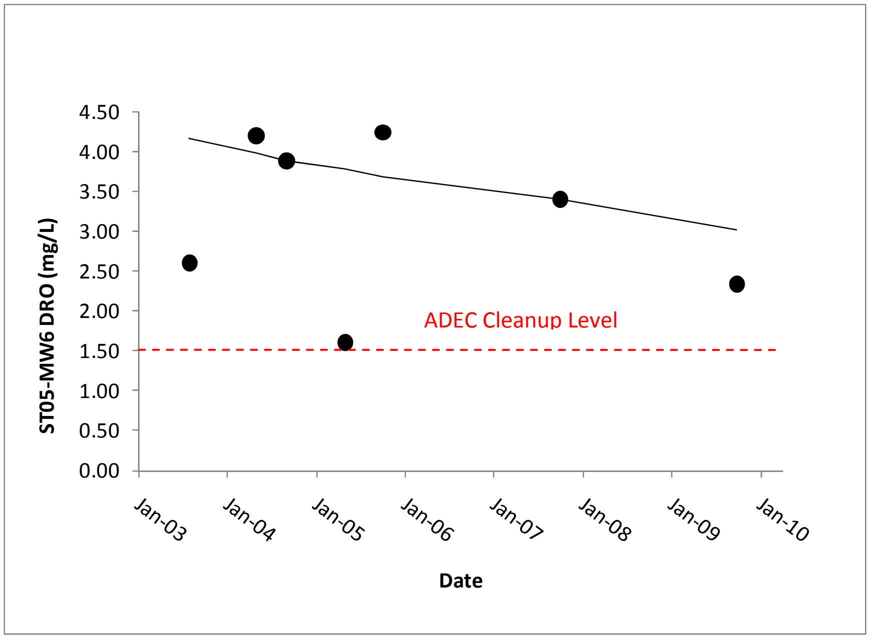
n=8, S=+6, confidence level=73%



n=7, S=-13, confidence level=97%

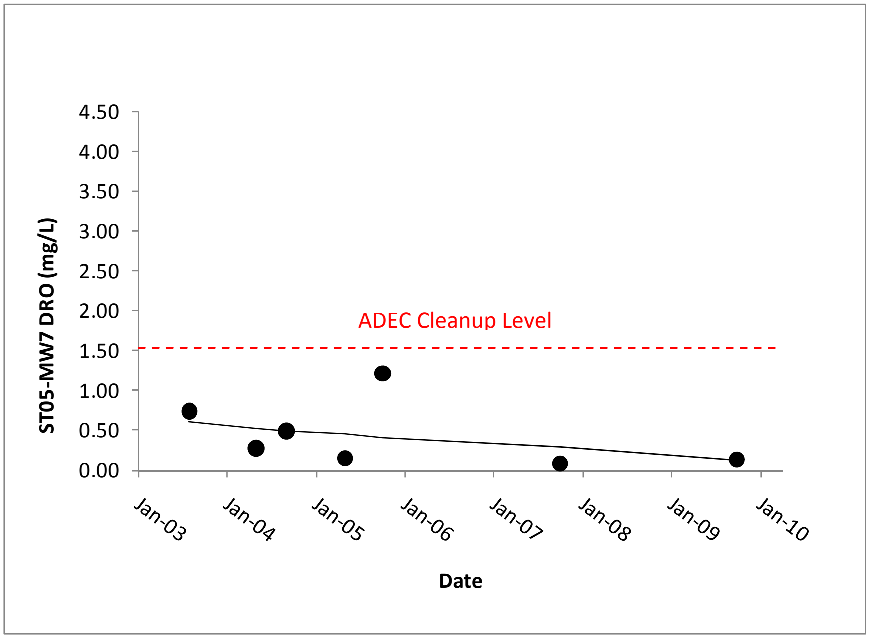
Figure 4-1 Site ST05 Groundwater Monitoring DRO Concentration Trends (continued)

