KIRTLAND AIR FORCE BASE
ALBUQUERQUE, NEW MEXICO

Quarterly Pre-Remedy Monitoring and Site Investigation Report for April – June 2011

Bulk Fuels Facility Spill
Solid Waste Management Units ST-106 and SS-111

September 2011

377 MSG/CEANR
2050 Wyoming Blvd. SE
Kirtland AFB, New Mexico 87117-5270

KIRTLAND AIR FORCE BASE
ALBUQUERQUE, NEW MEXICO

QUARTERLY PRE-REMEDY MONITORING AND SITE INVESTIGATION REPORT APRIL – JUNE 2011

BULK FUELS FACILITY SPILL SOLID WASTE MANAGEMENT UNITS ST-106 AND SS-111

September 2011

Prepared for
U.S. Army Corps of Engineers
Albuquerque District
Albuquerque, New Mexico 87109

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This Quarterly Pre-Remedy Monitoring and Site Investigation Report for April – June 2011 has been prepared in response to correspondence from the New Mexico Environment Department Hazardous Waste Bureau (NMED-HWB) (NMED, 2010a) to Kirtland Air Force Base (AFB) dated June 4, 2010, outlining the reporting, sampling, and analysis requirements related to the characterization and remediation of contaminated groundwater at Solid Waste Management Units ST-106 and SS-111, Bulk Fuels Facility (BFF) Spill, Kirtland AFB, New Mexico. Quarterly reporting will incorporate information and data collected in support of ongoing remediation and site characterization activities related to the Stage 2 abatement action for the Former Fuel Offloading Rack (FFOR), designated as ST 106, and the phase-separated hydrocarbon-impacted groundwater, designated as SS-111. As specified by the NMED-HWB, quarterly reporting for the ST-106 and SS-111 sites has been integrated due to the interrelated nature of the sites and the applicability of different data sets to characterization and remediation activities at the BFF Spill site.

Quarterly remediation and site investigation reporting presents field and analytical data and information associated with the operation, maintenance, and performance of the interim remedial measures soil-vapor extraction and treatment systems; characterization and remediation activities associated with the groundwater and vadose zone and FFOR investigations; and pre-remedy quarterly monitoring for groundwater and soil vapor at the BFF Spill site.

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Commander

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377 ABW Public Affairs

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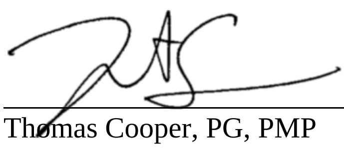
PREFACE

This Quarterly Pre-Remedy Monitoring and Site Investigation Report for April – June 2011 was prepared by Shaw Environmental and Infrastructure, Inc. (Shaw) for the U.S. Army Corps of Engineers (USACE), under contract W912DY-10-D-0014, Delivery Order 0002. It pertains to the Kirtland Air Force Base (AFB) Bulk Fuels Facility (BFF) Spill, Solid Waste Management Units ST-106 and SS-111, located in Albuquerque, New Mexico. This report was prepared in accordance with all 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 Air Force, dated April 2, June 4, August 6, and December 10, 2010.

This work was performed under the authority of the USACE Contract No. W912DY-10-D-0014, Delivery Order 0002. All work was conducted from April through June 2011. Mr. Walter Migdal is the USACE Albuquerque District Project Manager; Mr. Wayne Bitner, Jr. is the Kirtland AFB Restoration Section Chief; and Mr. Thomas Cooper is the Shaw Project Manager. This report was prepared by Pamela Moss, Diane Agnew, Gary Hecox, Dale Flores, and Kim Truong.



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CONTENTS

Section **Page**

CONTENTS (continued)

Section **Page**

CONTENTS (concluded)

APPENDICES

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PLATES

Plate

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FIGURES

Figure

FIGURES (continued)

Figure

FIGURES (continued)

Figure

FIGURES (continued)

Figure

TABLES

Table

TABLES (concluded)

Table

ACRONYMS AND ABBREVIATIONS

3D	three-dimensional
AFB	Air Force Base
APH	Air Phase Petroleum Hydrocarbons
ARCH	air rotary casing hammer
ASTM	ASTM International
BFF	Bulk Fuels Facility
bgs	below ground surface
BTOC	below top of casing
C&D	Construction and Demolition
CFR	Code of Federal Regulations
CO	carbon monoxide
CO_2	carbon dioxide
CSS	Colorado silica sand
DO	dissolved oxygen
DOT	U.S. Department of Transportation
DPT	direct-push technology
DRE	destruction removal efficiency
DRO	diesel range organics
EDB	1,2-dibromoethane/ethylene dibromide
EPA	U.S. Environmental Protection Agency
ERP	Environmental Restoration Program
FD	field duplicate
FFOR	Former Fuel Offloading Rack
ft	foot/feet
GPS	global positioning system
GRO	gasoline range organics
GW	groundwater
GWM	groundwater monitoring
GWQB	Ground Water Quality Bureau (NMED)
HWB	Hazardous Waste Bureau (NMED)
ICE	internal combustion engine
ID	identification
IDW	investigation-derived waste
Jet West	Jet West Geophysical Services
°K	degrees Kelvin
KAFB	Kirtland AFB

ACRONYMS AND ABBREVIATIONS (continued)

LAS	Log ASCII Standard
LNAPL	light non-aqueous phase liquid
$\mu g/L$	microgram per liter
$\mu g/m^3$	microgram per cubic meter
MADEP	Massachusetts Department of Environmental Protection
MCL	maximum contaminant level
mg/kg	milligram per kilogram
msl	mean sea level
MW	molecular weight
NAPL	non-aqueous phase liquid
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
O_2	oxygen
O.D.	outside diameter
ORP	oxidation-reduction potential
oz	ounce
PAH	polycyclic aromatic hydrocarbon
PG	Professional Geologist
PLC	programmable logic controller
PMP	Project Management Professional
ppmv	parts per million by volume
PSH	phase-separated hydrocarbon
PVC	polyvinyl chloride
QA	quality assurance
QAPjP	Quality Assurance Project Plan
QC	quality control
RCRA	Resource Conservation and Recovery Act
RSI	Remediation Service International
RTK	real-time kinematic
scfm	standard cubic feet per minute
Shaw	Shaw Environmental & Infrastructure, Inc.
SM	Standard Method
SVE	soil-vapor extraction
SVEW	soil-vapor extraction well
SVM	soil-vapor monitoring
SVMW	soil-vapor monitoring well
SVOC	semivolatile organic compound
1,2,4-TMB	1,2,4-trimethylbenzene
TPH	total petroleum hydrocarbons

ACRONYMS AND ABBREVIATIONS (concluded)

USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force
USCS	Unified Soil Classification System
VA	Veterans Affairs
VOA	volatile organic analysis
VOC	volatile organic compound

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EXECUTIVE SUMMARY

This report has been prepared in response to correspondence dated June 4, 2010, from the New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB) (NMED, 2010a) to Kirtland Air Force Base (AFB) outlining the reporting, sampling, and analysis requirements related to the characterization and remediation of contaminated groundwater at Solid Waste Management Units ST-106 and SS-111, Bulk Fuels Facility (BFF) Spill, Kirtland AFB, New Mexico. Quarterly reporting will incorporate information and data collected in support of ongoing remediation and site characterization activities related to the Stage 2 abatement action for the Former Fuel Offloading Rack (FFOR), designated as ST-106, and the phase-separated, hydrocarbon-impacted groundwater, designated as SS-111. As specified by the NMED-HWB, quarterly reporting for the ST-106 and SS-111 sites has been integrated due to the interrelated nature of the sites and the applicability of different data sets to characterization and remediation activities at the BFF Spill site.

Quarterly remediation and site investigation reporting presents field and analytical data and information associated with the operation, maintenance, and performance of the interim remedial measures soil-vapor extraction (SVE) and treatment systems; characterization and remediation activities associated with the groundwater and vadose zone and FFOR investigations; and pre-remedy quarterly monitoring for groundwater and soil vapor at the BFF Spill site.

The major findings in this quarterly report are summarized as follows:

- Volatile organic compound mass recovery rates in two of the four operating internal combustion SVE units have become asymptotic, and it is recommended that Unit 335 (KAFB-1065) be shut down and Unit 344 (KAFB-1068) be scaled back to one engine. If performance of Unit 344 (KAFB-1068) does not improve and remains at the level observed during this quarter, this unit also will be shut down.
- Once the data to be collected in the SVE Optimization Plan (USACE, 2011a) become available, the entire SVE system will be reassessed to improve mass recovery from the vadose zone.

- Rising groundwater levels continue to result in decreases in non-aqueous phase liquid (NAPL) thickness and observations in monitoring wells. During the quarter, NAPL was consistently observed only in one historical and two new monitoring wells.

- Based on the three-dimensional distribution of vadose zone soil and vapor concentrations from wells installed and sampled to date, it appears that the majority of the vadose zone contaminant mass is located approximately 50 to 100 feet above the water table at depths of approximately 400 to 490 feet below ground surface.

- Based on the data collected to date, the soil concentrations indicate that the NAPL migrated in a predominantly vertical direction along relatively narrow pathways until it reached the capillary fringe above the water table where it spread out in horizontal directions. The planned Pneulog testing will further delineate these pathways.

- The groundwater flow direction in downgradient areas of the Shallow Zone of the aquifer appears to be North 35° East instead of North 20° East as previously assumed. The groundwater levels and organic compound concentrations support this revised flow direction.

- The extent of 1,2-dibromoethane (EDB) in groundwater is not currently defined to the northeast, and better definition will be accomplished when the newly installed wells are sampled in Third Quarter 2011. The new KAFB-106055 well cluster is downgradient of KAFB-10622. Water supply well KAFB-3 is located 4,200 feet downgradient in a northeasterly direction. No EDB has been detected in this well.

- The centerline of the EDB groundwater plume appears to cross through KAFB-10622 and not KAFB-10625 as previously assumed.

- Initial groundwater analytical data from new monitoring wells indicate that organic compounds may be present in some Intermediate and Deep Zone wells. Subsequent sampling is required to confirm or refute these initial results.

- Based on the analysis of the degradation indicator compounds and the spatial extent of the organic compounds, it appears that microbial degradation is slowing the migration rate and limiting the extent of a majority of the organic compounds including benzene, toluene, and m,p-xylenes. Additional evaluations are required to quantify the degradation rates and impact on future plume migration. The effect of microbial degradation on EDB migration rates and extent is less clear. Additional compound-specific data are required to determine whether microbial degradation is having any effect on EDB migration.

1. INTRODUCTION

The Bulk Fuels Facility (BFF) Spill site is located within the western portion of Kirtland Air Force Base (AFB), New Mexico (Figure 1-1) and is comprised of two solid waste management units, designated as ST-106 and SS-111. The component of the BFF Spill project related to investigation and remediation of the vadose zone near the Former Fuel Offloading Rack (FFOR) is designated as ST-106. The phase-separated hydrocarbon (PSH)-impacted groundwater component of the project is designated as SS-111.

This report has been prepared to summarize ongoing site investigation, remedial, and pre-remedy monitoring activities at ST-106 and SS-111, BFF Spill, Kirtland AFB, New Mexico (U.S. Environmental Protection Agency [EPA] Identification [ID] Number NM9570024423/HWB-KAFB-10-004). As specified by the New Mexico Environment Department (NMED) – Hazardous Waste Bureau (HWB) in its regulatory letter, dated June 4, 2010, to Kirtland AFB (NMED, 2010a), quarterly reporting for ST-106 and SS-111 has been integrated due to the interrelated nature of the sites and the applicability of different data sets to characterization and remediation activities at the BFF Spill site.

On April 2, 2010, regulatory control of the BFF Spill site was transferred from the NMED Ground Water Quality Bureau (GWQB) to the NMED-HWB (NMED, 2010b). Historically, semiannual reports have presented data regarding ongoing remediation of ST-106 vadose zone contamination associated with the FFOR and ongoing characterization and interim remediation instituted to begin recovery of PSH on the groundwater at SS-111. Activities and data related to ST-106 were conducted as the Stage 2 abatement action under the NMED-GWQB–approved *Stage 2 Abatement Plan for the Bulk Fuels Facility (ST-106)* (U.S. Air Force [USAF], 2002). This plan identified soil-vapor extraction (SVE) as the preferred abatement option to be implemented at ST-106 to attain abatement standards and requirements set forth in Section 4103 of Title 20, New Mexico Administrative Code (NMAC), Chapter 6, Part 2. ST-106 remediation was initiated before the discovery of PSH impacts to groundwater. Following the discovery of SS-111, Kirtland AFB instituted PSH recovery directly from the aquifer surface at three well locations, using the same SVE technology approved for the Stage 2 abatement action for ST-106. These actions were conducted as interim measures while site characterization activities continue.

This quarterly remediation, site investigation, and pre-remedy monitoring report describes the operation, maintenance, and performance of interim remedial measures as well as site characterization and monitoring activities completed at the BFF Spill site during the period of April through June 2011. Quarterly reports present data and information related to ongoing activities at the BFF Spill site, including:

- Groundwater and vadose zone investigations,
- Pre-remedy groundwater and soil-vapor monitoring,
- Interim measure investigation at the FFOR, and
- SVE unit monitoring and maintenance.

