DEPARTMENT OF THE AIR FORCE
377TH AIR BASE WING (AFGSC)

Colonel Richard W. Gibbs
377 ABW/CC
2000 Wyoming Blvd SE
Kirtland Air Force Base NM 87117

JUL 15 2017

Mr. John Kieling
Hazardous Waste Bureau Chief
New Mexico Environment Department (NMED)
2905 Rodeo Park Drive East, Building 1
Santa Fe NM 87505-6303

Dear Mr. Kieling

Please find attached the *Risk Assessment Report, Bulk Fuels Facility Spill; Solid Waste Management Unit ST-106/SS-111,* Kirtland Air Force Base, New Mexico, dated July 2017. This report is submitted in response to NMED's Notice of Deficiency dated May 24, 2017 and approval of extension request dated July 5, 2017.

If you have any questions or concerns, please contact Mrs. Holly O'Grady at (505) 853-3484 or at holly.ogrady@us.af.mil or Mr. Scott Clark at (505) 846-9017 or at scott.clark@us.af.mil.

Sincerely

Richard W. Gibbs

RICHARD W. GIBBS, Colonel, USAF
Commander

Attachment:
Risk Assessment Report, July 2017, Bulk Fuels Facility Spill, Solid Waste Management Unit ST-106/SS-111.

cc:
NMED, Deputy Secretary (Borrego), letter
NMED-GWQB (Agnew, Hunter), letter
EPA Region 6 (Ellinger, King), letter
SAF-IEE (Lynnes), electronic only
AFCEC/CZ (Bodour, Clark, O'Grady), electronic only
USACE-ABQ District Office (Dreeland, Phaneuf, Salazar, Sanchez, Simpler), electronic only
Public Info Repository, Administrative Record/Information Repository (AR/IR) and File

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KIRTLAND AIR FORCE BASE
ALBUQUERQUE, NEW MEXICO

RISK ASSESSMENT
BULK FUELS FACILITY RELEASE
SOLID WASTE MANAGEMENT UNIT ST-106/SS-111
KIRTLAND AIR FORCE BASE, NEW MEXICO

July 2017

377 MSG/CEI
2050 Wyoming Boulevard SE
Kirtland Air Force Base, New Mexico 87117-5270

KIRTLAND AIR FORCE BASE
ALBUQUERQUE, NEW MEXICO

Risk Assessment
Bulk Fuels Facility Release
Solid Waste Management Unit ST-106/SS-111

July 2017

Prepared for

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

USACE Contract No. W912PP-16-C-0002

Prepared by

Sundance Consulting, Inc.
8210 Louisiana Blvd NE., Suite C
Albuquerque, NM 87113

with support from

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This Risk Assessment (RA) was prepared by Kirtland Air Force Base (AFB) to evaluate the potential for human and ecological exposure to contaminants of potential concern (COPC) and any associated potential human health effects and ecological risks related to fuel releases at the Bulk Fuels Facility (BFF) site (Site). Kirtland AFB, located in Albuquerque, New Mexico, discovered the release in November 1999 at the Former Fuel Offloading Rack at the BFF and determined through environmental investigations that subsurface fuel releases occurred over a period of decades, as described in Section 2 of the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Report (United States Army Corps of Engineers [USACE], 2017a). Resulting from these investigations, two solid waste management units (SWMU) identified as ST-106 and SS-111 were created. These SWMUs are comprised of the source area at the Site (ST-106) and the light non-aqueous phase liquid identified in the groundwater (SS-111), and are discussed in greater detail in the RFI Report (USACE, 2017a). Site investigations and interim measures have been ongoing since 1999. This RA uses Site data for soil, soil gas, and groundwater collected between 2014 and 2016 to evaluate the potential for exposure and associated risk to COPCs.

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DOCUMENT CERTIFICATION

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations.

Richard W. Gibbs

RICHARD W. GIBBS, Colonel, U.S. Air Force
Commander, 377th Air Base Wing

16 Jul 17
Date

This document has been approved for public release.