ST05-MW6



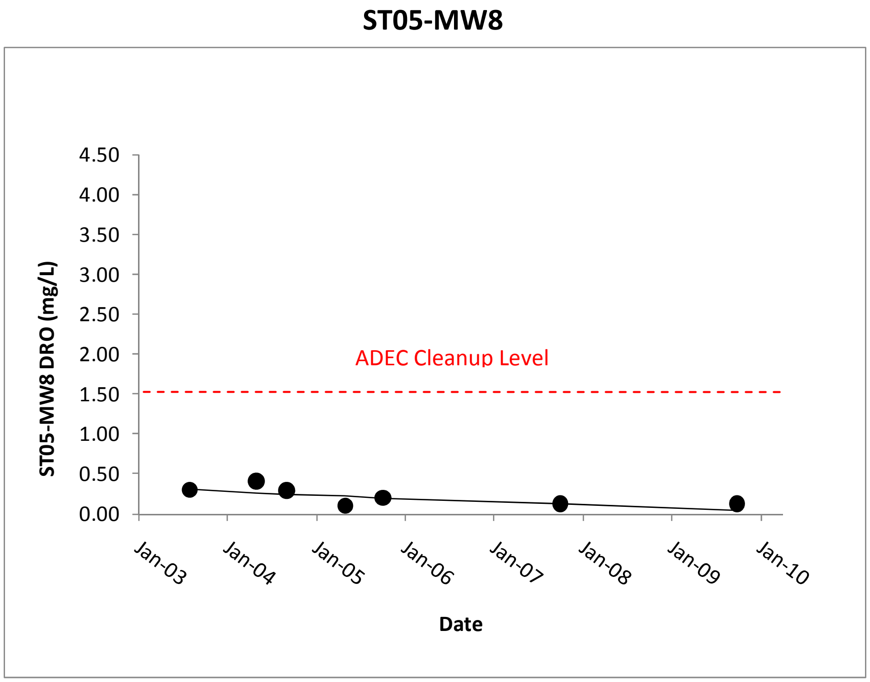
n=7, S=-3, confidence level=61%

ST05-MW7



n=7, S=-9, confidence level=88%

Figure 4-1 Site ST05 Groundwater Monitoring DRO Concentration Trends (continued)



n=7, S=-11, confidence level=93%

5.0 EVALUATION OF MONITORED NATURAL ATTENUATION PARAMETERS

Biological activity can be assessed by comparing concentrations of potential electron acceptors (groundwater geochemical parameters) both upgradient and downgradient of the areas of known contamination (Wiedemeier et al., 1999). Geochemical indicators of intrinsic (natural) biodegradation can be categorized as:

- Indicators used to estimate biological activity, such as DO, nitrate, manganese, sulfate, sulfide, and iron;

- Indicators used to determine whether conditions are favorable for biological activity, such as alkalinity, temperature, pH, and ORP; and

- Indicators used to evaluate whether the sampling locations are within the same hydrogeologic unit, such as conductivity.