Quarterly reports will continue to allow information regarding successive investigation phases to be regularly disseminated to stakeholders, presented in context with other site-related data. Data collected during each quarter will be presented in the quarterly report text; however, cumulative information will be presented in the report appendices. Reporting requirements specified in the letter dated June 4, 2010, from the NMED-HWB include the following:

- Field and laboratory analytical results for groundwater, soil, and soil vapor;
- Laboratory analysis of soil-vapor samples collected from the SVE systems;
- Graphs showing trends of major contaminants versus time;
- A table of surveyed well locations;
- Descriptions of the installation of groundwater and soil-vapor monitoring (SVM) wells (SVMWs) (if applicable);
- Measurements of light non-aqueous phase liquid (LNAPL), also referred to as PSH;

- A table of water levels and water-level map;
- Plume contaminant maps and cross-sections;
- Geologic and geophysical logs of wells and boreholes (if applicable);
- Operation, maintenance, and performance data for remedial measures;
- Quality assurance (QA)/quality control (QC) data; and
- Recommendations for future site activities.

All these requirements are incorporated into this Second Quarter report for April through June 2011, as applicable. The following appendices provide information that supplements this quarterly report for April through June 2011:

- Appendix A, Summary of SVE System Operation, Maintenance, Repair, and Hydrocarbon Recovery Calculations
- Appendix B, Data Quality Evaluation Reports
- Appendix C, Waste Disposal Documentation
- Appendix D, Well Installation Forms
- Appendix E, Historical Data Summaries
- Appendix F, Hydrographs
- Appendix G, Field Sampling Data and Records

In the following discussions, the term non-aqueous phase liquid (NAPL) is used to describe the mixture of separate phase organic liquid that has been observed in the subsurface. Because this NAPL is less dense than water it is sometimes referred to as LNAPL. In this discussion the term NAPL is used for convenience.

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2. SVE REMEDIATION SYSTEM PERFORMANCE

This section describes the operations and performance of the BFF SVE system during the reporting period from April through June 2011. The SVE extraction and monitoring wells are presented on Figure 2-1. Detailed operations data and calculations are presented in Appendix A for the four systems.

2.1 SVE Remediation System Description, Monitoring, and Calculations

2.1.1 Description of System

Each of the four SVE and treatment systems in use at the BFF consists of trailer-mounted units that include specialized on-board computer controllers, sensors, and a pair of 460-cubic-inch displacement Ford Model LSG-875 internal combustion engines (ICEs). These ICEs have been modified and remanufactured to the specifications of Remediation Service International (RSI). Within each SVE system, the programmable logic controller (PLC) uses the engines as the vacuum pump to extract vapor from the vadose zone, and the catalytic converters on each engine provide treatment of the hydrocarbon vapors. Operation of each unit is controlled by the PLC through adjustments to the influent soil-vapor, ambient air, and a supplemental fuel source valves. The PLC adjusts the feed from the vapor well, ambient air, and supplemental fuel source to maintain the proper air/fuel ratio to support combustion in the engine. Propane is used as the fuel source during engine starting and warm-up, after which the system consumes recovered petroleum hydrocarbon vapors as the primary fuel source, using propane as needed to help stabilize engine performance. The higher the influent soil-vapor concentration, the less supplemental fuel is used for operations. These four units are operating under air permit NMAC Permit Number 1984 issued by Albuquerque Environmental Health Department on April 30, 2009.

For system performance analysis, the PLC calculates various operational parameters including the hydrocarbon mass recovery in pounds per period and gallons NAPL equivalent per period. To simplify system reporting and calculations, the PLC for each unit is downloaded on or about the last day of each month and compiled into a database. For consistency with historical reporting, the cumulative mass recovery values reported in the following sections are those calculated by the PLC and are not determined from the influent laboratory analytical results.

The ST-106 FFOR SVE unit (RSI Unit 249) was installed in April 2003 (fully operational in July 2003), the Kirtland AFB (KAFB)-1065 unit (RSI Unit 335) was installed in August 2008, and the KAFB-1066 (RSI Unit 345) and KAFB-1068 (RSI Unit 344) units were installed in March 2009. The ST-106 unit is connected through manifold piping to nine soil-vapor extraction wells (SVEWs), SVEW-01 through SVEW-09, shown on Figure 2-1. The SVE units installed on the groundwater monitoring wells are directly connected to the wellheads. Table 2-1 lists the SVEWs used for active extraction during April through June 2011.

2.1.2 Vapor Monitoring and Sampling

During the reporting period, vapor samples from vapor extraction and monitoring wells and SVE system inlet and exhaust ports were analyzed using the field Horiba Mexa 554J emissions analyzer for petroleum hydrocarbon concentration in parts per million by volume (ppmv) and for percent oxygen (O_2), carbon monoxide (CO), and carbon dioxide (CO_2) (Table 2-2).

Soil-vapor samples for laboratory analysis were collected from all SVE and SVM wells (including new soil-vapor wells) during Second Quarter 2011. Laboratory analytical data packages for vapor samples collected during the First and Second Quarters in 2011 are included (with all other site analytical data) in Appendix B. Appendix B presents the Data Quality Evaluation Report for the SVE unit data collected during First Quarter 2011.

Samples for laboratory analysis of the combined influent soil vapor, pre-catalytic converter, and post-catalytic converter exhaust streams were collected during the reporting period. These samples were collected into pre-evacuated Bottle-Vac canisters. The canisters were packaged and shipped under chain of custody to RTI Laboratories, Inc. in Livonia, Michigan, for the following analyses:

- Volatile organic compounds (VOCs) including acetone, 1,2-dibromoethane (EDB), 1,2-dichloroethane, 1,2,4-trimethylbenzene (1,2,4-TMB), 1,3,5-trimethylbenzene, methyl tertiary butyl ether, and methyl ethyl ketone (or 2-butanone) by EPA Method TO-15;
- Fixed gases (oxygen, nitrogen, carbon monoxide, carbon dioxide, and methane) by Method ASTM International [ASTM]-D2504; and
- Total petroleum hydrocarbons (TPH) by EPA Method TO-13A.

The First Quarter 2011 SVE unit analytical results and concentrations of contaminants of concern in the extracted influent vapor are summarized in Table 2-3. The highest total VOC concentrations detected in vapor extracted from Unit 249 (ST-106) and Unit 345 (KAFB-1066) are 39,340 and 37,778 ppmv, respectively. Vapor extracted from Unit 344 (KAFB-1068) has a VOC concentration of 5,313 ppmv. Vapor extracted from Unit 335 (KAFB-1065) has the lowest VOC concentration of 101 ppmv.

2.1.3 Calculation of Destructive Removal Efficiency

Field or laboratory analytical data from the SVE system influent and exhaust samples provide information on the treatment efficiency of each SVE unit. The treatment destruction removal efficiency (DRE) for each unit is calculated as:

$$DRE = \frac{Influent\ Conc. - Effluent\ Conc.}{Influent\ Conc} \times 100.$$

The DRE values for each unit are presented in Table 2-3.

2.1.4 Calculation of Hydrocarbon Remediation Attributable to Natural Attenuation through Bioventing

The Air Force Center for Engineering and the Environment has published guidance to account for the attenuation of petroleum hydrocarbons by bioventing (Leeson and Hinchee, 1996a and b). The mass of petroleum hydrocarbons biodegraded can be calculated using the following equation:

$$HC_{Bio} = (C_{V,bkgd} - C_{V,O2})/100 \times Q \text{ x } C \times \rho_{O2} \times MW_{O2} \times (\text{kg}/1{,}000\text{g}) \times (1{,}440 \text{ min/day})$$

Where:

HC_{Bio}	=	Mass of hydrocarbons biodegraded (kilograms per day)
$C_{V,bkgd}$	=	Concentration of oxygen in background, uncontaminated area (%)
$C_{V,O2}$	=	Concentration of oxygen in extracted off-gas (%)
Q	=	Flow rate (standard cubic feet per minute (scfm)
C	=	Mass ratio of hydrocarbon to oxygen degraded based on stoichiometry (1/3.5)
ρ_{O2}	=	density of oxygen (moles/liter)
MW_{O2}	=	Molecular weight of oxygen (grams/mole)

2.2 ST-106 FFOR SVE System (Unit 249)

The following sections summarize the operations and remedial performance for the ST-106 (FFOR) SVE Unit 249.

2.2.1 System Operation

During the April through June 2011 reporting period, extraction wells SVEW-01 through SVEW-05 were used for vapor extraction (Table 2-1). Active extraction wells open to the SVE system are adjusted to extract the highest VOC concentration vapor from the subsurface. Engines 1 and 2 of Unit 249 were operational 97.2 and 93.6% of the time, respectively. Routine system maintenance was performed on the engines in accordance with the site-specific *Operations and Maintenance Manual for the Soil Vapor Extraction Systems* (USAF, 2009a). A summary of the major maintenance activities, non-routine maintenance or repair activities, and system downtime during the reporting period is presented in Appendix A.

The DRE values for SVE-Unit 249 based on the Horiba field measurements are 93 and 95% for Engines E1 and E2, respectively, during the May 2011 sampling event (Table 2-3).

2.2.2 Hydrocarbon Recovery and Degradation

The ST-106 SVE System (Unit 249) extracted approximately 9,642 NAPL-equivalent gallons from April through June 2011 (Table 2-4) and approximately 215,000 gallons of NAPL have been removed from the vadose zone by SVE Unit 249 from July 2003 through June 2011 (Table 2-4). As presented on Figure 2-2, the recovery rate of this system has essentially remained constant since late 2006. The somewhat steeper slope to the mass recovery vs. time graph in 2011 represents a change in which vadose zone wells are used as extraction wells.

With an assumed average flow rate of 43 scfm and an operational runtime of 95% for the reporting period, using the equation described in Section 2.1.3, an estimated 2,015 NAPL-equivalent gallons were treated by bioventing during the second quarter from April through June 2011 by the biodegradation.

2.3 SS-111 SVE System

The following sections summarize operations and remedial performance for the SS-111 SVE system consisting of three operational RSI units (335, 344, and 345).

2.3.1 System Operation

During the reporting period, the individual SVE systems (Units 335, 345, and 344) located at wells KAFB-1065, KAFB-1066, and KAFB-1068, respectively, were operational. The operational time percentages for each unit are presented as follows:

Well/Unit	Engine 1 Operational Percentage	Engine 1 Operational Percentage	Average Operational Percentage
KAFB-1065 (RSI Unit 335)	54	80	67
KAFB-1066 (RSI Unit 345)	80	76	78
KAFB-1068 (RSI Unit 344)	84	57	71

The systems were not operational 100% of the time because they periodically had to be taken offline for routine and non-routine engine maintenance and repairs and engine controller malfunction. Appendix A presents a summary of the major maintenance activities, non-routine maintenance or repair activities, and system downtime during the reporting period.

The DRE values for three SVE units during the May 2011 sampling event (Table 2-3) are listed as follows:

- SVE Unit 335: 97 and 98% for Engines E1 and E2, respectively
- SVE Unit 345: 98 and 99% for Engines E1 and E2, respectively
- SVE Unit 344: 94 and 97% for Engines E1 and E2, respectively

2.3.2 Hydrocarbon Recovery and Degradation

The KAFB-1065 SVE system (Unit 335) extracted approximately 1,036 NAPL-equivalent gallons from April through June 2011, and approximately 84,900 gallons of NAPL have been removed from the vadose zone by Unit 335 from August 2008 through June 2011 (Table 2-5). With an average flow rate of 14 scfm and an operational runtime of 67%, approximately 437 NAPL-equivalent gallons were treated by bioventing during the second quarter. As presented on Figure 2-2, the recovery rate of this system has declined markedly in the last two years and currently demonstrates only marginal remedial effectiveness.

The KAFB-1066 SVE system (Unit 345) extracted approximately 6,224 NAPL-equivalent gallons from April through June 2011, and approximately 58,800 gallons of NAPL have been removed from the vadose zone by Unit 335 from March 2009 through June 2011 (Table 2-6). With an average flow rate of

38 scfm and an operational runtime of 78%, approximately of 174 NAPL-equivalent gallons were treated by bioventing during the second quarter. As presented on Figure 2-2, the recovery rate of this system has remained constant over the last two years and currently demonstrates adequate remedial effectiveness.

The KAFB-1068 SVE system (Unit 344) extracted approximately 2,679 NAPL-equivalent gallons from April through June 2011, and approximately 55,200 gallons of NAPL have been removed from the vadose zone by Unit 335 from March 2009 through June 2011 (Table 2-7). With an average flow rate of 48 scfm and an operational runtime of 70%, approximately of 969 NAPL-equivalent gallons were treated by bioventing during the second quarter. As presented on Figure 2-2, the recovery rate of this system has declined over the last two years and currently shows signs of declining remedial effectiveness.

2.4 Waste Generation

Maintenance activities for the SVE and treatment systems generate both non-hazardous and Resource Conservation and Recovery Act (RCRA) hazardous wastes. Liquid condensate is another waste stream associated with SVE operation. The liquid condensate is primarily generated during cooler-season months (typically October through April) as warm, moisture-laden subsurface soil vapor moves up the extraction wells to the cooler ground surface where it condenses in the system piping. During this reporting period, insufficient liquid condensate was generated to require offsite disposal.

All waste generated at the site is disposed of in compliance with the site-specific waste management procedures outlined in the site-specific Operations and Maintenance Plan (USAF, 2009a). Procedures in the Operations and Maintenance Plan comply with the *Kirtland AFB, Environmental Restoration Program, Investigation-Derived Waste Management Plan*, issued in 2009 (USAF, 2009b), which incorporated specific direction and consideration of the waste streams generated in association with the BFF Spill site remediation. Disposal documentation for waste generated during this reporting period is provided in Appendix C.

2.5 SVE and Treatment System Operational Summary

Operational changes and additional infrastructure modifications continue to be evaluated to optimize the operation of the ST-106 and SS-111 interim SVE and treatment systems. The goal of the optimization efforts is to extract the maximum amount of combustion constituents (fuel and oxygen) from the subsurface, thereby maximizing overall mass recovery rates and achieving the highest possible total mass removal from the four combined SVE systems in their current configurations. Work planning efforts continue to identify additional modifications to the SVE approach in use at the site, which may modify the use of current SVE systems or supplement this approach with other remediation approaches in the future. Recommendations for optimization are presented in the *SVE Optimization Plan, Bulk Fuels Facility (BFF) Spill, Solid Waste Management Units ST-106 and SS-111, Kirtland AFB, Albuquerque, New Mexico* (USACE, 2011a).

