KIRTLAND AIR FORCE BASE
ALBUQUERQUE, NEW MEXICO

QUARTERLY MONITORING REPORT – OCTOBER-DECEMBER 2018 AND ANNUAL REPORT FOR 2018 BULK FUELS FACILITY SOLID WASTE MANAGEMENT UNIT ST-106/SS-111 KIRTLAND AIR FORCE BASE, NEW MEXICO

March 2019

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Quarterly Monitoring Report – October-December 2018
and Annual Report for 2018
Bulk Fuels Facility
Solid Waste Management Unit ST-106/SS-111
Kirtland Air Force Base, New Mexico

March 2019

Prepared for
U.S. Army Corps of Engineers
Albuquerque District
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NOTICE

This report was prepared for the U.S. Army Corps of Engineers by EA Engineering, Science, and Technology, Inc., PBC for the purpose of documenting the progress of an Interim Action being implemented by the U.S. Air Force Environmental Restoration Program (ERP) at Kirtland Air Force Base. As the report relates to actual or possible releases of potentially hazardous substances, its release prior to a final decision on remedial action may be in the public's interest. The limited objectives of this report and the ongoing nature of the ERP, along with the evolving knowledge of site conditions and chemical effects on the environment and health, must be considered when evaluating this report, since subsequent facts may become known that may make this report premature or inaccurate.

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14. ABSTRACT

This Quarterly and Annual Report describes activities performed from October 1 through December 31, 2018 and the annual progress of the Resource Conservation and Recovery Act interim measures for soil and groundwater remediation at Solid Waste Management Unit ST-106/SS-111, the Bulk Fuels Facility site, at Kirtland Air Force Base, New Mexico. During the quarter, soil vapor, groundwater, drinking water from supply wells, and the groundwater treatment system (GWTS) samples were collected and analyzed for contaminants of concern (notably ethylene dibromide [EDB]) and other relevant field and laboratory parameters. The GWTS extracted and treated 47,135,900 gallons of groundwater through a granular activated carbon filtration system and discharged the treated effluent to the Tijeras Arroyo Golf Course main pond and injection well KAFB-7 in the fourth quarter (Q4) 2018. The GWTS was operational 93 percent (%) of the time and removed approximately 5,064 milligrams of EDB in Q4 2018. The Q4 2018 performance assessment of horizontal capture within the Target Capture Zone shows the GWTS has hydraulically captured (horizontally) 100% of the dissolved-phase EDB volume and mass. The performance assessment of vertical capture within the Target Capture Zone shows that the GWTS is less effective at producing vertical plume containment. The GWTS has captured (vertically) 99% of the dissolved-phase EDB volume and 99% of the mass. Dissolved-phase EDB volume and mass have decreased in the Target Capture Zone in 2018. Review of these regional hydraulic data have shown a shift in groundwater flow direction from north-northeast (toward the Water Authority Ridgecrest Wellfield and the historical dissolved-phase EDB migration direction) toward the east and southeast (toward Kirtland Air Force Base and the production wells on-Base).

15. SUBJECT TERMS

Bulk Fuels Facility, Solid Waste Management Unit ST-106/SS-111, ethylene dibromide, EDB, Interim Measures, RCRA, soil vapor, groundwater sampling, groundwater treatment system operation, granular activated carbon, ethylene dibromide, vertical capture, horizontal capture, dissolved-phase mass, performance assessment, numerical modeling, FEFLOW

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KIRTLAND AIR FORCE BASE
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PREFACE

This Quarterly Monitoring Report – October-December 2018 and Annual Report for 2018 has been prepared by EA Engineering, Science, and Technology, Inc., PBC (EA) for the U.S. Army Corps of Engineers, under Contract Number W912DR-12-D-0006, Delivery Order DM01 and pertains to the Base Bulk Fuels Facility, Solid Waste Management Unit ST-106/SS 111, located in Albuquerque, New Mexico.

This report contains data collected by EA itself as well as from other entities/sources that are not under EA's direct control (collectively "non-EA Data"). All non-EA data reported herein are displayed in the form they were received from its source entity, and EA assumes no liability for the accuracy of any non-EA data in this report.

This report was prepared in accordance with applicable federal, state, and local laws and regulations, including the New Mexico Hazardous Waste Act, New Mexico Statutes Annotated 1978, New Mexico Hazardous Waste Management Regulations, Resource Conservation and Recovery Act, and regulatory correspondence between the New Mexico Environment Department Hazardous Waste Bureau and the U.S. Air Force, dated March 25 and May 20, 2016.

Monitoring of soil vapor, groundwater, and drinking water, and operation of the groundwater treatment system were conducted from October 1 through December 31, 2018. Mr. Behnaum Moayyad, PE, is the U.S. Army Corps of Engineers–Albuquerque District Project Manager. The Environmental Restoration Section Chief for this program is Mr. Scott Clark of Kirtland Air Force Base. Ms. Devon Jercinovic is the EA Project Manager.

Devon Jercinovic, PG, CPG, PMP
Project Manager
EA Engineering, Science, and Technology, Inc., PBC

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LIST OF ACRONYMS AND ABBREVIATIONS

$\mu g/m^3$	microgram(s) per cubic meter
µg/L	microgram(s) per liter
µS/cm	microSiemens per centimeter
%	percent
AFB	Air Force Base
AOI	area of interest
BFF	Bulk Fuels Facility
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and total xylenes
CFR	Code of Federal Regulations
CMI	Corrective Measures Implementation
CO_2	carbon dioxide
DO	dissolved oxygen
DP	discharge permit
EA	EA Engineering, Science, and Technology, Inc., PBC
EDB	ethylene dibromide
EFF	effluent
EPA	U.S. Environmental Protection Agency
ERP	Environmental Restoration Program
ft	foot (feet)
GAC	granular activated carbon
GCMP	Golf Course main pond
gpm	gallon(s) per minute
GWM	groundwater monitoring
GWTS	groundwater treatment system
HC	hydrocarbon
ID	identification
IDW	investigation-derived waste
INF	influent
Kh	hydraulic conductivity
LNAPL	light non-aqueous phase liquid
MCL	maximum contaminant level
mg	milligram(s)
mg/L	milligram(s) per liter

LIST OF ACRONYMS AND ABBREVIATIONS (CONCLUDED)

NMED	New Mexico Environment Department
NMWQCC	New Mexico Water Quality Control Commission
No.	number
O_2	oxygen
ORP	oxidation reduction potential
ppmv	part per million by volume
psi	pound(s) per square inch
PSL	project screening level
Q1	first quarter of the year, January 1 through March 31
Q2	second quarter of the year, April 1 through June 30
Q3	third quarter of the year, July 1 through September 30
Q4	fourth quarter of the year, October 1 through December 31
RCRA	Resource Conservation and Recovery Act
REI	reference elevation interval
RFI	Resource Conservation and Recovery Act Facility Investigation
SE	Southeast
SM	Standard Method
SVE	soil vapor extraction
SVM	soil vapor monitoring
SVMP	soil vapor monitoring point
SWMU	Solid Waste Management Unit
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VA	Veterans Affairs
VANI	vertical anisotropy
VOC	volatile organic compound

EXECUTIVE SUMMARY

The investigation and remediation of the Kirtland Air Force Base (AFB) Bulk Fuels Facility (BFF) leak (Solid Waste Management Units [SWMUs] ST-106/SS 111) are being implemented pursuant to the Resource Conservation and Recovery Act (RCRA) corrective action provisions in Part 6 of Kirtland AFB's Hazardous Waste Treatment Facility Operating Permit (Permit Number NM9570024423 –"RCRA Permit) (New Mexico Environment Department [NMED], 2010). This Quarterly Report for the fourth quarter (Q4) of calendar year 2018 and Annual Report for 2018 summarizes the activities performed from October 1 through December 31, 2018 and annual summaries of activities during 2018. These activities are part of ongoing monitoring for the Phase RCRA Facility Investigation (RFI) and to support the evaluation of the dissolved-phase ethylene dibromide (EDB) groundwater pump and treat interim measure and the EDB *in situ* biodegradation pilot study.

This Executive Summary describes the following Q4 2018 soil vapor monitoring (SVM), groundwater monitoring (GWM), and interim measure and pilot activities performed at the BFF between October and December 2018 and summarizes all activities conducted during 2018:

- Coring and soil sampling completed at eight of 11 locations in the vadose zone for biogeochemical conditions of subsurface soil impacted by residual light non-aqueous phase liquids (LNAPL)

- Installation of five of nine planned nested groundwater monitoring wells in the cored boreholes, each consisting of a water table well and a shallower contingency well (above the current groundwater elevation)

- Sampling the soil vapor monitoring points (SVMPs)

- Sampling the Q4 2018 designated wells in the GWM network

- Sampling the drinking water supply wells located in the vicinity of the plume containing dissolved-phase benzene (south of Ridgecrest Drive Southeast [SE]) and dissolved-phase EDB

- Operation and maintenance of the groundwater treatment system (GWTS) for groundwater extracted from the dissolved-phase EDB located in the distal portion of the plume (Target Capture Zone)

- GWTS performance assessment using the U.S. Environmental Protection Agency (EPA) Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems (EPA, 2008) and the Q4 2018 hydraulic head measurements and groundwater chemistry sample collected from the field sampling program

- Plume capture numerical modeling using FEFLOW for second line of evidence in Step 4 of EPA Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems (EPA, 2008)

- Continuation of Phase 3 and the start of Phase 4 of the EDB *in situ* biodegradation pilot study

- Projected activities in the first quarter (Q1) 2019.

ES-1 Vadose Zone Monitoring

ES-1.1 Vadose Zone Coring and Well Installation Project

Data collected from the project will support vadose zone treatability studies and address data gaps in the horizontal and vertical extent of LNAPL in the vadose and saturated zones. The objectives of the continuous coring are to provide supplemental data on the nature and extent of the residual fuels and to characterize the subsurface biogeochemical conditions relative to residual hydrocarbon and EDB treatment potential.

As of December 2018, coring has been completed at eight locations. Coring will be performed at three additional locations in Q1 2019 (Figure 2-1). Nested soil vapor wells and GWM wells are planned for installation in the boreholes. Coring and well installation will be completed in Q1 2019. A detailed discussion of the drilling and sampling program that includes the results of the assessment will be provided to NMED by November 1, 2019 under separate cover.

ES-1.2 Vadose Zone Q4 Summary

Soil vapor samples were collected from 56 SVM locations (comprised of 284 individual SVMPs) for field parameter measurements and laboratory analyses in Q4 2018 (Figure 2-2). Each SVM location is comprised of up to six SVMPs that are screened at discrete intervals ranging from approximately 25 to 450 feet (ft) below ground surface (bgs).

SVM locations were separated into the three areas of interest (AOIs) to evaluate soil vapor concentrations: (1) off-Base SVM locations, (2) on-Base SVM locations outside the source area, and (3) on-Base SVM locations inside the source area. All soil vapor AOIs are located south of Ridgecrest Drive SE (Figure 2-2). The source area is defined as a 100-ft buffer zone around the original jet fuel pipeline that was the source of the BFF releases. Within each AOI, EDB, benzene, and total hydrocarbon (HC) concentrations were evaluated to determine areas of relatively high or low contamination. Percent oxygen (O_2) and carbon dioxide (CO_2) were measured at each SVMP and evaluated as indicators of aerobic HC biodegradation.

Comparison concentrations are used in this report to illustrate the SVMPs with relatively high or low concentrations. These comparison concentrations were determined using historical maximum and minimum soil vapor concentrations and are 3,800 micrograms per cubic meter ($\mu g/m^3$), 3,200 $\mu g/m^3$, and 1,000 parts per million by volume (ppmv) for EDB, benzene, and HC, respectively. Results from the Q4 2018 SVM event indicate the following (Figures 2-2 through 2-9):

- Off-Base soil vapor concentrations are very low in comparison to the on-Base AOIs. The low contaminant concentrations offer limited opportunity for aerobic biodegradation.

- Results in the on-Base SVM AOI located outside of the source area are consistent with previous sample events. The highest soil vapor concentrations in this AOI are located adjacent to the source area and above the dissolved-phase benzene in groundwater. Measured O_2 and CO_2 levels suggest aerobic microbial activity is occurring in this AOI.

- Consistent with previous quarters, the SMVPs within the source area AOI had the highest EDB, benzene, and HC concentrations compared to the other AOIs. Measured O_2 indicate that active aerobic biodegradation has depleted O_2 at most SVMP locations in this AOI.

ES-1.3 Vadose Zone Annual Summary

The annual statistical analysis, which is included in every Q4 report, evaluates soil vapor data collected from 2016 through 2018 to determine the presence of long-term trends. Soil vapor analytical data from 2018 continued to support most conclusions of the 2015 shutdown test results that were reported in the 2016 Kirtland AFB BFF Pilot Soil Vapor Extraction Shutdown Test Report (U.S. Army Corps of Engineers [USACE], 2016a). SVMPs sampled in Q4 2018 with O2 concentrations less than 5 percent (%) were generally located within the same areas with highest concentrations of residual fuel as determined in the shutdown test report (USACE, 2016a). O_2 levels lower than 5% represent suboptimal conditions for aerobic degradation.

Concentrations of HCs at 203 SVMPs were below the established background concentration of 20 ppmv and were, therefore, too low to evaluate trends. This includes off-Base SVMPs at all depths (28 SVMPs), and on-Base shallow (25 ft bgs) SVMPs. There are no SVM locations north of Ridgecrest Drive since the data indicate that the vapor plume does not extend that far north (Figure 2-3 through Figure 2-9).

Mann-Kendall statistical analysis was performed on the remaining 81 SVMPs that were determined to have concentrations above background. Results are presented in Table 2-6 and Appendix K-1. The findings are summarized below:

- Where a statistically significant trend was identified, the majority of SVMPs with EDB trends are decreasing and there are more decreasing than increasing EDB trends in Q4 2018 in comparison to Q4 2017. Of the 13 SVMPs with EDB trends, 10 are decreasing and three are increasing. More decreasing EDB trends may be due to the fact that EDB is a relatively large molecule, which limits transport because it may not diffuse from the source area as readily as other volatile organic compounds (VOCs). The limited transport and ongoing degradation may result in decreasing EDB concentrations.

- The total number of benzene trends (both increasing and decreasing) rose from 24 trends in Q4 2017 to 34 trends in Q4 2018. However, the ratio of decreasing to increasing benzene trends has remained constant between Q4 2017 and Q4 2018, with slightly more increasing than decreasing trends. The decreasing trends are in locations where the rate of aerobic degradation of benzene in the vadose zone is occurring faster than the rate of diffusion from residual LNAPL. The increasing trends are in locations where the diffusion of benzene from residual LNAPL is greater than the rate of degradation.

- The sample depth with the greatest number of HC and benzene trends is 450 ft. Increasing trends at this depth interval are located south and east of the source area, approximately above the dissolved-phase benzene constituents in groundwater south of Ridgecrest Drive SE. This is most likely due to the rising water table, which has brought the dissolved-phase benzene in groundwater closer to the 450 ft bgs SVMPs. These SVMPs are showing increasing benzene and HC concentrations due to the diffusion of constituents from contaminated groundwater.

- In the source area, the number of SVMPs with less than 5% O_2 increased from 15 SVMPs in Q1 2016 to 23 SVMPs in Q4 2018. This indicates that in the source area, ongoing aerobic microbial activity was depleting O_2 as fuel constituents were consumed and creating suboptimal conditions for microbial degradation. The rate of diffusion from residual LNAPL exceeding the rate of biodegradation may be contributing to the increasing HC trends on-Base.

ES-2 Groundwater Monitoring Network Gauging and Sampling

ES-2.1 Groundwater Q4 Summary

In Q4 2018, 150 Kirtland BFF GWM wells (Figure 3-1) were sampled and depths to groundwater were measured in 156 GWM wells. Six wells were gauged and not sampled, five of which are located in the BFF and were determined to not be necessary for plume delineation based on proximity to other GWM wells in the BFF. The sixth well that is gauged and not sampled is KAFB-106211, which is currently dry but is gauged in anticipation of rising water levels. Findings from the Q4 2018 sampling and gauging event include:

- Groundwater levels showed an overall average increase across the GWM network of 0.20 ft since the third quarter (Q3) 2018 (Figures 3-3, 3-4, and 3-5). Twenty-six GWM well screens spanned the current water table allowing for representative sample collection from the top of the water table, while the remaining 130 wells are screened at various depths below the water table allowing for a detailed analysis of the vertical extent of the contaminant concentrations. The number of wells with no submerged screens (26) is consistent with the previous quarter.

- LNAPL was detected and measured in three wells (KAFB-106076, KAFB-106150-484, and KAFB-106154-484) during gauging (Figure 3-6). All three wells are on-Base and inside the BFF. Of the three wells where LNAPL was measured, KAFB-106150-484 and KAFB-106154-484 are screened across the water table. The thickest layer of LNAPL was in KAFB-106150-484 at 0.11 ft.

- Eighteen newly added wells were sampled in Q4 2018 (Figure 3-1). Eleven of the newly added wells had baseline sampling completed in Q4 2018. These wells will be designated as GWM wells and integrated into the long-term sampling regime beginning in Q1 2019.

- All groundwater samples collected for the Q4 2018 monitoring event were analyzed for EDB, VOCs, select total and dissolved metals, anions, and alkalinity.

- The lateral extent of the dissolved-phase EDB decreased in the Target Capture Zone (defined as the dissolved-phase EDB north of Ridgecrest Drive SE) between the second quarter (Q2) and Q4 2018; both the mass and volume of the plume significantly decreased as a result of continued groundwater extraction conducted under the interim measure. As of Q4 2018, the dissolved-phase EDB in the Target Capture Zone was reduced to two, small localized areas centered around extraction well KAFB-106228 and extraction well KAFB-106234, and a small protrusion north of Ridgecrest Drive SE near extraction well KAFB-106239 (Figures 3-7 through 3-9). The highest dissolved-phase EDB concentrations were detected in the groundwater samples collected from KAFB-106036 (0.19 micrograms per liter [µg/L]) and KAFB-106225 (0.17 µg/L); both of those GWM wells are near extraction wells (KAFB-106228 and KAFB-106234, respectively).

- The extent of the dissolved-phase EDB in the plume south of Ridgecrest Drive SE has remained fairly stable between Q2 and Q4 2018 due to the inherently low hydraulic gradient and flow across the groundwater monitoring network. As expected, the primary EDB mass and the highest concentrations of EDB continue to be on-Base in the source area. The highest concentration of EDB in Q4 2018 (300 µg/L was detected in KAFB-106153-484 (located in the source area), which is an increase in Q2 2018 from 220 µg/L.

- In Q4 2018, the extent of the dissolved-phase benzene in groundwater was modeled three-dimensionally for the first-time using the same methodology that has been employed for EDB modeling (C-Tech MVS Premier software). The Q2 2018 benzene plume model was generated using Golden Software Surfer and adjusted with professional judgment. The models indicate that the extent of the dissolved-phase benzene in the plume south of Ridgecrest Drive SE did not change significantly between Q2 and Q4 2018 (notwithstanding the difference in models). The northern-most boundary continues to be south of Ridgecrest Drive SE and the highest concentrations continue to be detected in the source area on-Base (Figures 3-10, 3-11, and 3-12). Benzene concentrations remained consistent in all off-Base wells between Q2 2018 and Q4 2018. In particular, the two wells with the highest benzene concentrations off-Base (KAFB-106010 and KAFB-106028) changed very little (2,100 and 2,300 µg/L and 6,600 and 6,800 µg/L, respectively). On-Base in the source area, benzene concentrations remained fairly unchanged with the exception of the increase in KAFB-106008 (2,100–to 5,800 µg/L) and the decrease in KAFB-106149-484 (19,000–to 11,000 µg/L).

- Concentrations and contaminant extents for the other organic compounds (toluene, ethylbenzene, and total xylenes) remained consistent between Q2 and Q4 2018; the extent of all three contaminants remained south of the Target Capture Zone. There were no benzene, toluene, ethylbenzene, and total xylenes (BTEX) detections within the Target Capture Zone and the highest concentrations continued to be present in wells in the source area on-Base.

- Concentrations of inorganic compounds also remained fairly consistent between Q2 and Q4 2018 with the highest concentrations being on-Base. The most notable change was that there were no detections of nitrate nitrogen above the maximum contaminant level (MCL) of 10 milligrams per liter (mg/L) in Q4 2018 around the former sewer line leak. There was one detect in Q2 2018 above 10 mg/L MCL in KAFB-106009 (10.9 mg/L estimated).

The USGS monitors 14 sentinel wells between the Kirtland AFB BFF EDB plume and the Albuquerque Bernalillo County Water Utility Authority water supply wells as a means of providing independent observation of water quality in the vicinity of the Albuquerque Bernalillo County Water Utility Authority water supply wells. Samples are collected from these sentinel wells quarterly. For Q4 2018, these samples were collected using dual membrane samplers during the time period of November 26-29, 2018. The samples were analyzed for VOCs and EDB by the USGS National Water Quality Laboratory (NWQL). NWQL analyzed the sample using method O-4127-96 (Connor and others, 1998). The USGS transmittal letter, including the Q4 2018 data results and an updated Q3 2018 data summary table, is provided in Appendix E-5.

ES-2.2 Groundwater Annual Summary

GWM of the entire GWM network and the subsequent generation of contaminant concentration figures occur twice per year (Q2 and Q4), thus limiting comparisons of contaminants extents to between Q2 and Q4 data sets. The following summarizes the annual groundwater elevation and analytes for the BFF GWM network:

- Groundwater levels continued to rise throughout the GWM network over the course of the year from Q4 2017 to Q4 2018. The average increase in groundwater level during the year was 1.79 ft. Both KAFB-106150-484 and KAFB-106154-484 had measurable LNAPL sheens present throughout 2018 (0.02–0.11 ft). KAFB-106076 and KAFB-106079 had measurable LNAPL present intermittently throughout 2018. The LNAPL thickness in KAFB-106076 remained the same between Q1 and Q4 2018 (0.01 ft), although it was not detectable in Q2. The LNAPL thickness in KAFB-106079 decreased from 0.02 ft in Q1 to not detectable in Q4. All the wells where LNAPL was present in 2018 were on-Base in the source area.

- The configuration of the dissolved-phase EDB changed notably in the Target Capture Zone (defined as the area north of Ridgecrest Drive SE) between Q4 2017 and Q4 2018; both the mass and volume of the dissolved-phase EDB decreased as a result of continued groundwater extraction conducted under the interim measure. As of Q4 2018, the dissolved-phase EDB extent in the Target Capture Zone is now reduced to two, small localized area centered around extraction well KAFB-106228 and extraction well KAFB-106234, and a small protrusion just north of Ridgecrest Drive SE near extraction well KAFB-106239 (Figures 3-7, 3-8, and 3-9).

- The extent of dissolved-phase EDB in the source area portion of the plume south Ridgecrest Drive SE is not part of the interim measure and has remained fairly stable between Q4 2017 and Q4 2018 due to the inherently low hydraulic gradient and flow across the groundwater monitoring network.

- The primary EDB mass is in the portion of the dissolved-phase plume south of Ridgecrest Drive SE and the highest concentrations of EDB in groundwater continue to be on-Base in the source area. The highest concentration of EDB in groundwater in Q4 2018 (300 µg/L) was detected in KAFB-106153-484 (located in the source area), which is an increase from Q1 2018 (not sampled in Q4 2017) from 240 µg/L.

- The horizontal extent of dissolved-phase benzene in the plume south of Ridgecrest Drive SE remained stable and did not change significantly between Q4 2017 and Q4 2018 with some notable intra-well differences (Figure 3-10). Within the benzene plume footprint, dissolved-phase benzene concentrations decreased in two key wells off-Base (KAFB-106010 from 2,700 to 2,300 µg/L and KAFB-106028 from 9,200 to 6,800 µg/L) between Q4 2017 and Q4 2018. On-Base in the source area, benzene concentrations increased in groundwater, while the extent of the highest concentration range expanded due to the addition of four existing monitoring wells that were not sampled for benzene in Q4 2017 (Figures 3-10, 3-11, and 3-12).

- Similar to the distribution in groundwater of both the dissolved-phase EDB and the dissolved-phase benzene in the source area, the lateral extent of toluene, ethylbenzene, and total xylenes remain relatively unchanged between Q4 2017 and Q4 2018. Off-Base, these three contaminants are centered around KAFB-106028 and KAFB-106010 and nearly all of the contaminant concentrations have decreased slightly between Q4 2017 and Q4 2018 (Figures 3-13, 3-14, and 3-15). On-Base, there were increases in all three contaminant concentrations.

ES-3 Drinking Water Supply Well Monitoring

ES-3.1 Drinking Water Q4 Summary

Four drinking water supply wells (KAFB-003, KAFB-015, KAFB-016, and ST106-VA-2) are located in the vicinity of the plume containing dissolved-phase EDB. These wells were sampled monthly from October to December in Q4 2018 and analyzed for EDB and BTEX. No EDB or BTEX were detected in groundwater samples collected from these four drinking water supply wells in Q4 2018 (Figure 4-1).

Additionally, all four drinking water supply wells were sampled for inorganic compounds in October 2018. All inorganic compounds detected in the samples collected from drinking water supply wells KAFB-003 and ST106-VA-2 were below their respective EPA MCL. The arsenic concentrations detected in the samples collected from KAFB-015 and KAFB-016 in October 2018 were 0.0161 and 0.0233 mg/L, respectively, which both exceeded the MCL of 0.01 mg/L. These arsenic concentrations are consistent with naturally occurring arsenic observed in the Albuquerque Basin (Bexfield and Plummer, 2003). Consequently, Kirtland AFB operates an arsenic compliance system to ensure that arsenic concentrations in the Kirtland AFB drinking water supply do not exceed drinking water criteria (Kirtland AFB, 2003). All other inorganic compounds in KAFB-015 and KAFB-016 were detected at concentrations below their respective MCLs.