KIRTLAND AIR FORCE BASE
377th Air Base Wing Public Affairs

12 JUL 17
Date

PREFACE

This Risk Assessment (RA) Report was prepared by Sundance, Consulting, Inc. (Sundance) for the U.S. Army Corps of Engineers (USACE) under contract number W912PP-16-C-0002. It pertains to the Kirtland Air Force Base (AFB) Bulk Fuels Facility Site at Solid Waste Management Unit (SWMU) ST-106/SS-111, located in Albuquerque, New Mexico. This RA Report was prepared in accordance with the permit issued to Kirtland AFB under the Resource Conservation and Recovery Act (RCRA) and applicable federal, state, and local laws and regulations.

This RA Report presents and describes data from the RCRA Facility Investigation performed at SWMU ST-106/SS-111, which has been used to characterize risks to human and ecological receptors. Ms. Amy Sanchez is the Contracting Officer's Representative for the USACE Albuquerque District, and Mr. Trent Simpler, Professional Engineer, is the Project Manager. Mr. Scott Clark is the Kirtland AFB Restoration Interim Section Chief. This Report was prepared by Rachel Hobbs, Professional Geologist (P.G.) the Sundance Project Manager, and Ryan Wortman, Sundance project geologist with assistance from Cynthia Cheatwood and Dan Hinckley of EA Engineering, Science, and Technology, Inc., PBC.

Rachel Hobbs

Rachel Hobbs, P.G.
Sundance Consulting, Inc.
Project Manager

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ACRONYMS AND ABBREVIATIONS

%	percent
1,2-DCA	1,2-dichloroethane
1,2,4-TMB	1,2,4-trimethylbenzene
95UCL	95^{th} percentile upper confidence limit of the mean
AFB	Air Force Base
AOC	area of concern
AvGas	aviation gas
BFF	Bulk Fuels Facility
bgs	below ground surface
CARB	California Air Resources Board
COPC	contaminant of potential concern
CSEM	conceptual site exposure model
CSM	conceptual site model
DL	detection limit
DQO	data quality objective
DTIC	Defense Technical Information Center
EDB	ethylene dibromide
e.g.	for example
EPA	United States Environmental Protection Agency
EPC	exposure point concentration
ERA	Ecological Risk Assessment
ERP	Environmental Restoration Program
ESL	ecological screening level
etc.	etcetera
FFOR	Former Fuel Offloading Rack
GWM	groundwater monitoring
HC	hydrocarbon
HHRA	Human Health Risk Assessment
HI	hazard index
HQ	hazard quotient
HWB	Hazardous Waste Bureau

ACRONYMS AND ABBREVIATIONS (CONTINUED)

i.e.	in other words
INRMP	Integrated Natural Resources Management Plan
JP-4	jet propellant 4
JP-8	jet propellant 8
KAFB	Kirtland Air Force Base
LANL	Los Alamos National Laboratory
LNAPL	light non-aqueous phase liquid
LUC	land use control
MEK	methyl ethyl ketone
$\mu g/m^3$	microgram per cubic meter
µg/L	microgram per Liter
mg/kg	milligram per kilogram
NM	New Mexico
NMED	New Mexico Environment Department
No.	number
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effect level
Permit	Permit identification number NM9570024423 (NMED, 2010)
P.G.	Professional Geologist
PVC	polyvinyl chloride
Q	Quarter
QAPjP	Quality Assurance Project Plan
RA	Risk Assessment
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
Ridgecrest	Ridgecrest Drive
RL	reporting limit
RSL	Regional Screening Level
SDWA	Safe Drinking Water Act
Site	SWMU ST-106/SS-111
SL	screening level
SLERA	screening level ecological risk assessment
SLRA	screening level risk assessment
SSL	soil screening level
Sundance	Sundance Consulting, Inc.
SVE	soil vapor extraction