Tables 2-5 through 2-7 present the propane consumption and ratio of gallons of propane used per NAPL-equivalent gallon of contaminated vapor recovered.

- For ST-106 Unit 249, the ratio is 0.15 gallons of propane used per gallon of NAPL recovered. This is consistent with the long-term remedial performance of this system and no adjustments will be made.
- Unit 335 (KAFB-1065) is consuming 6.1 gallons of propane for each gallon of NAPL recovered. This unit will be shut down based on marginal remedial effectiveness and moved to another location based on the SVE Optimization Plan results.
- Unit 345 (KAFB-1066) is consuming 0.23 gallons of propane for each gallon of NAPL recovered. This is consistent with the long-term remedial performance of this system and no adjustments will be made.
- Unit 344 (KAFB-1068) is consuming 2.2 gallons of propane for each gallon of NAPL recovered. One engine on this unit will be shut down and the performance monitored. If remedial performance continues to decline, this unit will be shut down and moved to another location based on the SVE Optimization Plan results.

3. SITE INVESTIGATION

3.1 Site Investigation Objectives

This quarterly report presents the monitoring methods and results for activities performed at the Kirtland AFB BFF Spill site for the period of April 1 through June 30, 2011. BFF Spill groundwater investigation and monitoring are currently being implemented in conjunction with the vadose zone investigation and interim measures for ST-106 and SS-111. Approved work plans (USACE, 2011b,c,d) for these three projects provide guidance for the work activities performed during the quarter. Additionally, the activities described herein comply with the NMED technical directives to Kirtland AFB for performing interim measures for the BFF Spill (ST-106 and SS-111) as elaborated in the August 6, 2010 (NMED, 2010c) and December 10, 2010 (NMED, 2010d) letters from the NMED to Kirtland AFB. This section describes in detail the monitoring methods used and activities performed to characterize and monitor the groundwater and soil at the BFF. Sections 4 and 5 present the monitoring results for the vadose zone and groundwater, respectively.

3.2 Site Investigation Activities

Appendix E (electronic files in Excel format) and Appendix H present cumulative tables of field sampling data locations and well construction details. The tables are updated each quarter as new data locations are established and wells installed. Detailed discussions of field investigation activities this quarter are presented in the following sections.

3.2.1 Geophysical Logging

Geophysical logging is being conducted at newly installed groundwater monitoring (GWM) and SVM wells at the BFF Spill site to define the lithologic and hydrogeologic characteristics of geologic units beneath the site. The goal of geophysical borehole logging investigations is to use the data to refine the conceptual site model of the potential source location and extent of LNAPL contamination to optimize placement of remedial SVE and groundwater extraction wells and potential future monitoring wells. The geophysical logs will also be incorporated into the site geologic model once all the newly installed wells have been logged.

Geophysical logging was conducted at 20 GWM wells and 3 SVMWs at the BFF Spill site during Second Quarter 2011, as identified in Table 3-1. The geophysical logs are included with the geologic cross sections to continue to develop the conceptual site model. An evaluation of the geophysical logs will be presented when the well installations are complete and all geophysical logs are available.

3.2.1.1 Geophysical Well Logging

Geophysical well logging at the BFF Spill site during this reporting period involved the following activities:

- Perform pre-logging instrument functional checks as follows:
  - The induction tool functionality check is performed at the beginning and end of each day and includes assessing background readings and the use of a calibrated sleeve.
  - The induction tool is placed in a 4-foot-tall “jig” to hold the tool in a horizontal position above the ground. The tool must be far enough away from cultural features to avoid interference in the data being recorded.
  - Average conductivity readings are recorded over 100 samples. The attached natural gamma tool also measures the background over 100 samples.
  - A calibration disc is placed over the medium and deep receiver coils and 100 samples are recorded. A calibration sleeve is also placed over the natural gamma crystal and data are recorded.
  - The neutron tool functionality check is performed in a similar manner to the induction tool check with the attached natural gamma tool being checked in a similar fashion.
  - The neutron tool is placed in a jig to measure the background. The neutron source is not attached while performing natural gamma measurements.
  - A calibration sleeve is placed over the neutron receiver after the neutron source is attached and the recorded values are averaged over 100 samples. Radiation warning cones are placed around the test area when the neutron source is removed from the canister.

- Record the starting depth in relation to ground surface prior to tool being sent down the well.
- Record the total depth of the well when the tool reaches the bottom.
- Record the start time of the log when the tool starts coming up the well.
- Record the average logging speed of the tool as the tool comes up the borehole.
- Observe tool response and identify any significant zone(s) that could be used for the repeat section.
- Record the end time when the tool reaches the original position at the top of the well.
- Record the depth and subtract from starting depth to obtain the depth error.
- Select a repeat section after the log is reviewed.
- Perform same sequence of events listed above for the repeat log.
- Review data for the original and repeat logs and verify that significant zones or anomalies occur at the same depth and have similar log characteristics.

Subsequent to the geophysical well logging activity, two QC reviews are performed on the field data as described in the following sections.

3.2.1.2 Field Quality Control Review

The Wireline Summary Sheet is used in the field to document parameters for each logging run and instrument functional checks for each probe used. Instrument functional checks are transferred to a Microsoft Excel spreadsheet and assessed in graphical form over the duration of the project. Hard-copy printouts of the logs are reviewed in real time by the logging engineer and Shaw Environmental & Infrastructure, Inc. (Shaw) QC geophysicist to determine repeat interval(s) and ensure measurements from each probe are reasonable in terms of the expected response. At the end of borehole logging operations each day, raw digital data from the probes are transferred to the Shaw QC geophysicist for backup, and the data are also transferred to Shaw's geophysical subcontractor, Jet West Geophysical Services (Jet West) processing center for additional analysis and processing. Geophysical Logging QC Forms are included in Appendix G-5.

3.2.1.3 Data Processing Quality Control Review

Shaw's geophysical subcontractor, Jet West, performs processing of the data for each logging tool and generates a Log ASCII Standard (LAS) file and hard-copy printouts of the final processed data for each well. The Jet West Geophysical Logs are included in Appendix G-6. The LAS files are reviewed for consistent format, including revising the log curve names so they are compatible with input into Rockware software. After review of the LAS file format, digital data for each probe are transferred to Microsoft Excel, as requested by the NMED, and are included in Appendix G-7. Limited processing in Excel is performed and includes smoothing of the natural gamma data (if necessary) and plotting of the induction and neutron data on logarithmic scales. Excel logging curves are visually compared with the curves from the hard-copy printouts of the final processed data from JetWest to ensure consistency.

3.2.2 Well Installation

3.2.2.1 Groundwater Monitoring Wells

A total of 45 GWM wells were completed during the Second Quarter 2011 by the subcontractor drilling companies, WDC Exploration and Wells (42) and Yellow Jacket Drilling (3). Groundwater monitoring wells were installed at 16 NMED-prescribed locations, at depths specified for these locations in the Groundwater Investigation Work Plan (USACE, 2011b) and in accordance with Table 4 of the NMED-HWB August 6, 2010 letter (NMED, 2010c). The number and types of wells installed during this reporting period are as follows:

- 13 water table wells
- 16 intermediate depth wells
- 16 deep wells

The groundwater wells at Cluster 5 (KAFB-106041, -106042, and -106043) were installed from May 10 to June 6, 2011, but were not surveyed before the end of the quarter due to issues with the surface completions. The well surface completions were redone; the wells will be surveyed during the next quarter, and the survey data included in the third quarterly report for 2011. Therefore, this quarterly report does not include the well construction details and well reports. However, the details of the well installation are discussed.

All three wells at Cluster 5 (GWM-5) were installed such that the tops of the screens are too shallow relative to the requirements specified in the Final Groundwater Investigation Work Plan (USACE. 2011b). As a result, the water table well (KAFB-106041) is dry, and the intermediate well (KAFB-106042) and deep well (KAFB-106043) do not meet work plan requirements. The screens in all three wells were set based on an erroneous water level measurement causing the screen placements to be off by approximately 12 to 15 feet (ft). The error was most likely due to the combination of water added during drilling and formation material coming up in the 9-⅝-inch drive casing that formed a “plug” in the bottom of the drive casing. The plug holds water in the casing and causes mounding of water, resulting in an erroneous water level measurement. The Field Work Variance for GWM-5 is included in Appendix G-9 and summarized in the following table:

Well ID	Water Level (ft BTOC)	Work Plan Requirements for Screened Interval Depth	Height of Water and Screen as Installed (ft)	Screened Interval (ft BTOC)
KAFB-106041 (water table well)	472.43	Top of screen 5 ft above water level; 15 ft below water table	Dry, water level below bottom of screen	449–469
KAFB-106042 (intermediate well)	468.93	Top of screen 15 ft below water table	Top of screen 0.07 ft below water table	469–483.5
KAFB-106043 (deep well)	468.90	Top of screen 85 ft below water table	Top of screen 74.1 ft below water table	543–557.3
BTOC below top of casing				

- A minimum of one quarter of monitoring data from the closest GWM well clusters, GWM-8, GWM-10, and GWM-28, will be collected to determine whether there is a data gap, requiring another well to be drilled.
- Soil boring/groundwater monitoring well locations are shown on Figure 3-1. Table 3-2 presents the completion information for each well, surveyed elevations, well construction materials, and placement depths. Only the wells that were installed, surveyed, and developed during the second

quarterly reporting period are included in this report. Well installation reports for each well, which are included in Appendix D, consist of soil boring logs, well completion diagrams, and well development records.

- The three wells at GWM-5 (KAFB-106041, -106042, and -106043) were installed during the second quarterly reporting period, but surveying could not be conducted due to issues with the surface completions. The installation information for these three wells will be presented in the third quarterly report for 2011, following measurement and validation of the survey data for each of these wells.

Each monitoring well was completed in a separate borehole in clusters of three wells spaced no more than 50 ft apart. At NMED locations 13, 24, and 25, a shallow (water table) monitoring well is present and only intermediate and deep monitoring wells were installed. Before beginning drilling, each borehole was tested for utility clearance to 5 ft with a hand auger or air-knifed to ensure no utilities were present. Borehole advancement (drilling) was performed using the air rotary casing hammer (ARCH) drilling method. The ARCH method uses steel-insulator casing, advanced with a drill bit/rod, to prevent borehole collapse and seal off any contaminated zones to avoid cross-contamination of stratigraphic units. The boreholes were drilled using an 11-¾-inch outside diameter (O.D.) drive casing to a depth of 200 ft below ground surface (ft bgs), and 9-⅝-inch O.D. casing was advanced to the total depth of the borehole. These drive casing sizes effectively advance a 12-inch-diameter borehole to 200 ft bgs and a 10-inch-diameter borehole from 200 or 240 ft bgs to the total depth of the borehole.

During borehole advancement, the soil cuttings were logged every 5 ft by the site geologist. The soil samples were described according to the Unified Soil Classification System (USCS). Other details, such as changes in lithology, petrology of gravel units, mineralogy, observed contamination, odor, and groundwater encountered, were also noted on the soil boring log. Soil classification logs for the wells completed during the Second Quarter 2011 are included in Appendix D-1. Soil samples were collected during borehole advancement from the deepest borehole at NMED locations 11, 12, 17, and 18, which are located inside the LNAPL plume. Soil samples were collected at a frequency of 1 sample every 10 ft for the first 50 ft and then every 50 ft to the bottom of the borehole using a split-spoon sampler. Soil samples were submitted to Gulf Coast Analytical Laboratories, Inc., in Baton Rouge, Louisiana, for analysis of

VOCs; semivolatile organic compounds (SVOCs); TPH-gasoline range organics (GRO) and -diesel range organics (DRO); and lead. Soil sampling analytical results reported during First Quarter 2011 are presented in Table 4-1 and discussed in Section 4 (Vadose Zone Sampling and Monitoring).

Continuous core soil samples were collected from six boreholes (wells KAFB-106059, -106060, -106063, -106078, -106080, -106081) for NAPL mobility testing. The continuous core soil samples were collected by pushing a 4-inch-wide by 5-foot-long acetate sleeve into undisturbed soil. Table 3-3 presents the well locations, sample intervals, sample numbers, and USCS symbols for the continuous core soil samples. The discussion and evaluation of these data will be presented in the third quarterly report for 2011.

All monitoring wells were constructed using 5-inch-diameter, schedule 80 polyvinyl chloride (PVC) riser pipe and 0.010-slot, schedule 80 PVC well screens with a 5-ft blank schedule 80 PVC sump. The shallow (water table) monitoring wells were installed with 20 ft of screen, and the four intermediate and deep monitoring wells were fitted with 15-ft-length screens as prescribed for wells completed below the water table. Following placement of the well screen and riser pipe, a 10/20 Colorado silica sand (CSS) filter pack was tremied to approximately 2 ft above the top of the well screen followed by approximately 1 ft of fine sand seal consisting of 20/40 CSS. A bentonite seal (30 to 40 ft), consisting of 3/8-inch bentonite chips, was placed above the filter pack. The bentonite chip seal was hydrated in lifts using a “clean” water source. A high-solids bentonite grout was placed above the bentonite seal to near ground surface. A cement surface seal was placed above the bentonite grout to the ground surface. Well completion diagrams for the 45 wells are provided in Appendix D.