ES-3.2 Drinking Water Annual Summary

The four drinking water supply wells (KAFB-003, KAFB-015, KAFB-016, and ST106-VA-2) were sampled monthly for EDB and BTEX from January through December 2018. All samples were nondetect for EDB and BTEX.

The four drinking water supply wells were also sampled for inorganic compounds in April and October 2018. All inorganic compounds detected in drinking water supply wells KAFB-003 and ST106-VA-2 were below their respective MCLs for both sampling events. Arsenic was detected in samples collected from KAFB-015 and KAFB-016 that exceeded the MCL of 0.01 mg/L in both April and October 2018; drinking water samples from KAFB-015 had arsenic concentrations of 0.0178 and 0.0161 mg/L in April and October, respectively, and KAFB-016 had concentrations of 0.0253 and 0.0233 mg/L in April and October, respectively. As noted above, these arsenic concentrations are consistent with naturally occurring arsenic observed in the Albuquerque Basin (Bexfield and Plummer, 2003) and Kirtland AFB operates an arsenic compliance system to ensure that the drinking water supply does not exceed drinking water criteria (Kirtland AFB, 2003).

ES-4 Groundwater Treatment System Operation

ES-4.1 Operation Q4 2018 Summary

The GWTS consists of two treatment trains with each train made up of a lead granular activated carbon vessel followed by a polishing granular activated carbon vessel. The GWTS was 93% operational from October 1 to December 31, 2018, and 47,135,900 gallons of groundwater was treated during this period. Of the total gallons treated in Q4 2018, Trains 1 and 2 treated 24,882,400 and 22,253,500 gallons, respectively. All analyte concentrations for effluent samples collected from Trains 1 and 2 during Q4 2018 were below their respective limits of detection. During Q4 2018, a calculated 5,064 milligrams (mg) of EDB was captured in the lead granular activated carbon vessels. Of this total, 2,167 mg was removed by Treatment Train 1, and 2,897 mg were removed by Treatment Train 2.

On March 14, 2018, the KAFB-7 V-smart valve hydraulic assembly failed. Repairs were completed on November 9, 2018. From March 14 to November 14, 2018, all treated effluent was discharged to the Tijeras Arroyo Golf Course main pond (GCMP). KAFB-106228, KAFB-106233, and KAFB-106239 experienced reduced run times during Q4 2018 due to the discharge volume restrictions associated with the GCMP reaching capacity. During Q4 2018, all four extraction wells were operational based on GCMP capacity with the following priority: KAFB-106234 (highest priority), KAFB-106228, KAFB-106239, and KAFB-106233 (lowest priority). KAFB-106233 was inactive during the Q4 2018 synoptic gauging event.

ES-4.2 Operation Annual Summary

Extraction well KAFB-106239 was brought on line in February 2018. Throughout the year 2018, the GWTS was operational 94% of the time, and treated a total of 217,194,100 gallons of groundwater and removed approximately 24,553 mg of EDB. Of the treated water, 149,707,900 gallons was discharged to the GCMP, and 67,486,200 gallons was discharged to a gravity-fed injection well KAFB-7.

Concentrations for all compounds analyzed in the effluent samples collected during the entire year of 2018 were below their respective regulatory limits. Run times for pumps in extraction wells KAFB-106228, KAFB-106233, KAFB-106234, and KAFB-106239 were 72, 66, 94, and 71%, respectively.

ES-4.3 Performance Assessment Summary

One of the goals of the groundwater interim measure is to hydraulically capture the dissolved-phase EDB utilizing well pumping, thereby halting plume expansion. GWTS performance assessment is performed using the EPA's Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems (EPA, 2008) guidance to assess the effectiveness of plume capture. Plume capture numerical modeling was performed for the first time in Q2 2018 using the finite element software FEFLOW. The U.S. Air Force will run this model twice a year (i.e., Q2 and Q4) throughout the investigation phase of the corrective action. The performance assessment is a "snap shot" of the system performance and is not intended to be a final remedy evaluation.

A summary of the results for the analyses, as they pertain to the Target Capture Zone (dissolved-phase EDB north of Ridgecrest Drive SE), is listed below:

- The delineation of the Target Capture Zone, which is an EDB concentration in groundwater of 0.05 µg/L, shows that the volume and mass of the dissolved-phase EDB has decreased by 23% and 11%, respectively, when compared to Q2 2018 (Figure 5-3; Table 5-16). This continues the trend of plume reduction observed since the activation of interim measure extraction in 2015.

- Delineation of the interim measure extraction well capture zones shows that 100% of the dissolved-phase EDB is being hydraulically contained in the horizontal direction in Q4 2018 (Figures 5-4, 5-5, and 5-6; Table 5-16). A total of 99% of the dissolved-phase EDB is being hydraulically contained in the vertical direction (Figures 5-8 and 5-9; Table 5-18).

- Delineation of plume capture using particle tracks shows that 92% of the dissolved-phase EDB volume and 91% of the mass in the Target Capture Zone is being captured by interim measure extraction wells (Figure 5-12; Table 5-20).

- Concentrations at sentinel wells continue to be below detection and concentrations at performance monitoring wells are at or below detection limits (Figure 5-16).

EDB mass is collecting around extraction wells KAFB-106228 and KAFB-106234 in the Target Capture Zone. The plume has been segmented between KAFB-106228 and KAFB-106234 and between KAFB-106239 and KAFB-106228. Overall, the plume analysis demonstrates the expected dissolved-phase EDB volume and mass reduction response due to interim measure system extraction in the Target Capture Zone (Section 5.4.7; Figure 5-18). Plume mass and volume movement are not uniform, and no region of mass increase or reduction is outside of expectation when allowing for the error incurred by assuming linear concentration gradients between water chemistry data points. This performance assessment will be conducted every second and fourth quarter moving forward so that continued plume comparisons can be performed, plume reduction can be analyzed, and capture changes due to the regional hydrogeologic variation can be quantified.

A comparison of all performance assessment analyses suggests that the interim measure extraction system failed to produce hydraulic containment for 100% of the dissolved-phase EDB within the Target Capture Zone in Q4 2018. Results from the numerical model show that flow from a portion of the plume along the southern boundary of the Target Capture Zone is outside of the interim measure Target Capture Zone. Loss of full containment in Q4 2018 is likely due to interim measure extraction well KAFB-106233 being inactive due to discharge limitations at the GCMP before and during the Q4 2018 gauging period and, therefore, inactive in the model design this reporting period. In order to test this hypothesis, a model scenario was developed to simulate flow under identical Q4 2018 conditions, but with KAFB-106233 active at 100% capacity. The results from this scenario show that KAFB-106233 being active increases the extent of capture produced by KAFB-106228, thereby producing hydraulic containment for 100% of the dissolved-phase EDB in the Target Capture Zone (Figures 5-13 and 5-14). The conclusion is that the interim measure would produce 100% containment of the plume within the Target Capture Zone under Q4 2018 conditions as long as all extraction wells are active.

ES-5 Ethylene Dibromide *In Situ* Biodegradation Pilot Study

ES-5.1 Ethylene Dibromide *In Situ* Biodegradation Pilot Study Q4 Summary

The main objective for conducting the *in situ* biodegradation pilot test is to investigate the viability of *in situ* anaerobic bioremediation of EDB in groundwater. Phase 3 of the pilot test began with the distribution of treatment amendments in recirculated groundwater. The passive monitoring portion of Phase 3, which was designed to evaluate the effectiveness of additional biostimulation, began on September 9, 2018 and was completed on November 19, 2018. Phase 4, long-term rebound monitoring, is currently underway and will continue into 2019. An independent report summarizing all activities associated with the pilot test through the first Phase 4 sampling event (to be conducted in January 2019) will be submitted on May 1, 2019.

ES-5.2 Ethylene Dibromide *In Situ* Biodegradation Pilot Study Annual Summary

Active and passive portions of Phases 2 and 3 of the pilot test were completed in 2018 and Phase 4 long-term rebound monitoring was initiated. Both Phases 2 and 3 included the evaluation of biostimulation in the subsurface after distribution of treatment amendments in recirculated groundwater. Groundwater samples were collected at extraction, injection, and monitoring wells on a weekly basis during active recirculation and on a monthly basis during passive portions of the Phases to evaluate the effectiveness of biostimulation. Because LNAPL was observed in KAFB-106MW1-S in Fall 2017 soon after well development, this well was repeatedly measured throughout 2018 for LNAPL; however, none was observed. An independent report summarizing all activities associated with the pilot test through the first Phase 4 sampling event will be submitted on May 1, 2019.

ES-6 Projected Activities

Planned activities for Q1 2019 include:

- Complete the vadose zone coring and well installation project and submit a report to NMED summarizing the LNAPL investigation findings by November 1, 2019.

- Continue Phase 4 long-term rebound monitoring for the EDB *In Situ* Biodegradation Pilot Study and submit a report to NMED. The report summarizing the results of the EDB *In Situ* Biodegradation Pilot Study will be submitted to NMED by May 1, 2019.

- Initiate construction for the bioventing pilot test. A report summarizing the available results of the bioventing pilot tests will be submitted to NMED by January 31, 2020.

- Sample the Q1 2019 designated wells in the GWM network beginning in January 2019.

- Measure depth to water in all wells in the GWM network.

- Sample drinking water supply wells for organic compounds on a monthly basis.

- Operate the GWTS and extraction wells KAFB-106228, KAFB-106233, KAFB-106234, and KAFB-106239 with discharge to the GCMP and injection well KAFB-7.

1. INTRODUCTION

The investigation and remediation of the Kirtland Air Force Base (AFB) Bulk Fuels Facility (BFF) leak (Solid Waste Management Units (SWMUs) ST-106/SS 111) are being implemented pursuant to the Resource Conservation and Recovery Act (RCRA) corrective action provisions in Part 6 of Kirtland AFB's Hazardous Waste Treatment Facility Operating Permit (Permit Number [No.] NM9570024423 – "RCRA Permit) (New Mexico Environment Department [NMED], 2010). This Quarterly Report for the fourth quarter (Q4) of calendar year 2018 and Annual Report for 2018 summarizes the activities performed from October 1 through December 31, 2018 and during 2018. This Q4 2018 Quarterly and Annual Report presents both non-cumulative data for Q4 2018 and a compilation of the data collected over the four quarters of 2018 with more in-depth data analysis, conclusions, and recommendations for the calendar year. Appendix A contains key regulatory correspondence for Q4 2018. Analytical data from all four quarters of 2018 are provided electronically in Appendix K.

The BFF site is located within the northwestern portion of Kirtland AFB, on the southern end of the city of Albuquerque, as shown on the site location map (Figure 1-1). The Phase I RCRA Facility Investigation (RFI) (U.S. Army Corps of Engineers [USACE], 2017a) provides a detailed site description, history, and conceptual site model. Vadose zone and groundwater investigation and remediation activities are required to address the potential impact of fuels that were released from leaking pipelines at the former fuel off-loading rack.

Soil vapor monitoring (SVM), groundwater monitoring (GWM), and interim measures for SWMUs ST-106/SS-111 were conducted concurrently. The Q4 2018 monitoring program was performed in accordance with multiple work plans: (1) soil vapor (NMED, 2017a; NMED, 2017b; USACE, 2017b), (2) GWM (NMED, 2017c; USACE, 2017c), and (3) drinking water supply wells (NMED, 2017a; USACE, 2017b). Groundwater treatment system (GWTS) operations, sampling, and treated effluent discharge were performed under the Operations and Maintenance Plan (USACE, 2016b; USACE, 2017d, USACE, 2018a). GWTS performance assessment followed the U.S. Environmental Protection Agency (EPA) *Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems* (EPA, 2008) and plume capture numerical modeling using FEFLOW are performed in the second (Q2) and Q4 of each year as approved by NMED on April 23, 2018 (NMED, 2018a) in resolution of the modeling component of the Notice of Deficiency issued to Kirtland AFB on November 16, 2017 (NMED, 2017d).

2. VADOSE ZONE MONITORING

This section describes the field activities for the vadose zone coring project (Figure 2-1) and semiannual soil vapor sampling for the Q4 2018 monitoring of 56 SVM locations at Kirtland AFB (Figure 2-2). Section 2.1 provides a brief summary of the coring project and the field activities that will be completed in the first quarter (Q1) 2019. Semiannual soil vapor sampling is conducted to characterize and monitor fuel-related contaminant concentrations in the vadose zone. Sections 2.2 through Section 2.4 of this report discuss field sampling and laboratory testing procedures, data usability, and results of soil vapor data collected during Q4 2018. Section 2.5 includes provides an annual soil vapor data summary.

2.1 Vadose Zone Coring Project

Implementation of the vadose zone coring and well installation project was initiated in October 2018 in accordance with the Vadose Zone Coring, Vapor Monitoring, and Water Supply Sampling Work Plan (USACE, 2017b). The project includes coring up to 12 locations in the vadose zone (Figure 2-1) with up to 10 boreholes cored below the water table. Three locations were optional pending NMED approval and one of the 12 locations is a background coring. Nested soil vapor and GWM wells are planned for installation in the boreholes. Five nested GWM wells were completed in Q4 2018 in five of the boreholes. A well completion report for these five wells will be provided in the Q1 2019 quarter report. The remaining monitoring wells will be installed in the Q1 2019.

Data collected from the project will support vadose zone treatability studies and address data gaps in the horizontal and vertical extent of light non-aqueous phase liquids (LNAPL) in the vadose and saturated zones. The objectives of the continuous coring are to provide supplemental data on the nature and extent of the residual fuels and to characterize the subsurface biogeochemical conditions relative to residual hydrocarbon (HC), including benzene, and ethylene dibromide (EDB) treatment potential.

Soil samples were collected based on lithology and the presence of HCs as well as at predetermined depths as indicated in the Work Plan. Soil samples are sent to analytical laboratories for analysis of:

- Volatile organic compounds (VOCs) (EPA Method 8260C), EDB (EPA Method 8011), total petroleum hydrocarbons – gasoline range organics/diesel range organics/oil range organics (EPA Method 8015D), and moisture analysis (ASTM International D2216)
- Microbial analysis (QuantArray Chlor) and mineralogy (x-ray diffraction and energy dispersive x-ray spectrometry)
- The presence of LNAPL by ultraviolet light analysis
- LNAPL transmissivity and mobility, grain size, fluid properties, capillary pressure, free product mobility, relative permeability, and hydraulic conductivity (Kh)
- LNAPL (if available) physical properties including gravity, HC component analysis, flash point, and viscosity.

As of December 2018, coring has been completed at KAFB-106S1, KAFB-106S2, KAFB-106S3, KAFB-106S4, KAFB-106S5, KAFB-106S9, KAFB-106V1, and KAFB-106V2 (Figure 2-1). Coring will be performed at locations KAFB-106S7 (optional required), KAFB-106S8 (optional required), and background location ST-106-SBBG (well KAFB-106247) in Q1 2019 (Figure 2-1). Optional coring location KAFB-106S6 was not required by NMED based on field screening results obtained from

KAFB-106S5 (NMED, 2018b). Field screening data obtained from KAFB-106S5 did not indicate the presence of LNAPL and thus negated the need for an additional well. A detailed discussion of the drilling and sampling program that includes the results of the assessment will be provided following completion of the field program.

2.2 Vadose Zone Data Collection

Each SVM location is comprised of up to six soil vapor monitoring points (SVMPs), each screened at discrete intervals ranging from approximately 25 to 450 feet (ft) below ground surface (bgs). Each SVMP has a unique database identification (ID), which includes the SVM location followed by a number identifying the approximate depth of the screened interval associated with an individual SVMP (e.g., SVMW-04-250 describes an SVMP located at SVMW-04 that is screened at approximately 250 ft bgs). Table 2-1 lists each SVM location, its associated SVMPs, the screen intervals, and the pre-calculated purge volume.

To the extent possible, samples collected in Q4 2018 represent the vadose zone conditions without the influence of induced air flow. All SVMP sample ports are sealed to atmospheric air, which minimizes exchanges with atmospheric “inhalation” and “exhalation” cycles that are driven by barometric pressure fluctuations. In addition, the SWMUs ST-106/SS-111 soil vapor extraction (SVE) system was shut down in Q2 2015 and subsequently dismantled. The components from the system have been disposed of.

Soil vapor samples were collected from all 284 SVMPs and submitted for laboratory analysis. Field parameters were measured and recorded during the Q4 2018 sampling event. The condition of the vault and the pneumatic quick-connect fittings at each SVMP was documented on a purge log to ensure sample representativeness.

2.2.1 Field Soil Vapor Data

Field parameters including total HC concentration, oxygen (O_2), and carbon dioxide (CO_2) were measured and recorded at each SVMP using a Horiba MEXA-584L auto emissions analyzer (Horiba). Differential air pressure (inches of water column) readings were measured using an electric manometer and recorded for pre-purging and post-purging conditions of each well. SVMPs were purged of their respective casing volume before field measurements were recorded and before samples were collected. Purge data were recorded on purge logs (Appendix C-1); field data are listed in Table 2-2. Horiba calibration and sample system leak tests were performed and documented on calibration logs (Appendix C-2); daily quality control reports are provided in Appendix C-2.

2.2.2 Laboratory Soil Vapor Analytical Data

In Q4 2018, soil vapor samples were collected between October 23 and November 6. Two hundred eighty-four SVMP field samples and 29 field duplicates were collected using certified pre-evacuated Summa® canisters fitted with a specialized pneumatic connector to allow only the vapor from the SVMP to enter the canister. Sample information was recorded on sample collection logs (Appendix C-1). Chain-of-custody records are provided in Appendix C-3. After collecting each SVMP sample, the canister was immediately placed into protective packaging and shipped to ALS Environmental in Simi Valley, California, for analysis of VOCs by EPA Method TO-15.

The Data Quality Assessment Report is provided in Appendix D-1. Analytical results are reported in the ALS Environmental Laboratory Report (Appendix D-2). Soil vapor analytical data were validated by

Environmental Data Services, Ltd., Newport News, Virginia. Data validation reports are provided in Appendix D-2 and soil vapor analytical results are listed in Table 2-3, Table 2-4, and Table 2-5.

2.3 Data Review and Usability

Environmental Data Services performed 23 percent (%) Level III data validation of Q4 2018 soil vapor analytical data. All data were validated as usable; no data were qualified as rejected. The technical data completeness was 100%. The data met data quality objectives and were determined to be appropriate for use in project decision making. Some analytical results were flagged as estimated (J-flagged), which occurred when an analyte was positively identified in the sample; however, the associated numerical value was determined to be estimated. The results of the quality control parameter and data quality indicator evaluation (precision, bias [accuracy], representativeness, completeness, comparability, and sensitivity) are provided in the Data Quality Evaluation Report (Appendix D-1). Validated soil vapor data are listed in Table 2-3, Table 2-4, and Table 2-5.

2.4 Q4 2018 Soil Vapor Data

The Q4 2018 analytical results and field data from the 284 SVMPs were used to generate two-dimensional plan-view maps (Figure 2-3 through Figure 2-9) that depict benzene, EDB, and HC concentrations at depths of 25, 50, 100, 150, 250, 350, and 450 ft bgs, respectively. Field parameters collected during the SVM event are listed in Table 2-2. Soil vapor analytical results are listed in Table 2-3, Table 2-4, and Table 2-5.

The SVM locations have been categorized into three areas of interest (AOIs), which are all located south of Ridgecrest Drive Southeast (SE) (Figure 2-2): (1) off-Base SVM locations, (2) on-Base SVM locations outside the source area, and (3) on-Base SVM locations inside the source area. There are no SVM locations north of Ridgecrest Drive since the data indicate that the vapor plume does not extend that far north (Figure 2-3 through Figure 2-9). Soil vapor analytical data are discussed in relation to each AOI. The source area (Figure 2-2 through Figure 2-9) is defined as a 100-ft buffer zone around the original jet fuel underground pipelines that were the source of the BFF releases. These pipelines were removed in 2010.

The RCRA Permit does not specify cleanup levels for soil vapor. The quarterly reports are not intended to assess risk; the vapor data are used to assess concentration trends. The Risk Assessment compares vapor concentrations to the vapor intrusion screening levels in NMED’s Risk Assessment Guidance for Site Investigations and Remediation (NMED, 2017e).

All EDB and benzene concentrations are compared against 3,800 and 3,200 micrograms per cubic meter ($\mu g/m^3$), respectively, and HC concentrations are compared against 1,000 parts per million by volume (ppmv). The comparison concentrations used in this report were determined by historical maximum and minimum soil vapor results to show which SVMPs had relatively high or low concentrations. Reporting units for EDB and benzene were parts per billion by volume in previous reports but were changed to micrograms per cubic meter in this report to be consistent with the units used in NMED regulatory guidance documents.

At fuel release sites, microorganisms biodegrade fuel-related constituents under aerobic conditions, which consumes O_2 and produces CO_2. Depleted O_2 and elevated CO_2 levels within each AOI indicate that microbial degradation is ongoing at the BFF site, primarily in and around the source area. O_2 levels lower than 5% represent suboptimal conditions for aerobic degradation.

Refer to Figure 2-2 through Figure 2-9 for discussion of data presented in Sections 2.4.1 through 2.4.3.

2.4.1 Off-Base Soil Vapor Monitoring Points

- There are five off-Base SVM locations consisting of 28 SVMPs, which are screened at intervals from approximately 25 to 450 ft bgs.

- Off-Base soil vapor concentrations are very low in comparison to the on-Base AOIs. The low contaminant concentrations offer limited opportunity for aerobic biodegradation.

- EDB was detected in two of the 28 off-Base SVMPs, at concentrations below the comparison level of 3,800 $\mu g/m^3$. EDB was detected at a concentration of 2.5 $\mu g/m^3$ at KAFB-106028-450 and an estimated concentration (J-flag value) of 0.41 $\mu g/m^3$ at KAFB-106142-450.

- Benzene was detected in 24 of the 28 SVMPs. Twenty-two of the 24 benzene detections were estimated concentrations (J-flag values) of 1.9 $\mu g/m^3$ or less. The two non-qualified detections had concentrations of 3.2 $\mu g/m^3$ at KAFB-106138-350 and 8.5 $\mu g/m^3$ at KAFB-106142-450, with both below the comparison level of 3,200 $\mu g/m^3$.

- HC concentrations in the 28 off-Base SVMPs ranged between 1 and 6 ppmv. The highest HC concentration (6 ppmv) was detected at KAFB-106136-250.

- O_2 concentrations at off-Base SVMPs averaged 20.05%, or near atmospheric levels (approximately 21%) (Berner et al., 2007). However, CO_2 was measured at levels of up to 4.12% (KAFB-106138-025) in this AOI (although most were less than 1%).

2.4.2 On-Base Soil Vapor Monitoring Points Outside of Source Area

- There are 40 on-Base SVM locations outside of the source area, consisting of 224 SVMPs that are screened at intervals from approximately 25 to 450 ft bgs.

- Results in the on-Base SVM AOI located outside of the source area are consistent with previous sample events. The highest soil vapor concentrations in this AOI are located adjacent to the source area and above the groundwater containing dissolved-phase benzene. Measured O_2 and CO_2 levels suggest aerobic microbial activity is occurring in this AOI.

- At SVMPs located on-Base outside the source area, samples with detectable EDB did not exceed the comparison concentration (3,800 $\mu g/m^3$; Table 2-4) except for an estimated concentration (J-flag value) of 4,500 $\mu g/m^3$ at KAFB-106128-450.

- Benzene was detected in 207 of the 224 on-Base SVMPs and 112 of these 207 SVMPs with benzene detections were at estimated concentrations (J-flag values). Benzene concentrations met or exceeded the comparison value of 3,200 $\mu g/m^3$ at 27 SVMPs. The highest benzene concentration of 320,000 $\mu g/m^3$ was detected at SVMW-06-252, located approximately 200 ft east of the source area.

- HC was detected at concentrations below 1,000 ppmv in 209 of the 224 SVMPs. The 13 SVMPs with concentrations greater than 1,000 ppmv were screened from approximately 100 to 450 ft bgs. The highest HC concentration (10,580 ppmv) was detected at SVMW-02-100, located approximately 25 ft north of the source area.

- Twenty-seven SVMPs had relatively low O_2 levels, below 15% with correspondingly higher CO_2 levels ranging between 1.82 and 12.72%. For example, KAFB-106117-350 and KAFB-106117-450 had high CO_2 levels of 12.14 and 12.72%, respectively, with corresponding low O_2 levels below 5%. This suggests that, at these SVMPs, there are rate-limiting conditions for aerobic microbial activity and that aerobic biodegradation may be occurring at less than optimal conditions.

2.4.3 On-Base Soil Vapor Monitoring Points Inside the Source Area

- There are 11 on-Base SVM locations inside the source area, consisting of 32 SVMPs that are screened at intervals from approximately 25 to 450 ft bgs. These SVMPs are within 100 ft of the original location of the underground jet fuel pipeline. SVMW-08-266 is plugged and could not be monitored (Table 2-2).

- Consistent with previous quarters, the SMVPs within the source area AOI had the highest EDB, benzene, and HC concentrations compared to the other AOIs. Measured O_2 indicate that active aerobic biodegradation has depleted O_2 at most SVMP locations in this AOI.

- The highest EDB, benzene, and HC concentrations obtained from soil vapor for Q4 2018 were encountered on-Base within the source area AOI, with maximum concentrations of 17,000 $\mu g/m^3$ (SVMW-11-100), 1,300,000 $\mu g/m^3$ (SVMW-10-150), and 31,620 ppmv (SVMW-10-100), respectively. This AOI had the highest percentage of EDB and benzene detections (Table 2-5).