ACRONYMS AND ABBREVIATIONS (CONCLUDED)

SVM	soil vapor monitoring
SVMP	soil vapor monitoring point
SWMU	solid waste management unit
TSL	tapwater screening level
UCL	upper confidence limit
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
VA	Veterans Affairs
VISL	Vapor Intrusion Screening Level
VOC	volatile organic compounds
Water Authority	Albuquerque Bernalillo County Water Utility Authority

EXECUTIVE SUMMARY

This Risk Assessment (RA) was prepared by Kirtland Air Force Base (AFB) to evaluate the potential for human and ecological exposure to, and potential risks from such exposures to, contaminants of potential concern (COPCs) related to the historical fuel leak at the Bulk Fuels Facility (BFF) site (Site). Kirtland AFB, which is located in Albuquerque, New Mexico, discovered the fuel release in November 1999 at the Former Fuel Offloading Rack at the BFF and determined through environmental investigations that subsurface fuel releases occurred over a period of decades. Site investigations and interim measures have been ongoing since 1999. This RA uses Site data for soil, soil gas, and groundwater from the Resource Conservation and Recovery Act (RCReA) Facility Investigation (RFI) Report (United States Army Corps of Engineers [USACE], 2017a) to evaluate the potential for exposure and associated risk to identified COPCs.

The investigation and remediation activities at the Site and this RA are being implemented pursuant to the RCRA corrective action provisions in Part 6 of Kirtland AFB's Hazardous Waste Treatment Facility Operating Permit (Permit Number NM9570024423—"Permit"). The Permit identified two BFF-related solid waste management units (SWMUs): ST-106 and SS-111. These SWMUs are comprised of the source area at the Site (ST-106) and the light non-aqueous phase liquid that was identified in the groundwater (SS-111), which are discussed in greater detail in the RFI Report.

The RCRA Permit requires the performance of a RA using the current version of New Mexico Environment Department (NMED) Risk Assessment Guidance for Site Investigations and Remediation (NMED, 2017). This guidance, which was developed by NMED, provides generic screening levels for soil, tapwater, and vapor intrusion for chemicals commonly found at contaminated sites based upon conservative default exposure assumptions for both residential and non-residential land use scenarios. The objective of this RA is to evaluate the potential human health and ecological risks associated with COPCs detected in environmental samples related to the Site.

There are two parts to this RA, the Human Health Risk Assessment (HHRA), and the Ecological Risk Assessment (ERA). The HHRA investigates whether there is any risk to human receptors from contamination at the Site, and the ERA examines whether there is any risk to ecological receptors, such as plants, birds, or mammals, from Site contaminants. For the purposes of the RFI Report, a list of fuel-related analytes was developed for soil, soil gas, and groundwater which are referred to in this RA as COPCs. In total, there are 20 COPCs across all three media. The list of COPCs differs slightly for soil, soil gas, and groundwater; however, ethylene dibromide; benzene, toluene, ethylbenzene, and xylenes constituents; naphthalene; 1,2,4-trimethylbenzene; and 1,2-dichloroethane are common to all three media.

Both the HHRA and the ERA ask two questions to determine whether unacceptable risk exists. The first question is whether there is an exposure pathway for contaminated media to come in contact with human or ecological receptors. For example, if subsurface soil is contaminated, and construction workers disturb the soil while performing their work, they could be exposed to contaminated soil by skin contact, accidental ingestion, or inhalation while they are working.

In this RA, existing land use controls (LUCs) are incorporated in the conceptual site exposure model for current receptors, in that ongoing institutional, engineering, and administrative practices may prevent exposure to current human receptors. However, future exposure scenarios are also considered in the RA, in the case that land use may change, or LUCs may change or be removed in the future. For example, current land use at the BFF is industrial, and is expected to remain industrial for the foreseeable future.

However, in the absence of LUCs, if land use were to change in the future, the BFF could become a residential area. Hypothetical future on-Site residential receptors are evaluated in the RA to inform risk management decisions, and assess unrestricted site use.