All installed groundwater monitoring wells were developed within 30 days of installation. Initial development consisted of swabbing and bailing for approximately 2 hours until the sediment load was reduced as much as possible. Following initial development, the well was continuously pumped using an electric submersible pump. Temperature, pH, specific conductivity, and turbidity were monitored during pumping, and readings were taken after every well casing volume during purging. The volume of water introduced into the formation during drilling was removed from the well during development. The well was developed until the column of water in each well was free of visible sediment, and the pH, temperature, turbidity, and specific conductance had stabilized within 10%. Development and purge water was containerized for each well at the BFF site, labeled as investigation-derived waste (IDW), and sampled for waste disposal. Well development logs for each well are provided in Appendix D.

3.2.2.2 Soil-Vapor Monitoring Wells

A total of eight "nested" SVMWs were installed during this reporting period. SVMW locations are shown on Figure 2-1. Each nested well location consisted of six individual (one 3-inch-diameter and five 3/4-inch-diameter), schedule 80, PVC SVMWs installed in the same borehole. Nested wells included a 10-ft-length of machine-slotted (0.050-inch) screen. Planned depths for the bottom of the nested well screens were 25, 50, 150, 250, 350, and 450 ft bgs. In some cases, the screened intervals were adjusted based on lithology observed during borehole advancement (e.g., screens were placed in transmissive zones). If proposed vapor-monitoring screened intervals were observed to be in fine-grained lithologic intervals (clay or silt), screened intervals were adjusted up or down to the nearest coarser-grained unit. Screens separated by 100 ft (150, 250, 350, and 450 ft bgs) were adjusted by no more than 25 ft, and screens separated by 25 ft (25 and 50 ft bgs) were adjusted by no more than 5 ft. Table 3-4 presents the well completion information for the SVMWs and actual screen interval depths. The following summarizes the SVMWs, corresponding NMED number, and area of location area:

- KAFB-106116 (SVM-09), KAFB-106117 (SVM-10), and KAFB-106128 (SVM-21) – Fuel Percolation Area
- KAFB-106121 (SVM-14), KAFB-106123 (SVM-16) – Tank Farm
- KAFB-106138 (SVM-04), KAFB-106141 (SVM-08), and KAFB-106142 (SVM-09) – Far Field

Filter pack (sand) consisting of Tacna 0.25-8 washed gravel was placed from the bottom of the screen to approximately 2 ft above the top of screen around the lowest nested well. A 3/8-inch bentonite chip seal was installed from the top of the filter pack to just below the screen for the next lowest well. Bentonite chip seals were hydrated every foot for the first 10 ft using a clean water source. This process was repeated for each nested well screen/riser pipe with the exception of the last (25-ft) well. Bentonite was placed to within 5 ft followed by a cement seal to the ground surface. Nested SVMWs were completed at ground surface in steel, flush-mounted, protective covers (well vaults) with gasketed, bolt-down covers. The well vaults were completed with a 4- by -4-foot concrete pad, sloped to direct runoff away from the well.

As with the GWM wells (Section 3.2.2.1), during SVWM borehole advancement, soil cuttings were logged every 5 ft by the site geologist. Soil samples were described according to the USCS. Other details, such as changes in lithology, petrology of gravel units, mineralogy, observed contamination, odor, and groundwater encountered, were also noted on the soil boring log. Soil classification logs for the wells completed during Second Quarter 2011 are provided in Appendix D. Soil samples were collected during borehole advancement in accordance with the Vadose Zone Investigation Work Plan (USACE, 2011c) and the NMED-HWB letter, dated August 6, 2010 (NMED, 2010c). Soil samples were collected every 10 ft for the first 50 ft and every 50 ft thereafter to the total depth of the borehole. Discrete soil samples were collected using a stainless-steel, 2-inch O.D., split-spoon sampler driven into undisturbed soil using a 140-pound hammer falling 30 inches until either approximately 2 ft was penetrated or 100 blows within a 6-inch interval had been applied per ASTM D1586-08a, (*Standard Test Method for Standard Penetration Test [SPT] and Split-Barrel Sampling of Soils*). Soil samples were shipped to Gulf Coast Analytical Laboratories, Inc. in Baton Rouge, Louisiana, for analysis of VOCs, SVOCs, TPH-GRO and TPH-DRO, and lead. The analytical results for soil samples collected during First Quarter 2011 are presented in Table 4-1 and discussed in Section 4 (Vadose Zone Sampling and Monitoring).

3.2.3 Surveying

All completed well installations are surveyed in accordance with the Groundwater Investigation Work Plan (USACE, 2011b) and the NMAC *Minimum Standards for Surveying in New Mexico* (NMAC Title 12, Chapter 8, Part 2) and are performed by a New Mexico-licensed professional land surveyor. Horizontal coordinates are based on the New Mexico State Plane Coordinate System, Central Zone (North American Datum, 1983), as published by the National Geodetic Survey. Elevations are determined to the nearest 0.01 ft and referenced to the 1988 National Geodetic Vertical Datum, as obtained from permanent benchmarks.

A subcontracted two-man survey crew surveyed completed wells using a Topcon RTK [real time kinematic] GPS [global positioning system] unit. This instrument is a survey-grade GPS rover unit and base station, tied into known control points with horizontal and vertical accuracies within 0.01 ft. The crew would mobilize to the well location, remove the vault cover and all well caps, and collect data points of the wells and related surfaces. Survey points collected at all wells consisted of ground surface north of the well pad, the well pad north of the well's outer steel casing, the steel casing itself on the northern edge (marked with black permanent marker), and the northern edge of the inner PVC casing, also marked with black permanent marker. In the case of groundwater wells where a dedicated Bennett sample pump had been installed, the northern edge of the sampling point on top of the cap was surveyed.

Nomenclature used for these elevation measurement points are as follows: well name and either ground, concrete well pad, case, or PVC, respectively. At SVMW locations, in addition to the above, points also were taken to include the five 1-inch wells. These are listed as PVC plus the depth of the well. Once all survey points were obtained, a measurement was collected from the top of the outer steel casing down to the inner PVC well(s), using a steel tape, as an elevation check for QC during data processing by the surveyor.

During Second Quarter 2011, 45 GWM wells and 8 SVM wells were installed. In addition, 317 direct-push technology (DPT) soil sampling locations were surveyed around the FFOR fuel line and the excavated fuel lines leading from Building 1033 to former Fuel Tanks 2420 and 2422. A single point on the location of the boring was collected, and points were located using a grid program in the RTK unit to position on the centerline of the fuel pipe, to position 5-ft step-out points from the centerline, and maintain 5-, 10-, and 20-ft centers depending on location sampling requirements as outlined in the Final Interim Measures Work Plan (USACE, 2011d). Further information pertaining to FFOR field activities is presented in Section 3.2.4. Well installation survey data are presented in Table 3-5.

3.2.4 FFOR Investigation

Soil sampling along the former fuel line at the FFOR commenced on June 2, 2011, and is ongoing. The objective of the FFOR soil sampling is to identify areas of shallow soil containing LNAPL or hazardous constituents that exceed NMED Soil Screening Levels as part of the NMED-directed interim measure investigation. The work is being performed as specified in the correspondence dated December 10, 2010, from the NMED to Kirtland AFB (NMED, 2010d) and with procedures outlined in the Final Interim Measures Work Plan (USACE, 2011d). During the period of June 2 through June 29, 2011, DPT was utilized to collect soil samples along the former pipeline at the FFOR to the pump house (Building 1033) and from Building 1033 to the former aboveground storage tanks. DPT activities were performed by the subcontractor, JR Drilling, a licensed New Mexico drilling company. A total of 136 boreholes were completed during Second Quarter 2011 (Figure 3-2); a total of 317 original DPT sampling locations are outlined in the Final Interim Measures Work Plan (USACE, 2011d), and additional step-out locations will be added as needed based on analytical data evaluation. The borehole number, collection dates, and coordinates are presented in Table 3-6.

Prior to soil sampling, a survey of all locations was conducted by Albuquerque Surveying Company in accordance with the NMAC *Minimum Standards for Surveying in New Mexico* (NMAC Title 12, Chapter 8, Part 2). DPT sampling started at the easternmost location, near well KAFB-106115, and continued west along the north side of the former pipeline. DPT sampling continued at the westernmost location of the FFOR and continued east along the pipeline towards Building 1033. Sampling locations between the FFOR and Building 1033 were spaced 10 ft apart with 5-ft step-out locations on each side of the former pipe centerline as directed in the NMED correspondence (NMED, 2010d) and as described in the Final Interim Measures Work Plan (USACE, 2011d). Three suspected leak locations have been identified along the pipeline at approximately 18, 150, and 200 ft from the west end of the FFOR (Figure 3-2). These three locations were marked in a 5-ft grid to better evaluate the area of the suspected leaks. Sampling locations along the former pipeline south of Building 1033 to the former fuel storage tanks were marked 20 ft apart along two lines oriented parallel to the pipe centerline and no more than 5 ft from the pipe centerline (Figure 3-2) as outlined in the work plan.

Shallow borings were advanced to 20 ft bgs using a 2-inch-diameter by 4-foot-long, acetate-lined split-spoon macrocore barrel. Soil samples were collected from the surface and every 5 ft to the total depth of 20 ft. A total of 136 boreholes were sampled during the second quarter (June 1 through June 30, 2011). Plate 3-1 identifies the location numbers of completed and remaining boreholes. The QA/QC samples were collected at a frequency of 10% to verify the accuracy of field sampling procedures. The QC samples included field duplicates, trip and field blanks for VOCs, and equipment rinse blank samples. Sample collection methods for sampling from the DPT core are summarized as follows:

- ***Step 1.*** Once sampling depth was reached, the sample barrel was pulled up smoothly and the split-spoon barrel opened. Each 5-ft interval was logged according to the USCS by a qualified geologist. Descriptions of soil, such as color, classification, thickness, odor, and headspace readings were recorded on Soil Boring Logs (Appendix D-3). The DPT subcontractor personnel then cut the acetate sleeve encasing the sample. The sample technician determined the appropriate sample interval, as approved by the geologist, and collected the soil in a stainless-steel sampling bowl.
- ***Step 2.*** For each soil sample, two sodium bisulfate TerraCore volatile organic analysis (VOA) vials, two methanol TerraCore VOA vials, one 2-ounce (oz) jar for percent moisture, one 16-oz jar, and one Mason jar for headspace were filled with soil from the depth interval and covered with aluminum foil. A headspace reading was collected from the Mason jar through the aluminum foil cover using a

photoionization detector. Headspace readings were recorded on both the Soil Classification Logs and Sample Collection Logs for each sample.

- ***Step 3.*** The TerraCore kit (which included the four VOA vials and the 2-oz jar in a foam holder) were placed inside a 1-gallon Ziploc bag with bubble wrap. A preprinted label was affixed to the inside of the bag to prevent water damage. The 16-oz jar was placed into a Ziploc bag with a label affixed directly to jar. The jar lid was then sealed with packing tape to prevent water from entering the sample. After properly packing and checking each sample, the samples were immediately placed in a cooler on ice. Sampling equipment was decontaminated after very sample by using deionized water and Alconox to ensure that no cross-contamination occurred.
- ***Step 4.*** After the completion of a borehole, the coolers containing the samples for that borehole were taken to the project field office trailer where they were placed into a sample refrigerator. The samples remained in the refrigerator until they were packed and ready for shipment to the laboratory.

After the completion of each borehole, sample names, times, dates, and depth intervals are logged into ShawView (an Oracle-based Environmental Information Management System), and an associated chain-of-custody form is produced for that day. The chain-of-custody forms are reviewed against the samples as a QC procedure to ensure sample names, dates, and times correspond. Samples are packaged and shipped in accordance with the Interim Measures Work Plan (USACE, 2011d).

FFOR soil samples were shipped to Gulf Coast Analytical Laboratories, Inc., located in Baton Rouge, Louisiana, for analysis. Samples were analyzed for VOCs, SVOCs, TPH-GRO and TPH-DRO, and lead. FFOR soil sampling analytical data will be presented in the third quarterly report for 2011.

3.2.5 Quarterly Groundwater Sampling Field Activities

Existing dedicated Bennett sample pump systems were pulled to evaluate the current condition, repaired as indicated, and then reinstalled for operations. New dedicated Bennett pump sampling systems were also received from the manufacturer and installed in monitoring wells. Table 3-7 summarizes the Bennett pump sampling systems installed for BFF wells. The following describes the well maintenance and new pump installation activities:

- April 19, 2011 – Previously installed water-level measurement drop tubes were found to be obstructed in monitoring wells KAFB-10613 and KAFB-1069. The dedicated pump systems and drop tubes were removed, repairs were made, and the systems were reinstalled. Also the inoperable, dedicated Bennett sample pump in well KAFB-1063 was pulled and replaced with a rebuilt spare pump.
- April 20, 2011 – The monitoring wells and surface completions were prepared, and dedicated Bennett pump sampling systems installed in KAFB-10621 and KAFB-10628. Additionally, KAFB-1069 could not pump water to the surface, and the pump was again removed and the tubing bundle repaired for leaks.
- April 21, 2011 – Existing monitoring well surface completions were modified and dedicated Bennett pump sampling systems were installed in KAFB-10625 and KAFB-10626.
- April 28, 2011 – New Bennett sample pump systems were installed in wells KAFB-106044 and KAFB-106045. The Bennett pump sampling system in well KAFB-1069 was reinstalled and tested satisfactorily.
- May 5, May 12, May 24, and May 25, 2011 – The monitoring well surface completions were removed and replaced with configurations allowing new Bennett pump sampling systems to be installed in wells KAFB-10610, KAFB-10622, KAFB-10623, and KAFB-10624.
- June 23, June 24, and June 27, 2011 – Dedicated Bennett pump sampling systems were installed in new monitoring wells KAFB-106077, KAFB-106078, KAFB-106101, KAFB-106102, KAFB-106059, KAFB-106060, and KAFB-106061.