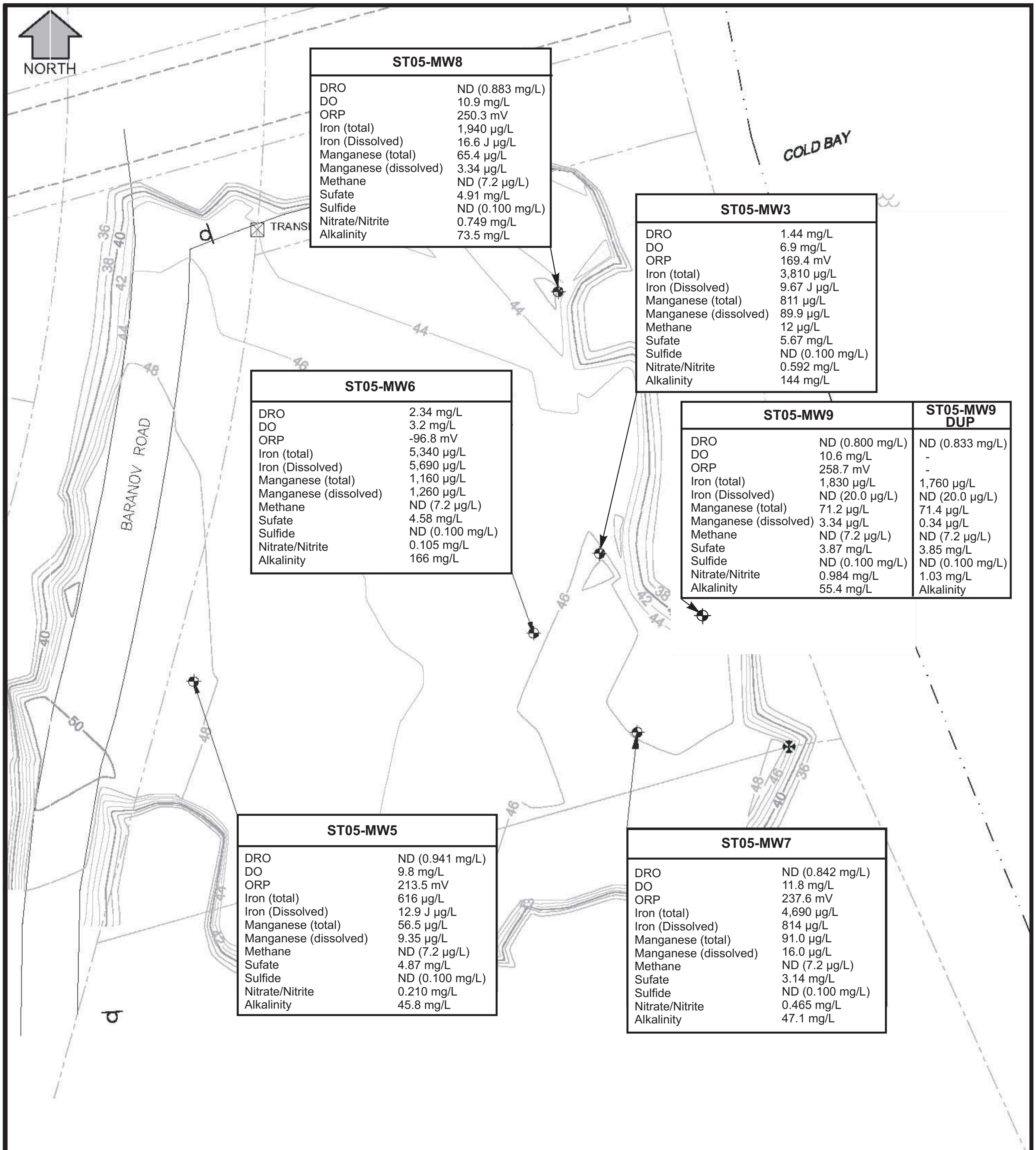
After the available DO is depleted and anaerobic conditions dominate the interior regions of the hydrocarbon plume, facultative or obligate anaerobic microorganisms utilize other electron acceptors in the following order of preference: nitrate, manganese-IV, iron-III, sulfate, and carbon dioxide. As each electron acceptor becomes depleted, the next most preferable electron acceptor may be utilized. Each successive electron acceptor provides less energy to the microorganisms. Disequilibrium is common and a steady influx of DO and nutrients may allow several pathways to operate simultaneously.

Concentrations of DO, nitrate, manganese iron, sulfate, sulfide and methane measured at the six wells at ST05 during the September 2009 monitoring event were used to evaluate the processes associated with intrinsic biodegradation. Well ST05-MW5, the most upgradient at the site, and peripheral wells ST05-MW7 and ST05-MW8 are each considered reflective of background concentrations for the purposes of this evaluation. Wells ST05-MW6 and ST05-MW3 are within the fuel plume, and well ST05-MW9 is downgradient of the soil removal excavation. Tables 3-2 and 3-3, and Figure 5-1 present laboratory and field MNA parameter results.

5.1 DISSOLVED OXYGEN

DO, the most thermodynamically favored electron acceptor, is typically the key factor affecting natural biodegradation of hydrocarbons in the saturated zone. Mineralization (oxidation to carbon dioxide and water) of fuel hydrocarbons by aerobic respiration (i.e., DO) is represented by the following stoichiometric equation (Wiedemeier et al., 1999):

$$7.5\ O_2 + C_6H_6 \rightarrow 6\ CO_2 + 3\ H_2O$$



ST05-MW8	
DRO	ND (0.883 mg/L)
DO	10.9 mg/L
ORP	250.3 mV
Iron (total)	1,940 µg/L
Iron (Dissolved)	16.6 J µg/L
Manganese (total)	65.4 µg/L
Manganese (dissolved)	3.34 µg/L
Methane	ND (7.2 µg/L)
Sufate	4.91 mg/L
Sulfide	ND (0.100 mg/L)
Nitrate/Nitrite	0.749 mg/L
Alkalinity	73.5 mg/L