- EDB was detected in 10 of the 32 SVMPs inside the source area, of which five exceeded the comparison concentration of 3,800 $\mu g/m^3$. EDB concentrations greater than 3,800 $\mu g/m^3$ were detected in the screened interval ranging from approximately 50 to 260 ft bgs.

- Benzene was detected in 31 of the 32 SVMPs inside the source area. Benzene concentrations greater than 3,200 $\mu g/m^3$ were detected at screened interval depths ranging between 50 and 300 ft bgs.

- HC was detected at concentrations below 1,000 ppmv in 10 of 32 SVMPs. HC concentrations above 1,000 ppmv were detected at screened intervals ranging from approximately 50 to 300 ft bgs.

- The O_2 levels at the on-Base inside the source area SVMPs ranged from 0.16 to 20.15%. Twenty-three SVMPs had O_2 levels below 5%, at depths ranging from approximately 50 to 300 ft bgs. CO_2 levels ranged from 0.16 to 14.64%. The maximum CO_2 level (14.64%) was detected at SVMW-11-260.

  In general, the higher EDB and benzene concentrations coincided with lower O_2 levels (less than 5%) and elevated CO_2 levels (Table 2-2). This relationship suggests that current conditions are not conducive for aerobic microbial activity (i.e., native bacteria need more O_2 to degrade residual fuel-related constituents) in this AOI. Continued aerobic microbial activity likely depletes the O_2 levels over time, which effectively limits microbial activity and HC degradation rates.

2.4.4 Maintenance and Repairs

Maintenance and/or repairs were performed at all 56 SVM locations following completion of the Q4 2018 sampling event. Any maintenance needs, which included corroded quick connects, worn or damaged gaskets, overgrown vegetation, and overall cleanliness of locations were noted during the sampling event and addressed during the subsequent weeks.

Rusty pneumatic quick connects were observed at the following 17 SVMPs during the Q4 2018 sampling event and were repaired upon completion of the event:

- SVMW-02-150
- SVMW-03-050
- SVMW-03-250
- SVMW-03-300
- SVMW-06-050
- SVMW-06-100
- SVMW-06-252
- SVMW-06-302
- SVMW-10-150
- SVMW-13-350
- KAFB-106128-150
- KAFB-106133-025
- KAFB-106133-050
- KAFB-106133-170
- KAFB-106133-250
- KAFB-106133-350
- KAFB-106133-450.

Pneumatic quick connects were replaced from November 13 through November 14, 2018, as part of periodic maintenance of the SVM network. In addition to the pneumatic quick-connect maintenance, SVM locations were also swept and cleared of vegetation and miscellaneous debris as necessary. Damaged or missing parts—typically gaskets and pneumatic quick connects—were repaired or replaced. Upon inspection, SVMW-08 vault lid had one hasp that did not allow the bolt to thread properly. This was repaired after the main maintenance event on December 13, 2018. These maintenance activities were performed after Q4 2018 samples were collected and had no effect on the results.

2.5 Soil Vapor Trends

Although there were fluctuations in soil vapor concentrations between Q2 2018 and Q4 2018, significant changes were not observed in the data between the two sampling events. This section evaluates soil vapor data collected in 2015, 2016, 2017, and 2018 to determine the presence of long-term trends. Section 2.5.1 describes the results of the trend analysis.

Mann-Kendall trend analysis was performed on 81 SVMPs with HC concentrations greater than 20 ppmv (HC concentrations less than 20 ppmv are considered background concentrations for the purposes of this report). Out of 284 SVMPs, 203 had HC concentrations below 20 ppmv between Q1 2016 and Q4 2018 and were identified as background. The Mann-Kendall trend analysis was performed to determine whether there was a statistically significant increasing or decreasing trend at a 95% confidence interval in EDB, benzene, and HC. Eight data points corresponding to the eight separate sampling events that occurred between Q1 2016 and Q4 2018 were evaluated for each analyte. A catalytic oxidizer SVE system was operational at the site from Q1 2013 through Q2 2015. The SVE system was shut down in Q2 2015 to perform rebound and respiration testing. Rebound and respiration testing was ongoing through Q4 2015 and is summarized in the Kirtland AFB BFF Pilot SVE Shutdown Test Report (USACE, 2016a). Mann-Kendall analysis was performed using Q1 2016 through Q4 2018 data to evaluate how concentration trends changed following rebound and respiration testing, and to remove the impact of SVE operation and rebound on the trend analysis. If an analyte at an SVMP was reported as non-detect four or more times between Q1 2016 and Q4 2018, the statistical analysis was not performed due to insufficient data. In datasets containing one to three non-detect values, the values were assumed to be the method detection limit used by the laboratory at the time of reporting. This results in greater uncertainty at locations with a higher number of non-detects. Likewise, there is inherent uncertainty at SVMPs with estimated detections below the limit of quantitation, as the value used for the trend analysis is an estimate. Trend analysis results and conclusions are discussed in the sections below. The Mann-Kendall analysis is described in detail in Appendix K-1.

Time series graphs were created for the same 81 SVMPs that were used for the Mann-Kendall analysis. Time series graphs included soil vapor data collected between Q1 2015 and Q4 2018. Soil vapor data from Q1 2015 to Q4 2018 and the SVE shutdown data are included in the time series graphs to illustrate concentration changes before and after shutdown. There are two time series graphs per SVMP: one illustrating EDB, benzene, and HC and one illustrating O_2 and CO_2 levels for the same time period. These time series graphs are presented in Appendix L-1.

2.5.1 Trend Analysis Results

Of the 81 SVMPs evaluated, 51 had either statistically significant increasing or decreasing trends in EDB, benzene, and HC between Q1 2016 and Q4 2018; 30 had no statistically significant trend. Table 2-6 lists the 81 SVMPs included in the analysis and identifies whether any statistically significant EDB, benzene, or HC trends were observed at each one. Refer to Appendix K-1 for visual representations of each trend analysis.

1. Concentrations measured in off-Base SVMPs were determined to be too low to evaluate trends. HC concentrations at all off-Base SVMPs are below the 20 ppmv that is considered "background." In addition, there were only two EDB detections in off-Base SVMPs in 2018; these were both measured at 450 ft bgs.

2. Similarly, concentrations at 25 ft bgs both on-Base and off-Base were determined to be too low to evaluate trends. HC concentrations at SVMPs in all three AOIs were below the 20 ppmv that is considered "background."

3. In Q4 2017, there were 53 statistically significant trends of EDB, benzene, and HC; and, in Q4 2018, there were 86 statistically significant trends.

4. Of the 13 SVMPs with EDB trends, 10 are decreasing, and three are increasing. There are more decreasing than increasing EDB trends in Q4 2018 in comparison to Q4 2017. In Q4 2017, there was one decreasing EDB trend and four increasing EDB trends. SVMPs with decreasing EDB trends were screened at depths between 50 and 450 ft bgs. Six of these SVMPs are located within the source area and four are located on-Base outside the source area. Statistically significant increasing EDB trends were observed in three SVMPs screened at depths between depths of 350 and 410 ft bgs. All three of these SVMPs are approximately 400 ft east and southeast of the source area.

5. In Q4 2018, 34 statistically significant trends were identified for benzene, 18 were increasing trends, while 16 were decreasing. In Q4 2017, only 24 statistically significant trends were identified for benzene, although there was a similar ratio of increasing to decreasing trends with 13 increasing and 11 decreasing.

6. Eighteen SVMPs had statistically significant increasing benzene trends. Increasing trends were observed in SVMPs screened at depths between 50 and 450 ft bgs. Four of these SVMPs are located within the source area and 14 are located on-Base outside the source area, within approximately 800 ft southeast, east, and northeast of the source area.

7. Sixteen SVMPs had statistically significant decreasing benzene trends. These decreasing trends were observed in SVMPs screened at depths between 50 and 460 ft bgs at eight SVMPs within the source area and eight SVMPs on-Base outside the source area. Decreasing trends outside the source area were observed at SVMPs within approximately 400 ft east and southeast of the source area, except for KAFB-106137-450, which is approximately 900 ft northeast of the source area.

8. In Q4 2018, 38 statistically significant HC trends were identified—32 were increasing trends and seven were decreasing. In Q4 2017, only 24 statistically significant HC trends were identified, although there was a similar ratio of increasing to decreasing trends with 20 increasing and 4 decreasing.

9. Based on the Mann-Kendall analysis, 32 SVMPs showed a statistically significant increasing HC trend, seven located within the source area and 24 located on-Base but outside the source area. Increasing trends were observed in SVMPs screened at depths between 50 and 450 ft bgs. Increasing trends on-Base outside the source area generally occurred within approximately 700 ft east and southeast of the source area in the approximate area of the groundwater containing dissolve-phase benzene.

10. Seven SVMPs showed a statistically significant decreasing HC trend and all seven SVMPs were located on-Base outside the source area. Decreasing trends were observed in SVMPs screened at depths between 252 and 450 ft bgs, within approximately 1,000 ft to the south and southeast of the source area.

Elevated concentrations of benzene at KAFB-106134-450 persisted in Q4 2018. Anomalous concentrations at this location were identified in Q4 2017 and were attributed to drilling activities related to the Environmental Security Technology Certification Program *in situ* biodegradation pilot test that began in Q1 2017 (USACE, 2016c). Although HC concentrations have begun to decrease at this location following the end of drilling activities, benzene concentrations remain elevated, possibly due to recirculation activities. This location will continue to be monitored in upcoming quarters.

2.5.2 Trend Analysis Conclusions

Review of the statistical analysis in conjunction with the time series graphs provide the following conclusions:

1. Concentrations measured in off-Base SVMPs and at shallow (25 ft) SVMPs both on-Base and off-Base were determined to be too low to evaluate trends. HC concentrations at all off-Base SVMPs are below the 20 ppmv that is considered "background." In addition, there were only two EDB detections in off-Base SVMPs in 2018; these were both measured at 450 ft bgs.

2. The additional data collected in 2018 increased the number of statistically significant trends observed at the site—53 trends were identified in Q4 2017 and 86 trends were identified in Q4 2018. There are many locations that subjectively appear to have trends that have not been determined to be statistically significant. Some examples include: EDB concentrations at SVMW-11-260, benzene concentrations at KAFB-106127-450, and HC concentrations at KAFB-106119-250. These may become statistically significant trends as more data are collected in 2019.

3. There is a higher ratio of statistically significant decreasing to increasing EDB trends in Q4 2018 in comparison to Q4 2017. More decreasing EDB trends may be due to the fact that EDB is a relatively large molecule, which limits transport. It may not diffuse from areas of residual LNAPL as readily as other VOCs. The limited transport and ongoing degradation in the source areas may result in more decreasing EDB trends.

4. The ratio of decreasing to increasing benzene trends has remained constant between Q4 2017 and Q4 2018, with slightly more increasing than decreasing trends. The decreasing trends may indicate locations where the rate of aerobic degradation of benzene in the vadose zone is occurring faster than the rate of diffusion from residual LNAPL. The increasing trends may indicate locations where the diffusion of benzene from residual LNAPL is greater than the rate of degradation.

5. The ratio of decreasing to increasing HC trends has remained constant between Q4 2017 and Q4 2018, with approximately from four to five times as many increasing trends than decreasing trends. Locations with increasing trends indicate that HC is diffusing from areas of residual LNAPL at a higher rate than aerobic microbial degradation is lowering HC concentrations. Locations with decreasing trends indicate HC is diffusing at a lower rate than degradation is consuming HC. The majority of HC trends are increasing at the site; therefore, the rate of diffusion of HC from residual LNAPL is generally greater than the rate of degradation. This may be due to aerobic microbial degradation being rate-limited by low oxygen concentration and/or limited moisture in the vadose zone.

6. The sample depth with the greatest number of HC and benzene trends is 450 ft. Increasing trends at this depth interval are located south and east of the source area, approximately above the groundwater containing dissolved-phase benzene. The rising water table has brought the groundwater containing dissolved-phase benzene closer to the 450 ft bgs SVMPs. These SVMPs may be showing increasing benzene and HC concentrations due to the diffusion of constituents from contaminated groundwater.

The 2016, 2017, and 2018 soil vapor analytical results continue to support the conclusions of the 2016 Kirtland AFB BFF Pilot SVE Shutdown Test Report (USACE, 2016a). In the source area, the number of SVMPs with less than 5% O_2 increased from 15 SVMPs in Q1 2016 to 23 SVMPs in Q4 2018. Depleted O_2 levels less than 5% at SVMPs with high HC concentrations (greater than 1,000 ppmv) may be limiting microbial degradation. The rate of diffusion of constituents from residual LNAPL may have exceeded the rate of biodegradation causing an increasing trend. Biodegradation continues to play a substantial role in remediating HC in 2018, but it also continues to deplete O_2. Additionally, the lack of moisture in soil may be affecting rates of biodegradation at several SVMPs where sufficient O_2 and HC are present. For example, HC concentrations at SVMW-02-100 have been above 1,000 ppmv since Q1 2016 and O_2 concentrations at SVMW-02-100 decreased from approximately 18% in third quarter (Q3) 2015 and have stabilized at 9% in Q4 2018 (Appendix L-1). This indicates that O_2 is not limiting biodegradation at these locations and soil moisture may be the limiting reagent. Similar conditions were observed at SVMW-10-100 and KAFB-106128-350.

Soil vapor data also continue to indicate that, in addition to O_2, moisture content may be limiting microbial activity. Vadose zone coring activity, which is currently ongoing, will help increase an understanding of residual LNAPL and how it is contributing to soil vapor concentrations in the vadose zone.

3. GROUNDWATER MONITORING NETWORK GAUGING AND SAMPLING

At the end of Q4 2018, the BFF GWM well network was comprised of 156 GWM wells (Figure 3-1, Table 3-1); 150 wells were sampled in Q4 in accordance with the monitoring schedule shown in Table 3-2.

Throughout this report, GWM wells, and their associated groundwater data, are described based on reference elevation intervals (REIs). REIs are below ground surface elevations that divide the GWM network into datasets comprised of wells that are screened across their respective elevations, allowing for a vertical evaluation of groundwater parameters and contaminant locations (Figure 3-2). Currently, there are three REIs (4857, 4838, and 4814). A detailed explanation of how the REIs are defined is presented in the Q4 2016 Quarterly and Annual Report (USACE, 2017e).

In previous reports, GWM wells were assigned designations based either on their location related to the groundwater gradient and their spatial relationship to the dissolved-phase EDB or simply on their location (i.e., source area, etc.). However, due to the changing regional groundwater gradient (Q2 2018 Quarterly Monitoring Report [USACE, 2018b]), these designations may no longer be appropriate or meaningful. In order to present analytical data and data summaries conveniently at the project scale, all GWM wells will hereafter be designated simply as "groundwater monitoring well," except for newly added wells (which includes any newly installed wells), and the presentation of analytical data will be centered on analytes as opposed to former well designation. The former well designations and monitoring well objective are provided in Table 3-1 along with the current sampling regime by quarter. A brief description of the former well designations and the frequency of samples collected by designation is provided below.

Newly Added Wells—Newly added wells include both existing wells that are added to the GWM network as well as newly installed wells that have not completed four quarters of baseline sampling. Newly added GWM wells require a minimum of four consecutive quarters of baseline full-suite analytical sampling before receiving a designation that determines the long-term sampling regime. These wells have been added to define the plume boundary and provide additional water table monitoring due to the rising groundwater elevation.

Source Area Wells—Primarily located in the BFF south of Randolph Road SE and proximal to the spill site on-Base. Sampled during Q2 and Q4. These wells monitor the higher concentrations of dissolved-phase contaminants on-Base.

Downgradient Proximal Wells—Located north of Ridgecrest Drive SE surrounding the historical low concentration dissolved-phase EDB to the west, north, and east into the distal portion of the GWM network. Analytical data for these wells have been historically below the maximum contaminant level (MCL) for EDB. Sampled every quarter. These wells assist in plume boundary definition.

Veterans Affairs (VA) Proximal Wells—Three sets of nested wells located between the historical dissolved-phase EDB south of Ridgecrest Drive SE and the Raymond G. Murphy VA Medical Center as a means to detect any potential contaminant migration toward the VA medical campus. Sampled every quarter. These wells provide additional wellhead protection monitoring for the VA supply well.

Signal Wells—Three wells located along the south side of Ridgecrest Drive SE to monitor benzene, toluene, ethylbenzene, and total xylenes (BTEX) and provide early indication if theses dissolved-phase constituents are migrating from the source area into the interim measure Target Capture Zone. Sampled during Q2 and Q4.

GWM Wells—Primarily located north of Ridgecrest Drive SE within the historical footprint of the dissolved-phase EDB. Analytical data from these wells serve to define the volume and mass of the dissolved-phase EDB throughout the GWM network. Sampled in Q2 and Q4.

GWM activities included measuring the depths to groundwater and LNAPL (Tables 3-3 and 3-4 and Figures 3-3 through 3-5) and measuring field parameters in wells sampled with low-flow sampling pumps (Table 3-5). Field parameter measurements cannot be accurately obtained from the wells that are sampled using the passive sampling methodology, as discussed in more detail in the Q4 2017 Quarterly and Annual Report (USACE, 2018c). Groundwater samples were collected and submitted for laboratory analysis from all Q4 2018 wells (Tables 3-6 through 3-9 and Figures 3-7 through 3-21).

Appendices pertinent to GWM are listed below:

- E-1 – Daily Quality Control Reports – Groundwater Sampling
- E-2 – Groundwater and LNAPL Measurements
- E-3 – Groundwater Purge Logs and Sample Collection Logs
- E-4 – Groundwater Sample Chain-of-Custody Forms
- E-5 – U.S. Geological Survey (USGS) Sentinel Well Data
- F-1 – Data Quality Evaluation Report – Groundwater Samples
- F-2 – Data Packages – Groundwater Samples.

3.1 New Groundwater Monitoring Activities

Six new data gap well nests were approved for installation in February 2018 (NMED, 2018c) and installed per the Work Plan for Data Gap Monitoring Well Installation (USACE, 2017f); the wells were completed in Q3 and Q4 2018. The nested wells consist of one GWM well screened across (partially above and below) the groundwater table and a second well (contingency well) constructed with the well screen above the current water table elevation. The contingency well will be available to monitor the upper zone of the plume in the future as the water table continues to rise. The six new nested GWM wells are KAFB-106240-449, KAFB-106241-428, KAFB-106242-418, KAFB-106243-425, KAFB-106244-445, and KAFB-106245-460 (Figure 3-1). In addition, KAFB-106246-428 was installed as a replacement contingency well for KAFB-106240-449. Well completion reports and water quality data for KAFB-106241-428, KAFB-106242-418, KAFB-106245-460, and KAFB-106246-428 are provided in Appendix B-1. The well completion reports for the first three completed wells (KAFB-106240-449, KAFB-106243-425, and KAFB-106244-445) were included in the Q3 2018 Quarterly Monitoring Report (USACE, 2018d). All six new well nests were sampled in Q4 2018; analytical data are provided in Section 3.6.

Eleven of the newly added wells had baseline sampling completed in Q4 2018. These wells will be designated as GWM wells and integrated into the long-term sampling regime beginning in Q1 2019.

3.2 Groundwater and Light Non-Aqueous Phase Liquid Gauging

Depth to water was measured in 156 GWM wells between October 8 and 11, 2018 (Figure 3-1; Table 3-3), using a Solinst Model 122 oil-water interface probe, in accordance with the approved work plan (USACE, 2017b). Each well was also checked for the presence of LNAPL. Depth to water in wells KAFB-106063 and KAFB-106064 could not be measured due to the presence of dedicated downhole equipment related to the Environmental Security Technology Certification Program pilot test project for EDB *in situ* biodegradation. Of the 156 GWM wells gauged in Q4 2018, 26 had screens that intersected the current water table while the remaining wells had submerged well screens (Table 3-4 and Figure 3-6). Well screen submergence ranged from 0.4 to 134.8 ft (Table 3-2).

The interface probe was checked for proper operation and cable integrity prior to each use and was decontaminated after gauging each well. If LNAPL was detected using the interface probe, a plastic bailer was used to confirm the presence and thickness of the LNAPL. Additionally, during the sampling using Bennett pumps, every well was checked for the presence of LNAPL. Depths to LNAPL and groundwater were recorded in the field on well gauging forms (Appendix E-2).

Depth to water in the GWM wells was gauged using three different Solinst Model 122 oil-water interface probes (Serial Nos. 253053, 253054, and 253056). Depth to water measurements between the three interface probes was calibrated by measuring depth to water with each interface probe in three GWM wells near the source area. Water level interface probe 253054 was designated as the benchmark instrument as it had the least amount of stretch in the measuring tape. Depths measured using interface probe 253056 varied from the benchmark instrument on average of 0.05 ft while values measured using interface probe 253053 varied an average of 0.07 ft. Depth to water measurements were adjusted by the corresponding average differences based on which instrument was used to measure the depth to water in each well. Appendix Table E-2-1 presents the uncorrected and corrected depth to water measurements for each GWM well and also provides the correction factor applied per well. Depth to water measurements in Tables 3-3 and 3-4 have been corrected based on the calibration method described above.

LNAPL was measured in KAFB-106076, KAFB-106150-484, and KAFB-106154-484 in Q4 2018 at thicknesses of 0.01, 0.11, and 0.04 ft, respectively (Table 3-3 and Figure 3-6). KAFB-106150-484 and KAFB-106154-484 had measurable LNAPL sheens present in Q3 2018 (0.05–0.02 ft) while KAFB-106076 did not have LNAPL present. The three wells with LNAPL in Q4 2018 are located south of Ridgecrest Drive SE on-Base.

Changes in the potentiometric surfaces for the three REIs are provided on Figures 3-3, 3-4, and 3-5, respectively; potentiometric surfaces are provided on Figures 5-4, 5-5, and 5-6. Groundwater levels showed an overall average increase across the GWM network of 0.19 ft since Q3 2018, with a maximum increase of 1.39 ft in KAFB-106092 and KAFB-106229, both located north of extraction well KAFB-106233. The maximum decrease in groundwater level from Q3 2018 to Q4 2018 was 0.57 ft observed in KAFB-106030 located northwest of KAFB-106233. Twenty-six GWM well screens spanned the current water table, which is consistent with the previous quarter.

3.3 Groundwater Sampling

Quarterly groundwater samples were collected from 150 wells in the GWM network between October 1 and November 13, 2018 using dedicated and portable low-flow pump systems or passive sampling methods (Table 3-2). Well locations are shown on Figure 3-1. All groundwater samples collected for the Q4 2018 monitoring event were analyzed for EDB, VOCs, including BTEX, metals, anions, and alkalinity (Table 3-2). All groundwater samples were analyzed by Eurofins Lancaster Laboratories Environmental, LLC located in Lancaster, Pennsylvania, which maintains current Department of Defense Environmental Laboratory Accreditation Program certification. The groundwater purge and sampling forms are provided in Appendix E-3 and the chain-of-custody forms are provided in Appendix E-4.

For low-flow sampling, well water was purged continuously at a flow rate between 0.5 and 1 liter per minute, while field parameters (turbidity, temperature, dissolved oxygen [DO], specific conductivity, pH, and oxidation reduction potential (ORP) were measured and recorded every 5 minutes. Purging continued until parameters stabilized for three consecutive readings within 10% of one another, at which point samples were collected. If stabilization was not attained for any one of the field parameters after

1 hour, samples were collected. Field parameters were recorded on the field forms (Appendix E-3) and are summarized in Table 3-5. To be consistent with previous quarterly sampling events, wells without a dedicated low-flow pump sampling system were designated, based on historical analytical data, as either clean, intermediate, or hazardous. Decontaminated non-dedicated tubing and portable low-flow pumps were used to sample wells designated as clean. The entire sampling assembly was decontaminated following use at each well. Conversely, wells designated as intermediate or hazardous had dedicated tubing that was specific to that well.

Field parameters were not collected from wells that were sampled using passive sampling methods due to the unreliable field parameter data associated with this technology. This is discussed in more detail in the Q2 2017 quarterly report (USACE, 2017g). Field parameters were measured only from wells that were sampled using the low-flow methodology.

3.3.1 Sampling Deviations

None.

3.4 Data Review and Usability Results

The Q4 2018 groundwater analytical data underwent EPA Level 3 data validation by an independent third-party subcontractor. Subsequent to performing data validation, the data qualifiers were uploaded to the EQuIS® project database. Data were further assessed for accuracy, precision, representativeness, comparability, completeness, and sensitivity and determined to achieve the project data quality objectives in Q4 2018. All groundwater data presented and discussed in this report are final validated data. The Environmental Resources Program Information Management System data deliverable is scheduled for submittal on March 3, 2019. The Data Quality Evaluation Report for groundwater samples collected in Q4 2018 is provided in Appendix F-1, and the final laboratory data reports are included in Appendix F-2.

3.5 Project Screening Levels

The project screening levels (PSLs) were selected to satisfy the requirements of the Kirtland AFB RCRA Permit (NMED, 2010) as the lower of:

- New Mexico Water Quality Control Commission (NMWQCC) standards per the New Mexico Administrative Code, Title 20.6.2.3103, Standards for Groundwater of 10,000 milligrams per liter (mg/L) Total Dissolved Solids Concentration or Less (New Mexico Administrative Code, 2004). For metals, the NMWQCC standard applies to dissolved metals and total mercury.

- EPA National Primary Drinking Water Regulations, MCLs and secondary MCLs, and Title 40 Code of Federal Regulations (CFR) Part 141, 143 (EPA, 2017).

If no MCL or NMWQCC standard existed for an analyte, the PSL used was the EPA Tapwater Regional Screening Level (EPA, 2017).

The analytical method utilized to analyze for total nitrate/nitrite nitrogen concentrations (Method 353.2) cannot identify individual nitrate and nitrite concentrations without modification. Typically, in highly oxidizing and near neutral aquifers, nitrate is the primary nitrogen species found in groundwater (Langmuir, 1997). Previous studies in the Albuquerque Basin have used total nitrate/nitrite nitrogen concentrations as equivalent to nitrate nitrogen concentrations (Longmire, 2016; Anderholm et al., 1995).