No additional monitoring well maintenance activities or new Bennett sample pump installations were performed during the period from April through June 2011.

4. VADOSE ZONE SAMPLING AND MONITORING

In the following sections, the three-dimensional (3D) analysis of the vadose zone soil and vapor plume concentrations are evaluated by presenting the results of the 3D plume modeling in a series of two-dimensional horizontal plan view maps at different elevations and north-south and east-west cross-sections through the vadose zone soil concentrations and vapor plume.

- RockWorks 3D inverse-distance-weighting gridding algorithm of logarithms of concentrations was used for development of all vadose zone 3D plumes and soil concentrations. A horizontal exponent of 2 and a vertical weighting exponent of 4 were used in conjunction with horizontal and vertical gridding extent ranges of 300 and 50 ft, respectively. All applicable data points are used in the gridding.
- By presenting all plan-view maps on one drawing, the reader can readily see concentration changes with elevation across the vapor plume without resorting to 3D views that may be difficult to understand.
- In a similar manner, the cross-sections through the 3D plumes present the vertical distribution of soil and vapor concentrations.
- The vadose zone data locations used in this analysis are presented and labeled on Figure 4-1. For clarity in presentation, the data location symbols are presented on the respective plan-view maps without labels.
- The data used in this evaluation are presented in respective data tables and posted on the cross-sections. The data are not posted on the plan-view maps because only some well are screened at a given elevation. In addition, posting data values creates a misleading presentation of the available data used in the 3D gridding. Shaw is developing a Geographic Information System procedure to allow data posting on 3D plan-view maps in the next quarterly report.

4.1 Soil Sampling

During installation of the various SVM and GWM wells and drilling of the boreholes, soil samples were collected from beneath the BFF area and analyzed for a wide range of organic compounds. The soil analytical results for the January through March 2011 well installation sampling activities are presented in Table 4-1 and indicate that TPH-GRO, TPH-DRO, benzene, toluene, and lead are the more frequently detected compounds in the soil boring samples.

The First Quarter 2011 soil analytical data were validated for precision, accuracy, representativeness, comparability, and completeness in accordance with the BFF Spill Quality Assurance Project Plan (QAPjP) (USACE, 2011e), and appropriate data qualifiers are appended to the analytical data in the project database. The analytical laboratory results are presented in Table 4-1, and the data validation results are presented in the Data Quality Evaluation report included in Appendix B. Accuracy and precision for the First Quarter 2011 soil analytical results indicate data are of sufficient quality to achieve the BFF project data quality objectives. Based on previous experience at other NAPL sites, soil TPH concentrations are typically greater than 10,000 milligrams per kilogram (mg/kg) in NAPL zones. The Kirtland AFB 2011 data set shows only one sample with a TPH-GRO+DRO greater than 1,000 mg/kg (KAFB-106078, 400-450 ft bgs), and the vast majority of the soil sampling results are less than 100 mg/kg. Similarly, concentrations of other compounds are relatively low. For example, the highest benzene concentration is 3 mg/kg and most of the benzene soil detections are less than 0.01 mg/kg. The low-level concentrations of TPH compounds are not typical for a NAPL site. Table 4-2 presents the TPH and benzene soil sampling results from First Quarter 2011 soil boring sampling activities.

For three-dimensional (3D) spatial analysis of soil analytical data, the 2011 soil boring data were combined with historical data from 2007 – 2010 into a comprehensive data set. Using RockWorks 3D interpolation methods, 3D TPH (GRO+DRO) and benzene soil contaminant volumes were created. From these 3D volumes, plan-view maps at elevations of 5,300; 5,200; 5,100; 5,000; and 4,900 feet above mean sea level (msl) (corresponding to approximate depths of 50, 150, 250, 350, and 450 ft bgs) were created by cutting sections at appropriate elevations from 3D volumes.

The TPH soil maps for the five elevations are presented on Figure 4-2, and the benzene soil maps on Figure 4-3. As illustrated on the TPH maps, the overall footprint and TPH concentrations do not change markedly from elevations of 5,300 ft down to 5,000 ft above msl. At an elevation 4,900 ft above msl, just above the groundwater table, the area of soil concentrations between 10 and 100 mg/kg increases to cover the majority of the soil contamination area. The benzene soil contamination area at elevation 5,300 ft above msl is less than 0.01 mg/kg over the area. The area of benzene contamination greater than 0.01 mg/kg expands with each subsequent depth and the concentrations at the elevation of 4,900 ft above msl are the highest observed, with a sizable area of benzene concentrations greater than 0.1 mg/kg.

4.2 Vadose Zone Monitoring

The SVE monitoring/remediation system currently consists of 231 individual vapor wells plus the vapor data from four operational SVE units. Most of the wells are installed in 46 SVE well clusters consisting of between two and six wells at different depths in each cluster. Cluster well locations are shown on Figure 2-1. The Second Quarter 2011 vapor samples were collected from SVMWs using pre-evacuated Bottle-Vac canisters sampled through sampling ports installed at the top of each individual well casing for offsite laboratory analysis.

Soil-vapor hydrocarbon concentration (ppmv), percent O_2, percent CO, percent CO_2, and pressure were measured at the SVE wells during Second Quarter 2011, using a Horiba Model MEXA 584 L portable auto emissions analyzer. Horiba field measurements for SVMWs sampled are presented in Table 4-3. Pressure measurements that indicate the vadose zone is subject to vacuum are reported in Table 4-3 as negative numbers. Measurements that indicate the vadose zone is subject to positive pressure are shown as positive numbers. Measurements that indicate the vadose zone is at equilibrium with ambient atmospheric pressure and have neither pressure nor vacuum (zero gauge reading) are reported as being at atmospheric pressure.

Soil vapor samples were collected during the First and Second Quarter 2011 monitoring events from January through June 2011, in accordance with the Vadose Zone Investigation Work Plan procedures (USACE, 2011c) and Kirtland AFB BFF Spill QAPjP requirements (USACE, 2011e) and shipped to RTI Laboratories, Inc. in Livonia, Michigan, for the following list of analytical parameters:

- VOCs – EPA Method TO15.
- Air Phase Petroleum Hydrocarbons – Massachusetts Department of Environmental Protection
- TPH-GRO – EPA Method TO 13
- Fixed gases – ASTM Method D2504

Field QC samples were collected in accordance with the BFF Spill QAPjP and include field duplicate samples and trip blanks for VOCs.

First and Second Quarter 2011 SVE vapor analytical data were validated for precision, accuracy, representativeness, comparability, and completeness in accordance with the Kirtland AFB BFF Spill QAPjP, and appropriate data qualifiers are appended to the analytical data in the project database. The analytical laboratory results are presented in Table 4-3 for First Quarter 2011 and Table 4-4 for Second Quarter 2011. The data validation results are presented in the Data Quality Evaluation report included in Appendix B. Accuracy and precision for the First and Second Quarter 2011 SVE vapor analytical data indicate data are of sufficient quality to achieve the BFF project data quality objectives.

4.3 Soil-Vapor Data Evaluation

As presented in Table 4-3, during First Quarter 2011, the primary compounds detected in soil vapor are TPH in the gasoline (C5-C8) and diesel (C9-C12) ranges; benzene, toluene, ethylbenzene, and xylenes; 1,2,4-TMB; 1,3,5-trimethylbenzene; cyclohexane; heptane; propylene; and C6N (hexane). Detected vapor concentrations range from a few hundred up to 4 million parts per billion by volume (ppmv) for specific compounds and detected TPH concentrations range from approximately 10,000 micrograms per cubic meter ($\mu g/m^3$) up to 86 million $\mu g/m^3$.

As with the first quarterly report, the Second Quarter 2011 Horiba field and laboratory analytical vapor total VOC values for SVM and SVE wells were used to generate a 3D vapor plume. For the laboratory analytical data, the total VOC concentration was calculated by totaling the individual compound vapor concentrations plus the TPH results. The TPH conversion from μg/m^3 to ppb$_v$ formula is

$$ppb_v = {}^{\mu g}/_{m^3} \cdot \frac{0.08205 \cdot T}{MW}$$

where

ppbv = vapor concentration in parts per billion vapor

μg/m3 = micrograms of compound per cubic meter of air

0.080205 = Universal Gas Constant in (atm L)/(mol K)

T = vapor temperature in degrees Kelvin (°K) = 273.15 + degrees Celsius (°C)

MW = molecular weight of compound

Molecular weight of 65.15 g/mol was used for C5-C8 Aliphatic Hydrocarbons, 142.3 g/mol for C9-C12 Aliphatic Hydrocarbons, and 120.2 g/mol for C9-C10 Aromatic Hydrocarbons in the above equation. A temperature 293.15 °K was used for temperature.

From these two 3D plumes, plan-view maps at elevations of 5,300; 5,200; 5,100; 5,000; and 4,900 ft above msl (corresponding to approximate depths of 50, 150, 250, 350, and 450 ft bgs) were created by creating horizontal plan-view maps at appropriate elevations and two vertical cross-sections were cut through the 3D plume. Concentrations are posted on the plan view maps and cross-sections. Vadose zone vapor data locations are presented on Figure 4-4 because there is insufficient space on the plan view maps to clearly show the well names.

Figure 4-5 presents the five plan view maps of the field vapor total VOC distribution at various elevations beneath the BFF, and Figures 4-6 and 4-7 present east-west and north-south cross-sections through the vadose zone vapor plume. Figure 4-8 presents plan view maps for vadose zone laboratory analytical total VOC distribution, and Figures 4-9 and 4-10 present field total VOC and laboratory analytical total VOC vertical distribution along the two section lines. As illustrated in the 10 maps and 4 cross-sections, the vadose zone total VOC vapor concentrations can be characterized as follows:

- Field and laboratory VOC vapor concentrations at the elevation of 5,300 ft above msl (approximately 50 ft bgs) are less than 1,000 ppmv except for three small areas with concentrations between 1,000 and 10,000 ppmv at cluster well locations SVEW-08/09, SVMW-11, and KAFB-106112.
- At a lower elevation, down to 5,000 ft above msl, the extent of the field and laboratory VOC vapor plume remains essentially constant with some changes in the areal extent of the 100- to 1,000-ppmv and 1,000- to 10,000-ppmv concentration footprints.
- The most dramatic change is at the elevation of 4,900 ft above msl, immediately above the groundwater table, where the extent of the overall vapor plume is somewhat larger than it is at shallower elevations, but the areas covered by the 100- to 1,000-ppmv and 1,000- to 10,000-ppmv concentration footprints have noticeably expanded, and an area of field and laboratory vapor concentrations greater than 10,000 ppmv are present in the vicinity of vapor well clusters KAFB-106116, KAFB-106117, and KAFB-106128.

4.4 Vadose Zone Migration Conceptual Model

Based on the 3D distribution of soil and vapor data in the vadose zone, a relatively simple vadose zone NAPL migration model becomes apparent. The comparatively low concentrations and constant contaminant footprint at elevations of 5,000 ft above msl and above and expansion of the areal extent and increase in concentrations at the elevation of 4,900 ft above msl are consistent with the following vadose zone NAPL migration conceptual model:

- As surface or near-surface releases of NAPL occurred at the facility in broad scale, the NAPL essentially migrated vertically downward with some minor horizontal movement related to the heterogeneities in the lithologic intervals. Once the NAPL encountered the capillary fringe above the water table, the NAPL spread out horizontally away from the release areas. The NAPL then accumulated on the water table and started migrating in a northeasterly direction in the downgradient direction of groundwater flow.

- The pattern of TPH and benzene soil concentrations is a strong indication that NAPL did not spread out substantially as it migrated through the vadose zone. If the vertical NAPL migration occurred over a widespread area or had spread out along vadose zone capillary barriers, it would be expected that higher soil and vapor concentrations would be observed at shallower elevations. The soil concentration data indicate that the NAPL migrated in a predominantly vertical direction along relatively narrow pathways until it reached the capillary fringe on the top of the water table where it spread out in horizontal directions.
- Because vapor can migrate in the vadose zone, the vapor concentrations present the overall volume of the vadose zone that is affected by residual NAPL contamination in the soil.
- Based on the 3D distribution of soil and vapor concentrations, it appears that the majority of the vadose zone contaminant mass is located approximately 50 to 100 ft above the water table. The majority of the vadose zone contamination appears to be approximately 400 to 490 ft bgs. As more data become available from the ongoing investigations, more detailed evaluations of contaminant mass distribution will be performed.

4.5 General Effects of Current SVE Systems on the Vadose Zone

The SVE Optimization Plan (USACE, 2011a) has been prepared and submitted to the NMED for approval. This optimization plan proposes collection of the data necessary to quantitatively evaluate the overall effectiveness of the SVE remediation system and determine whether the SVE system is remediating the vadose zone contamination at Kirtland AFB. As these data are obtained, updated remediation evaluation criteria will be developed and reported in this section.

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5. GROUNDWATER MONITORING

Groundwater monitoring consists of collecting monthly liquid level groundwater elevation and LNAPL measurement data and performing quarterly groundwater sampling for field chemical parameters and offsite laboratory analysis. In the following discussions, the aquifer beneath the BFF Spill site has been classified into the following four zones for purposes of data analysis:

- **Shallow Zone.** This is the monitored zone across the water table and extends 5 to 10 ft below the water table. If the water table continues to rise (Section 5.2), a number of these wells may become flooded (water level above the top of screen) within the next several years. Table 5-1 presents a comparison of top of screen and June 2011 water table elevations wells in the Shallow Zone.
- **Intermediate Zone.** This is the aquifer zone that is monitored by wells that extend 15 to 30 ft below the 2009 water table elevation. As the water table rises, this zone will become deeper in the aquifer.
- **Deep Zone.** This is the aquifer zone that is monitored by wells that extends 30 to 100 ft below the 2009 water table elevation. As the water table rises, this zone will become deeper in the aquifer.
- **Regional Aquifer.** This is the aquifer zone where most of the water supply wells in the area are completed. Generally these wells are completed 500 ft or more below the 2009 water table (typically greater than 1,000 ft bgs).