ST05-MW3	
DRO	1.44 mg/L
DO	6.9 mg/L
ORP	169.4 mV
Iron (total)	3,810 µg/L
Iron (Dissolved)	9.67 J µg/L
Manganese (total)	811 µg/L
Manganese (dissolved)	89.9 µg/L
Methane	12 µg/L
Sufate	5.67 mg/L
Sulfide	ND (0.100 mg/L)
Nitrate/Nitrite	0.592 mg/L
Alkalinity	144 mg/L

ST05-MW6	
DRO	2.34 mg/L
DO	3.2 mg/L
ORP	-96.8 mV
Iron (total)	5,340 µg/L
Iron (Dissolved)	5,690 µg/L
Manganese (total)	1,160 µg/L
Manganese (dissolved)	1,260 µg/L
Methane	ND (7.2 µg/L)
Sufate	4.58 mg/L
Sulfide	ND (0.100 mg/L)
Nitrate/Nitrite	0.105 mg/L
Alkalinity	166 mg/L

	ST05-MW9	ST05-MW9 DUP
DRO	ND (0.800 mg/L)	ND (0.833 mg/L)
DO	10.6 mg/L	-
ORP	258.7 mV	-
Iron (total)	1,830 µg/L	1,760 µg/L
Iron (Dissolved)	ND (20.0 µg/L)	ND (20.0 µg/L)
Manganese (total)	71.2 µg/L	71.4 µg/L
Manganese (dissolved)	3.34 µg/L	0.34 µg/L
Methane	ND (7.2 µg/L)	ND (7.2 µg/L)
Sufate	3.87 mg/L	3.85 mg/L
Sulfide	ND (0.100 mg/L)	ND (0.100 mg/L)
Nitrate/Nitrite	0.984 mg/L	1.03 mg/L
Alkalinity	55.4 mg/L	Alkalinity

ST05-MW5	
DRO	ND (0.941 mg/L)
DO	9.8 mg/L
ORP	213.5 mV
Iron (total)	616 µg/L
Iron (Dissolved)	12.9 J µg/L
Manganese (total)	56.5 µg/L
Manganese (dissolved)	9.35 µg/L
Methane	ND (7.2 µg/L)
Sufate	4.87 mg/L
Sulfide	ND (0.100 mg/L)
Nitrate/Nitrite	0.210 mg/L
Alkalinity	45.8 mg/L

ST05-MW7	
DRO	ND (0.842 mg/L)
DO	11.8 mg/L
ORP	237.6 mV
Iron (total)	4,690 µg/L
Iron (Dissolved)	814 µg/L
Manganese (total)	91.0 µg/L
Manganese (dissolved)	16.0 µg/L
Methane	ND (7.2 µg/L)
Sufate	3.14 mg/L
Sulfide	ND (0.100 mg/L)
Nitrate/Nitrite	0.465 mg/L
Alkalinity	47.1 mg/L

LEGEND

- SUREVY MARKER-
- UNDERGROUND CABLE MARKER
- MONITORING WELL
- —10— SURFACE CONTOUR

ABBREVIATIONS

DO	DISSOLVED OXYGEN
DUP	DUPLICATE
J	RESULT IS AN ESTIMATED VALUES; ANALYTE WAS POSITIVELY IDENTIFIED BUT WAS LESS THAN PRACTICAL QUANTITATION LIMIT BUT GRATER THAN OR EQUAL TO THE METHOD DETECTION LIMIT
µg/L	MICROGRAMS PER LITER
mg/L	MILLIGRAMS PER LITER
mV	MILLIVOLTS
ND	NOT DETECTED; PRACTICAL QUANTITATION LIMITS PROVIDED IN PARENTHESES

0 30 60 120

SCALE IN FEET

Figure modified from Jacobs Engineering 2008 MNA Evaluation Report

SEPTEMBER 2009 MNA ANALYTICAL RESULTS AND SELECT PARAMETERS

COLD BAY LRRS, ALASKA

CONTRACT NO:	PROJECT NO:	DATE:	SCALE:	FIGURE:
GS-10F-0533N	306	2/5/10	APPROX 1" = 60 FEET	5-1

During the September 2009 monitoring event, DO measurements were taken from bailed groundwater emptied into an open container, rather than from a sealed flow-through cell (except for ST05-MW5), therefore DO values are biased high due to agitation. For this reason DO cannot be rigorously assessed as a potential electron acceptor for the September 2009 sampling event. Nevertheless it is noteworthy that the two in-plume wells with elevated DRO concentrations, ST05-MW6 and ST05-MW3, also have DO concentrations that are roughly one half that of upgradient and peripheral wells with no detectable DRO (Figure 5-1), including ST05-MW5 which was the only well to have DO measured with a flow-through cell via low-flow purge technique (i.e. not biased high). This observation is consistent with oxygen being consumed within the plume by aerobic respiration, and suggests MNA is ongoing at the site.