Therefore, total nitrate/nitrite nitrogen concentrations were compared to the 10 mg/L MCL for nitrate in this report.

Groundwater MCLs or PSLs for all analytes are provided in the groundwater analytical data tables included in this report.

3.6 Groundwater Quality Data

All groundwater samples collected for the Q4 2018 monitoring event were analyzed for EDB, VOCs, total metals (arsenic, lead, calcium, magnesium, potassium, and sodium), dissolved metals (iron and manganese), anions (bromide, chloride, sulfate, and nitrate/nitrite nitrogen), and alkalinity (Table 3-2). Alkalinity, sulfate, dissolved iron, and dissolved manganese concentrations provide direct and indirect evidence of anaerobic conditions and thus are important indictors of bioremediation (Section 3.6.5). Contaminant concentrations were compared to their respective MCLs or PSLs and are discussed in the following sections. The analytical results for field duplicate samples are presented in the tables and were used to assess field and laboratory analytical precision. However, field duplicate results are not discussed in this text for comparison purposes unless otherwise noted and duplicate data are not provided on figures. The results for the duplicate sample analyses are included in the Data Quality Evaluation Report (Appendix F-1).

The status of baseline sampling of newly added wells is provided in Table 3-6. Analytical data for the newly added wells is provided in Table 3-7 and data for GWM wells is provided in Table 3-8.
In Q4 2018, the extent of dissolve-phase benzene was modeled three-dimensionally for the first time using the same methodology that is employed for dissolved-phase EDB modeling (C-Tech MVS Premier software). As a result, the dissolved-phase benzene is presented for each of the three REIs similar to EDB. Concentrations for various compounds are depicted on figures as listed below.

- EDB on Figures 3-7, 3-8, and 3-9 for REIs 4857, 4838, and 4814, respectively
- Benzene on Figures 3-10, 3-11, and 3-12 for REIs 4857, 4838, and 4814, respectively
- Toluene on Figure 3-13
- Ethylbenzene on Figure 3-14
- Total xylenes on Figure 3-15
- Total alkalinity on Figure 3-16
- Nitrate/nitrite nitrogen on Figure 3-17
- Sulfate on Figure 3-18
- Bromide on Figure 3-19
- Dissolved iron on Figure 3-20
- Dissolved manganese on Figure 3-21
- DO on Figure 3-22
- ORP on Figure 3-23
- Acetone on Figure 3-24.

3.6.1 Organic Compounds Analytical Results

3.6.1.1 EDB Analytical Results

EDB analytical results are presented in Tables 3-7 and 3-8, and on Figures 3-7, 3-8, and 3-9.

- Eighteen newly added wells were sampled in Q4 2018 (Figure 3-1). KAFB-106229 was sampled in Q4 2018 but is not formally part of the GWM network and not subject to four quarters of baseline sampling. However, analytical results from KAFB-106229 are presented along with the newly added wells in this report.

- EDB was detected in groundwater samples collected from seven of the 18 newly added wells. All of the newly added wells are screened in REI 4857 (Figure 3-2).

- EDB was detected in two of the newly installed data gap wells (KAFB-106241-428 and KAFB-106243-425) below the MCL of 0.05 µg/L (estimated 0.022 and 0.0.18 µg/L, respectively).

- Samples from KAFB-106149-484 and KAFB-106153-484 (both in the BFF) were the only EDB exceedances (34 and 300 µg/L, respectively) of 0.05 µg/L MCL in newly added wells.

- EDB was detected in groundwater samples collected from 40 of the 150 GWM wells sampled in Q4; 19 of those samples exceeded the 0.05 µg/L MCL.

- Of the 19 total EDB exceedances, 16 were in REI 4857, six in REI 4838, and none detected in REI 4814. Three of the exceedances occurred in wells that are screened in both REI 4857 and 4838.

- Six of the EDB exceedances were from wells that are north of Ridgecrest Drive SE. The highest EDB concentrations north of Ridgecrest Drive SE were detected in the groundwater samples collected from KAFB-106036 (0.19 µg/L) and KAFB-106225 (0.17 µg/L); both of those GWM wells are near extraction wells (KAFB-106228 and KAFB-106234, respectively) (Figures 3-7, 3-8, and 3-9).

- Thirteen of the EDB exceedances were from wells that are south of Ridgecrest Drive SE and nine of those were on-Base in the immediate vicinity or within the BFF. The highest EDB concentrations south of Ridgecrest Drive SE were detected in the groundwater samples collected from newly added wells KAFB-106153-484 and KAFB-106149-484 (300 and 34 µg/L, respectively, [on-Base, in the BFF]).

3.6.1.2 Volatile Organic Compound Analytical Results

VOC analytical results are presented in Tables 3-7 and 3-8, and on Figures 3-10 through 3-15.

- Benzene was detected in groundwater samples collected from three of the 18 newly added wells in the source area; all three exceeded the 5 µg/L MCL: KAFB-106149-484 (11,000 µg/L), KAFB-106152-484 (71 µg/L), and KAFB-106153-484 (4,700 µg/L). Benzene was not detected in any newly added wells off-Base.

- Toluene was detected in groundwater samples collected from three of the 18 newly added wells in the source area; two exceeded the 750 µg/L PSL: KAFB-106149-484 (16,000 µg/L) and KAFB-106153-484 (1,400 µg/L). Toluene was not detected in any newly added well off-Base.

- Ethylbenzene was detected in groundwater samples collected from three of the 18 newly added wells in the source area; one detection (KAFB-106149-484 [880 µg/L]) exceeded the 700 µg/L PSL. Ethylbenzene was not detected in any newly added well off-Base.

- Xylenes, total was detected in groundwater samples collected from three of the 18 newly added wells in the source area; one detection (KAFB-106149-484 [3,400 µg/L]) exceeded the 620 µg/L PSL. Xylenes, total was not detected in any newly added well off-Base.

- Naphthalene was detected at concentrations above the 30 µg/L PSL in groundwater samples collected from two of the 18 newly added wells in the source area; KAFB-106149-484 (150 µg/L) and KAFB-106153-484 (220 µg/L).

- Detections of 1,2-dichloroethane, 1,2,4-trimethylbenzene, or 2-hexanone were detected above their respective PSLs in newly added wells KAFB-106149-484 and KAFB-106153-484 located in the source area.

- Benzene was detected in groundwater samples collected from 22 of the 150 GWM wells; 16 exceeded the 5.0 µg/L MCL. Of the benzene exceedances, 13 were in REI 4857, and three in REI 4838; all exceedances were south of Ridgecrest Drive SE. The highest benzene concentration was detected in KAFB-106059 (17,000 µg/L) in the source area.

- Toluene was detected in groundwater samples collected from 30 of the 150 GWM wells; eight exceeded the 750 µg/L PSL. Of the toluene exceedances, seven were in REI 4857, and one was in REI 4838; all exceedances were south of Ridgecrest Drive SE. The highest toluene concentrations were detected in KAFB-106059 and KAFB-106063 located south of Randolph Road SE at 20,000 µg/L each. Toluene concentrations in REI 4857 are presented on Figure 3-13.

- Ethylbenzene was detected in groundwater samples collected from 16 of the 150 GWM wells; five exceeded the 700 µg/L PSL. Of the exceedances, four were in REI 4857, and one was in REI 4838; all exceedances were south of Ridgecrest Drive SE. The highest ethylbenzene concentration was detected in KAFB-106063 (2,000 µg/L) and KAFB-106028 (1,400 µg/L). Ethylbenzene concentrations in REI 4857 are presented on Figure 3-14.

- Xylenes, total were detected in groundwater samples collected from 14 of the 150 GWM wells; six exceeded the 620 µg/L PSL. Of the xylenes, total PSL exceedances, all were in REI 4857 and south of Ridgecrest Drive SE. The highest xylenes, total concentration was detected in KAFB-106063 (5,700 µg/L). Xylenes, total concentrations in REI 4857 are presented on Figure 3-15.

- Naphthalene was detected at concentrations above the 30 µg/L PSL in groundwater samples collected from five GWM wells; the highest naphthalene concentration was detected in KAFB-106153-484 (220 µg/L) in the source area.

- 1,2,4-trimethylbenzene was detected at concentrations above the 56 µg/L PSL in groundwater samples collected from five GWM wells; the highest 1,2,4-trimethylbenzene concentration was detected in KAFB-106153-484 (220 µg/L) in the source area.

- 1,2-dichloroethane was detected at concentrations above the 5 µg/L PSL in groundwater samples collected from four GWM wells; the highest 1,2-dichloroethane concentration was detected in KAFB-106008 (12 µg/L) in the source area.

- 2-hexanone was detected at concentrations above the 38 µg/L PSL in groundwater samples collected from seven GWM wells; the highest 2-hexanone concentration was detected in KAFB-106153 (910 µg/L) in the source area.

- Methylene chloride was detected at concentrations above the 5 µg/L PSL in groundwater samples collected from one GWM wells; the one methyl chloride exceedance concentration was detected in KAFB-106064 (7 µg/L) south of Randolph Road SE.

- VOCs 1,1-dichloroethane, 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, 1,3,5-trimethylbenzene, 2-butanone, 2-chlorotoluene, 4-Isopropyltoluene, 4-methyl-2-pentanone, acetone, bromodichloromethane, carbon disulfide, chloroform, chloromethane, dichlorodifluoromethane, hexachloro-1,3-butadiene, isopropylbenzene, m,p-Xylene, methyl tert-butyl ether, n-Butylbenzene, n-propylbenzene, sec-butylbenzene, tert-butylbenzene, tetrachloroethene, and trichloroethene were detected in groundwater samples collected from various GWM wells in the source area; however, none exceeded their respective PSL (Tables 3-7 and 3-8).

3.6.2 Inorganic Compounds Analytical Results

Inorganic compounds include total alkalinity, nitrate/nitrite nitrogen, sulfate, bromide, and dissolved iron and manganese. Inorganic analytical results are presented in Tables 3-7 and 3-8, and on Figures 3-16 through 3-21.

- Total alkalinity was detected in groundwater samples collected from all 18 newly added wells, however, there is no PSL. Alkalinity concentrations in REI 4857 are presented on Figure 3-16.

- Sulfate was detected in groundwater samples collected from all 18 newly added wells; three exceeded the 250 mg/L PSL. The highest sulfate concentration was detected at a concentration of 413 mg/L, in the groundwater samples collected from KAFB-106151-484. Sulfate concentrations in REI 4857 are presented on Figure 3-18.

- Bromide was detected in groundwater samples collected from four of the 18 newly added wells. There is no PSL for bromide. Bromide concentrations in REI 4857 are presented on Figure 3-19.

- Dissolved iron was detected in groundwater samples collected from four of the 18 newly added wells; none exceeded the 1 mg/L PSL. Dissolved iron concentrations in REI 4857 are presented on Figure 3-20.

- Dissolved manganese was detected in groundwater samples collected from 11 of the 18 newly added wells; two exceeded the 0.2 mg/L PSL (KAFB-106152-484 [1.33 mg/L] and KAFB-106243-425 [0.777 mg/L]). Both exceedances were in REI 4857. Dissolved manganese concentrations in REI 4857 are presented on Figure 3-21.

- Total alkalinity was detected in groundwater samples collected from all GWM wells; however, there is no established PSL. Alkalinity concentrations in REI 4857 are presented on Figure 3-16.

- Nitrate/nitrite nitrogen was detected in groundwater samples collected from 99 GWM wells; none exceeded the 10 mg/L PSL. Nitrate/nitrite nitrogen concentrations in REI 4857 are presented on Figure 3-17.

- Sulfate was detected in groundwater samples collected from 146 GWM wells; seven exceeded the 250 mg/L PSL. The highest sulfate concentration was detected at a concentration of 517 mg/L, in the groundwater samples collected from KAFB-106005. Sulfate concentrations in REI 4857 are presented on Figure 3-18.

- Bromide was detected in groundwater samples collected from 22 GWM wells. There is no PSL for bromide. Bromide concentrations in REI 4857 are presented on Figure 3-19.

- Dissolved iron was detected in groundwater samples collected from 25 GWM wells; nine exceeded the 1 mg/L PSL. The three highest iron concentrations were found in KAFB-106061 (9.34 mg/L), KAFB-106063 (7.03 mg/L), and KAFB-106059 (5.59). Exceedances are found within and in the vicinity of the BFF. Dissolved iron concentrations in REI 4857 are presented on Figure 3-20.

- Dissolved manganese was detected in groundwater samples collected from 58 GWM wells; 24 exceeded the 0.2 mg/L PSL. Of the dissolved manganese exceedances, 19 were in REI 4857, seven in REI 4838; three were in wells screened in both intervals. The three highest dissolved manganese concentrations were detected in KAFB-106064 (6.36 mg/L), KAFB-106008 (6.13 mg/L), and KAFB-106080 (5.44 mg/L). Dissolved manganese concentrations in REI 4857 are presented on Figure 3-21.

- Chloride was detected in all groundwater samples collected from GWM wells; concentrations ranged from 4.4 to 212 mg/L at KAFB-106025 and KAFB-106009, respectively. There were no exceedances of the 250 mg/L PSL.

3.6.3 Sampling Results for U.S. Geological Survey Sentinel Wells

The USGS monitors 14 sentinel wells between the Kirtland AFB BFF EDB plume and the Albuquerque Bernalillo County Water Utility Authority water supply wells as a means of providing independent observation of water quality in the vicinity of the Albuquerque Bernalillo County Water Utility Authority water supply wells. Samples are collected from these sentinel wells quarterly. For Q4 2018, these samples were collected using dual membrane samplers during the time period of November 26-29, 2018. The samples were analyzed for VOCs and EDB by the USGS National Water Quality Laboratory (NWQL). NWQL analyzed the sample using method O-4127-96 (Connor and others, 1998). The USGS transmittal letter, including the Q4 2018 data results and an updated Q3 2018 data summary table, is provided in Appendix E-5.

3.6.4 Field Parameters

Field parameters were collected for the 61 wells south of Ridgecrest Drive sampled using the low-flow sampling method. Field parameter data are presented in Table 3-5.

- Groundwater temperatures ranged from 14.5 to 20.6 degrees Celsius in KAFB-106066 and KAFB-3411, respectively.

- Sample pH ranged from 6.63 to 8.17 in KAFB-106064 and KAFB-106027, respectively, with a mean of 7.6.

- Specific conductivity ranged from 230.2 to 1245 microSiemens per centimeter (µS/cm) in KAFB-106006 and KAFB-106080, respectively.

- DO ranged from an anaerobic value of 0.1 mg/L (KAFB-106063 and KAFB-106064) to a nearly atmospheric value of 8.32 mg/L at KAFB-106003.

- ORP ranged from -242.5 to 229.4 mV in KAFB-106028 and KAFB-106047, respectively.
- Turbidity ranged from 0.2 to 129.0 nephelometric turbidity units in KAFB-106097 and KAFB-106020, respectively.

3.6.5 Bioremediation Indicators

Alkalinity, sulfate, dissolved iron, and dissolved manganese concentrations provide direct and indirect evidence of subsurface conditions impacted by microbial activities.

Changed alkalinity and dissolved metals concentrations relative to “background” are often associated with biological activity, as carbon dioxide respiration is a common component of many microbiological systems. The associated carbonate system is complex and can respond differently to dissolved carbon dioxide depending on initial pH. The dissolution of minerals would be associated with dissolved carbon dioxide reacting with water to express the activity of the hydronium ion (pH) as carbonic acid. The highest total alkalinity measurements are observed collocated with the dissolved-phase benzene. Wells situated outside of the dissolved-phase benzene extent had total alkalinity concentrations more similar to one another as compared to those within the plume (Figure 3-16).

Decreased concentrations of nitrate/nitrite nitrogen and sulfate are often associated with microbial activity. Nitrogen is incorporated into microbial biomass and sulfate/ sulfite transitions can be used as an energy bank by some microorganisms. Generally, lower concentrations of nitrate/nitrite nitrogen and sulfate were observed near the source area and the near dissolved-phase benzene, with the notable exceptions of KAFB-106005, and KAFB-106009, which had the highest sulfate (517 mg/L) and nitrogen (8.6 mg/L) levels recorded in Q4 2018, although not the highest historically reported in that well. An investigation by Kirtland AFB found that nearby sewer lines are intact, while a junction manhole may have been a source of sanitary waste release to the subsurface. A replacement manhole was installed in Q4 2017. Nitrogen levels in the area have been decreasing significantly since Q4 2017 and are now detected only in KAFB-106009 slightly below the MCL, while sulfate levels have remained fairly consistent to concentrations measured prior to the manhole replacement in Q4 2017.

In REI 4857, the PSL exceedances for dissolved iron and manganese were clustered in the vicinity of the dissolved-phase benzene (Figures 3-20 and 3-21, respectively). The combination of elevated alkalinity and dissolved metals concentrations is likely associated with increased microbial degradation of organics in the benzene plume, resulting in the creation of anaerobic conditions. Aerobic microorganisms require the presence of DO to effectively break down organic compounds found in the environment. Decreased DO and ORP can be indicators of microbial degradation of HC in the subsurface.

Dissolved-phase acetone was detected or estimated in groundwater samples collected from 10 GWM wells, at concentrations above 10 µg/L with a maximum concentration of 1,200 µg/L, significantly below the 14,000 µg/L PSL (Figure 3-24). Numerous detections of acetone at locations where acetone has never been detected and at concentrations below the reported detection limit, with no contamination of QC samples, suggests laboratory contamination (Appendix F-1). Transient production of acetone is generally correlative to anoxic to methanogenic environments. It is assumed that acetone production transpires before the system becomes fully anaerobic (Mueller, 2011). The presence of acetone generally coincides with the DO and ORP trends that are observed in the source area (Figures 3-22 and 3-23). The dissolved-phase acetone extent has been persistent in the source area (Q4 2017 Quarterly and Annual Report [USACE 2018c]), although somewhat variable in particular wells (i.e., concentrations were not detected consistently in specific wells). Due to the reported half-life of acetone of 19-197 days (Mueller, 2011), the persistence of the compound would indicate an active, continuing bioremediation signature.

3.7 Groundwater Gauging and Monitoring Annual Summary

3.7.1 Annual Time-Series Analysis of Groundwater Elevations and Light Non-Aqueous Phase Liquid Thicknesses

Groundwater levels continued to rise throughout the GWM network over the course of the year from Q4 2017 to Q4 2018. The average increase in groundwater level during the year was 1.79 ft. The average annual rise in water table in 2017 was 1.3 ft, and the calculated annual average of water table rise from Q1 2016 through Q4 2018 was 1.61 ft. The maximum observed increase in groundwater level in between Q4 2017 and Q4 2018 was 3.39 ft observed in KAFB-106092; the minimum observed increase in groundwater level for the same time period was 0.2 ft observed in KAFB-106202. Water level hydrographs for select wells are provided in Appendix L-2 and all groundwater and LNAPL elevations for 2018 are provided in Appendix K-3.

In 2018, the limited extent of floating fuel on the water table (i.e., LNAPL) was restricted to four out of the 156 wells that are gauged quarterly. These four wells are located on-Base in the source area. All GWM wells are gauged quarterly and evaluated for LNAPL as a precaution. KAFB-106063 and KAFB-106064 were not gauged in Q4 2018due to downhole equipment associated with the *in situ* biodegradation pilot study (Section 5.5). However, nearby pilot study wells remained free of LNAPL during 2018. KAFB-106150-484 and KAFB-106154-484 had consistent measurable LNAPL present throughout 2018; the thickness of the LNAPL increased in both wells (0.08 and 0.02 ft increases respectively). KAFB-106076 and KAFB-106079 had measurable LNAPL present intermittently throughout 2018. The LNAPL thickness in KAFB-106076 remained the same between Q1 and Q4 2018 (0.01 ft), though it was not detectable in Q2 2018. The LNAPL thickness in KAFB-106079 decreased from 0.02 ft in Q1 2018 to not detectable in Q4 2018.

3.7.2 Annual Analysis of Analytes in Groundwater

This section discusses general trends and observations for organic and inorganic compounds throughout the GWM network from Q4 2017 to Q4 2018. A detailed analysis and discussion of the mass and volume of the dissolved-phase EDB within the Target Capture Zone were conducted using modeling and are presented in the performance assessment in Section 5.4.

A discussion of the notable changes observed in both organic and inorganic compounds is provided in the subsections below. Analytical data and gauging information for all wells sampled in 2018 are provided in Appendices K-2 and K-3. Historical groundwater analytic trends for KAFB-106005, KAFB-106009, and KAFB-106012R are provided in Appendix L-3.

3.7.2.1 Annual Analysis of EDB in Groundwater

The configuration of the dissolved-phase EDB changed notably in the Target Capture Area north of Ridgecrest Drive between Q4 2017 and Q4 2018, primarily due to decreases in EDB concentrations below the 0.05 µg/L MCL between extraction well KAFB-106228 and KAFB-106234; specifically, in KAFB-106041 (EDB decreased from 0.058 to 0.013 µg/L) and KAFB-106055 (EDB decreased from 0.082 to 0.020 µg/L.) Additionally, decreasing concentrations in KAFB-106086 (EDB decreased from 0.05 µg/L to nondetect) and KAFB-106022 (EDB decreased from 0.067 to 0.038 µg/L) below the MCL along with the newly added water table well KAFB-106243-425 EDB concentration of 0.018 estimated, divided the plume into two small areas and a small protrusion north of Ridgecrest Drive SE.

Wells in the Target Capture Area where EDB concentrations decreased from above the 0.05 µg/L MCL to below the MCL as follows:

- KAFB-106086: EDB decreased from 0.05 µg/L to nondetect
- KAFB-106055: EDB decreased from 0.082 to 0.020 µg/L
- KAFB-106022: EDB decreased from 0.067 to 0.038 µg/L
- KAFB-106226: EDB decreased from 0.33 to nondetect µg/L
- KAFB-106041: EDB decreased from 0.058 to 0.013 µg/L
- KAFB-106225: EDB decreased from 0.57 to 0.17 (not below MCL) µg/L.

KAFB-106225 is the only well in the dissolved-phase EDB distal region hat had a detection of EDB that exceeded the 0.05 µg/L MCL in Q4 2018 (0.17 µg/L). KAFB-106225 has an unsubmerged screen and is in direct proximity to extraction well KAFB-106234. This proximity to the extraction well is most probably the reason for the continued presence of EDB in KAFB-106225. EDB contaminated water passes through KAFB-106225 prior to being extracted and treated by the GWTS, resulting in isolated EDB detections above the MCL in KAFB-106225 in contrast to wells in the surrounding area. However, EDB concentrations in KAFB-106225 are also decreasing as the mass of EDB remaining decreases. EDB in KAFB-106225 has decreased from 0.70 to 0.57 to 0.17 µg/L between Q4 2016, 2017, and 2018 respectively. The same effect is observed near extraction well KAFB-106228, resulting in an "island" of EDB in wells surrounding the extraction well.

Wells in the Target Capture Area where EDB slightly increased from below the 0.05 µg/L MCL to above the MCL are as follows:

- KAFB-106085: EDB concentrations increased from nondetect to 0.054 µg/L. The nondetect for EDB in Q4 2017 was the first nondetect in KAFB-106085. Prior to that, the concentration was above the MCL, then decreased to nondetect in Q4 2017.

The largest decreases in EDB concentrations in wells in or in the vicinity of the BFF included:

- KAFB-106010: EDB decreased from 8.1 to 2.1 µg/L
- KAFB-106059: EDB decreased from 5.9 to 2.7 µg/L
- KAFB-106079: EDB decreased from 0.21 to 0.011 µg/L.

The largest decrease in EDB concentrations between Q4 2017 and Q4 2018 was in KAFB-106064 (on-Base in the vicinity of the BFF and part of the *in situ* bioremediation project): EDB decreased from 62 to 0.25 µg/L.

The largest increases in EDB concentration in wells in or in the vicinity of the BFF included:

- KAFB-106008: EDB increased from 4.1 to 20 µg/L
- KAFB-106063: EDB increased from nondetect to 3.6 µg/L
- KAFB-106028: EDB increased from 10 to 13 µg/L.

EDB concentrations in these three wells fluctuated in 2018. From Q4 2017 to Q2 2018, the EDB concentration in all three wells decreased, then from Q2 to Q4 2018 increased as stated above.

3.7.2.2 Annual Analysis of BTEX in Groundwater

BTEX analytical results for groundwater samples collected from GWM wells did not vary significantly from Q4 2017. Although some intra-well concentrations of BTEX fluctuated from Q4 2017 to Q4 2018, the extent of the dissolved-phase BTEX constituents have not moved over time (Figure 3-10). The maximum benzene concentration in Q4 2018 was 17,000 µg/L in the sample collected from KAFB-1060059, which is an increase from 15,000 µg/L in Q4 2017; KAFB-106059 is in the source area.

3.7.2.3 Annual Analysis of Inorganic Compounds in Groundwater

Inorganic compounds analyzed from groundwater samples collected from through the GWM network varied from Q4 2017; both increasing and decreasing concentrations were observed. Of particular note were the following:

- Dissolved Iron:
  - As shown in Figure 3-20, the dissolved-phase iron lateral extent has been stable since Q4 2017; not extending into the Target Capture Zone north of Ridgecrest Drive SE. The concentrations of dissolved iron have decreased north of Randolph Road SE and the maximum iron concentrations remain in the BFF source area and in particular in the *in situ* bioremediation pilot test area.

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- Dissolved Manganese:
  - As shown in Figure 3-21, the dissolved-phase manganese lateral extent appears to have increased to the east-northeast approximately 750 ft north of Ridgecrest Drive SE since Q4 2017 into the Target Capture Zone based on data from a new well KAFB-106243-425. This value will require confirmation is subsequent baseline monitoring events. The concentrations of dissolved manganese are increasing south of Randolph Road SE with the maximum manganese concentrations in the BFF source area and in particular in the *in situ* bioremediation pilot test area.