5.1 Quarterly Pre-Remedy Groundwater Monitoring

The groundwater investigation and monitoring program includes collecting monthly groundwater elevation and LNAPL measurement data and conducting quarterly groundwater sampling at BFF Spill site monitoring wells and nearby production wells. Groundwater elevation data and LNAPL thickness measurements are presented and discussed in Section 5.2. The wells sampled during Second Quarter 2011 include the following:

- Groundwater wells KAFB-1061 through KAFB-10628; and KAFB-3411 (installed for investigation of another adjacent site and provides a monitoring location upgradient of the FFOR).
- Newly installed groundwater wells KAFB-106044 through KAFB-106048, KAFB-106059 through KAFB-106064, KAFB-106067 through KAFB-106069, KAFB-106073 through KAFB-106084, KAFB-106059 through KAFB-106064, and KAFB-106097 through KAFB-106102.

- KAFB-3, KAFB-15, and KAFB-16 – KAFB drinking water production wells.
- VA-2 – Veterans Affairs (VA) Medical Center drinking water production well.

Groundwater sampling was conducted between April 1 and June 20, 2011. All samples were collected in accordance with the Groundwater Investigation Work Plan and BFF Spill QAPjP (USACE, 2011 b, e). Sampling was performed using either dedicated Bennett sample pumps (27 wells) or a portable Bennett pump sampling system. Dedicated pumps will be installed for sampling in all GWM wells at the BFF site. Groundwater sampling included purging of one well bore volume and monitoring of field parameters for stabilization of temperature, pH, and specific conductance to within an estimated 10% prior to collecting water quality measurements for pH, conductivity, temperature, alkalinity, dissolved oxygen [DO], turbidity, and oxidation-reduction potential [ORP]) during well purging, testing for alkalinity, and collecting groundwater samples for laboratory analysis. After collection of water quality measurements, the wells were purged at an approximate rate of 1.0 liter per minute. Sample collection at the Kirtland AFB production wells and the VA Medical Center groundwater production well are purged by flushing the dedicated sample line and then collecting the samples. Samples are collected from non-chlorinated taps from the production wells.

Groundwater samples collected during Second Quarter 2011 were analyzed by Empirical Laboratories, Nashville, Tennessee, for the following list of parameters:

- VOCs – EPA 8026B;
- EDB – EPA 8011;
- SVOCs – EPA 8270C;
- TPH- GRO and DRO – EPA 8015B;
- Polycyclic aromatic hydrocarbons (PAHs) – EPA 8270C low-level (VA-2 well only);
- Lead and major cations – EPA 6010C;
- Dissolved iron and manganese – EPA 6010C;
- Anions (chloride, sulfate, and nitrate [as nitrogen]) – EPA 300.0;
- Ammonia nitrogen – SM [Standard Method] 4500NHB;
- Total sulfide – SM 4500 S-2CF; and
- Carbonate/bicarbonate alkalinity – SM 2320B.

During this reporting period, SVOCs were analyzed in samples from newly installed monitoring wells and production wells. The August 6, 2010 NMED letter (NMED, 2010c) to Kirtland AFB directed Kirtland AFB to substitute SVOCs for PAHs in the Groundwater Investigation Work Plan (USACE, 2011b). Analysis for SVOCs is not required for existing BFF Spill wells based on the June 4, 2010 NMED letter (NMED, 2010a), which specifies sampling and analysis requirements for quarterly monitoring at the BFF Spill site.

Field QC samples were collected in accordance with the BFF Spill QAPjP and included trip and ambient blanks for VOCs, field duplicate samples, and equipment rinse blank samples.

Groundwater analytical data were validated for precision, accuracy, representativeness, comparability, and completeness in accordance with the BFF Spill QAPjP, and appropriate data qualifiers are appended to the analytical data in the project database. The analytical laboratory results and field parameters are presented in Table 5-2; the data validation results are presented in the Data Quality Evaluation report included in Appendix B. Accuracy and precision for the Second Quarter 2011 groundwater analytical data indicate data are of sufficient quality to achieve the BFF project data quality objectives.

5.2 Liquid Level Data

On a monthly basis, liquid levels are measured in all completed wells (Figure 5-1 and Table 5-3), including those with active SVE systems. All liquid levels are measured with a Solinst Model 122 interface probe in wells that potentially contain NAPL or a Solinst Model 101 water-level meter for wells that do not contain NAPL. All instruments are checked for proper operation and cable integrity before use and are decontaminated between each well.

5.2.1 Groundwater Levels

Groundwater level data are presented in Table 5-3, and groundwater level contour maps for April, May, and June 2011 are presented in Figures 5-2 though 5-5. During the QC process, water levels are compared to historical water levels in each wells. If the liquid level being measured differs by more than 2 ft from the previous month's liquid level and is inconsistent with liquid level changes in nearby wells, the liquid level is judged to be invalid. These data are posted as such on the maps and not used in the generation of liquid level contours.

A comprehensive historical groundwater level table is presented in Appendix F along with water level elevation and NAPL thickness hydrographs. All water levels used to generate the contour maps have been corrected for NAPL thickness using the density correction described by Mayer and Hassanizadeh (2005, Eq. 4.5).

As presented in Figure 5-2, the northern portion of the groundwater flow direction in the Shallow Zone is approximately North 35° East. This is a critical addition to the understanding of groundwater flow directions in the northern portion of the groundwater plume. Prior to installation of the new wells, it was assumed that the groundwater flow direction was approximately along a line connecting KAFB-10625 and KAFB-10626 or a direction of approximately North 20° East. This revised groundwater flow direction is also reflected in the updated compound plumes discussed in Section 5.3. Additional water level and sampling data will refine the plume flow direction over the next several months but current data are consistent with this revised groundwater flow direction.

Based on analysis of the monitoring well hydrographs in Appendix F, groundwater levels at the site have risen between 4 and 6 ft since 2009. This can be attributed to the water conservation practices implemented by the City of Albuquerque to reduce groundwater withdrawals, starting in 2008 and 2009.

As presented on Figure 5-5, it is unclear from well cluster to well cluster what the vertical gradients are across the site. Some well pairs indicate downward gradients while other pairs indicate upward gradients. As additional cluster wells are installed and monitored, better definition of these vertical gradients may be possible; however, because of the slight differences in water level elevations between wells in a given cluster, this may be difficult.

5.2.2 NAPL Thicknesses

As presented in Table 5-3, during the April through June 2011 time period, NAPL was observed in only five wells. Based on the analysis of NAPL thickness data over time (Appendix F), it is apparent the NAPL thickness observed in wells since 2009 has markedly declined as groundwater levels have risen. While this declining trend of NAPL thickness in wells may be taken to indicate that NAPL is no longer an issue at the site, because of the physics of NAPL migration, the reduction of NAPL thickness in wells more likely indicates that the NAPL interval is now flooded, with most of the NAPL being submerged below the water table. This is because the buoyancy force that could make the NAPL rise along with the rising water levels is controlled by the density difference between the fuel and water that causes the LNAPL to "float" on the water table. Based on the limited data available for Kirtland AFB, this density difference is approximately 0.23 grams per cubic centimeter. If the resulting buoyancy force is less than the displacement pressure (the capillary pressure required for NAPL to migrate into a soil pore space displacing the water), then the NAPL cannot rise when the water table rises. Quantitative analysis of the potential for the NAPL at Kirtland AFB to rise along with the rising water table will be conducted when grain-size analyses and fluid physical properties data become available.

5.3 Groundwater Quality Data

The analysis of groundwater quality data has been divided into organic compounds that are derived from the NAPL (fuel) plume and other compounds that relate to microbial degradation of those fuel-related compounds. This section presents a narrative discussion of the distribution of organic compounds based on the data in Table 5-2. The water quality analysis used the following procedures:

- Field and laboratory analytical water quality results data were posted on “dot” maps using a graduated color scheme with postings of well names and concentrations beside the dot. This allows for visual point pattern analysis of concentration distribution for each compound evaluated. For the color scheme, the lowest concentration break is set at the applicable regulatory value, if such a value exists.
- Shallow Zone concentration plume contour maps were prepared for compounds with sufficient detections to warrant interpolation of contours. For all contour maps, an inverse distance weighting algorithm was used for the interpolations. The specific weighting and range values used are dependent on the data and are presented as notes on the individual maps.
- Using a combination of the dot and contour maps, a preliminary qualitative evaluation of fate and transport was conducted. Quantitative fate and transport analysis will be conducted as additional wells are installed and additional degradation data are collected.

5.3.1 Organic Compound Results

The following are key Second Quarter 2011 analytical data findings based on the results presented in Table 5-2 and the associated maps generated from these data. The data in Table 5-2 indicate that the vast majority of the groundwater contamination is concentrated in the Shallow Zone but detections of some compounds are present in the Intermediate and Deep Zones as described below. Additional data collected during Third Quarter 2011 will be used to further refine the thickness of the contaminant plumes.

Compound-specific dot and plume maps were prepared for TPH-GRO, TPH-DRO, EDB, benzene, toluene, xylenes, and 1,2,4-TMB.

- **TPH-GRO.** The well concentrations and concentration contours for the Shallow Zone are presented on Figure 5-6 for this compound group. Intermediate and Deep Zone well concentrations are presented on Figures 5-7 and 5-8, respectively. Because no regulatory limit is available for TPH-GRO, the reporting limit of 150 µg/L was used for the lower concentration contour limit.
  - The highest Shallow Zone TPH-GRO concentrations are in the historical NAPL area with the highest detected concentration at 53,000 micrograms per liter (µg/L). The downgradient extent of the TPH-GRO plume is approximately 1,500 ft north of the edge of the historical NAPL area. The extent of TPH-GRO concentrations greater than 150 µg/L in the northeastern and northwestern portions of the Shallow Zone plume is not currently defined, but better definition should be possible when the newly installed wells are sampled in Third Quarter 2011.

  - TPH-GRO concentrations greater than 150 µg/L were detected in samples from two Intermediate Zone wells, KAFB-106080 and KAFB-106083, and a concentration of 68 J (where "J" represents an estimated result) was reported for Deep Zone well KAFB-106062 (screen interval at 575 to 590 ft bgs).

  - TPH-GRO was detected at concentrations of approximately 65 µg/L (J-qualified results) in samples from water supply wells KAFB-15 and VA-2.

- **TPH-DRO.** The well concentrations and concentration contours for the Shallow Zone are presented on Figure 5-9 for this compound group. Intermediate and Deep Zone well concentrations are presented on Figures 5-10 and 5-11, respectively. Because no regulatory limit is available for TPH-DRO, 150 µg/L was used for the lower concentration contour limit.

  - The highest Shallow Zone TPH-DRO concentrations are in the historical NAPL area with the highest detected concentration at 140,000 µg/L. The downgradient extent of the TPH-DRO plume is approximately 1,000 ft north of the edge of the historical NAPL area.

  - TPH-DRO concentrations greater than 150 µg/L were detected in samples from two Intermediate Zone wells, KAFB-106080 and KAFB-106083. All TPH-DRO concentrations in samples from the Deep Zone wells are below detection limits.

- **EDB.** The concentrations and concentration contours for the Shallow Zone are presented on Figure 5-12 for this compound. Intermediate and Deep Zone well concentrations are presented on Figures 5-13 and 5-14, respectively. The EPA maximum contaminant level (MCL) of 0.05 µg/L was used for the lower concentration contour limit.

  - As presented, the highest EDB concentrations are in the historical NAPL area with the highest detected concentration at 360 µg/L. The downgradient extent of the EDB plume is at least 2,400 ft north of the edge of the historical NAPL area, but the full downgradient extent is not defined at this time.

  - EDB was detected in samples from five Intermediate Zone wells and three Deep Zone wells. The maximum top of screen well depth with detected EDB is 563 ft bgs in KAFB-106078.

  - EDB concentrations in samples from KAFB-10622 have increased from 0.60 µg/L, when the well was installed in mid-2009, to 1.12 µg/L in this quarterly data set with progressive increases during each quarter (Table 5-4). This increase is important in light of the revised groundwater flow direction described in Section 5.2. Based on the Second Quarter 2011 groundwater level maps and associated flow directions, KAFB-10622 may be the downgradient well near the center of the contaminant plume and not KAFB-10625 as previously assumed.

  - The extent of EDB in groundwater is not currently defined to the northeast, but better definition will be accomplished when the newly installed wells are sampled in Third Quarter 2011. The new KAFB-106055 well cluster is downgradient of KAFB-10622 in a North 30° East direction. Water supply well KAFB-3 (screen interval at 450 to 900 ft bgs, pumping level at 550 ft bgs, and flow rate of approximately 750 gallons per minute) is located 4,200 ft downgradient in a North 50° East direction. No EDB has been detected in this well.

- **Benzene.** The concentrations and concentration contours for the Shallow Zone are presented on Figure 5-15 for this compound. Intermediate and Deep Zone well concentrations are presented on Figures 5-16 and 5-17, respectively. The EPA MCL of 5 µg/L was used for the lower concentration contour limit.
  - In the Shallow Zone, the highest benzene concentrations are in the historical NAPL area with the highest detected concentration at 8,300 µg/L. The downgradient extent of the benzene plume in the Shallow Zone is approximately 500 ft north of the edge of the historical NAPL area or approximately 1/3 the extent of the TPH-GRO plume.
  - In the Intermediate Zone, the sample from a single well, KAFB-106080, has benzene concentrations greater than 5 µg/L, and benzene was detected at less than 1 µg/L in samples from three other Intermediate Zone wells.
  - No sample from wells in the Deep Zone has benzene concentrations greater than 5 µg/L, but benzene was detected in samples from two wells at less than 5 µg/L.