5.2 NITRATE AND NITRITE

After DO is depleted and anaerobic conditions are established, nitrate is the most thermodynamically favored electron acceptor for biodegradation of fuel hydrocarbons. Nitrate respiration, also called dissimilatory nitrate reduction, converts nitrate to nitrogen gas as fuel hydrocarbons are mineralized. The mineralization of fuel hydrocarbons by nitrate respiration is represented by the following stoichiometric equation:

$$6\ NO_3^- + C_6H_6 + 6\ H^+ \rightarrow\ 6\ CO_2 + 6\ H_2O + 3\ N_2$$

Groundwater samples collected at Site ST05 had total nitrate/nitrite concentrations that ranged from 0.105 mg/L to 1.03 mg/L. Nitrate reduction does not appear to be a significant pathway for biodegradation at the site, based on low levels for nitrate and nitrite available as nutrient at the site. The nitrate/nitrite concentration at the well with the highest DRO concentration (ST05-MW6) is depleted relative to the other wells suggesting that the available nitrate/nitrite is being consumed within the contamination zone and MNA is ongoing.

5.3 MANGANESE

Manganese is a redox-sensitive metal occurring naturally as the oxidized manganese IV (Mn^{4+}) and the reduced manganese II (Mn^{2+}). In an aerobic aquifer, manganese will be oxidized and present as a solid oxide (MnO_2). In a biologically active anaerobic aquifer, however, manganese may be reduced to Mn^{2+}, which is soluble. In the absence of DO and nitrate, manganese IV can serve as an electron acceptor during biodegradation. Thus, increased manganese II may reflect manganese IV reduction during microbial degradation of fuel hydrocarbons. The process of fuel oxidation through manganese reduction is represented by the following stoichiometric equation (Wiedemeier et al., 1999):

$$30H^+ + 15MnO_2 + C_6H_6 \rightarrow CO_2 + 15Mn_2^+ + 18H_2O$$

Manganese II concentrations varied across the site with the most notable concentrations detected at wells ST05-MW6 and ST05-MW3, which correspond to the highest DRO concentrations detected across the site. At the well with the highest DRO concentration (ST05-MW6), all of the manganese is present in the dissolved form, suggesting that all available manganese IV has been reduced. Reduced manganese II concentrations are highest in wells that historically have low DO concentrations, suggesting that biodegradation of hydrocarbons via manganese reduction is occurring across the site.

5.4 IRON

Like manganese, iron is a redox-sensitive metal. It occurs naturally as the oxidized ferric iron (iron-III, Fe^{3+}) and the reduced ferrous iron (iron-II, Fe^{2+}). In an aerobic aquifer, iron will be oxidized and present as a solid oxyhydroxide (represented as $Fe(OH)_3$). In a biologically active anaerobic aquifer, however, iron may be reduced to Fe^{2+}, which is soluble. After DO and nitrate are consumed, and often in parallel with manganese reduction, ferric iron can serve as an electron acceptor during biodegradation. Therefore, higher ferrous iron concentrations may reflect anaerobic biodegradation. The mineralization of fuel hydrocarbons by iron reduction is represented by the following stoichiometric equation (Wiedemeier et al., 1999):

$$30\ Fe(OH)_3 + C_6H_6 + 60\ H^+ \rightarrow 6\ CO_2 + 30\ Fe_2^+ + 78\ H_2O$$

Sample results for total iron at Site ST05 ranged from 616 to 5,340 micrograms per liter (µg/L). The high concentration of dissolved iron at well ST05-MW6, and that fact that all of the iron is present in the dissolved state, is consistent with the chelation and reduction of ferric iron within the contaminated zone and the use of ferric iron as a terminal electron acceptor during the anaerobic degradation of hydrocarbons.