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- Nitrate/Nitrite Nitrogen:
  - Nitrogen concentrations (Figure 3-17) remained fairly consistent throughout the GWM network between Q4 2017 and Q4 2018. Of particular note was the decrease in KAFB-106009 from 10.6 to below the 10 mg/L MCL (8.6 mg/L). KAFB-106009 is located in the vicinity of a sewer leak that was repaired in Q4 2017 (Section 3.6.5). With this decrease, there were no detections above the 10 mg/L MCL anywhere in the GWM network.

- Sulfate:
  - With the decrease in sulfate concentrations (Figure 3-18) in KAFB-106029 from above the 250 mg/L PSL (329 mg/L in Q4 2017) to below the PSL (154 mg/L in Q4 2018), there remains only one exceedance north of Ridgecrest Drive SE (KAFB-106049, estimate 418 mg/L). There were four exceedances on-Base and two new exceedances in newly added wells KAFB-105240-449 and KAFB-106244-445. While the off-Base wells upgradient of the dissolved sulfate concentrations have not changed, the extent of the dissolved sulfate boundary near these wells has been extended in the upgradient direction based on the new spatial data provided by wells KAFB-106240-449 and KAFB-106244-445.

3.8 Groundwater Monitoring Well Network Operation and Maintenance

The GWM well network was inspected between October 7 and December 6, 2018 to ensure that the condition of all protective covers and wellheads met the intended requirements for performance and security. During the inspection period, the necessary cleaning and maintenance were performed and all GWM wells were determined to be fully serviceable.

In addition to the required maintenance activities, total depths of the GWM well network were measured. Measurements indicate that all wells still have substantial screen lengths available, and that sampling methods and sample integrity are not impacted by any accumulated sediment in the bottom of the wells.

As of the end of Q4 2018, EA Engineering, Science, and Technology, Inc., PBC (EA) had removed 87 dedicated Bennett pumps from the GWM well network. One dedicated Bennett pump (KAFB-106095) was removed during Q4 2018 and subsequently sampled using a portable Bennett pump sampling system (Figure 3-25). Although several wells are sampled using portable Bennett pumps, ongoing issues with this sampling system continue to arise due to corrosion of components and mechanical failure due to aging parts.

4. DRINKING WATER SUPPLY WELL MONITORING

Three drinking water supply wells (KAFB-003, KAFB-015, and KAFB-016) provide drinking water to on-Base employees and tenants of Maxwell Housing, which is located off-Base. One drinking water supply well (ST106-VA-2) provides drinking water to VA Medical Center patients, employees, and visitors. These drinking water wells are community water systems that are regulated by the NMED Drinking Water Bureau in accordance with the Safe Drinking Water Act.

As part of the monitoring associated with the BFF site, these wells are sampled monthly and analyzed for EDB and BTEX due to their proximity to the BFF plume containing dissolved-phase EDB and benzene. Additionally, in Q4 2018, all four wells were sampled for inorganic constituents including select total and dissolved metals, anions, and alkalinity as part of the scheduled semiannual monitoring.

4.1 Drinking Water Supply Well Sampling and Analysis Procedures

All field measurements, sample collection, packaging, shipping, and analyses were performed in accordance with the Vadose Zone Coring, Vapor Monitoring, and Water Supply Sampling Work Plan and associated Quality Assurance Project Plan (USACE, 2017b). Field DO, pH, ORP, conductivity, and temperature measurements were measured using an YSI Professional Plus multiparameter water quality probe; turbidity was measured using a Hach 2100Q. Instrument calibrations were performed at the start of each day of the sampling event to ensure accurate readings. The sample port at each drinking water well head was opened for 60 seconds prior to sampling to purge any entrained sediment. Volatile organic analysis samples were collected first prior to collecting inorganic parameter samples. Upon filling, the sample containers were immediately sealed, checked for headspace bubbles, labeled, and put into an iced cooler. Daily quality control reports are presented in Appendix G-1. Completed sample collection logs and chain-of-custody forms are presented in Appendix G-2.

Drinking water supply samples were collected and submitted for the following analyses:

- EDB using EPA Method 504.1
- BTEX using EPA Method 524.2.

Samples were submitted to TestAmerica Laboratories in Savannah, Georgia, for analytical testing. Analytical results were validated by Environmental Data Services, Ltd. The Data Quality Evaluation Reports are included in Appendix H-1. The TestAmerica Laboratories Analytical Reports for October, November, and December 2018 are included in Appendix H-2.

In addition, semi-annual water samples were collected in October 2018, and analyzed for the following inorganic parameters:

- Total metals (calcium, magnesium, potassium, and sodium) using EPA Method 6010C
- Dissolved metals (iron and manganese) using EPA Method 6010C
- Total metals (arsenic and lead) using EPA Method 6020A
- Anions (bromide, chloride, and sulfate) using EPA Method 300.0A
- Anions (nitrate/nitrite nitrogen) using EPA Method 353.2
- Ammonia nitrogen using Standard Method (SM) 4500NH3B/C
- Sulfide using SM4500S2CF
- Alkalinity-bicarbonate/carbonate using SM2320B.

Inorganic parameter samples collected were submitted to Eurofins Lancaster Laboratories Environmental, LLC for analytical testing. The Data Quality Evaluation Reports and data packages are presented in Appendices F-1 and F-2, respectively.

4.2 Data Review and Usability

Environmental Data Services, Ltd. performed a 100% Level 3 data validation for Q4 2018 organic and inorganic compound analytical data. All data were valid based on necessary criteria, and no data were qualified as rejected. The technical data completeness was 100%. The data met data quality objectives and were appropriate for use in project decision-making. The quality control parameter and data quality indicators (precision, bias [accuracy], representativeness, comparability, completeness, and sensitivity) evaluation results are provided in the Data Quality Evaluation Report and Data Validation Report presented in Appendix H-1 for organic and inorganic compounds. Final validated data are presented in Table 4-1.

4.3 Drinking Water Supply Well Water Quality for Q4 2018

The collected data were compared to drinking water MCLs and Secondary MCLs. The MCLs for drinking water supply wells are established in the EPA National Primary Drinking Water Regulations, MCLs and Secondary MCLs, Title 40 CFR Parts 141 and 143 (EPA, 2017). Analytical results for October, November, and December 2018 are presented in Table 4-1, Figure 4-1, and Appendix H-2. All four wells continue to show no detectable concentrations of EDB or BTEX in the drinking water that is supplied to Kirtland AFB employees and tenants and VA Medical Center patients, employees, and visitors.

All inorganic compounds detected in the samples collected from drinking water supply wells KAFB-003 and ST106-VA-2 were below their respective EPA MCL. The arsenic concentrations detected in the samples collected from KAFB-015 and KAFB-016 in October 2018 were 0.0161 and 0.0233 mg/L, respectively, which both exceeded the MCL of 0.01 mg/L. These arsenic concentrations are consistent with naturally occurring arsenic observed in the Albuquerque Basin (Bexfield and Plummer, 2003). Consequently, Kirtland AFB operates an arsenic compliance system to ensure that arsenic concentrations in the Kirtland AFB drinking water supply do not exceed drinking water criteria (Kirtland AFB, 2003). All other inorganic compounds in KAFB-015 and KAFB-016 were detected at concentrations below their respective MCLs.

4.4 Drinking Water Supply Well Water Quality Annual Summary

The four drinking water supply wells (KAFB-003, KAFB-015, KAFB-016, and ST106-VA-2) were sampled monthly for EDB and BTEX from January through December 2018. All samples were nondetect for EDB and BTEX. Analytical results for 2018 are provided in Appendix K-4.

The four drinking water supply wells were also sampled for inorganic compounds in April and October 2018. All inorganic compounds detected in drinking water supply wells KAFB-003 and ST106-VA-2 were below their respective MCLs for both sampling events. Arsenic was detected in samples collected from KAFB-015 and KAFB-016 that exceeded the MCL of 0.01 mg/L in both April and October 2018; drinking water samples from KAFB-015 had arsenic concentrations of 0.0178 and 0.0161 mg/L in April and October, respectively; and KAFB-016 had concentrations of 0.0253 and 0.0233 mg/L in April and October, respectively. As noted above, these arsenic concentrations are consistent with naturally occurring arsenic observed in the Albuquerque Basin (Bexfield and Plummer, 2003) and Kirtland AFB operates an arsenic compliance system to ensure that the drinking water supply does not exceed drinking water criteria (Kirtland AFB, 2003).

5. GROUNDWATER TREATMENT SYSTEM OPERATION AND PERFORMANCE

This section presents Q4 2018 and annual summaries of the GWTS operation, evaluation metrics, expansion and maintenance, and plume capture evaluation.

5.1 Groundwater Treatment System Operation

The GWTS is part of the interim measure performed pursuant to the corrective action provisions in Kirtland AFB's RCRA Permit to collapse and treat the dissolved-phase EDB that extends north of Ridgecrest Drive SE 3,650 ft to the northwest. It was operated during Q4 2018 to treat groundwater extracted from the distal portion of the plume north of Ridgecrest Drive SE. The GWTS is comprised of four extraction wells (KAFB-106228, KAFB-106233, KAFB-106234, and KAFB-106239), conveyance piping, a dual train 800-gallon per minute (gpm) capacity carbon treatment system located within the GWTS building, and effluent conveyance lines discharging to either the Tijeras Arroyo Golf Course main pond (GCMP) or gravity-fed injection well KAFB-7 (Figure 5-1).

In addition to the operational procedures outlined in the Operations and Maintenance Plan (USACE, 2016b; USACE, 2017d, USACE, 2018a), the GWTS is also subject to the terms of a Class V Underground Injection Well Discharge Permit (DP) No. 1839 (NMED, 2017f) for injecting treated groundwater to KAFB-7. The DP became effective on April 28, 2017. The requirements associated with the conditions of the DP and the location of reporting requirements in this report are summarized in Table 5-1.

5.1.1 Groundwater Treatment System Treatment Volumes and Percentage Run Time

5.1.1.1 Quarterly Run Time

For the purpose of run-time evaluation, GWTS operation is defined as the time when groundwater was being pumped from at least one extraction well and was subsequently treated and discharged. Table 5-3 provides a monthly and quarterly summary of the extraction well performance that includes individual extraction well run times.

During Q4 2018, the GWTS treated 47,135,900 gallons of groundwater. Of this total, 30,597,900 gallons was discharged to KAFB-7, and the remaining 16,538,000 gallons was discharged to GCMP. Of the total gallons treated in Q4 2018, Trains 1 and 2 treated 24,882,400 and 22,253,500 gallons, respectively. Table 5-2 provides a cumulative summary of groundwater quantities extracted, treated, and discharged.

From October 1 through December 31, 2018, the GWTS was operational 93% of the time (Table 5-3). Planned and unplanned system shutdowns affecting GWTS overall run time during Q4 2018 are described in Sections 5.3.1.1 and 5.3.3.1.

5.1.1.2 Annual Run Time

Throughout 2018, the GWTS treated 217,194,100 gallons of groundwater. Of this total, 67,486,200 gallons was discharged to KAFB-7, and 149,707,900 gallons was discharged to GCMP. Of the total gallons treated in 2018, Trains 1 and 2 treated 126,520,600 gallons and 90,673,500 gallons, respectively. Table 5-2 provides a cumulative summary of groundwater quantities extracted, treated, and discharged.

Table 5-3 provides a quarterly summary of the extraction well performance that includes individual extraction well run times. Table 5-4 summarizes the individual extraction wells for 2018.

From January 1 through December 31, 2018, the GWTS was operational 94% of the time (Table 5-4). Planned and unplanned system shutdowns affecting GWTS overall run time during 2018 are described in Sections 5.3.1.2 and 5.3.3.2.

5.1.2 Extraction Well Performance Metrics

The following subsections provide a summary of the performance metrics for the four extraction wells. Quarterly and annual extraction well performance data are provided in Tables 5-3 and 5-4, respectively. Average operational extraction flow rates do not include flow rates during downtime. Well performance figures are provided in Appendix I-1.

5.1.2.1 Quarterly Extraction Rates

KAFB-106228, KAFB-106233, and KAFB-106239 experienced reduced run times since Q2 2018 due to the March 14, 2018 V-smart valve hydraulic assembly failure at KAFB-7 (the well was returned to service on November 14, 2018) and discharge volume restrictions associated with the GCMP reaching capacity. During Q4 2018, all four extraction wells were operational based on GCMP capacity with the following priority: KAFB-106234 (highest priority), KAFB-106228, KAFB-106239, and KAFB-106233 (lowest priority).

Groundwater was extracted from KAFB-106228 during Q4 2018 at an average operational flow rate of 140 gpm with a run time of 62% (Table 5-3).

Groundwater was extracted from KAFB-106233 during Q4 2018 at an average operational flow rate of 164 gpm with a run time of 48% (Table 5-3).

Groundwater was extracted from KAFB-106234 during Q4 2018 at an average operational flow rate of 163 gpm with a run time of 92% (Table 5-3).

Groundwater was extracted from KAFB-106239 during Q3 2018 at an average operational flow rate of 76 gpm with a run time of 58% (Table 5-3).

5.1.2.2 Annual Extraction Rates

Groundwater was extracted from KAFB-106228 in 2018 at an average operational flow rate of 141 gpm with a run time of 72% (Table 5-4).

Groundwater was extracted from KAFB-106233 in 2018 at an average operational flow rate of 159 gpm with a run time of 66% (Table 5-4).

Groundwater was extracted from KAFB-106234 in 2018 at an average operational flow rate of 164 gpm with a run time of 94% (Table 5-4).

Groundwater was extracted from KAFB-106239 in 2018 at an average operational flow rate of 75 gpm with a run time of 71% (Table 5-4).

5.1.3 Injection Well Performance Metrics

The following subsections provide a summary of the performance metrics for the injection well KAFB-7. The well was offline between March 14 and November 8, 2018 due to the hydraulic assembly failure. KAFB-7 repairs were completed on November 9, 2018. The shakedown tests were completed on November 14, 2018. Quarterly and annual injection well performance data required for DP reporting compliance are provided in Table 5-5 and Table 5-6, respectively. Injection well performance figures are provided in Appendix I-1.

5.2 Groundwater Treatment System Performance Monitoring and Ethylene Dibromide Removal

GWTS performance monitoring is performed in conformance with the most recently approved Work Plan (USACE, 2017c) as well as Appendix L of the Operations and Maintenance Plan, Sampling and Analysis Plan, and any subsequent revisions. DP-1839 provides additional sampling criteria. Table 2 of DP-1839 provides a list of the constituents of concern that are most frequently monitored at the GWTS (NMED, 2017f).

For both Train 1 and Train 2, GWTS samples were collected monthly from the untreated influent (GWTS-BFF-INF1 and GWTS-BFF-INF2), at ports located after the lead granular activated carbon (GAC) vessel (GWTS-BFF-GAC1 and GWTS-BFF-GAC2), and from the treated effluent (GWTS-BFF-EFF1 and GWTS-BFF-EFF2) in Q4 2018 (Appendix I-3). These samples were analyzed for EDB, BTEX, and dissolved metals (iron and manganese). EDB concentrations and mass removal in Q4 2018 and throughout 2018 are summarized in Tables 5-7 and 5-8, respectively. The sample results and effluent discharge limits (which are the MCLs/PSL) are provided in Table 5-9 for Train 1 and Table 5-10 for Train 2.

5.2.1 Quarterly Sampling and Analysis

In Q4 2018, an estimated 5,064 milligrams (mg) of EDB was captured in the lead GAC vessels. Of this total, 2,167 mg was removed by Train 1 and 2,897 mg was removed by Train 2. These quantities of mass were calculated by taking the sum of each monthly influent concentration multiplied by the respective total weekly treated volume (Table 5-7).

EDB in the influent sample of Train 1 was detected at estimated concentrations (J-flag) of 0.022 and 0.024 µg/L in November and December 2018, respectively (Table 5-9). Train 1 was not sampled in October due to repair of the Train 1 influent skid pump motors (Section 5.3.3.1). EDB in the influent samples of Train 2 was detected at estimated concentrations (J-flag) of 0.027, and 0.039 in October and December 2018, respectively (Table 5-10). Train 2 was not sampled in November due to reduced flow requirements imposed by Tijeras Arroyo GCMP capacity limitations while KAFB-7 was offline. Throughout early November, KAFB-106234 was predominantly producing influent at the GWTS while KAFB-7 was offline, and KAFB-106228, KAFB-106233, and KAFB-106239 were run intermittently when there was freeboard in the GCMP. BTEX and dissolved iron were not detected in any influent samples collected from either train during Q4 2018. Dissolved manganese was detected below the PSL in all monthly influent samples collected from Train 2, which is comprised of groundwater extracted from KAFB-106228 and KAFB-106239 (Table 5-10).

EDB, BTEX, dissolved iron, and manganese were nondetect in all post-GAC and effluent monthly samples collected from either train during Q4 2018.

5.2.1.1 Annual Analytical Metrics

All analyte concentrations for post-GAC 1 and effluent samples collected during 2018 were below their respective limits of detection continuing to demonstrate that there has not been breakthrough of the lead GAC vessel (Appendix K-5). For 2018 operations (defined as December 26, 2017 through December 31, 2018, based on weekly data collection), an estimated 11,342 and 13,211 mg of EDB was adsorbed in the lead GAC vessel of Train 1 and Train 2, respectively (Table 5-8), for an annual total of 24,553 mg of EDB captured.

Wells KAFB-0505, ST105MW507, and KAFB-0508, associated with the Kirtland ST-105 abatement plan, were sampled on November 5, 2018 in the vicinity of KAFB-7. As a requirement of DP-1839, these wells are sampled annually; this was the second sampling event for these wells since the DP-1839 was issued on April 28, 2017. Analytical results are presented in Table 5-11. No analytes exceeded any of the MCLs/PSLs from the groundwater samples collected from these wells.

5.2.2 Data Validation

All GWTS analytical data throughout 2018 underwent EPA Stage 3 data validation by Environmental Data Services, Inc. Additionally, the data were assessed for accuracy, precision, representativeness, comparability, completeness, and sensitivity to determine if the project data quality objectives were achieved and usable for their intended purpose. The data validation results are included in the Data Quality Evaluation Report provided in Appendix I-4 and the final laboratory data reports included in Appendix I-5.

5.3 Groundwater Treatment System Maintenance and Expansion Activities

GWTS maintenance activities throughout 2018 were performed in accordance with the Operations and Maintenance Plan. All 2018 GWTS maintenance activities are provided in the following sections.

5.3.1 Routine Maintenance Activities

Routine maintenance is any activity described as such in the GWTS Operations and Maintenance Plan. A summary of routine maintenance activities is provided below.

5.3.1.1 Quarterly Routine Maintenance Activities

During Q4 2018, the influent and effluent bag filters were changed out for both Train 1 and Train 2 on October 15, 2018. The differential pressure along the lead GAC vessel on Train 1 was 6.9 pounds per square inch (psi) on October 5, 2018; and, on January 3, 2019, the differential pressure was 7.8 psi (Appendix I-1) showing no change in lead GAC vessel differential pressure throughout the quarter without the need to skim or backwash the GAC. On October 2, 2018, the differential pressure along the lead GAC vessel of Train 2 was 5.8 psi. The differential pressure in the lead GAC of Train 2 was 6.0 psi as of January 3, 2019.

Sand filters were installed to pretreat groundwater (remove biologic material and solids) prior to entering the GAC treatment trains.

The influent Wye strainers were cleaned 10 times for both Train 1 and Train 2 throughout Q4 2018. Wye strainers were cleaned to maintain equalization of the influent tanks and prevent cavitation at the influent pump intakes.

On October 3, 2018, the oil was changed out in all six skid pumps (Train 1: P-112A, P-112B, P-118; Train 2: P-212A, P-212B, P-218).

The GWTS routine maintenance schedule is provided in Table 5-12 and non-routine maintenance activities that were performed during Q4 2018 are discussed in Section 5.3.3 and in Table 5-13.

5.3.1.2 Annual Routine Maintenance Activities

During 2018, the GWTS was intentionally shut down on several occasions for routine maintenance including changing bag filters, cleaning Wye strainers, changing pump oil, and greasing pump bearings. Routine maintenance was performed as per the GWTS Operations and Maintenance Plan throughout 2018. Table 5-12 contains a comprehensive list of all routine maintenance activities and their respective frequencies.

5.3.2 Conveyance Line Security and Administrative Controls

Kirtland AFB is registered as a line-owner with New Mexico 811 for the off-Base portion of the conveyance lines. U.S. Air Force 103 permits are required for all on-Base excavation projects.

5.3.2.1 Quarterly Conveyance Line Security

During Q4 2018, Kirtland AFB responded to 30 off-Base tickets requested through New Mexico 811 (Appendix I-2). There were no conveyance line breaches and all off-Base conveyance lines remained intact.

5.3.2.2 Annual Conveyance Line Security

Over the course of 2018, Kirtland AFB responded to 89 off-Base tickets requested through New Mexico 811. Throughout 2018, there were no conveyance line breaches and all off-Base conveyance lines remained intact.

5.3.3 Non-Routine Maintenance Activities

Non-routine maintenance activities are defined as maintenance items that fall outside of the routine maintenance scope of the GWTS Operations and Maintenance Plan but need to be addressed in order to maintain consistent GWTS operation. A summary of shutdowns associated with non-routine maintenance activities occurring during Q4 2018 and throughout 2018 are provided on Table 5-13 and Table 5-14, respectively. Major non-routine maintenance performed in Q4 and throughout 2018 are listed below in Sections 5.3.3.1 and 5.3.3.2.

5.3.3.1 Quarterly Non-Routine Maintenance Activities

The entire system was offline for approximately 2 hours on October 16, 2018 to install a new drain valve for the sodium hypochlorite generator, and extraction wells KAFB-106228, KAFB-106233, and KAFB-106239 were offline for approximately 3 hours on October 16 to install a new valve outlet to Train 2 influent skid pump motors P-212A and P-212B, and to replace the Train 1 influent skid pump motor P-112B with a new unit.

Extraction wells KAFB-106228, KAFB-106233, and KAFB-106239 were again offline for approximately 2 hours on October 29, 2018 to replace the Train 1 influent skid pump motor P-112A with the refurbished motor.

New water level transmitters were installed at extraction wells KAFB-106233 and KAFB-106234 on November 5, 2018, causing both extraction wells to remain offline for a total of approximately 2 hours. The water level transmitters replaced the original *in situ* transducers due to the high failure rate of the transducer vented cables (Section 5.3.3.2).

From November 7 to November 14, 2018, KAFB-106239 was offline for an approximate total of 7 days to rehabilitate and disinfect the well to maintain performance impacted by biofouling. Disinfection was performed in accordance with the Standard Operating Procedure (USACE, 2018e) approved by NMED on August 6, 2018 (NMED, 2018d) and the analytical sampling suites for pre-treatment and post-treatment groundwater samples approved on November 16, 2018 (NMED, 2018e). Pre-treatment samples were not available for KAFB-106239 in November as the analytical methods approval was received after the emergency rehabilitation was initiated. Post-treatment samples were analyzed for bromate and chlorite using Method E300.1 and perchlorate was analyzed using Method E331.0. Bromate and chlorite were not detected in the sample and perchlorate was detected at a concentration of 0.15 µg/L, below the PSL of 14 µg/L (Appendix I-1, Table I-1-5). Groundwater from the Middle Rio Grande Basin has naturally-occurring perchlorate concentrations of 0.12–1.8 µg/L (Plummer et al., 2006).

On November 9, 2018, temporary repairs to KAFB-7 were completed. On November 14, 2018, shakedown testing of KAFB-7 was completed and the injection well was returned to service on November 15, 2018.

The disinfection of extraction well KAFB-106228 occurred from November 28 to November 29, 2018 and kept the well offline for an approximate total of 38 hours to maintain performance and reduce biofouling. Extraction well KAFB-106234 was disinfected from December 12 to December 13, 2018 and was offline for an approximate total of 21 hours. Extraction well KAFB-106233 was disinfected from December 13 to December 14, 2018 and was offline for an approximate total of 22 hours. All pre-treatment samples and post-treatment samples for all three wells were reported nondetect for bromate and chlorite and below the PSL for perchlorate (Appendix I-1, Table I-1-5).

In the event of a third-party construction project breach of the conveyance lines, emergency piping supplies for the ASAHI double-walled high-density polyethylene conveyance lines for extraction wells KAFB-106233, KAFB-106234, and KAFB-106239 were received and stockpiled on December 19, 2018. SECOR double-walled high-density polyethylene for KAFB-106228 is scheduled for delivery in Q1 2019.

Building slats at the KAFB-106228 control area were repaired on December 27, 2018 after attempted incursions by homeless in the area.

5.3.3.2 Annual Non-Routine Maintenance Activities

Repairs and routine maintenance were performed throughout 2018 to comply with the GWTS Operations and Maintenance Plan, including multiple unscheduled system shutdowns. High water level alarms at the GCMP occurred several times throughout 2018 in response to the pond reaching capacity when there was an interruption in irrigation schedules. GWTS discharge was directed to KAFB-7 when the GCMP was at maximum volume capacity; however, discharge to KAFB-7 was not an option between March 14, and November 14, 2018 during repairs.

The flowmeter at KAFB-7 was replaced on February 27, 2018, with a duplicate McCrometer MLI1-10 flowmeter. The initial totalizer reading on the replacement flowmeter faceplate was 15,400 gallons and the meter was factory calibrated on November 2, 2017.