- **Toluene.** The concentrations and concentration contours for the Shallow Zone are presented on Figure 5-18 for this compound. Intermediate and Deep Zone well concentrations are presented on Figures 5-19 and 5-20, respectively. The New Mexico groundwater standard of 750 µg/L was used for the lower concentration contour limit.
  - In the Shallow Zone, the highest toluene concentrations and the entire toluene plume greater than the regulatory concentration are within the historical NAPL area with a highest detected concentration at 12,000 µg/L.
  - In the Intermediate Zone, no toluene concentrations exceeded the groundwater standard (750 µg/L), but toluene was detected in samples from nine Intermediate Zone wells at concentrations ranging from less than 1 µg/L to 260 µg/L.
  - In the Deep Zone, no toluene concentrations exceeded the groundwater standard (750 µg/L), but toluene was detected in samples from eight Deep Zone wells at concentrations less than 6 µg/L.

- **M,P-Xylenes.** The concentrations and concentration contours for the Shallow Zone are presented on Figure 5-21 for this compound. Intermediate and Deep Zone well concentrations are presented on Figures 5-22 and 5-23, respectively. The EPA MCL of 10,000 µg/L was used for the lower concentration contour limit.
  - In the Shallow Zone, no m,p-xylene concentrations exceeded the MCL with the m,p-xylene detections within or immediately downgradient of the historical NAPL area. The highest detected m,p-xylene concentration is 1,900 µg/L.
  - In the Intermediate Zone, no m,p-xylene concentrations exceeded the MCL, but m,p-xylene was detected in samples from four Intermediate Zone wells at concentrations ranging from less than 1 µg/L to 46 µg/L.
  - In the Deep Zone, no m,p-xylene concentrations exceeded the MCL, but m,p-xylene was detected in samples from two Deep Zone wells at concentrations less than 2 µg/L.

- **1,2,4-TMB.** The concentrations and concentration contours for the Shallow Zone are presented on Figure 5-24 for this compound. Intermediate and Deep Zone well concentrations are presented on Figures 5-25 and 5-26, respectively. An arbitrary cutoff concentration of 35 µg/L was used for the lower concentration contour limit.
  - In the Shallow Zone, the highest 1,2,4-TMB concentrations and the plume are within the historical NAPL area with the highest detected concentration at 630 µg/L.
  - In the Intermediate Zone, 1,2,4-TMB was detected in samples from two wells, including one with a concentration greater than 35 µg/L.
  - In the Deep Zone, 1,2,4-TMB was not detected in samples from any wells.

- **Naphthalene.** The concentrations and concentration contours for the Shallow Zone are presented on Figure 5-27 for this compound. Intermediate and Deep Zone well concentrations are presented on Figures 5-28 and 5-29, respectively. The EPA MCL of 30 µg/L was used for the lower concentration contour limit.
  - In the Shallow Zone, all but one of the naphthalene detections are within the historical NAPL area with the highest detected concentration at 330 µg/L.
  - In the Intermediate Zone, naphthalene was detected in samples from two wells, including one with a concentration greater than 30 µg/L.
  - In the Deep Zone, naphthalene was not detected in samples from any wells.

5.3.2 Microbial Degradation Indicators

Fundamentally, microbial degradation occurs when bacteria metabolize organic compounds. In this process, electron donors release electrons and become more positively charged, electron acceptors receive electrons and become more negatively charged, and nutrients are consumed. Metabolism thereby increases the bacteria population according to the following general equation (Wiedermeier et al., 1999):

Microorganisms + Electron donors + Electron acceptor + Nutrients →
Metabolic by products + Energy + Additional microorganisms

As a first step in determining the final remedy for the Kirtland AFB BFF fuel plume, a dot map evaluation of selected degradation indicator compounds (Table 5-5) was performed to relate various indicators to the extent of the NAPL area and dissolved plumes. For this first step, DO, ORP, ammonia, nitrate, iron (only dissolved [filtered] iron data were available, but as ferric iron is relatively insoluble in water, the majority of the dissolved iron is assumed to be ferrous iron), manganese, sulfate, sulfide, and alkalinity. For this report, dots maps of ammonia and sulfide were not prepared because these two compounds were not detected in a sufficient number of wells to allow meaningful map analysis.

- **DO.** Concentrations of this degradation indicator compound for the three aquifer zones are presented on Figures 5-30 through 5-32. Microbial degradation will result in decreased DO concentrations.
  - In the Shallow Zone, DO concentrations overall are lower within and adjacent to the NAPL area and dissolved plume, indicating that microbial degradation is consuming oxygen from the groundwater. Away from the organic compound plume area, the DO concentrations are in the range of 7 to 9 mg/L, which is near the atmospheric saturation concentration at the elevation and temperature of the groundwater.
  - In the Intermediate and Deep Zone wells, DO depletion is observed only in a single well in each zone (KAFB-106047 in Intermediate Zone and KAFB-106064 in Deep Zone), indicating a slow rate of microbial degradation consistent with the overall low concentrations of most organic compounds in these two zones.

- **ORP.** Measurements of this degradation indicator compound for the three aquifer zones are presented on Figures 5-33 through 5-34. Microbial degradation will result in decreased ORP values.
  - As with DO, the ORP concentrations in the Shallow Zone overall are lower within and immediately downgradient of the NAPL area, with most values within the plume ranging from slightly less than zero to a -293 millivolts. Further downgradient in the KAFB-10622 and KAFB-10625 plume area, the ORP is strongly positive with values greater than 200 millivolts. In comparing the ORP results with the various plume maps, it appears that microbial degradation is occurring within the Shallow Zone within the area of the TPH-GRO plume. Data from the new monitoring wells will further refine the area of Shallow Zone microbial degradation.
  - As with DO, low ORP values in the Intermediate and Deep Zones are observed only in a single well in each zone, the same two wells with depressed DO results. This is further indication that microbial degradation is slow in the Intermediate and Deep Zones.

- **Alkalinity.** Concentrations of this degradation indicator compound are presented on Figures 5-36 through 5-38. Microbial degradation can result in increased alkalinity concentrations.
  - The point pattern analysis indicates that alkalinity is somewhat elevated within the Shallow Zone NAPL area. No obvious pattern is apparent in the alkalinity data for plume areas away from the NAPL area.
  - No obvious pattern is apparent in the alkalinity data in the Intermediate and Deep Zones. More data from the new monitoring wells are necessary to assess the usability of this indirect by-product as a degradation indicator.

- **Iron.** Concentrations of this degradation indicator compound are presented on Figures 5-39 through 5-41. Microbial degradation can result in increased iron concentrations.
  - In the Shallow Zone, iron is distinctly elevated in the NAPL area and the area of the dissolved plume immediately downgradient of the NAPL area. Iron was detected in samples from most wells with detections of TPH-GRO. Because microbial degradation causes increased iron groundwater concentrations, iron will very likely be a reliable degradation indicator.
  - In the Intermediate Zone, iron was detected in samples from two wells, KAFB-106047 and KAFB-106080, both of which are inside the Shallow Zone NAPL area footprint.
  - In the Deep Zone, iron was detected in the sample from a single well, KAFB-106081, located inside the Shallow Zone NAPL area footprint.

- **Manganese.** Concentrations of this degradation indicator compound are presented on Figures 5-42 through 5-44. Microbial degradation can result in increased manganese concentrations.
  - In the Shallow Zone, manganese, like iron, is distinctly elevated in the NAPL area and the area of the dissolved plume immediately downgradient of the NAPL area. Manganese is definitely elevated in samples from those wells with detections of TPH-GRO. Downgradient well KAFB-10622 appears to have an elevated manganese concentration of 150 µg/L. Because microbial degradation causes increased manganese groundwater concentrations, manganese will very likely be a reliable degradation indicator.
  - In the Intermediate Zone, manganese is elevated in samples from two wells, KAFB-106047 and KAFB-106080, both of which are inside the Shallow Zone NAPL area footprint. These two wells also have detections of iron, and KAFB-106047 has low DO and ORP values (field parameters are not available for KAFB-106080 for Second Quarter 2011 as a result of instrument malfunction).
  - In the Deep Zone, manganese is elevated in the sample from a single well, KAFB-106081, located inside the Shallow Zone NAPL area footprint. Other than a detection of iron, other degradation indicators do not indicate microbial degradation in this well.

- **Nitrate.** Concentrations of this degradation indicator compound are presented on Figures 5-45 through 5-47. Microbial degradation will cause decreases in nitrate concentrations. More data from the new monitoring wells will be required to assess the viability of this electron acceptor as a degradation indicator.
  - In the Shallow Zone, nitrate is depleted in the NAPL area and the area of the dissolved plume immediately downgradient of the NAPL area with most NAPL area nitrate concentrations nondetections or low concentration, J-qualified results. However, it appears that background nitrate concentrations are sufficiently low that this compound may not be a robust degradation indicator.
  - No obvious pattern is apparent in the Intermediate and Deep Zone nitrate results. Additional data from the new monitoring wells may clarify the nitrate pattern in these zones.

- **Sulfate.** Concentrations of this degradation indicator compound are presented on Figures 5-48 through 5-50. Microbial degradation can cause decreases in sulfate concentrations. More data from the new monitoring wells will be required to assess the viability of this electron acceptor as a degradation indicator.
  - In the Shallow Zone, sulfate appears to be somewhat depleted in the NAPL area. However, it appears that background sulfate concentrations are sufficiently low that this compound may not be a robust degradation indicator.
  - No obvious pattern is apparent in the Intermediate and Deep Zone sulfate results. Additional data from the new monitoring wells may clarify the sulfate pattern in these zones.

Based on this analysis of the degradation indicator compounds and the spatial extent of the organic compounds discussed in Section 5.3.1, it appears that microbial degradation is slowing the migration rate and limiting the extent of a majority of the organic compounds, including benzene, toluene, and m,p-xylenes. Additional evaluations are required to quantify the degradation rates and impact on future plume migration. The effect of microbial degradation on EDB migration rates and extent is less clear. Additional compound-specific data are required to determine whether microbial degradation is having any effect on EDB.

6. INVESTIGATION-DERIVED WASTE

6.1 Well Installation Investigation-Derived Waste

Both GWM and SVM wells are being installed at the BFF Spill site to support the groundwater and vadose zone investigations. As a result of the well installations, drill cuttings and decontamination and development water are being generated, stored, and disposed of as described in the following sections.

6.1.1 Drill Cuttings

All monitoring wells associated with the BFF Spill site are being drilled using the ARCH method, and the drill cuttings are being containerized in plastic-lined, steel, roll-off bins, pending laboratory analysis for waste characterization and disposal. Approximately 10 to 15 cubic yards of drill cuttings are being generated for each 20-cubic-yard, roll-off container. A composite sample is collected from each roll-off container for all SVMWs and submitted to the subcontractor laboratory for analysis in accordance with the Kirtland AFB Construction and Demolition (C&D) Landfill Acceptance Memorandum, dated January 2009 (USAF, 2009c). For groundwater well installations, a composite sample is collected for each well location. A request for disposal letter is provided to Kirtland AFB for approval for each container, and approved roll-off bins are transported to the C&D Landfill by a subcontractor. Analytical results for most of the BFF Spill drill cuttings generated during Second Quarter 2011 confirmed that the drill cuttings are not considered to be RCRA hazardous waste and meet the requirements for disposal at the C&D Landfill. One roll-off container, Bellio Number 11 at KAFB-106083, did not meet the requirements for disposal at the C&D Landfill. The contents of this roll-off bin were disposed of offsite as non-hazardous waste by RINCHEM Company, Inc. Table 6-1 details the sampling and disposal of each IDW roll-off bin generated during Second Quarter 2011.

6.1.2 Decontamination and Development Water

Drill rig and associated equipment used in monitoring well installations are decontaminated using hot pressurized water. Decontamination water is collected and stored in 250-gallon totes, combined with well development water for groundwater wells, and stored in 1,500-gallon tanks. Wastewater is stored at the BFF Spill site pending analytical results for disposal in accordance with the *Kirtland AFB Bulk Fuels Development and Sampling Purge Water Decision Tree – 12/17/10* (NMED, 2010e). Once approval for discharge is obtained from NMED-GWQB and Kirtland AFB, the wastewater is discharged from the storage container to an approved location on the BFF Spill site, away from any water course. Seven wastewater samples from Second Quarter 2011 required offsite disposal due to elevated detections of regulated contaminants. Table 6-2 details the sampling and disposal of each wastewater container generated during the second quarter well installation activities.

6.2 Groundwater Sampling Investigation-Derived Waste

Quarterly groundwater sampling at BFF Spill site monitoring wells generated IDW purge water. Purge water was generated and stored at each monitoring well location or at the BFF Spill site pending the analytical results and subsequent disposal determination in accordance with the *Kirtland AFB Bulk Fuels Development and Sampling Purge Water Decision Tree-12/17/10* (NMED, 2010e). Purge water was stored in labeled, 55-gallon, polyethylene, open-top drums with sealable lids. For monitoring wells located on Kirtland AFB, the purge water drums were labeled, closed and sealed, and stored proximate to the well location. Purge water generated from sampling of monitoring wells located on property outside of Kirtland AFB was contained in drums, labeled, sealed, transported back to Kirtland AFB, and stored at the BFF Spill site, pending groundwater sample analyses and IDW disposal decisions. Exceptions to these procedures were for monitoring wells that historically, or presently, exhibit the presence of LNAPL on the groundwater. For these wells, purge water was stored at the well in 55-gallon, polyethylene, sealable, open-top, U.S. Department of Transportation (DOT) shipping drums and then manifested as hazardous waste for benzene, not otherwise specified, and removed from the site by a subcontracted waste management firm for offsite disposal. Table 6-3 details the monitoring well, volume of purge water generated during the Second Quarter 2011 sampling event, and final disposition of water. During Second Quarter 2011, purge water for 10 wells was disposed of offsite as hazardous waste (KAFB-1065, KAFB-1066, KAFB-1068, KAFB-1069, KAFB-10610, KAFB-10614, KAFB-10628, KAFB-106059, KAFB-106076, and KAFB-106080). For all other monitoring wells, purge water was stored pending analytical results to determine final disposition, which will occur during Third Quarter 2011.