Once the complete and potentially complete exposure pathways are identified, the next question is whether the contamination is present at levels that could cause an unacceptable risk to human or ecological receptors, thus not protecting human health and the environment.

To evaluate potential risk to human receptors, both carcinogenic and non-carcinogenic COPCs are evaluated in the HHRA. NMED Guidance (2017) sets the target level for carcinogenic risk equal to or less than $1x10^{-5}$, meaning that the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen at the BFF is less than one in 100,000. For non-carcinogenic contaminants, NMED sets a hazard quotient (HQ) target of 1.0, below which, it is unlikely sensitive populations would experience adverse health effects (NMED, 2017).

To evaluate potential risk to ecological receptors, maximum concentrations of COPCs are evaluated in comparison to ecological screening levels (SLs). Similar to the HHRA, NMED sets a HQ target of 1.0, below which, it is unlikely sensitive populations would experience adverse ecological effects (NMED, 2017). If the HQ exceeds 1, additional evaluation is warranted.

ES-1 Human Health Risk Assessment Results

The HHRA concludes there are no estimated unacceptable risks to current human receptors from contaminated soil, soil gas, or groundwater either on-Site (in other words, within the area of investigation on-Site) or off-Base as summarized in Table ES-1.

The HHRA identified potential unacceptable risks for exposure to groundwater under a future domestic use scenario both on-Site and off-Base, and for on-Site soil gas via vapor intrusion to indoor air under a future hypothetical on-Site residential scenario. However, current interim measures prevent exposure to impacted groundwater, and residential use is prevented on-Site. As a result, no additional interim measures are recommended. Consideration of a LUC in any final remedy may be warranted to prevent residential use on-Site until soil gas concentrations have reached acceptable levels.

ES-1.1 Soil

Complete and potentially complete soil exposure pathways were identified for the on-Site current/future commercial/industrial workers at the BFF, future construction workers at the BFF, and future hypothetical residents at the BFF. No contaminated surface or mixed zone soil is present off-Base, therefore, there are no complete or potentially complete exposure pathways for impacted soil for off-Base receptors. Maximum detected concentrations in soil from 0 to 10 feet below ground surface (bgs) were below NMED soil screening levels (SSLs) for commercial/industrial, construction worker, and residential receptors. Total soil risks based on the maximum detected concentrations were at or below NMED target risk levels. No unacceptable risk was identified based on exposure to on-Site surface or mixed zone soil within the BFF. The maximum detected concentration of lead in soil (0 to 10 feet bgs) was below the NMED SSL. No additional interim measures for soils (0 to 10 feet bgs) are recommended to address human health risks.

ES-1.2 Soil Gas

Fuel contaminants can volatilize from contaminated soil into soil gas, which may migrate into indoor air spaces if buildings are present, or may be released to ambient air. The migration of vapors from subsurface sources to indoor air within buildings is defined as vapor intrusion. NMED has developed Vapor Intrusion Screening Levels (VISLs) for areas where buildings currently exist or may be built in the future above contaminated soil gas.

On-Site Soil Gas

The soil gas exposure pathway via vapor intrusion is potentially complete for current/future commercial/industrial workers at the BFF. Although unlikely, a future hypothetical on-Site residential scenario was evaluated to inform risk management decisions. Only four buildings (Buildings 1044, 1049, 2426, and 1055) at, or adjacent to, the BFF are regularly occupied during business hours. Results of the risk characterization based on exposure point concentrations indicate that no unacceptable risk exists for current/future commercial/industrial workers at the BFF via the vapor intrusion pathway. Under the hypothetical future on-Site resident scenario, the total carcinogenic risk slightly exceeded NMED's target cancer risk level of $1x10^{-5}$.