5.5 SULFATE AND SULFIDE

Sulfate-reducing bacteria use sulfate for anaerobic biodegradation of fuel contamination after the oxygen, nitrate, and manganese IV have been consumed in the groundwater system. The sulfate is reduced to sulfide, and the reduction in sulfate concentration or increase in sulfide concentration can be used as an indicator of anaerobic degradation of fuel hydrocarbons. The mineralization of fuel hydrocarbons by sulfate reduction is represented by the following stoichiometric equation (Wiedemeier et al., 1999):

$$7.5\ H^+ + 3.75\ SO_4^{2-} + C_6H_6 \rightarrow 6\ CO_2 + 3.75\ H_2S + 3\ H_2O$$

The sulfate concentrations measured at Site ST05 were relatively comparable from well to well, with concentrations ranging from 3.14 mg/L to 5.67 mg/L. Sulfide was not detected in any of the site wells during the September 2009 monitoring event. These data are not consistent with the consumption of sulfate in the biodegradation of hydrocarbons.

5.6 METHANOGENESIS

Methanogenesis is an indicator of anaerobic, strongly reducing conditions, indicating that the preceding inorganic electron acceptors may have been consumed or absent, but is not a rapid pathway for natural biodegradation of most fuel hydrocarbons (Wiedemeier et al., 1999). Under such conditions, most methane is formed by reduction of carbon dioxide. Saturated aliphatic hydrocarbons can be hydrogenated to form methane, but such a metabolic pathway offers little free energy and is of negligible importance. Unsaturated and aromatic hydrocarbons offer slightly more free energy, but such compounds are generally only minor constituents of fuel hydrocarbons. Methane was detected only in ST05-MW3 at a concentration of 12 μg/L, indicating that little if any methanogenesis may be occurring at the site. Methane was not detected in the remaining site wells, including the most DRO-contaminated well (ST05-MW6).

5.7 ORP

ORP, determined in the field relative to a silver/silver chloride reference electrode, is a measure of the ability of groundwater to oxidize contaminants or other species of interest. ORP values greater than 0 millivolts (mV) typically correspond to aerobic conditions, and increasingly negative values correlate with nitrate respiration, manganese and iron reduction, sulfate reduction, and finally methanogenesis at ORP values near –600 mV. The ORP value provides a rough indicator of potentially active pathways for biodegradation, but disequilibrium is common, with the potential of the ORP electrode determined by aqueous species other than those important for biodegradation. ORP is distinct from the redox potential (Eh), which is measured relative to a cumbersome hydrogen electrode and is typically approximately 230 mV less.

The moderately negative ORP at ST05-MW6 (-96.8 mV) is consistent with the elevated dissolved manganese, and iron concentrations observed in the well, indicating that active biodegradation is occurring and is dominated by these pathways. At ST05-MW3, the well with the second highest DRO concentration, the moderately positive ORP (169.4 mV) suggests that the oxygen reduction, denitrification, and manganese reduction pathways are dominant.

5.8 ALKALINITY

Alkalinity in groundwater is a measure of the water's capacity to neutralize acid. Alkalinity is important in the maintenance of groundwater pH because it buffers the groundwater system against acids generated through both aerobic and anaerobic biodegradation processes. In general, areas contaminated by fuel hydrocarbons exhibit a total alkalinity that is higher than that seen in background areas. This is expected because the microbially mediated reactions causing biodegradation of fuel hydrocarbons cause an increase in total alkalinity in the system.

The highest alkalinity concentrations were measured at ST05-MW6 and ST05-MW3, the in-plume wells. Alkalinity concentrations (expressed as calcium carbonate) at these two wells were 144 and 166 mg/L, respectively, and are two to three times higher than the background wells. This observation suggests that microbial activity within the plume has lead to an increase in alkalinity relative to the un-impacted areas and that MNA is occurring.

5.9 TEMPERATURE

Groundwater temperature directly affects the solubility of oxygen and the metabolic activity of bacteria. DO is more soluble in colder water temperatures; however, groundwater temperatures below 5 degrees Celsius (°C) typically inhibit biodegradation rates, with biodegradation typically doubling for every 10° C increase in water temperature. However, the degradation rates seen in several MNA studies conducted in Alaska have proven that

MNA is viable in cold groundwater (AFCEE, 1999). Groundwater temperatures at the ST05 site are not significantly influenced by surface climatic conditions. Table 5-1 presents groundwater temperatures for each well for all previous monitoring events. Average groundwater temperatures at the Site ST05 are just above 5° C.