Water level elevation data from KAFB-106239 were unavailable between April 1 and April 23, 2018 due to transducer cable failure. The KAFB-106239 transducer cable was replaced on April 23, 2018.
The flowmeter transmitter at KAFB-106228 failed on May 2, 2018. The transmitter was replaced on June 25, 2018. Flow data collected between May 3, and June 25, 2018 were manually recorded on a daily basis from the flowmeter at KAFB-106228.

The entire system was offline for approximately 5 hours on September 4, 2018 to install breakers for the sodium hypochlorite generator. Repairs of a minor leak associated with the Train 1 sodium hypochlorite injection saddle were performed on September 7, 2018. Extraction wells KAFB-106228, KAFB-106233, and KAFB-106239 were offline for approximately 40 hours beginning on September 6, 2018 following the failure of an air relief valve associated with the Tijeras Arroyo Golf Course irrigation system.

Installation of a fiber optic line near the off-Base influent conveyance pipeline for KAFB-106233 and KAFB-106234 was performed on September 11, 2018. As a result, GWTS personnel shut down KAFB-106233 and KAFB-106234 for approximately 3.5 hours to reduce hydraulic pressure within the influent lines and mitigate potential risks associated with the excavation and a possible breach.

The entire system was offline for approximately 5 hours on September 20, 2018 in conjunction with the installation of chlorinated polyvinyl chloride injection headers and valves on the influent conveyance piping.

The GWTS was offline for approximately 2.5 hours on September 28, 2018 during repairs to the KAFB-106228 communications line. The communications line was damaged during third-party excavation activities associated with the installation of a protective cap over the lines on September 27, 2018.

The GWTS was shut down several times due to GCMP maintenance activities, rain events, and electrical disruptions throughout 2018.

On March 14, 2018, the KAFB-7 V-smart valve hydraulic assembly failed. When the hydraulic assembly failure on March 14, 2018, all treated water was discharged to the GCMP until KAFB-7 was repaired. The system was operated between 3 and 12 hours a day between March 14 and 24, 2018, depending on available capacity at the GCMP. Between March 25, and November 15, 2018, the system and KAFB-106234 were operated continuously, with the remaining extraction wells cycled on during times when available capacity at the GCMP existed. Repairs were completed on November 9, 2018, and shakedown was completed on November 14, 2018.

Documentation for KAFB-7 of final repairs and well maintenance is presented in Appendix I-1.

5.3.4 Effluent Conveyance Line Integrity

Effluent line testing was not performed during Q4 2018. Final retesting of the segment between the changeover valve and KAFB-7 will be performed after final valves are installed at KAFB-7.

5.3.5 Groundwater Treatment System Alarm Testing

To ensure system wide integrity within the GWTS and its peripheral operations, initial annual alarm testing was performed on 71 alarms in the programmable logic controller on November 26 and 27, 2018. Most alarms that were tested passed on the initial test by responding in the correct manner. Those alarms that failed were checked and/or corrected and retested on December 20, 2018. Eight secondary alarms failed both testing events and will be resolved with programmable logic controller updates in Q1 2019. Table 5-15 details the results of the 2018 GWTS annual alarm testing.

5.3.6 Annual Expansion Activities

Installation of influent sand filters and the extraction well KAFB-106239 conveyance line construction both were initiated in Q3 2017; however, construction and shakedown for both construction projects were completed during Q1 2018. A sodium hypochlorite generator was installed within the GWTS on September 20, 2018.

5.4 Groundwater Treatment System Performance Assessment

The pump and treat interim measure for capture of the dissolved-phase EDB in groundwater is being implemented pursuant to the corrective action provisions in Part 6 of Kirtland AFB's RCRA Permit. As discussed above, this interim measure focuses on the collapse and treatment of the dissolved-phase EDB in groundwater that extends north of Ridgecrest Drive SE. It does not address dissolved-phase EDB present in the source area located south of Ridgecrest Drive SE. At a minimum, the pump and treat system will continue to operate until the corrective measures evaluation is completed, NMED has selected the final remedy or remedies, and the corrective measures implementation plan is approved.

The principal goals of the groundwater interim measure are to: (1) hydraulically capture the dissolved-phase EDB utilizing well pumping, thereby halting plume expansion, and providing protection to water supply wells; and (2) collapse the dissolved-phase EDB north of Ridgecrest Drive SE, which includes reducing the volume and EDB mass over time. The first goal, referred to as plume capture by the EPA (EPA, 2008) and in this report, provides short-term protectiveness. The second goal, plume collapse, works toward the longer-term cleanup goal (permanent protectiveness), which will be dictated by the final remedy approved by NMED in the future. Measuring the attainment of these goals during implementation of both the interim measure and the final remedy is referred to as performance assessment. GWTS performance assessment and plume capture numerical modeling using FEFLOW are performed in Q2 and Q4 of each year using the EPA Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems (EPA, 2008) as approved by NMED on April 23, 2018 (NMED, 2018a) in resolution of the modeling component of the Notice of Deficiency issued to Kirtland AFB on November 16, 2017 (NMED, 2017d). This performance assessment is a "snap shot" of the systems performance and is not intended to be a final remedy evaluation.

The subsections below describe the methods of performance assessment being utilized to measure the progress of the interim measure.

EPA defines capture zone evaluation as a six-step process (EPA, 2008):

- Step 1: Review site data, site conceptual model, and remedy objectives
- Step 2: Define site-specific Target Capture Zone

- Step 3: Interpret water levels

  - Potentiometric surface maps (horizontal capture)
  - Water level difference maps (vertical capture)
  - Water level pairs (gradient control points)

- Step 4: Perform calculations

  - Estimate flow rate calculation
  - Capture zone width calculation
  - Modeling (analytical or numerical) to simulate water levels, in conjunction with particle tracking and/or transport modeling

- Step 5: Evaluate concentration trends

- Step 6: Interpret actual capture based on Steps 3 through 5, compare to Target Capture Zone, and assess uncertainties and data gaps.

As defined by EPA, a "Capture Zone" refers to the three-dimensional region in an aquifer system that contributes the groundwater extracted by one or more wells (EPA, 2008). The purpose of the performance assessment is to delineate hydraulic containment produced by each interim measure extraction well at a single point in time (period of gauging) and compare it to the Target Capture Zone (dissolved EDB concentrations above the MCL). The percentage of the plume contained will be identified as captured, meaning that if conditions do not change, the contained portion of the plume will eventually flow to the extraction well and be removed from the aquifer. The terms "capture" and "contained" are used interchangeably representing the above definition.

Steps 3 through 5 represent techniques for systematically evaluating capture, and each has limitations, meaning that no single line of evidence will conclusively differentiate between successful and failed capture. Therefore, in order to increase the confidence in the conclusions of a capture zone analysis, multiple techniques are applied so that converging lines of evidence can be developed. This section describes the methods and results for each line of evidence used to evaluate dissolved-phase EDB capture at Kirtland AFB BFF. Detailed descriptions of the methodologies utilized can be found in the Q4 2016 Quarterly and Annual Report (USACE, 2017e), in Appendix I-6 of the Q2 2018 Report (USACE, 2018b), and in Appendix I-6 of this report.

5.4.1 Step 1: Review Site Data, Site Conceptual Model, and Remedy Objectives

EPA (2008) identifies four prerequisites for establishing meaningful Target Capture Zones. These prerequisites are cited below, followed by responses to the posed questions.

1. *Is the plume adequately delineated in three dimensions?*

   - Plume delineation is accomplished through the groundwater monitoring network gauging and sampling activities described in Section 3. The groundwater level and water chemistry monitoring network includes 155 monitoring wells, 122 of which are part of 35 three- or four-well nested sites designed to monitor vertical gradients and three dimensional water chemistry. The plume is well defined in three dimensions.

2. *Is there adequate hydrogeologic information for performing capture zone evaluations?*

   Quarterly analyses are used to identify data gaps and define locations for additional monitoring wells, continually improving the performance of the monitoring well network. A summary of hydrogeologic information used for the capture zone evaluations follows:

   - Groundwater levels across the site are measured during 3- to 5-day synoptic periods every quarter. (Note that "groundwater level" and "head" are used interchangeably throughout Section 5.4). Based on screen interval elevations, the monitoring well network has been grouped into three REIs that allow for a systematic way to analyze the horizontal flow and vertical gradients at depth in the aquifer.

   - Water chemistry data are collected from the entire monitoring well network every second and fourth quarter in order to define and monitor the extent and character of contaminant concentrations, including dissolved-phase EDB addressed in this section.

   - Quarterly water level measurements have shown that the groundwater levels in the project area have been increasing at an average rate of approximately 3.3 ft per year since 2013. As of Q4 2018, well screens of 26 monitoring wells were unsubmerged due to the rising water table, including the six newly installed water table wells.

3. *Is there a site conceptual model (not a numerical model)?*

   - The plume exists in an unconfined aquifer characterized by coarse-grained, braided river deposits with a northeast-southwest-oriented channel axis (AECOM, 2016). Silt and clay units representing overbank, backwater, and/or floodplain deposits are interbedded with the coarser grained channel deposits. Due to relatively high evapotranspiration rates, recharge from the ground surface is usually negative. The primary source of recharge to the aquifer is from mountain front runoff and from seepage from the Rio Grande and its tributary streams and arroyos (AECOM, 2016).

   - In a study of the hydrologic system of the Middle Rio Grande Basin (Bartolino and Cole, 2002), USGS states: "Though the aquifer is under confined conditions locally, it is considered to be an unconfined aquifer as a whole. (For groundwater flow modeling, the upper part of the aquifer system is treated as unconfined and the lower part as confined.)"

   - The network currently incorporates 40 nested groundwater level monitoring locations (Figure 5-2), which measure pressure at two or three vertically distinct horizons in the aquifer at relatively the same horizontal location (for this discussion, wells are considered nested if the wells being compared are located less than 180 ft apart). Well pairs are evaluated across the entire plume in conjunction of the Step 3 potentiometric surface analysis. Aquifer confinement would be indicated by differences in pressure between vertical nested wells. In Q4 2018, vertical head differences could not be determined at one of the well nests as head measurements were not possible in KAFB-106063 and KAFB-106064 due to downhole equipment associated with the *in situ* biodegradation pilot study (Section 5.5) and measurements could only be obtained for the REI 4814 well (KAFB-106062).

   - A comparison of the average pressure difference between the shallow (REI 4857) and intermediate (REI 4838) monitoring location for each of the 39 well pairs shows that 69% (27 well pairs) represent unconfined conditions, having vertical pressure differences of between -0.1 and 0.1 ft (average head difference rounded to the nearest 0.1 ft). The remaining 12 well pairs are scattered throughout the monitored groundwater network for the BFF EDB plume representing localized aquifer separation due to discontinuous interbedded fine grain lenses between the nested well screens. A comparison of the average pressure difference between the intermediate (REI 4838) and deep (REI 4814) monitoring location for each of the 37 well pairs shows that 78% (29 well pairs) represents unconfined conditions, having vertical pressure differences of between -0.1 and 0.1 ft. Similar to the upper comparison, the remaining 8 well pairs are scattered around the project area representing localized aquifer separation due to discontinuous interbedded fine grain lenses between the nested well screens.

- The section of aquifer upon which the hydraulic containment analyses presented in this section are performed includes the upper part of the Santa Fe Group (Middle Rio Grande Basin), above the uppermost confining unit referred to as A2 (AECOM, 2015).

4. *Is the objective of the remedy clearly stated?*

   - The objective of the groundwater interim measure is hydraulic containment (capture) and collapse of the dissolved-phase EDB >0.05 µg/L north of Ridgecrest Drive SE.

5.4.2 Step 2: Define Site-Specific Target Capture Zone

According to EPA (2008), The *Target Capture Zone is defined herein as the three-dimensional zone of ground water that must be captured by the remedy extraction wells for the hydraulic containment portion of the remedy to be considered successful. This will depend on the site-specific remedy objectives (Step 1).”*

- The groundwater interim measure goal is to reduce the mobility and volume of contaminated media by containing, capturing, and treating contaminated groundwater in the plume north of Ridgecrest Drive SE. The three-dimensional zone of groundwater that must be captured by the interim measure extraction wells (i.e., the Target Capture Zone) is defined as the MCL for dissolved EDB, 0.05 µg/L. The iso-shell delineating the cleanup standard is defined as the three-dimensional polygon with a periphery concentration of 0.05 µg/L. Water chemistry samples collected from vertically nested wells have shown that EDB in concentrations above the detection limit do not extend throughout the entire thickness of the impacted portion of the aquifer; therefore, a three-dimensional delineation of the Target Capture Zone is required. The method for delineating the Target Capture Zone is described in the Q4 2016 Quarterly and Annual Report (USACE, 2017e).

EPA (2008) also states that *The Target Capture Zone should be defined in terms of specific criteria, such as a specific concentration contour or a geographical boundary along which an inward hydraulic gradient is to be established.*

- The effectiveness of the interim measure is evaluated by comparing the most recent dissolved-phase EDB delineation with past delineations. EDB concentration data are collected and analyzed from the full GWM network during the second and fourth quarters of each year. Therefore, dissolved-phase EDB delineations are updated on this schedule and plume comparisons are presented in the reports associated with these quarters. All delineation updates are performed using the same methodology with the only variations being the insertion of the current EDB concentration data, addition of any new monitoring wells since the last assessment, and allowance of volume increase due by resetting the plume upper surface to the current water table surface.

Figure 5-3 shows the modeled EDB delineations for the last six synoptic measuring periods. The plume volume defined by the 0.05 µg/L iso-shell changes between measuring periods as a result of the rising regional water table and interim measure extraction activity. The actual volumetric change is not presented or evaluated in Figure 5-3, but only provided for graphical visualization.

5.4.3 Step 3: Interpret Water Levels

EPA (2008) states that *For most sites it is appropriate to analyze ground-water flow patterns in three dimensions (i.e., both horizontal and vertical). The potential for vertical transport of contaminants to underlying or overlying aquifers should be considered. Three-dimensionality of ground-water flow patterns in the vicinity of pumping wells should also be considered.*

Hydraulic capture analyses, both in the horizontal and vertical directions, are based on defining the direction of groundwater flow through mapping pressure in the aquifer from discrete measuring points (monitoring wells). The purpose of the performance assessment is to delineate the zone of hydraulic containment produced by each interim measure extraction well at a single point in time (period of gauging) and compare the zone to the Target Capture Zone (dissolved-phase EDB north of Ridgecrest Drive SE). The percentage of the plume within the containment zone will be identified as contained; meaning that, if conditions do not change, the contained portion of the dissolved-phase EDB will eventually flow to the extraction well and be removed from the aquifer. The current capture zone analyses were conducted using groundwater head and EDB concentration data sets collected in Q4 2018. The synoptic groundwater head measuring event was from October 8 to 11, 2018, and included 156 monitoring wells. The synoptic water chemistry sampling event was from October 1 to November 13 and included 150 monitoring wells. A full description of how REIs are defined and of the method used to perform horizontal capture are included in the Q4 2016 Quarterly and Annual Report (USACE, 2017e).

The well network was resurveyed in 2017 by the USGS, and all measuring point elevations were officially updated in October 2017. As such, the measuring point elevations and, therefore, groundwater elevations for most of the GWM wells changed from historical values. Most of the changes were insignificant (less than 0.1 ft); however, several wells had elevation updates ranging from 0.3 to 0.6 ft. The capture analysis presented in this report (and future monitoring reports) uses the latest survey data and compares capture statistics to previous quarters by also using the same updated survey data. Tables containing results from previous performance assessments have been updated to represent the 2017 survey. However, previous quarterly reports, including Q4 2016 Quarterly and Annual Report (USACE, 2017e) and Q2 2017 Monitoring Report (USACE, 2017g) have outdated numbers due to this survey update.

5.4.3.1 Step 3a: Potentiometric Surface Maps (Horizontal Capture Analysis)

EPA (2008) states that *Horizontal capture is defined by a bounding flow line, within which all other flow lines reach an extraction location. The delineation of the capture zone in this manner is a derived interpretation, since water level contours must first be interpreted from water level values.*

Horizontal water level maps indicate contours of water levels within the aquifer from which the extent of horizontal capture can be interpreted. Flow lines are interpreted as perpendicular lines to water level contours. The method used in this analysis uses Environmental Systems Research Institute Spatial Analyst to develop potentiometric surface grids (analogous to groundwater level contours) from measured groundwater levels, then converts the potentiometric surface grid into a flow direction grids (analogues to flow lines). From the flow direction grids, still using Spatial Analyst, the hydraulic divide defining capture by each interim measure extraction well is defined.

Capture analyses are performed in Q2 and Q4 of each year when dissolved-phase EDB delineations are updated. The horizontal capture analysis for the Target Capture Zone north of Ridgecrest Drive SE for the current EDB delineation (Q4 2018) and the previous four delineations (Q4 2016, Q2 2017, Q4 2017, and Q2 2018) is summarized in Table 5-16.

Figure 5-4 shows the horizontal capture of the portion of the dissolved-phase EDB within REI 4857 during Q4 2018. Plume capture is divided among the three extraction wells, which were active during the synoptic gauging period (KAFB-106228, KAFB-106234, and KAFB-106239). With respect to the Target Capture Zone north of Ridgecrest Drive SE, the interim measure resulted in the horizontal capture of 100% of the dissolved-phase EDB volume and mass (Table 5-16). Within REI 4857 north of Ridgecrest Drive SE, extraction well KAFB-106234 was the most effective with capturing 39% of the dissolved-phase EDB volume and 41% of the mass, followed by KAFB-106228 capturing 35% of the dissolved-phase EDB volume and 32% of the mass, and KAFB-106239 capturing 26% of the dissolved-phase EDB volume and 26% of the mass (Table 5-17). KAFB-106233 has no capture statistics because it was inactive before and during the gauging period.

Figure 5-5 shows the horizontal capture of the Target Capture Zone within REI 4838 during Q4 2018. With respect to capture in the Target Capture Zone, the interim measure resulted in the horizontal capture of 100% of the dissolved-phase EDB volume and mass (Table 5-16). Within REI 4838 north of Ridgecrest Drive SE, extraction well KAFB-106228 is the most effective, capturing 90% of the dissolved-phase EDB volume and 91% of the mass; followed by KAFB-106234, capturing 9% of the dissolved-phase EDB volume and 8% of the mass; and KAFB-106239, capturing 1% of the dissolved-phase EDB volume and mass (Table 5-17). Horizontal capture for REI 4814, which does not contain any dissolved-phase EDB volume, is shown in Figure 5-6.

Combining dissolved-phase EDB volume and mass capture analyses for both REIs 4857 and 4838 discussed above, the interim measure resulted in the horizontal capture within the Target Capture Zone of 100% of the dissolved-phase EDB volume and mass in Q4 2018.

With the addition of the 15 water table wells in 2018 (both newly installed and existing), the flow directions and hydraulic containment along the saturated/unsaturated interface can start to be analyzed. There are not enough new wells dispersed across the plume area to create a distinctly different REI; however, combining data from the added wells and from the existing unsubmerged and slightly submerged wells (less than 3.5 ft of submergence) in REI 4857, a reasonably well-defined water table surface can be interpolated. Figure 5-7 shows the interpolated water table surface based on these wells for Q4 2018. Since this analysis merges with the REI 4857 at locations throughout the domain, a unique plume split cannot be developed; however, hydraulic containment can be represented graphically by placing delineated water table containment basins over the REI 4857 plume outline as defined by dissolved-phase EDB. The data presented in Figure 5-7 show that the dissolved-phase EDB in the Target Capture Zone is as well contained at the water table as it is in REI 4857, and that the rising water table is not causing EDB to migrate away from the extraction wells.

Interpreting horizontal capture from water level maps is subject to significant uncertainty. Below is a list of the potential issues cited by EPA (EPA, 2008) to be considered and how this assessment addresses them.

- Are the number and distribution of measurement locations adequate?
  - There is no rule regarding the "correct" amount of groundwater level data (EPA, 2008). Contouring accuracy will increase as the number of data points increase. Currently, each of the four interim extraction wells is surrounded by 5 to 8 nested monitoring wells indicating the direction of flow radially around the extraction well and at depth. Groundwater level monitoring is conducted within, at the perimeter, and downgradient of the Target Capture Zone to interpret groundwater flow patterns and the associated capture zone.
  - Measurement locations have improved with installation of six nested Data Gap wells KAFB-106240 through KAFB-106245 in 2018. Locations are shown on Figure 3-1.
- Are water levels included in vicinity of extraction wells (and have well inefficiency and losses been considered at extraction well locations)?
  - The water level measured in an extraction well is typically lower than the level in the adjacent aquifer due to well inefficiency and well losses (EPA, 2008). Therefore, groundwater levels at extraction wells are estimated through linear interpolation using the measured head in the closest monitoring well to the extraction well and all other neighboring monitoring wells.
  - Extraction wells KAFB-106228 and KAFB-106233 have nested monitoring wells located less than 55 ft away resulting in interpolated extraction well heads 0.1 ft lower than the closest monitoring wells.
  - The closest monitoring well to extraction well KAFB-106234 is 223 ft away. Linear interpolation yields an extraction well head 0.4 ft lower than in the closest monitoring well.
  - The closest monitoring well to extraction well KAFB-106239 is 150 ft away. Linear interpolation yields an extraction well head 0.2 ft lower than in the closest monitoring well.
- Has the horizontal capture evaluation been performed individually for all pertinent horizontal units?
  - The horizontal capture is performed in three REIs covering the extraction screen interval and is reported for each REI containing a portion of the Target Capture Zone.
- Is there bias based on contouring algorithm?
  - The potentiometric surface for each REI is interpolated using a natural neighbor algorithm that honors all measured values, places contours based on the distance between any one well and all of its neighboring wells and eliminates over- and under-run estimates related to the gradient between neighboring wells.
  - Uncertainty still exists as the method assumes that all ridges and valleys (divides) in the potentiometric surface are represented by the monitoring well network.

- Is representation of transient influences adequate?
  - It is recognized that extraction within and surrounding the project area is transient and, therefore, the regional gradient across the site is transient requiring continual updating of the capture assessment currently scheduled at twice a year. As discussed in Section 5.4 above, this performance assessment is a "snap shot" of the systems performance and is not intended to be a final remedy evaluation. The EPA guidance emphasizes that while the modeling used for this biannual performance assessment is a tool for evaluating and improving the site conceptual model, predicting capture zones and evaluating alternative remediation scenarios, capture zone effectiveness is "ultimately determined by field monitoring."
- Has potential for vertical transport been neglected when evaluating horizontal capture?
  - Vertical transport potential is assessed separately from, but in conjunction with, horizontal capture (see next section).

5.4.3.2 Step 3b: Water Level Difference Maps (Vertical Capture Analysis)

EPA (2008) states that *Water levels between adjacent hydrogeologic units are evaluated to indicate zones of upward versus downward flow. The analysis can be based on vertical head differences or vertical gradients (the head difference divided by the vertical distance between measurements).*

The vertical capture analysis for the interim measure Target Capture Zone north of Ridgecrest Drive SE for Q4 2018 is summarized in Table 5-18. A vertical capture analysis defines hydraulic containment by evaluating groundwater levels between adjacent hydrologic units to determine zones of upward versus downward flow. Containment is defined by zones with upward flow that prevents dissolved contaminants from being transported by advection deeper into the aquifer. Vertical flow direction can be evaluated by subtracting the groundwater head measured in an adjacent lower hydrologic unit from the groundwater head measured in the overlying unit. A head difference of less than zero indicates that the head in the lower unit is greater than the head in the upper unit and, therefore, water will flow vertically upward.

Vertical hydraulic gradient is the head difference divided by the vertical distance between measuring points. While vertical gradients can provide more information than head differences because they account for the distance between measurements, significant error exists in calculating vertical gradients from groundwater levels measured from long screen intervals. Also, vertical gradient values are typically very small reducing their ability to represent the magnitude of the vertical difference. Because of this and because interim measure monitoring well screen intervals range from 10 to 30 ft in length, this analysis uses vertical head differences to illustrate vertical capture as described in the EPA guidance above.

The well network was resurveyed in 2017 by USGS, and all measuring point elevations were officially updated in October 2017. As such, the measuring point elevations and, therefore, groundwater elevations for most of the GWM wells changed from historical values, as discussed in more detail in Section 5.4.3.

The method for delineating vertical containment was changed this quarter. Previously, the vertical head difference between REIs was calculated by subtracting the potentiometric surfaces developed for each REI. However, significant uncertainty was introduced using this method as the data resolution was different within each REI because the number of head measurements decreased with depth. This quarter, vertical head differences were calculated only at each nested well location. Those difference values were then used to interpolate the vertical head differences across the plume area using a linear interpolation method assigning head differences between data points based on the distance from and magnitude of all neighboring data points. While the new method removed the data resolution issues going forward, the change limits the usefulness of comparison of vertical containment with past analyses.

The entire dissolved-phase EDB volume delineated for Q4 2018 was sliced along the elevation surface dividing REI 4857 and REI 4838 and along the elevation surface dividing REI 4838 and REI 4814. The upper dissolved-phase EDB volume has two opportunities to be contained vertically. Initially, this plume volume can be contained by upward flow between REI 4838 and REI 4857. Portions of the plume not contained in this interval have the potential to move downward into the lower unit. Once in the lower unit, these portions can be contained by vertical upward flow between REI 4814 and REI 4838. The lower plume volume can only be contained by vertical upward flow between REI 4814 and REI 4838. No non-pumping potentiometric surface grids are developed and no pumping versus non-pumping difference maps are calculated.