Off-Base Soil Gas

There are currently no buildings in the area where soil gas has been detected off-Base, and as a result the exposure pathway to current receptors is incomplete. However, because COPCs in soil gas have been detected in the off-Base area within and adjacent to Bullhead Park, vapor intrusion was considered a potentially complete pathway under a future hypothetical off-Base residential scenario in the park area. Evaluating a future hypothetical residential receptor in Bullhead Park provides a conservative assessment of any current/future recreational visitors to the park, current/future commercial/industrial workers at the Veterans Affairs complex, or current/future residents beyond Ridgecrest Drive. Maximum detected concentrations in off-Base soil gas were below NMED residential soil gas VISLs. Total risks based on maximum detected concentrations in soil gas were below NMED target levels for the off-Base resident via the vapor intrusion pathway. No interim measures for off-Base soil gas are recommended.

Soil Gas to Ambient (Outdoor) Air

In addition to the vapor intrusion pathway, the HHRA also looked at potential risks from releases of soil gas to ambient air and potential uptake of soil gas by plants off-Base. Any release of soil gas COPCs into the atmosphere would be immediately diluted by ambient outdoor air movement. In addition, there is no risk to receptors from uptake by plants (gardening). The amount of soil gas at the shallow depths where garden plant roots would be found is negligible, therefore uptake of COPCs in soil gas via plant was considered an incomplete pathway.

ES-1.3 Groundwater

Impacted groundwater at the BFF is not currently used as a drinking water source and LUCs are in place to prevent exposure. Therefore, there are currently no complete exposure pathways for groundwater on-Site or off-Base. In order to inform risk management decisions and evaluate an unrestricted use scenario, domestic use of groundwater was evaluated on-Site and off-Base. Total risks calculated using NMED tapwater regional screening levels exceeded NMED target levels.

The New Mexico Office of the State Engineer issued a well drilling moratorium associated with BFF corrective action activities on February 9, 2017. The intent of this moratorium is to protect human health and prevent interference with ongoing corrective action activities by restricting the drilling of new wells and the transfer of water rights within the boundaries specified by NMED. COPCs have not been detected in off-Base water supply sentinel wells at concentrations exceeding drinking water standards. In addition, Kirtland AFB drinking water supply wells are sampled monthly and no COPCs exceeding SLs have been detected.

Based on the results of the HHRA, the interim measures and LUCs are needed to prevent direct contact with groundwater.

ES-2 Ecological Risk Assessment Results

The ERA concluded there is no risk to ecological receptors from soil, soil gas, or groundwater at the Site. There is no exposure pathway to ecological receptors from contaminated groundwater because groundwater is approximately 480 feet bgs. The potential exposure pathways to ecological receptors are through surface soil (0 to 1 foot bgs), mixed zone soil (0 to 10 feet bgs), and soil gas.

Plants and animals at the Site may be exposed to COPCs in surface soil through direct contact, accidental ingestion of soil, or ingestion of food items contaminated through bioaccumulation. Burrowing animals, such as prairie dogs and burrowing owls, could also contact mixed zone soil. Contaminants released to soil could volatilize into air voids in the soil column such as animal burrows created by burrowing mammals, birds, and reptiles. Soil gas is evaluated as a complete exposure pathway through burrow air; specifically, for the burrowing owl, which is listed as a federal species of concern.

Review of concentrations in the contaminated soil remaining on-Site indicates only lead concentrations exceeded ecological SSLs in soil. Although maximum concentrations of lead exceeded no-effects-based SLs, evaluation of other parameters such as mean and median concentrations within the Site suggest exceedances are limited in extent, or within background concentrations. In addition, the maintenance of the BFF for Site operations limits the amount and quality of ecological habitat present, and ecological exposures are expected to be minimal for this reason. The mean and median concentrations at the Site are at background concentrations, indicating the lead concentrations are naturally occurring. Given the limited extent of concentrations exceeding no-effects SLs and the limited ecological exposure potential, no unacceptable ecological risk exists at the Site due to COPCs in soils.