Table 5-1
Groundwater Temperature

Well ID	Groundwater Temperature (°C)							
	Aug-03	May-04	Sep-04	May-05	Oct-05	Oct-07	Sep-09	Average by Well
ST05-MW3	6.3	6.35	6.33	6.07	5.8	5.41	5.12	5.9
ST05-MW5	6.3	4.89	5.26	5.07	4.85	4.71	7.68	5.5
ST05-MW6	7	6.31	6.8	5.75	5.39	4.67	5.00	5.8
ST05-MW7	6.8	4.96	5.19	5.01	5.06	4.66	4.79	5.2
ST05-MW8	5.7	5.62	5.68	5.22	4.97	4.8	4.98	5.3
ST05-MW9	-	-	-	-	-	-	4.81	4.8
Average by Date	6.4	5.6	5.9	5.4	5.2	4.9	5.4	--

5.10 PH

Groundwater pH is an environmental indicator that affects the presence and activity of microbial populations. Bacteria capable of degrading petroleum hydrocarbons typically prefer pH values between 6 and 8. The pH measurements taken during the 2009 monitoring event at the ST05 site are within this range (Table 3-3) and average 6.5.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Long term groundwater monitoring was conducted at Site ST05 in September 2009. Monitoring included collecting groundwater elevation data, groundwater samples for DRO and MNA analyses, and MNA data from a direct read instrument in each of the six wells. DRO results were non-detect for four wells, DRO was detected at a concentrations below the cleanup level in one well, and exceeded the groundwater cleanup level of 1.5 mg/L in one well. Results from well ST05-MW6 exceeded the DRO cleanup level with a concentration of 2.34 mg/L. DRO was detected at 1.44 mg/L in the sample from ST05-MW3, with the DRO concentration remaining below the cleanup level for the fourth consecutive sampling event. Mann-Kendall analysis indicates trends of decreasing DRO concentration over time at ST05-MW5, ST05-MW7, and ST05-MW8 that are statically significant at the greater than 85% confidence level.

Evaluation of the MNA data indicates that natural attenuation is occurring within the fuel plume as supported by lower (and negative) OPR, lower DO, lower nitrate/nitrite, higher dissolved iron and manganese, and higher alkalinity at in-plume well ST05-MW6 relative to other wells.

As precipitation percolates through the contaminated soil, DRO dissolves in water and migrates downward to the shallow, unconfined aquifer. Because of relatively high DRO concentrations in the overlying soils (up to 9,720 mg/kg in excavation floor samples), this mechanism is expected to continue to contribute to groundwater contamination for the foreseeable future. However, the saturation concentration for diesel fuel in water is relatively low (approximately between 1 and 5 mg/L), and biodegradation remains an effective treatment mechanism. Thus, as seen at other old fuel spill sites, the probability for off-site migration of the contamination is minimal as demonstrated by non-detect concentrations of DRO in downgradient wells.

The DD for the Site ST05 (USAF, 2001) states that groundwater shall be monitored until DRO concentrations are no greater than 1.5 mg/L throughout the aquifer. DRO has not been detected in groundwater obtained from ST05-MW5, ST05-MW7, or ST05-MW8, in excess of the cleanup level, in any of the six monitoring events performed since August 2003. DRO has been detected on one of the two sampling events since installation of well ST05-MW9, but at a concentration less than the laboratory PQL. Since 2000, monitoring activities have been conducted at a frequency ranging from semiannually to biannually. ADEC has approved reducing the frequency to once every five years for future long term monitoring (ADEC, 2008). Therefore, the next sampling event should take place in 2014.

6.2 RECOMMENDATIONS

Data for the site indicates that groundwater concentrations are decreasing in five of the six wells monitored (although only three are statically significant). Currently, there is no exposure to groundwater contamination at the site and a Record of Survey has been filed with the Department of Natural Resources Recorder's Office to prevent future human health exposure. Therefore, adequate groundwater monitoring can be conducted at an interval of once every five years.