Figure 5-8 shows the results of the vertical containment analysis for the upper unit plume volume (above the 4838 REI midpoint) in Q4 2018. All “green” areas are vertically captured and “tan” areas do not have vertical capture. With respect to the dissolved-phase EDB within the interim measure Target Capture Zone north of Ridgecrest Drive SE, 100% of the dissolved-phase EDB volume and 100% of the mass were vertically contained in this unit (Table 5-18). Figure 5-9 shows the results of the vertical containment analysis for the lower plume volume (below the 4838 REI midpoint) in Q4 2018. Similar to Figure 5-8, the “green” areas are vertically captured and “tan” areas do not have vertical capture. With respect to the interim measure Target Capture Zone, 97% of the dissolved-phase EDB volume and 98% of the mass were vertically contained (Table 5-18). In total (above and below the 4838 REI mid-point), 99% of the dissolved-phase EDB volume and 99% of the mass in the interim measure Target Capture Zone were vertically contained in Q4 2018.

Vertical capture based on vertical head differences or vertical hydraulic gradients are subject to a similar set of uncertainties as described for horizontal capture. With respect to having an adequate vertical distribution of monitoring wells, 11 of the REI 4814 monitoring wells within the Target Capture Zone north of Ridgecrest Drive SE are screened above an elevation of 4,790 ft. Downward vertical flow at these well nests may be in response to the three-dimensional capture zone of an extraction well not loss of capture. The addition of deeper screened intervals within the gauging network could reduce the uncertainty.

This uncertainty in the vertical containment analysis has been addressed by comparing multiple lines of evidence (i.e., modeling). Section 5.4.4 describes the results of a numerical model designed for use in Step 4 of the EPA capture evaluation guidelines (EPA, 2008). The numerical model provides for a method to three-dimensionally estimate the containment produced by the interim measure extraction. In the Q4 2018 performance assessment, the model estimated containment contradicts the interpretation of loss of vertical containment from this analysis; therefore, it is likely that any loss of vertical containment defined by the Step 3b analysis is an artifact of available well placement.

It should be noted that Steps 3a and 3b are capture analyses that do not rely on the delineation or interpretation of drawdown. Drawdown is the change of water level due to groundwater extraction. It is calculated by subtracting the water level measured under pumping conditions from the water level measured without pumping. The “cone of depression” (i.e., drawdown) caused by extraction from one or more locations does not represent the capture zone associated with that extraction. If a regional hydraulic gradient exists (which it does across the project area), there are locations outside the capture zone where drawdown due to pumping is observed. These analyses define capture by delineating the flow field under pumping conditions only.

5.4.3.3 Step 3c: Water Level Pairs (Gradient Control)

To support the previously presented horizontal and vertical containment analyses, a water level pairs analysis was performed. Water level pairs analysis defines gradient control points and demonstrates the direction of flow relative to the plume boundary, thus providing an initial assessment of measure effectiveness and a supporting line of evidence for assumptions made during horizontal and vertical containment analyses. Two types of water level pairs analysis were performed, as described below.

To support the horizontal containment analyses, a horizontal water level pairs analysis was performed for REI 4857 and REI 4838. Thiessen polygons, which define the area that is closest to each point relative to all other points within a spatial dataset, were developed for each of the interval group wells. Water levels were then compared among a well in the center of a polygon and all of the wells with neighboring polygons. The graphical representation of the Q4 2018 horizontal water levels pairs analysis is shown on Figure 5-2. The arrows on these figures show the potential directions of flow from each well based off of the head comparison. Polygon colors delineate the plume area as: captured (by one or more extraction wells), possibly captured (flow could go to an extraction well or to an unidentified sink), or not captured (flow cannot go to an extraction well). The horizontal water level pairs analyses show that all well pair gradients within or surrounding the plume boundary in REI 4857 and REI 4838 flow toward one or more interim measure extraction wells, verifying the reasonableness of the capture zones defined in the horizontal capture analyses discussed in Section 5.4.3.1.

To support the vertical containment analysis, heads in vertically nested well sets were compared in order to verify the vertical flow direction. The locations of the centroid for each nested well pair are shown on Figures 5-8 and 5-9. The values associated with these wells represent the head difference when the lower unit's head is subtracted from the upper unit's head. A head difference of less than zero represents upward flow (wells shown as "green") and, therefore, vertical containment is achieved. A head difference greater than zero presents downward flow (wells shown as orange) and, therefore, vertical containment is not achieved. Results from this well pair analysis are shown on the figures to identify the location and magnitude of gradient control points for the vertical containment analysis.

5.4.4 Step 4: Perform Calculations

Step 4 of the EPA Systematic Approach for Evaluation of Capture Zones states that *specific calculations can be performed to add additional lines of evidence regarding the extent of capture, including the following:*

- *Simple horizontal analyses related to capture, such as estimated flow rate calculations and capture zone width calculations*
- *Modeling (analytical or numerical) to simulate heads, in conjunction with particle tracking and/or contaminant transport modeling.*

Determining the appropriate types of calculations to perform should be based on site complexity. For instance, numerical simulation of heads for evaluating capture may not be necessary for sites with very simple hydrogeology and only minor heterogeneity of aquifer parameters. (EPA, 2008)

Calculations performed in Step 4 can range from simple two-dimensional analyses estimating capture zone width based on extraction rates and aquifer properties to complex three-dimensional analytical or numerical simulations of head, producing particle track delineations of capture. EPA encourages the use of groundwater modeling at more complex sites as a tool for evaluating and improving the site conceptual model and predicting capture zones. Complexity can be defined as aquifer heterogeneity and anisotropy, non-uniform aquifer thickness, non-uniform hydraulic gradient, transient conditions, offsite aquifer stresses, and/or the presence of many partially penetrating extraction and/or injection wells.

If one or more of these complexities is present, the assumptions associated with simple two-dimensional methods are violated and a more complex form of additional lines of evidence should be examined. Heterogeneity and non-uniform hydraulic gradient have been identified as complexities that may need to be addressed with future use of the numerical model.

Performance assessment of the interim measure initially used a simple two-dimensional capture zone width calculation (bullet 1) to provide a supporting line of evidence to the measured data-based analyses described in Step 3 (presented in the Q4 2016 Quarterly and Annual Report [USACE, 2017e]). This calculation has the following simplifying assumptions:

- The aquifer is homogeneous and isotropic.
- The aquifer is confined and has uniform thickness.
- The aquifer contains fully penetrating wells.
- The aquifer has a uniform regional horizontal hydraulic gradient and steady-state flow.
- There is no net recharge to the aquifer.

However, the upper aquifer at the BFF site is not confined, does not have a uniform thickness, and none of the interim measure or supply wells are fully penetrating. In addition, the simple horizontal capture zone calculations do not pertain to vertical capture, which is an important aspect to assessing performance of the interim measure due to the abundance of supply wells screened below the interim measure extraction wells in the aquifer. Therefore, the three-dimensional numerical model was added (bullet 2), to simulate heads resulting from interim measure extraction and define the three-dimensional hydraulic containment produced by interim measure extraction at the point in time when groundwater heads are measured and compare these containment zones to the Target Capture Zone developed for the same time period.

5.4.4.1 Step 4a: Groundwater Flow Model Design

EPA guidelines do not dictate specific model types for use in Step 4 stating that different types of simulation models, ranging from analytical to numerical, can be applied to calculate hydraulic heads and produce particle tracks upon which capture can be evaluated (EPA, 2008). NMED deferred to Kirtland AFB for selection of an appropriate modeling approach and approved the proposed modeling approach on April 23, 2018 (NMED, 2018a). The numerical model used for the purpose of adding a supporting line of evidence to this capture zone evaluation was developed using the finite element software FEFLOW (DHI Group). FEFLOW was chosen primarily because of the superior mesh design capabilities of the finite-element method. The finite-element mesh allows for the articulation of each monitoring well and extraction well no matter how irregular or close the spacing, and it allows for localized refinement around each extraction well increasing the accuracy of simulated drawdown due to extraction at the well while minimizing the number of nodes and elements required, thus minimizing computation time.

The numerical flow model used in this quarter's analysis is a revised version (Version 2) of the model originally used in the Q2 2018 assessment (the Version 1 model is fully described in Appendix I-6 of the Q2 2018 Report [USACE, 2018b]). The Version 2 model revisions are based on how the hydrologic conditions and aquifer stresses outside of the model domain are interpolated and applied to the model boundaries. The model's domain, mesh, and layering were not modified; however, the model design no longer assumes a uniform gradient across the domain and this change necessitated a recalibration. The

Version 2 design and assumptions are given below, and a full description of the revisions made to the Version 2 model are located in Appendix I-6. This model revision is consistent with the iterative capture zone analysis process outlined in the EPA Guidance.

The Version 2 model is a three-dimensional model containing four layers, three representing each of the REIs described above and one representing the remaining aquifer below REI 4814 and above the A2 confining layer. The bottom elevation of the model follows the surface of the A2 unit allowing the aquifer thickness to increase moving from west to east. Model design has the following assumptions:

- The aquifer has a homogeneous horizontal Kh set at 120 ft/day.
- The aquifer has a uniform vertical anisotropy (VANI) set at 0.01.
- There is no recharge to the aquifer except for the recharge accounted for in the regional hydraulic gradient.

Figure 5-10 shows the groundwater flow model domain and key assigned features. A rigorous analysis of borehole lithology logs and electronic logs was performed, using both site-scale and regional monitoring and water supply wells, in order to define the region of aquifer around the dissolved-phase EDB that fit the homogeneous Kh assumption (described in Appendix I-6). The model domain was constrained by this analysis. The Kh and VANI values were derived from the model calibration process described in Appendix I-6. These model calibration parameters were bounded by the range for each produced from the 2015 aquifer pump test performed on interim measure extraction well KAFB-106228 (USACE, 2016d).

The regional hydrologic conditions assigned to the model boundaries are developed every second and fourth quarter from groundwater measurements taken from six monitoring wells located outside of the predicted drawdown produced by interim measure extraction. All gradient wells are screened within the saturated zone above the A2 confining unit. The role of each of these wells is described below:

- KAFB-3392 is a monitoring well located on the model boundary approximately 6,700 ft east of the dissolved-phase EDB boundary and it represents aquifer stresses produced by Kirtland supply well KAFB-20.
- KAFB-0118 is a monitoring well located on the model boundary approximately 2,900 ft south of the dissolved-phase EDB boundary.
- Trumbull 1A is a USGS-installed sentinel well located on the model boundary approximately 2,600 ft northeast of the dissolved-phase EDB boundary and it represents aquifer stresses produced by the Albuquerque Bernalillo County Water Utility Authority wellfields located north of the model domain.
- Jerry Cline C and Del Sol Divider 3 are USGS-installed monitoring wells located 1.8 miles north and 1.8 miles northwest of the model domain respectively.
- Montessa Park B is a USGS-installed monitoring well located 2.3 miles southwest of the model domain.

Figure 5-10 shows the model simulated non-extraction flow-field, with particle tracks, for Q4 2018. As a starting condition for the simulation, the head values defining the regional flow-field assigned to the model boundary represent an estimate of the flow-field across the model domain with no operating extraction wells. Once interim measure extraction is activated in the model, the assigned regional flow-field only controls simulated heads along the model boundary while the flow-field varies within the model domain in response to the assigned extraction rates.

The model layer elevations are assigned such that the top and bottom elevation of all model domain extraction wells can be precisely articulated in the model. The node spacing of the model mesh averages approximately 33 ft (10 meters) but is adapted to include the exact location of all extraction and monitoring wells within the model domain and is refined down to a spacing of approximately 1 ft around all extraction wells. This allows for an accurate representation of spatial distances between wells and of the drawdown produced by the extraction wells.

Extraction rates assigned to the interim measure wells are defined by the extraction rate measured from each well prior to gauging. Results from the 2015 constant rate aquifer test, performed using interim measure extraction well KAFB-106228, showed that the head in observation wells observed to have any related drawdown reach steady-state with respect to extraction within 5 days (USACE, 2016d). Therefore, extraction rates assigned to simulated interim measure wells are based on the extraction record for the well for the 5 days prior to gauging. Analysis of the interim measure extraction record showed that, for the 5 days prior to Q4 2018 gauging, KAFB-106228, KAFB-106234, and KAFB-106239 were operational 90, 95, and 81% of the time, respectively. KAFB-106233 was not operational before or during Q4 2018 gauging. Therefore, the operational rate, listed in Table 5-19, was assigned to each extraction well in the model.

The assigned extraction rate for KAFB-003 is the reported pump capacity for this well as it was running for the day before and during gauging. The assigned extraction rates for KAFB-20 and ST106-VA-2 are based on the portion of the screen interval above the A2 confining unit and the reported pump capacity of each well. The simplifying assumption was that the aquifer material above and below A2 has the same permeability and, therefore, could deliver an equal volume of water under identical stress per unit volume. Therefore, the percentage of the pump capacity assigned to the model equaled the percent of the screen interval above A2. Figure 5-10 shows the location of all model assigned extraction wells and the assigned extraction rates for Q4 2018. Table 5-19 lists the details of the flow model assigned extraction and injection wells for the Q4 2018 simulation.

The model is intended to be used as a supporting line of evidence as part of performance assessment every second and fourth quarter. For each assessment period, the model will be updated with the current extraction and injection rates for all interim measure and water supply wells and updated with the most recent regional flow-field estimate. This biannual update is consistent with the iterative capture zone analysis process outlined in the EPA Guidance.

5.4.4.2 Step 4a: Groundwater Flow Model Results

Step 4a (bullet 2) of the EPA guidelines (EPA, 2008) suggests:

- *Modeling (analytical or numerical) to simulate heads, in conjunction with particle tracking and/or contaminant transport modeling.*

Numerical modeling was utilized to delineate the capture zones for all model domain extraction wells and was performed using two sets of three-dimensional particle track exports. The first set was designed to visualize the capture produced by each simulated extraction well across the model domain. Three-dimensional location points were assigned at the top and bottom elevation of each simulated extraction well. Additional location points were assigned at 10-ft intervals along the length of each screen interval.

The 10-ft interval was chosen because 10 ft is the shortest screen interval in the monitoring well network and therefore represents the default resolution to vertical data. A ring of 72 “seed” points are assigned around each extraction well at a radius of 16.4 ft (5 meters). This ring of “seed” points is duplicated at each 5-ft interval. For example, the screen interval of KAFB-106228 is 100 ft long; therefore, it has 21 “seed” point rings (1,512 points) assigned along this depth.

The second set of three-dimensional particle track exports used backward particle tracks that were run from each “seed” point to define the volume of capture for the well. These particle tracks are fully three-dimensional and cross all layers until terminating at the recharge point. Therefore, when viewed in two-dimensions (Figure 5-11), there appears to be overlap along the capture boundaries. However, these lines are not crossing each other; instead, they pass above or under each other at depth in the aquifer.

While the above analysis allows for a visual analysis of model scale capture, it does not allow for quantifying capture produced by each extraction well specific to the entire dissolved-phase EDB volume. Particle tracks run backwards from the wells do not completely represent flow from the water table in the plume area, resulting in volumes of dissolved-phase EDB without particle track penetration and, therefore, without capture indication. EDB plume-specific capture was delineated using forward run particle tracks from over 10,800 “seed” points, which completely represent the three-dimensional volume of the dissolved-phase EDB as delineated for Q4 2018. A two-dimensional rendering of the results of the forward particle tracks defined capture of the Q4 2018 dissolved-phase EDB are shown in Figure 5-12. The method used to process these particle tracks into capture volumes and intersect these volumes with the dissolved-phase EDB volume is described in detail in Appendix I-6 of the Q2 2018 report (USACE, 2018b).

With respect to capture in the Target Capture Zone, the interim measure resulted in the capture of 92% of the dissolved-phase EDB volume and 91% of the mass (Table 5-20). North of Ridgecrest Drive SE, extraction well KAFB-106228 is the most effective with capturing 62% of the dissolved-phase EDB volume and 59% of the mass, followed by KAFB-106234 capturing 29% of the dissolved-phase EDB volume and 32% of the mass, and KAFB-106239 capturing 1% of the dissolved-phase EDB volume and mass (Table 5-20).

With the model showing 92% hydraulic containment being produced to capture all of the dissolved-phase EDB volume in the Target Capture Zone under Q4 2018 conditions, a scenario model was run, identical to the Q4 2018 conditions model, except with an active KAFB-106233 running at 100%. The results from this “KAFB-106233 on” scenario model with forward particle tracks showed that under Q4 2018 conditions, the interim measure extraction system would produce 100% capture of the dissolved-phase EDB in the Target Capture Zone if KAFB-106233 was active, graphically shown in Figure 5-13. Figure 5-14 shows capture zones produced by each active model domain extraction well in the “KAFB-106233 on” scenario with backward particle tracks. Comparing Figure 5-12 with Figure 5-2 indicates that hydraulic containment in the Target Capture Zone increases primarily due to an expansion of the KAFB-106228 capture zone. While an active KAFB-106233 does not directly capture any of the dissolved-phase EDB volume, it removes water otherwise going to KAFB-106228, forcing KAFB-106228’s capture zone to expand to meet its extraction requirement. Therefore, an active KAFB-106233 is important to maintaining full containment in the Target Capture Zone.

It was suggested in a Hydrologic Working Group meeting that a model scenario be designed to address the uncertainty in the model assigned Kh value. This concern was for Version 1 of the model, which had an assigned Kh of 80 ft/day, which was below the average value of 150 ft/day produced by the 2015 KAFB-106228 constant-rate aquifer test. Even though Version 2 of the model (used in this assessment) has a higher assigned Kh value of 120 ft/day, an uncertainty scenario with the aquifer test Kh value of 150 ft/day was developed and ran. Since the results of the Q4 2018 conditions model did not show 100%

hydraulic containment in the Target Capture Zone, there was no utility in showing less than 100% containment at a Kh value of 150 ft/day. However, since the "KAFB-106233 on" scenario did show 100% containment, this model was used as the base for testing containment at Kh equaling 150 ft/day. The results of this model, shown in Figure 5-15, show that at the elevated Kh estimate, 100% containment has been achieved under Q4 2018 conditions if all four interim measure extraction wells had been active.

Capture zone effectiveness is ultimately determined by field monitoring that includes hydraulic head measurement and groundwater sampling and analysis, in conjunction with field confirmation of pumping rates. Actual field monitoring must be carried out in order to provide information necessary to evaluate model predictions (EPA, 2008). Appendix I-6 contains a full description of model calibration to Q4 2017 and Q4 2018 groundwater head measurements. A calibrated numerical model adds an additional line of evidence regarding the extent of capture defined in Step 3 of the performance assessment.

Numerical model result files and fully rotatable three-dimensional plume viewing files are provided in Appendix I-6 on a compact disc. Appendix I-6 includes instructions for download and installation of free viewing software.

5.4.5 Step 5: Evaluate Concentration Trends

EPA (2008) states that *Contaminant concentrations can be monitored at two types of locations downgradient of the Target Capture Zone in an attempt to interpret capture…:*

- *Sentinel wells are located downgradient of the Target Capture Zone and are not currently impacted above background concentrations*

- *Downgradient performance monitoring wells are located downgradient of the Target Capture Zone and are currently impacted above background concentrations.*

Monitoring concentration trends downgradient of the dissolved-phase EDB provide supporting evidence to the primary capture analyses. Concentration trend monitoring is being conducted at two location types at Kirtland AFB: sentinel wells and downgradient performance monitoring wells. For sentinel wells, contaminant concentrations should remain at background levels over time if capture is successful. For downgradient performance monitoring wells, contaminant concentrations should decline to background levels (or below cleanup levels) over time if capture is successful. Figure 5-16 shows the location of the nine monitored sentinel wells and the location and concentration trends in the five distal performance monitoring wells. EDB concentrations in the sentinel wells have remained below detection since monitoring began. Furthermore, the "shallow" (i.e., REI 4857) well within each of the sentinel well clusters remains screened across the water table (non-submerged) as of Q4 2018.

Distal performance monitoring well concentration trends are shown from the beginning of 2015 to the present. Within this time period, water chemistry samples from KAFB-106205, located northeast of the distal end of the dissolved-phase EDB, have mostly been nondetect for EDB and have always been below the Target Capture Zone concentration of 0.05 µg/L. The increase of EDB to 0.041 µg/L in Q2 2017 is thought to be the result of system shutdown between January 19 and February 17, 2017. During this 30-day period, the system was offline for a total of 18 days and was running only during daytime hours for the remaining 12 days. Capture at this well has been reestablished with the interim measure extraction returning to full capacity and the concentration in KAFB-106205 is below the detection limit in Q4 2018. Groundwater samples collected from KAFB-106106, located on the western edge of the dissolved-phase EDB boundary, have historically had detectable EDB concentrations. Before interim measure extraction began in June 2015, EDB concentrations in this well were above the EDB MCL concentration (0.05

μg/L) and the well was within the dissolved-phase EDB boundary. Since interim measure wells KAFB-106233 and KAFB-106234 came on line in 2016, the EDB concentrations in KAFB-106106 have declined to at or below detection for the last three assessment periods. EDB was reported at an estimated value of 0.02 μg/L in the groundwater sample collected from KAFB-106106 in Q4 2018.

At the beginning of 2015, EDB was detected in groundwater samples collected from the three nested wells (KAFB-106055, KAFB-106057, and KAFB-106058; Figure 3-1). EDB concentrations decreased with depth, with concentrations above the MCL observed in the REI 4857 well KAFB-106055 and the REI 4838 well KAFB-106057. Since interim measure extraction began at KAFB-106234 in December 2015, the EDB concentrations in KAFB-106057 and KAFB-106058 have decreased and are currently at or below the detection limit (Figures 3-8 and 3-9, respectively). The increase in EDB concentrations observed in KAFB-106055 (0.082 μg/L) in Q4 2017 was thought to be indicative of preferential flow paths near the water table surface. It was anticipated that with continued interim measure extraction, the EDB concentrations at this well would decrease when sampled in Q2 2018. This was observed when the EDB concentrations in the groundwater samples collected from KAFB-106055 in Q2 2018 and Q4 2018 were estimated values, at the detection limit of 0.019 and 0.02 μg/L, respectively. In Q4 2018, the data gap associated with submergence at this well nest was eliminated by the installation of monitoring well KAFB-106241-428 with a screen interval across the water table. The EDB concentration measured in this new well in Q4 2018 was an estimated value of 0.022 μg/L.

It should be noted that the performance monitoring wells have submerged well screens (i.e., some of the REI 4857 wells no longer have screens across the water table). The submerged REI 4857 wells represent a data gap, and the observed EDB concentrations may not be reflective of the dissolved-phase EDB concentrations at the water table. Decreasing EDB concentration trends in these wells may be a function of mass rising above the screen interval with the water table rather than removal by interim measure extraction. Therefore, this supporting line of evidence is not as robust as desired. In addition to the installation of new monitoring wells with unsubmerged screens, several techniques for providing supporting lines of evidence to demonstrate capture have been initiated starting in Q2 2018 and are described in Section 5.4.4.

5.4.6 Step 6: Interpret Actual Capture and Compare to Target Capture Zone

EPA (2008) states that *Once multiple lines of evidence regarding capture have been evaluated, actual capture achieved by the extraction wells should be interpreted… To avoid bias, the actual capture should be interpreted independent of the Target Capture Zone (i.e., they should be compared after the actual capture zone is interpreted).*

Based on evaluations of multiple lines of evidence discussed in Step 3 through Step 5 described above, the actual capture achieved by the interim measure extraction wells is interpreted in Step 6, and the following items are addressed:

- Compare the interpreted capture zone to the Target Capture Zone
- Assess uncertainties in the interpretation of the actual capture zone
- Assess the need for additional characterization and/or monitoring.

In Step 3, the potentiometric surface analysis resulted in 100% capture of the volume and mass in the Target Capture Zone. In Step 4, the numerical flow model calculated 92% of the dissolved-phase EDB volume captured and 91% of the dissolved-phase EDB mass captured in the Target Capture Zone. In

Step 5, the concentration trends in the designated performance monitoring wells indicates decreasing trends indicating decreasing dissolved-phase EDB volume and mass reduction.

Table 5-21 presents the summary of the Target Capture Zone evaluation for this site. The Target Capture Zone analysis indicates that 92% of the dissolved-phase EDB volume is captured in Q4 2018 north of Ridgecrest Drive SE with KAFB-106233 off during assessment. The water level assessment of horizontal capture for Q4 2018 shows the extraction system producing a steady state condition capturing (horizontally) 100% of the plume volume and mass within the interim measure Target Capture Zone north of Ridgecrest Drive SE. The water level assessment of vertical capture within the Target Capture Zone shows that there is the potential for downward vertical migration of contaminant. In total, the vertical gradient analysis showed that 99% of the dissolved-phase EDB volume and mass in the interim measure Target Capture Zone were vertically contained in Q4 2018.

Results from the numerical flow model simulation, which provides a three-dimensional assessment of flow and capture, showed that 92% of the dissolved-phase EDB volume and mass, within the Target Capture Zone, was produced by interim measure extraction. A comparison of all lines of evidence suggests that less than 100% of the dissolved-phase EDB volume and mass, within the Target Capture Zone, is produced by interim measure extraction under Q4 2018 conditions.

Additional model simulations show that 100% dissolved-phase EDB containment in the Target Capture Zone would be achieved under Q4 2018 conditions if interim measure extraction well KAFB-106233 had been active during the synoptic gauging event. Numerical model results suggest that the observed vertical migration potential is occurring within the capture zone and will not result in migration outside of the interim measure influence. The actual capture interpretation for this performance assessment period is that the interim measure extraction system would produce sufficient hydraulic containment under Q4 2018 conditions if completely active; however, under these conditions, the loss of one or more extraction wells will result in the production of less than 100% hydraulic containment in the Target Capture Zone over time.

5.4.6.1 Uncertainty and Data Gaps

There is uncertainty in the analysis of water levels due to a linear estimate of the water levels at the extraction wells. However, the results from the numerical model show that, based on extraction rates and aquifer conductivity, the extraction well water levels used in the water level analysis were under-estimated and, therefore, do not overestimate the capture prediction. There is also uncertainty in the analysis of vertical gradients as 100% hydraulic containment of the dissolved-phase EDB in the interim measure Target Capture Zone cannot be shown. Again, the line of evidence produced through three-dimensional particle tracks from the numerical model strongly suggests that the dissolved-phase EDB is completely contained with respect to vertical flow.