The ERA concluded there is no unacceptable ecological risk from soil gas when burrowing owls are considered as ecological receptors. Concentrations of COPCs in on-Site soil gas were less than available ecological SLs. Maximum HQs for the eight volatile organic compounds with SLs were less than 0.3, indicating concentrations are low compared to effect levels. In addition, evaluating soil gas concentrations at the 15 to 25 feet bgs depth interval is conservative when compared to the typical maximum burrow depth of the burrowing owl (3 feet bgs). Soil gas concentrations at typical shallow burrow depths are expected to be less due to attenuation. Therefore, no further action is proposed for soil gas concentrations in on-Site soils for protection of ecological receptors.

1 INTRODUCTION

This Risk Assessment (RA) was prepared by Kirtland Air Force Base (AFB) to evaluate the potential for human and ecological exposure to contaminants of potential concern (COPC) and any associated potential human health effects and ecological risks related to fuel releases at the Bulk Fuels Facility (BFF) site (Site). Kirtland AFB, located in Albuquerque, New Mexico, discovered the release in November 1999 at the Former Fuel Offloading Rack (FFOR) at the BFF and determined through environmental investigations that subsurface fuel releases occurred over a period of decades, as described in Section 2 of the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Report (United States Army Corps of Engineers [USACE], 2017a). Resulting from these investigations, two solid waste management units (SWMU) identified as ST-106 and SS-111 were created. These SWMUs are comprised of the source area at the Site (ST-106) and the light non-aqueous phase liquid (LNAPL) identified in the groundwater (SS-111), and are discussed in greater detail in the RFI Report (USACE, 2017a). Site investigations and interim measures have been ongoing since 1999. This RA uses Site data for soil, soil gas, and groundwater collected between 2014 and 2016 to evaluate the potential for exposure and associated risk to COPCs.

Part 6.2.4.5 of Kirtland AFB's Hazardous Waste Treatment Facility Operating Permit (Permit Number [No.] NM9570024423—"Permit") allows the Permittee to submit a RA report during the investigation stage or with the Corrective Measures Evaluation Report. Kirtland AFB chose to submit this RA at the investigation stage to identify any potential human health or ecological risks at this phase of the Site cleanup (that is, near the end of the investigation stage and while interim measures are being implemented).

1.1 Risk Assessment Objectives

As stated above, the objectives of this RA are to evaluate the potential human health and ecological risks associated with COPCs detected in environmental samples related to the Site. It is noted that the Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (ERA) represent a site-specific RA for the BFF and only evaluate chemicals associated with the BFF. This site-specific RA includes samples collected on-Site (in other words [i.e.], within the area of investigation on-Site) and off-Base. The results of the RA will inform regulators and the public regarding present-day exposures and potential risks, and will guide future corrective action activities at the Site, if necessary, to reduce risks.

1.2 Regulatory Context

The investigation and remediation of the Site are being implemented pursuant to the RCRA corrective action provisions in Part 6 of Kirtland AFB's Permit. The Permit is enforced by the New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB), which is authorized to administer RCRA by the United States Environmental Protection Agency (EPA). Part 6 of the Permit provides requirements for investigating the nature and extent of contamination from SWMUs and areas of concern (AOC), establishes cleanup criteria, provides for the implementation of interim measures, details RA requirements, and establishes procedures for identifying and implementing any necessary corrective measures.

The RFI Report covers activities conducted under Part 6.2.2.1 of the Permit, which sets forth requirements for site investigations. The RFI Report provides the results from 16 years of investigation activities into the nature and extent of environmental media contaminated by the Site releases and describes the interim measures that have been implemented to-date at the Site. The RFI Report was submitted to the NMED HWB on January 31, 2017 (USACE, 2017a). This RA uses data collected in support of the RFI and the interim measures, and demonstrates sufficient data have been collected to assess potential risk to human health and the environment.