6.3 SVE Internal Combustion Engine Investigation-Derived Waste

SVE ICE systems were operating at four locations during Second Quarter 2011. SVE ICE systems are in operation at the FFOR, collectively known as ST-106, and on groundwater monitoring wells KAFB-1065, KAFB-1066, and KAFB-1068. The IDW generated by these SVE ICE systems include non-regulated or recyclable materials associated with routine, scheduled engine maintenance including used air filters, used oil filters, spark plugs, motor oil, and anti-freeze. Additionally, during periods of cold temperatures, the ICE systems generate condensate from the extracted soil vapor, which is captured in integrated knock-out system drums and manifested as hazardous waste. The condensate waste is removed by a subcontractor for disposal offsite.

Scheduled maintenance of the SVE ICE systems occurs biweekly and consists of oil and filter changes at a minimum and additional maintenance tasks performed at monthly, quarterly, semiannual, and annual intervals. Waste oil and waste anti-freeze are stored in 55-gallon, DOT, closed-top, steel drums at the ST-106 SVE ICE location. Once full, the drums are picked up for recycling by a vendor providing the service to Kirtland AFB. Drums are picked up for recycling on the vendor’s route schedule. During Second Quarter 2011, there was one pickup of waste oil and no pickups for anti-freeze. Drums stored onsite await pickup during Third Quarter 2011.

Soil-vapor condensate generated by the SVE ICE systems is disposed of offsite as hazardous waste. All drums of condensate are manifested as hazardous waste for flammable liquids, not otherwise specified, and contain benzene and water. There were no SVE ICE systems condensate hazardous waste pickups during Second Quarter 2011.

7. CONCEPTUAL SITE MODEL

7.1 Regional Geology

The geology at Kirtland AFB ranges from mountainous, with elevations reaching 7,900 ft above msl, in the eastern extent of the installation to the Albuquerque Basin in the west. The area lies within the Rio Grande Rift, a major tectonic zone that represents the continental extension during the Cenozoic. The tilted fault-block mountains in the eastern portion of Kirtland AFB are composed of Precambrian metamorphic and crystalline bedrock and Paleozoic sedimentary rock. The Kirtland AFB BFF Spill site is located in the western portion of the installation, in the Albuquerque Basin. The dominant lithology of the Albuquerque Basin includes unconsolidated and semiconsolidated sedimentary deposits.

The Albuquerque Basin contains the through-flowing Rio Grande. Basin-wide, the sedimentary deposits are primarily interbedded gravel, sand, silt, and clay. Well graded and poorly graded gravel and sand are heterogeneous in vertical and lateral extent throughout the basin. In addition, silt and clay layers are of variable thickness and laterally discontinuous. The thickness of the basin fill deposits is variable throughout the basin due to normal faulting, but is thicker than 3,000 ft in most of the basin (Kelly, 1977).

The geologic materials of interest for the Kirtland AFB BFF Spill site are the upper portion of the Santa Fe Group and the piedmont slope deposits. The Santa Fe Group consists of beds of unconsolidated to loosely consolidated sediments and interbedded volcaniclastic and mafic rocks. The sedimentary materials in the Santa Fe Group range from boulders to clay and from well sorted stream channel deposits to poorly sorted slope wash deposits. Silty alluvial fan sediments were deposited unconformably over the Santa Fe Group and extend westward from the base of the Sandia and Manzano mountains. Within the alluvial deposits, materials range from poorly sorted mud flow material to well sorted stream gravel. Beds consist of channel fill and interchannel deposits. The fan thicknesses range from 0 to 200 ft and thicken towards the mountains. The Santa Fe Group underneath the BFF Spill site is further divided into two depositional facies called the USF-1 and USF-2 (Hawley et al., 1995).

7.2 Site-Specific Geology

The NMED cross-section transects, A-A', B-B', C-C', D-D', and a new transect E-E', are shown on Figure 7-1. The cross-sections show that the lithology consists of younger deposits overlaying the Santa Fe Group; a system of unconsolidated Tertiary-aged fluvial (ancestral Rio Grande lithofacies); and alluvial deposits from the Middle Rio Grande Basin. The top 100 to 150 ft (Figure 7-2 through 7-6) consists primarily of silt and silty sand with interbedded clay and poorly graded sand layers. Generally, this silty unit thickens eastward with the silt and clay layers varying from a few feet to 170 ft in thickness (in KAFB-106135) (Figure 7-4). Sand deposits within this unit consist of silty, well graded, and poorly graded sand intervals that range in thickness from 0 to 60 ft.

Presumably, the discontinuous silt and clay layers are zones of low permeability and therefore are likely to impede downward flow of water and contamination. Whereas, the higher permeability sandy layers could provide pathways for water and contamination to easily migrate downward within the upper depositional unit. Underlying the silty upper unit is the Santa Fe Group. This unconsolidated depositional unit is observed in the subsurface geology at the BFF Spill site and appears to be a highly permeable unit. This unit is present at depths greater than 100 ft bgs and primarily consists of sand and gravel layers that extend to depths greater than 500 ft bgs.

The sand is generally poorly to well graded and ranges in thickness from 1 to 250 ft. Discontinuous gravel lenses, likely channel deposits, are approximately 50 ft in thickness within some regions, particularly to the north, and are of unknown lateral extent (Figures 7-3 and 7-4). Clay lenses are also observed heterogeneously within this unit, with the most notable lens shown in the A-A' cross section (Figure 7-2). This clay lens is approximately 35 ft in thickness at a depth of approximately 255 ft bgs and is documented in the well borehole logs for KAFB-106081 and KAFB-106066 (Figure 7-2 and Appendix D-1).

Geologic logs for existing and newly installed monitoring wells and geophysical logging data indicate a considerable amount of variability within the two depositional units. However, based on the lithologic logs and all five cross-sections, coarser materials, including gravel lenses, appear to be concentrated in the northern portion of the study area (Figures 7-3 and 7-4), whereas finer, silt-rich sediments appear to be more ubiquitous in the southern portion of the site (Figure 7-1).

7.3 Hydrology

The regional aquifer for the majority of the Albuquerque Basin is contained in the upper and middle units of the Santa Fe Group. The groundwater system at Kirtland AFB is also referred to as the Middle Rio Grande Basin. In general, the upper unit of the Santa Fe Group contains the most productive portion of the regional aquifer that supplies water to the City of Albuquerque, the VA, and Kirtland AFB.

Depths to water in the regional aquifer vary widely across the basin and are dependent on structural influence. Within the eastern extent of the basin, depths to water are approximately 190 ft bgs, whereas towards the western edge of the basin, depths to water are on the order of 450 to 570 ft bgs. Depths to water measured at the BFF Spill site range from 455.85 (KAFB-106029) to 498.66 ft bgs (KAFB-10619) (June 2011 measurements; Table 5-3).

Groundwater flow directions in the regional aquifer are generally westward, towards the Rio Grande. Locally to the BFF Spill site, the groundwater flow direction is approximately North 35°East. As mentioned in Sections 5.2 and 5.3.1, the second quarter groundwater level maps and associated flow directions indicate that GWM well KAFB-10622 may be the downgradient well near the center of the contaminant plume instead of KAFB-10625 and KAFB-10626. Groundwater flow direction at the BFF

Spill site is influenced by production well pumping for both the City of Albuquerque and Kirtland AFB. The groundwater gradient at the site varies from 0.0005 to 0.002 ft/ft. A 4- to 6-ft increase in water levels has been observed at the site since 2009, which is most likely due to the water conservation practices put into place by the Albuquerque Bernalillo County Water Utility Authority to reduce groundwater withdrawals from the aquifer.

7.4 Fate and Transport Conceptual Model

7.4.1 Vadose Zone

As presented in Section 4.4, the low soil TPH and benzene and vapor VOC concentrations at shallow elevations indicate that the majority of the NAPL migrated vertically downward in relatively narrow migration areas until it encountered the capillary fringe above the water table. Once the NAPL encountered the capillary fringe, it spread horizontally in all directions. When the NAPL reached the groundwater table, it migrated in a downward direction along the groundwater gradient. Figures 7-7 through 7-12illustrate the soil concentration profiles of TPH and benzene in the vadose zone for the NMED cross-section lines (A-A’, B-B’, C-C’, and D-D’) and the new E-E’ cross-section line.

7.4.2 Groundwater

This portion of the conceptual site model will be updated when the 3D groundwater contaminant plume analysis is completed. The revised conceptual site model for groundwater is anticipated to be included in the third quarterly report for 2011.

7.5 Data Gaps

Additional groundwater hydraulic conductivity and other data related to aquifer properties are currently being collected across the investigation area. These data will be reported in the third quarterly report for 2011. The only other outstanding data gap from the first quarterly report is information related to the EDB degradation and fate and transport mechanisms. Data gaps associated with the soil, soil vapor, and groundwater compounds and degradation indicators are being addressed by ongoing data collection efforts.

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8. PROJECTED ACTIVITIES

Anticipated activities to be conducted during Third Quarter 2011 at the BFF Spill site include, but are not limited to, ongoing groundwater and soil-vapor monitoring, completion of installation of GWM wells and SVMWs, and continued operation and maintenance of the BFF SVE systems. In addition, activities associated with the monitoring and remediation at the BFF Spill site will be ongoing, including analytical testing, data validation, data management, and reporting.

8.1 Quarterly Monitoring Activities

Quarterly groundwater and soil-vapor monitoring and related field activities will be ongoing during Third Quarter 2011 as follows:

- Depth to water measurements will be collected for existing monitoring wells on a monthly basis and for new monitoring wells as they become available after installation and development.
- Quarterly groundwater sampling activities will include collecting samples from the existing 4-inch-diameter monitoring wells and new 5-inch-diameter monitoring wells that have been installed and developed prior to the end of August, allowing at least two weeks to elapse after well development and before sample collection.
- Quarterly sampling of SVMWs, SVEWs, SVE ICEs, and GWM wells will begin on July 6, 2011, and continue throughout the third quarter ending September 30, 2011. All newly installed SVMWs and SVEWs will be sampled during this quarter.
- Dedicated Bennett sample pump systems will be installed in new 5-inch-diameter monitoring wells as the equipment is received from the manufacturer. At end of the third quarter (September 30, 2011), it is anticipated that approximately 60% of new 5-inch-diameter monitoring wells will have had dedicated Bennett pump sampling systems installed.
- Pump system repairs and maintenance will be performed throughout the quarter as needed and as determined based on observations during monthly water-level measurement collection and groundwater sampling activities.

8.2 Drilling Program

A total of 45 groundwater monitoring wells, representing 18 clusters, have been installed and surveyed through the end of Second Quarter 2011; a total of 49 wells have been installed during the First and

Second Quarters in 2011. The remaining 29 groundwater monitoring wells are all located within the residential areas north of Kirtland AFB. None of these remaining groundwater monitoring wells will require soil sampling and, based on the current rate of drilling, the groundwater well installation program is anticipated to be completed by late August 2011. Seven SVMWs remain to be installed on Kirtland AFB. Of theses, six are located around the former aboveground storage tanks, and one is located off base in Bull Head Park.

In addition, during Third Quarter 2011, slug testing of groundwater monitoring wells will be conducted. Bucket samples of soil from the groundwater monitoring well installations will continue to be collected and submitted to the geotechnical laboratory for analysis of grain size, hydraulic conductivity, porosity, and specific yield. Results of the testing will be provided in future quarterly reports.

DPT soil sampling associated with the Interim Measure investigation at the FFOR (USACE, 2011d) will also continue during Third Quarter 2011. Analytical data will be evaluated as it is received from the offsite laboratory to determine whether additional step-out sampling locations will be required. Following the collection of these data, the locations of Pneulog wells will be selected in a phased approach.

8.3 SVE Systems

With continued operations of the SVE and treatment systems at the BFF Spill site, the scheduled activities to maintain these systems and sampling protocols established to monitor the presence of hydrocarbons and treatment progression will continue. Monthly vapor field measurements were obtained during Second Quarter 2011 to characterize system influent vapor. Quarterly sampling with a Horiba analyzer will continue at SVMWs and SVEWs. Laboratory analytical data for Third Quarter 2011 will be reviewed and discussed in the third quarterly report for 2011, following validation of the data. Treatment optimization activities will take place to evaluate and improve the effectiveness of the systems. At this point in time the following adjustments may be made to the SVE system during Third Quarter 2011:

- ST-106, Unit 249 – No adjustments are necessary.
- KAFB-1065, Unit 335 – Unit will be shut down as a result of marginal remedial effectiveness and moved to another location based on the SVE Optimization Plan (USACE, 2011a).
- KAFB-1066, Unit 345 – No adjustments are necessary.
- KAFB-1068, Unit 344 – Remedial performance is on the decline and will be monitored to determine whether the unit will be shut down and moved to another location based on the SVE Optimization Plan (USACE, 2011a).

Recommended adjustments to the SVE system will be implemented in accordance with the *Bulk Fuels Facility SVE Optimization Plan* (USACE, 2011a) currently under review by the NMED.

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