There is uncertainty in the numerical modeling with respect to the assigned regional flow-field. The method used to define the gradient is described in detail in Appendix I-6. Uncertainty exists in that the method relies on interpolations from data measurements taken approximately two miles away from the model domain and on estimated groundwater levels associated with external extractions. An additional uncertainty component is the length of time the estimated regional flow-field persists over the model domain. The flow-field is sensitive to both on-Base and nearby public supply extractions and these stresses change seasonally and with local domestic demand allowing for the possibility that the simulated capture zones may change between each analysis period.

There is uncertainty in the numerical modeling associated with the assumption of homogeneous conductivity and the values assigned for Kh and VANI. Appendix I-6 describes the source of the assigned parameter values and the calibration process performed to define the values for these parameters. Analysis of vertical gradients at nested well locations show that the bulk of the measured aquifer volume behaves as a homogeneous unconfined aquifer. However, the vertical gradient analysis and numerical flow modeling show isolated areas where discontinuous confining conditions and preferential flow pathways may exist. The existence of these conditions is supported by borehole logs and lithologic cross sections of the aquifer. However, where observed, these conditions are expressed by groundwater head differences on the scale of tenths of a foot. In combination with the localized nature of these conditions, it is unlikely that the assumption of homogeneity significantly impacts the conclusion of capture.

Capture zone analysis is an iterative process, as shown on Figure 5-17, and includes the following:

- Evaluate capture based on existing data
- Identify any data gaps that create uncertainty in the conclusions of the capture zone analysis
- Fill any data gaps that are identified (e.g., add new monitoring wells), and re-evaluate capture
- Continue monitoring capture over time
- If capture is ever determined to not be sufficient, optimize the extraction system until capture is sufficient
- If capture is determined to be sufficient, continue routine monitoring and consider the potential to optimize extraction locations and/or rates to be reduce cost.

A performance assessment of the interim measure is performed every second and fourth quarter and capture is evaluated on current groundwater level measurements and groundwater chemistry sample results. The numerical model is updated with the current measured interim measure extraction rates and regional gradient estimate. Data gaps and uncertainties are defined, and new monitoring and extraction wells are proposed to address these issues. As discussed in Section 5.4 above, this performance assessment is a “snap shot” of the systems performance and is not intended to be a final remedy evaluation. The EPA guidance emphasizes that capture zone effectiveness is “ultimately determined by field monitoring.”

5.4.7 Dissolved-phase EDB Volume and Mass Analysis

The goal of the interim measure is not only to contain the migration of the dissolved-phase EDB, but also to reduce the volume and mass. This section describes the analyses designed to quantify the distribution of dissolved-phase EDB mass and volume within the aquifer over the course of the interim measure. Plume collapse in the Target Capture Zone is the long-term goal; therefore, establishing a consistent method of measurement that allows comparison of plume mass and volume trends over the duration of cleanup activities is essential.

Results

Figure 5-18 shows a cross-section comparison of the dissolved-phase EDB extent in Q2 2018 and Q4 2018. The plume has been cut along the AECOM T1A transect that, in general, runs along the longitudinal axis of the plume from southwest to northeast. The plume is shown transparent against the stratigraphic layers of the saturated portion of the aquifer along this transect developed by AECOM (2016) so that the shape and movement of the plume can be compared to the location and extent of coarse-grained (white) and fine-grained (gray) lithology as coarse-grained sediments are generally more permeable and conductive and may provide pathways for plume movement.

Analysis of dissolved-phase EDB mass and volume for Q2 2018 is performed within the same east-west transect intervals first presented and described in the Q4 2016 Quarterly and Annual Report (USACE, 2017e). There are 11 transect intervals (A-K) moving from south to north (Figure 5-18). Interval "F" is split between the Target Capture Zone and the area to the south of Ridgecrest Drive SE. However, the majority of the dissolved-phase EDB volume in this interval falls outside (to the south) of the interim measure Target Capture Zone (Figure 5-18) and this interval is, therefore, used as a general dividing line demarcating the Target Capture Zone. Both Figure 5-18 and Table 5-22 list the volume and mass of each interval and summarize these for total plume characterization. The dissolved-phase EDB mass values (in grams) assume a uniform total porosity of 25% for the contaminated thickness of the aquifer. While the porosity varies with stratigraphy, the porosity value used does not affect the percent change values for mass.

As shown in Table 5-22, dissolved-phase EDB mass in the interim measure Target Capture Zone (intervals G through K) was 81 grams in Q2 2017, 73 grams in Q4 2017, 15 grams in Q2 2018, and 13 grams in Q4 2018. Although dissolved-phase EDB volume has fluctuated in the Target Capture Zone from Q2 2017 to Q4 2018, dissolved-phase EDB mass has consistently decreased in this area.

Approximately 5 and 6 grams of EDB was removed by the GWTS in Q2 and Q3 2018, respectively (Table 5-8). The remaining reduction of mass in the interim measure Target Capture Zone is mostly due to dispersion and diffusion of mass in the aquifer below the MCL value.

Dissolved-phase EDB mass has been observed to fluctuate south of the interim measure Target Capture Zone. Possibilities of such temporal mass flux could be related to seasonal or gradient fluctuations, dissolution of residual contaminants in the vadose zone due to water table fluctuations, or, as is the case in Q4 2018, due to the addition of new water table monitoring wells in the source area.

Overall, the plume analysis reveals the general pattern of dissolved-phase EDB volume and mass response expected due to interim measure system extraction. Dissolved-phase EDB mass and volume movement are not uniform, and no region of mass increase or reduction is outside of expectation when allowing for the error incurred by estimating concentration gradients between water chemistry data points.

Challenges

The Kirtland BFF site is currently in the RFI stage of the RCRA corrective action process. Work plans have been approved to resolve data gaps for the Phase 2 RFI so that appropriate remedial alternatives can be proposed for the Corrective Measures Evaluation. In parallel with the RCRA RFI, interim measures were implemented for the BFF plume in groundwater containing dissolved-phase EDB north of Ridgecrest Drive SE (Target Capture Area). The measurement of plume collapse that allows comparison of dissolved-phase EDB mass and volume trends over the duration of cleanup activities is essential. This process is iterative and relies on site monitoring data collected from the GWM network in Q2 and Q4 of each calendar year.

The following discussion relates to the data provided in Figure 5-15 and Table 5-16. The interim measure extraction network, number and location of extraction wells, and assigned extraction rates have been designed to produce groundwater contaminant flow paths within the plume area that lead to an extraction well whereby contaminants are removed and treated. Over time, changes in dissolved-phase EDB volume and mass are expected to occur in response to this action. However, as contaminants are moving along new flow paths, shifted from the natural gradient toward the extraction wells, concentration changes at individual wells are expected to change, with some concentrations increasing and some decreasing. Nonetheless, over a longer timeframe (i.e., multiple quarters), this process is anticipated to reduce contaminant concentrations in the Target Capture Zone as contaminant mass is extracted and treated.

In the aquifer between the source area and the extraction wells, the expected initial response is an increase in dissolved-phase EDB mass and volume as groundwater extraction increases the groundwater flow rate toward the extraction wells. The extraction wells closest to the source area, previously KAFB-106228 but currently KAFB-106239, will become cut-off wells that may intermittently pull dissolved mass from the source area depending on local and regional gradient fluctuations. If the source area mass remains stationary, plume segmentation may occur in the vicinity of the southernmost hydraulic divide of the cut-off well. Near the extraction wells, the expected initial response is an increase in dissolved-phase EDB mass and volume. If the extraction well is properly positioned and performing as designed, radial migration of mass will increase the mass around the well and potentially increase the volume of the plume vertically along the screened interval of the well. On the distal edge of the plume, mass and volume are also expected to decrease as migration of mass to this region has stopped and extraction continues.

While this is the general plume response expected, the migration of the dissolved-phase EDB toward the extraction wells will not be uniform. Coarse sand and gravel channels will have greater flow velocities and transfer mass more quickly. Fine-grained deposits (i.e., clays and silts) will retard flow and slowly “leak” dissolved-phase EDB into the flow system. Pre-existing high concentration spots may move as pulses toward the extraction wells. Changes in the extraction network, such as loss of well function due to biofouling or pump failure, or the addition of new wells, will change the flow field and may cause temporary flow stagnation areas or intermediate high concentration zones. In addition, seasonal fluctuations, including regional gradient shifts as a result of external pumping stresses (e.g., production wells), could cause shifts in the migration and magnitude of dissolved-phase EDB.

There has been some concern that the rising groundwater levels have diminished the ability to accurately model the dissolved-phase EDB volume and mass using data from the existing monitoring network. In some areas, this may be true as model confidence is highest where volume and mass are interpolated between locations with concentration measurements. If the water table continues to rise above the network’s highest elevation screens, the model uncertainty increases in this region. This uncertainty was greatest in the source area where a majority of the monitoring wells were submerged. However, 12 of the 15 new water table wells activated in 2018 are located south of Ridgecrest Drive SE giving a total of 13 unsubmerged wells in this area, and additional wells are being installed in conjunction with the Q4 2018/Q1 2019 coring program.

In Q4 2018, uncertainty related to well submergence is controlled around the distal edge of the plume as eight of nine REI 4857 wells surrounding the edge of the plume are screened across the water table. Newly installed monitoring wells have closed the data gap and now include screen intervals above the water table to address future rising water table issues. Only well KAFB-106204 presents any additional uncertainty in the distal region having become submerged in 2017, with approximately 1.9 ft of water above the top of the screen as of Q4 2018. EDB was nondetect in KAFB-106204 in Q2 2018. With both the horizontal capture analysis and the numerical model showing flow toward extraction wells from KAFB-106204, it should not be expected that mass has moved into the region near KAFB-106204, or that the EDB concentration in the 1.9 ft of water above the well screen should be above the detection limit.

Additionally, monitoring wells KAFB-106041 and KAFB-106225 in the Target Capture Zone remain unsubmerged and the new water table monitoring well KAFB-106241-428 was added to the Target Capture Zone monitoring network. Dissolved-phase EDB observed in KAFB-106041 and KAFB-106241-428 in Q4 2018 was estimated at 0.013 µg/L (below the detection limit) and 0.022 µg/L, respectively.

In spite of the rising groundwater levels, there are multiple lines of evidence to support the effectiveness of the interim measure extraction system, including the new water table hydraulic containment analysis. As there has been no documented LNAPL in the interim measure Target Capture zone, no re-wetting of source material is expected and, therefore, no reason to suspect an increase in EDB concentrations related to groundwater elevation rise (i.e., all EDB in the interim measure Target Capture Zone is dissolved-phase that has migrated from the source area). This is supported by the decreasing mass and volume of EDB within the interim measure Target Capture Zone. It should be noted that multiple factors will affect the modeled mass within the plume, including the induced migration of EDB from the source area (from extraction wells), dispersion, and error incurred by interpolating concentration gradients. Therefore, the calculated (modeled) mass removal may not always be synchronized with the calculated (measured) mass removal at the GWTS during shorter reporting periods.

5.5 Ethylene Dibromide *In Situ* Biodegradation Pilot Test

The EDB *in situ* biodegradation pilot test has been ongoing on Kirtland AFB. It is being performed directly south of Randolph Avenue, near the BFF groundwater source area. The main objective of the pilot test is to investigate *in situ* anaerobic bioremediation of EDB in groundwater. This pilot test is being completed under an NMED approved work plan titled *EDB In Situ Biodegradation Pilot Test Work Plan* (USACE, 2016c).

Several new wells and existing monitoring wells (KAFB-106064 and KAFB-106063) are being utilized for this pilot test. The new wells include extraction wells KAFB-106EX1 and KAFB-106EX2; injection well KAFB-106IN1; and nested monitoring wells KAFB-106MW1-S, KAFB-106MW1-I, KAFB-106MW2-S, and KAFB-106MW2-I. Underground conveyance piping was also constructed to carry groundwater between the extraction and injection wells, directing the flow through an aboveground installation where amendments and/or tracers are introduced to the recirculated groundwater.

The pilot test was to be implemented in four phases, each briefly described below:

- ***Phase 1***—Evaluate baseline conditions and the distribution of recirculated water using tracer amendments.
- ***Phase 2***—Evaluate biostimulation in the subsurface after distribution of treatment amendments in recirculated groundwater.
- ***Phase 3***—Evaluate bioaugmentation in the subsurface after distribution of treatment amendments and dehalogenating bacteria in recirculated groundwater.
- ***Phase 4***—Continued monitoring with no active extraction/injection.

Per the Work Plan (USACE, 2016c), Phase 3 was to consist of both biostimulation and bioaugmentation; however, after review of field results from both Phase 1 and Phase 2, the U.S. Air Force recommended to NMED that a second round of biostimulation would be more beneficial. Due to the success of biostimulation during Phase 2, Phase 3 was modified to further evaluate biostimulation. The modified Phase 3 was approved by NMED in a letter dated August 7, 2018 (NMED, 2018f).

The passive monitoring portion of Phase 3, which began on September 9, 2018, was completed in November 2018. Phase 4 of the pilot test, long-term rebound monitoring, began on November 19, 2018 and will continue into 2019. During this time, groundwater samples will be collected on a bi-monthly basis at extraction, injection, and monitoring wells to evaluate the performance of the technology and quantify any rebound of EDB. The recirculation system will not operate for the remainder of the pilot test, except briefly during extraction well sampling.

An independent report summarizing all activities associated with the pilot test through the first Phase 4 sampling event (to be conducted in January 2019) will be submitted no later than May 1, 2019.

5.6 Ethylene Dibromide *In Situ* Biodegradation Pilot Test Annual Summary

The active portion of Phase 2 began on December 21, 2017. Injection of treatment amendments for biostimulation continued until February 6, 2018. The amendments that were introduced to groundwater during Phase 2 included a fermentable sodium lactate-based substrate with nutrients (WilClear Plus®), additional nutrients (diammonium phosphate), and an iodide tracer (potassium iodide). Throughout the active part of Phase 2, the following amounts of amendments and tracers were injected: 290 gallons of WilClear Plus®, 150 kilograms of diammonium phosphate, and 71 kilograms of potassium iodide. The passive portion of Phase 2 began on February 7, 2018 when the recirculation system was shut down and concluded in July 2018.

The recirculation system was restarted, and Phase 3 began on July 30, 2018. The amendments that were introduced to groundwater during Phase 3 included a fermentable sodium lactate-based substrate with nutrients (WilClear Plus®) and additional nutrients (diammonium phosphate). While the recirculation system was operated during Phase 3 (July 30 through September 9, 2018), 340 gallons of WilClear Plus® and 143 kilograms of diammonium phosphate were added to the subsurface; no additional tracers were used. The passive portion of Phase 3 began on September 9, 2018 and concluded on November 19, 2018. Phase 4 of the pilot test began on November 19, 2018 and will continue into 2019.

Groundwater samples were collected on a weekly basis during active recirculation and on a monthly basis during the passive portions of Phases 2 and 3 at extraction, injection, and monitoring wells to evaluate the effectiveness of biostimulation. Groundwater samples will be collected on a bi-monthly basis during Phase 4 to monitor any long-term rebound of EDB. No LNAPL has been observed in KAFB-106MW1-S since the one time detection soon after well development in Fall 2017.

6. INVESTIGATION-DERIVED WASTE

During Q4 2018, non-hazardous and hazardous investigation-derived waste (IDW) was generated. Non-hazardous IDW consisted of both liquid and solids that were sourced from GWM and monitoring well drilling operations. Liquid hazardous waste was generated from routine GWM operations and monitoring well construction activities.

In addition to the IDW generated specifically during Q4 2018, additional non-hazardous IDW generated during Q3 2018 was accumulated and managed during Q4 2018. This section discusses the details of waste generated and managed during the quarter.

6.1 Non-Hazardous Investigation-Derived Waste

Non-hazardous IDW liquids and solids comprised the majority of waste volume generated during the quarter. This waste was generated from both the quarterly GWM sampling event and drilling of monitoring wells during the quarter. Appendices J-1 and J-2 provide specific information regarding the non-hazardous liquid and solid IDW waste generated and disposed of during Q4 2018.

6.1.1 Groundwater Monitoring Liquid Waste

Non-hazardous, IDW purge water collected during the sampling of the GWM wells was placed in 55-gallon plastic (poly) drums. The drums were sealed with matching plastic lids with steel, locking-ring collars, labeled with vinyl non-hazardous waste labels, and transferred to the designated non-hazardous IDW yard located on Kirtland AFB. Small volumes of IDW water, typically generated from the sampling of drinking water wells, were placed in labeled, 5-gallon plastic buckets with sealing lids.

Eligibility for discharge of non-hazardous liquid IDW to the GWTS was determined by comparing historical, well-specific data from the previous two quarters to the acceptance criteria of the GWTS. Liquid IDW from monitoring wells that had historically met the GWTS acceptance criteria was discharged to the facility without further review. Liquid IDW sourced from wells with historical data from the previous two quarters that exceeded the GWTS acceptance criteria was held for further evaluation.

For Q4 2018, a total of 288.5 gallons of non-hazardous GWM purge water and equipment decontamination water met the GWTS acceptance criteria and was processed through the GWTS. All IDW water processed through the GWTS was discharged to the Tijeras Arroyo GCMP (Table J-1-1).

Any liquid IDW that is collected, but not yet processed through the GWTS, is temporarily accumulated in the “Pending Disposal” area of the IDW yard. Typically, this category includes non-hazardous purge water collected during the quarter that meets GWTS acceptance criteria, but was held due to GWTS discharge limitations, construction activities that delayed discharge, or operation and maintenance activities. By the end of Q4 2018, a total of 1,039.5 gallons of GWM purge water was being held in the “Pending Disposal” category (Table J-1-2a).

Any liquid IDW that is collected, but held pending receipt and evaluation of analytical data, is placed in the “Pending Analysis” area of the IDW yard. The only waste is this area at the end of Q4 2018 was one, 5-gallon pail of calibration fluid (Table J-1-2b) from GWM equipment.

6.1.2 Non-Hazardous Monitoring and Extraction Well Liquid Investigation-Derived Waste

During Q4 2018, the “Vadose Zone Source Area” drilling project was in progress. Liquid IDW was generated associated with well development from this drilling project as well as IDW (Section 2.1) generated during extraction well disinfection activities (Section 5.3.3.1). As of the end of December 2018, approximately 10,035 gallons of water in this category was generated and processed through the GWTS for disposal. The water was sourced primarily from the disinfection of extraction well KAFB-106239 (9,845 gallons) in November 2018. Small volumes were collected from excess water removed from waste roll off bins, and rainwater collected from secondary containment pads under drilling equipment (Table J-1-3).

6.1.3 Non-Hazardous Well Drilling Solid Investigation-Derived Waste

Approximately 167 cubic yards of non-hazardous, non-liquid IDW was managed and disposed during Q4 2018. This IDW included soil waste (drill cuttings and mud) associated with the drilling of the “Data Gap” (Section 3.1) and “Vadose Zone Source Area” coring and well installation (Section 2.1) projects. A total of 147 cubic yards of soil was disposed of at the Kirtland AFB construction and demolition landfill after receiving approval by the Kirtland solid waste program manager. Twenty yards of soil/mud was transported to the Twin Enviro landfill in Penrose, Colorado as this waste was too high in water content for the Kirtland construction and demolition landfill. One drum (approximately 0.26 yards) of well construction waste (cement and bentonite) was disposed of at an offsite construction landfill by the drilling contractor. Table J-2-1 (Appendix J-2) provides a list of all solid, non-hazardous IDW disposed of in Q4 2018.

Soil and mud waste generated from well drilling activities, that had not been disposed by the end of 2018, was held at the non-hazardous IDW yard. Table J-2-2 provides a list of containers holding the 73 cubic yards of non-hazardous material at the IDW yard as of December 31, 2018.

Additional non-hazardous, routine, and disposable solid wastes were generated during GWM activities. These included single-use dual membrane samplers, disposable in-line filters, nitrile gloves, and paper trash. These items were disposed of as municipal solid waste and volumes were not tracked.

6.2 Hazardous Investigation-Derived Waste

Hazardous or suspected hazardous IDW is accumulated in one of two RCRA less than 90-day accumulation areas associated with the Kirtland BFF Project. Hazardous waste generated from routine GWM sampling activities (purge water) is placed in the Kirtland AFB BFF RCRA less than 90-day accumulation area. Hazardous or suspected hazardous waste generated during the Vadose Zone Source Area drilling project are exclusively held in the Kirtland AFB Zia Park temporary RCRA less than 90-day accumulation area. The Zia Park area holds both liquids (borehole liquids and development water) and solids (drill cuttings) generated during coring and well construction activities.

Prior to the start of each quarterly GWM sampling event, a preliminary evaluation is made to identify monitoring wells that are anticipated to generate characteristically hazardous liquid IDW for initial waste segregation purposes. Based on historical analytical data available for each well, the water is suspected to be characteristically hazardous if the concentration of benzene exceeded 500 µg/L (per 40 CFR Part 261.24) in either of the previous two sampling events. Liquid IDW from these wells is managed as a potentially characteristically hazardous waste pending confirmation from laboratory analytical results. The hazardous waste classification code for benzene is D018.

All liquid hazardous waste (purge or well development water) is placed in 55-gallon steel drums with steel tops and locking rings. All waste containers are properly labeled, sealed, and placed on secondary containment pallets located within the BFF less than 90-day accumulation area. The accumulation area and waste containers are inspected on a weekly basis by trained personnel as required under 40 CFR 262.34.

Solid hazardous wastes are held in 15- or 20-yard capacity roll off bins. Bin doors are sealed with an expanding foam to minimize the potential of leaks and the bins are double lined with 10-millimeter plastic liners. Bins have either integrated hard cover tops with ratcheting straps or have removable, heavy-duty vinyl covers that are secured to the bin using heavy-duty rubber straps. In either case, the bin contents are protected from weather or access by local fauna. All bins are placed on secondary containment composed of plastic sheeting with rolled edges.

Upon receipt of analytical data, the IDW remains in the less than 90-day accumulation area if confirmed to be a hazardous waste. If the IDW is determined to not meet hazardous criteria based on analytical data, the non-hazardous waste is transferred to the “Pending Disposal” area of the non-hazardous IDW yard.

All hazardous waste must be removed from Kirtland AFB and properly disposed of off-Base within the required 90-day accumulation time limit. Hazardous waste is transported off Kirtland AFB after it is properly profiled, manifested, and approved for transport by the Kirtland AFB Hazardous Waste Management Group. Waste is transported by a licensed hazardous waste hauler to a permitted treatment, storage, and disposal facility.

When possible, liquid hazardous waste may be consolidated after analytical data have been received. This is typically done to combine small volumes of waste generated when using passive sampling methodologies as well as, to reduce the total number of drums that require offsite disposal.

6.2.1 Hazardous Investigation-Derived Waste Volume Q4 Summary

During Q4 2018, at total of 90 gallons (two drums) of hazardous purge water generated from GWM activities was disposed of prior to the end of the quarter. A hazardous waste disposal summary is provided in Table J-3-1 (Appendix J-3). The early RCRA less than 90-day accumulation area deadline for disposal of this purge water waste was January 9, 2019. The waste was taken offsite for disposal on December 19, 2018 by ACTenviro under Manifest No. 012267122 FLE.

No GWM hazardous waste was accumulated in the BFF less than 90-day accumulation yard beyond the end of Q4 2018. A total of 206 gallons of confirmed hazardous waste was accumulated in the Zia Park less than 90-day accumulation area at the end of 2018. Another 200 gallons of suspected hazardous waste (pending analytical confirmation) was also held in the area by the end of December 31, 2018. The accumulated characteristically hazardous waste consists entirely of well development water collected from monitoring wells constructed under the Vadose Zone Source Area drilling project (Section 2.1 and Table J-3-2).

No solid hazardous waste was generated, accumulated, or disposed of during Q4 2018 from any BFF site activities.

6.2.2 Hazardous Investigation-Derived Waste Annual Summary

For the calendar year 2018, the total confirmed volume of hazardous IDW purge and well development water generated during year 2018 is 406 gallons. This includes 200 gallons sourced for GWM activities and 206 gallons from well development activities.

The total volume of liquid hazardous waste disposed of in 2018 is 347 gallons. This includes 147 gallons of hazardous purge water generated in Q4 2017, but not disposed of until the first quarter of 2018 and 200 gallons of purge water generated and disposed of in 2018.

No solid hazardous waste was generated or disposed of during 2018.

7. PROJECTED ACTIVITIES

Q1 2019 will comprise the period between January 1 and March 31, 2019. Planned Q1 2019 activities are summarized below.

Vadose Zone Characterization and Monitoring

- Field activities related to the vadose zone coring and well installation project will be completed in Q1 2019.
- No vadose zone monitoring is performed in Q1 2019. The next scheduled monitoring will take place in Q2 2019. Begin construction for power supply to the bioventing pilot test system.

Groundwater Monitoring

- Perform and report on quarterly GWM in Q1 2019
- Report quarterly monitoring of USGS sentinel wells (by USGS).

Drinking Water Supply Well Monitoring

- Perform drinking water supply well monitoring monthly for organic compound analysis in Q1 2019 for the four wells sampled.

Groundwater Treatment System Operation

- Continue operating the GWTS and extraction wells KAFB-106228, KAFB-106233, KAFB-106234, and KAFB-106239
- Complete valve installation at KAFB-7
- Retest the effluent conveyance line between the changeover valve and the KAFB-7 following valve installation
- Perform GWTS well disinfection as required
- Complete reporting for the *in situ* EDB biodegradation pilot study.

Reporting

- A quarterly report will be prepared to detail the activities conducted during the quarter, and to summarize the activities and GWM data Q1 2019.

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