The casings for wells ST05-MW3 and ST05-MW8 have frost-jacked and were observed higher than their respective monuments. These casings (and others) should be trimmed to allow for securing of the monument covers. After trimming, each well's top of casing elevation should be resurveyed during the next sampling event. At a minimum, a closed-loop survey should be conducted to obtain current and accurate top of casing elevations for site wells already surveyed, and to tie in newly installed well ST05-MW9. In order to accurately reference this well relative to the other site wells, obtaining swing-tie measurements between ST05-MW9 and adjacent wells is also recommended.

Wells ST05-MW3, ST05-MW8, and ST05-MW9 cannot be secured with locks due to frost-jacking and/or damaged monuments. Repairing these wells would minimize the potential for contaminant entering the site's groundwater via the monitoring wells. Repairs should be made relatively soon rather than waiting for the next monitoring event which will not occur for another five years.

7.0 REFERENCES

ADEC (Alaska Department of Environmental Conservation). 2006 (December). *Oil and Hazardous Pollution Control Regulations*. 18 AAC 75.

ADEC. 2008 (1 July). Letter from ADEC to USAF Re: *Cold Bay Long-Range Radar Site, ST05 Monitored Natural Attenuation Evaluation Report, Draft June 2008*.

AFCEE (Air Force Center for Engineering and the Environment). 1999 (October). *Natural Attenuation of Fuel Hydrocarbons Performance and Cost Results from Multiple AF Demonstrations*. Prepared by Parsons.

AFCEE. 2001 (12 January). *Declaration of Decision POL Storage Area ST05, Cold Bay, Alaska*.

AFCEE. 2006 (May). *Quality Assurance Project Plan (QAPP),* Final Version 4.0.02.

AFCEE 2006 (July) *Guidance for Contract Deliverables, Quality Assurance Project Plan, Version 4.0.02*.

Boyaciogly, H and Boyaciogly, H, 2006. *Water quality evaluation and trend analysis in Buyuk Menderes Basin, Turkey*, JFS, Vol. 29 (2006), pp 8-17.

BNCI (BNC International, Inc.) 2009 (September). *Letter Work Plan Alaska Long-Term Monitoring & Ground Water Sampling - Cold Bay LRRS, Cold Bay, Alaska.*

BNCI. 2009 (September). *Final Site Health and Safety Plan for Alaska Long-Term Monitoring and Ground Water Sampling - Cold Bay LRRS, Cold Bay, Alaska*.

Jacobs Engineering Group. 2008 (30 October). Technical Memorandum Subject: Cold Bay Monitoring Well ST05-MW9.

Kendall, M. 1975. *Multivariate Analysis*. Charles Griffin & Company, London.

Salmi, T., Määttä, A., Anttila, P., Ruoho-Airola, T., and Amnell, T. 2002. *Detecting Trends of Annual Values of Atmospheric Pollutants by the Mann-Kendall Test and Sen's Slope Estimates - The Excel Template Application MAKESENS.* Publications on Air Quality No. 31, Report code FMI-AQ-31FIN-00101. August 2002.

USAF (U.S. Air Force). 2001 (January). *Declaration of Decision POL Storage Area ST05, Cold Bay, Alaska*.

USAF. 2002 (October). *Final Environmental Cleanup Plan, Cold Bay Long-Range Radar Site.*

USAF. 2008 (July). *ST05 Monitored Natural Attenuation Evaluation Report, Cold Bay Long-Range Radar Site, Cold Bay, Alaska.* Prepared for USAF by Jacobs Engineering Group.

US Environmental Protection Agency (EPA). 2004 (October). *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (EPA 540/R-04/004).

US EPA. 2008 (June). *Contract Laboratory Program National Functional Guidelines for Organic Data Review* (EPA 540/R-08/001).

Wiedemeier, T. H., D. C. Downey, J. T. Wilson, D. H. Kampbell, R. N. Miller, and J. E. Hansen. 1999. *Technical Protocol for Implementing Intrinsic Remediation with long-Term Monitoring for Natural Attenuation of Fuel Contamination Dissolved in Groundwater*. Prepared for AFCEE.

Willey, L. M., Y. K. Kharaka, T. S. Presser, J. B. Rapp, Ivan Barnes. 1975. "Short Chain Aliphatic Acid Anions in Oil Field Waters and Their Contributions to the Measured Alkalinity." *Geochimica et Cosmochimicia Acta*. Vol. 39, pp. 1707-1711.