This RA follows NMED's *Risk Assessment Guidance for Site Investigations and Remediation* (NMED, 2017). Typically, RAs are performed to determine risks under "baseline" or non-remediated conditions. However, appreciable removal of contamination and contaminated media has already occurred and is ongoing in the form of interim measures. Part 6.2.2.2.12 of the Permit explains that interim measures can be implemented if it is determined "such measures are necessary to reduce or prevent migration of hazardous wastes or hazardous constituents that have, or may result in, an unacceptable human or ecological receptor exposure to hazardous waste or hazardous constituents while long-term corrective action remedies are being evaluated and implemented." An interim measure is an important tool for protecting human health and the environment while other parts of the RCRA process are ongoing.

The following three community water systems, which are near the footprint of the Site groundwater plumes shown in Figure 1-1, are regulated under the Safe Drinking Water Act (SDWA):

- The Albuquerque Bernalillo County Water Utility Authority (Water Authority) provides drinking water to Bernalillo County and residential housing on-Site. The Water Authority operates the Ridgecrest Drive (Ridgecrest) well field, the closest municipal drinking water supply wells to the Site.

- The Veterans Affairs (VA) Medical Center owns and operates a drinking water supply well that serves the Medical Center and associated buildings. This well is located to the east of the Site.

- Kirtland AFB provides drinking water for on-Site industrial and office uses, the off-Base Maxwell housing complex, and the Child Development Center.

New Mexico (NM) sought and was granted primary authority for public water systems and has adopted state drinking water rules (NM Code R. §§ 20.7.10.1 – 2017.10.704). These rules are enforced by the NMED Drinking Water Bureau. All three community water systems are subject to SDWA requirements. Current and future water use is discussed in more detail in the RFI Report (USACE, 2017a; Section 7).

1.3 Summary of Site Contamination and Contaminant Transport

The RFI Report provides a detailed account of the past and current nature and extent of contamination and a Conceptual Site Model (CSM) detailing the movement of contaminants (USACE, 2017a). The following summary of the source of Site contamination and subsequent contaminant transport provides important context for the RA.

The source of contamination for the Site is historical fuel releases from the Kirtland AFB FFOR delivery infrastructure, specifically underground pipelines. These below-grade releases at the Site moved downwards through the soil until reaching groundwater located approximately 480 feet below ground surface (bgs). As discussed in RFI Report Section 7, and illustrated in the RFI Report as well as Figure 1-2 of this report, LNAPL migrated downward via a tortuous pathway, with lateral spreading occurring when less-permeable strata were reached (USACE, 2017a).

Fuel that leaked from the underground pipeline included aviation gasoline (AvGas), jet propellant 4 (JP-4), and jet propellant 8 (JP-8; USACE, 2017a). As outlined in the RFI Report, AvGas was the primary fuel stored and used at Kirtland AFB until 1975. Ethylene dibromide (EDB) was an additive used only in AvGas, so its presence is limited to before 1975 (USACE, 2017a). After 1975, Kirtland AFB transitioned to jet propellant fuels. Collectively, these types of fuel are referred to as LNAPL because they have a lower density than water and are comprised of compounds that are largely insoluble in water. In other words, if LNAPL infiltrates into the ground and reaches the water table, it will form a layer on top of the water table while the more soluble constituents dissolve into the groundwater. In addition, the volatile constituents of LNAPL can exist in vapor form in the air-filled pore space of soil (referred to as soil vapor in the RFI Report). The term “soil gas” is used by NMED in reference to this pore space in defining risk-based screening level concentrations, and the term is used in this report.

The releases of LNAPL from the fuel delivery infrastructure resulted in fuel-related contamination of environmental media in the vadose zone (the area from the ground surface to the water table) and in groundwater. Once released into this environment, fuel and constituents of fuel may exist in four phases:

1. Adsorbed (fuel constituents attached to soil particles)

2. LNAPL residual fuel (free product)

3. Soil gas (volatile fuel constituents as vapor in soil air pockets)

4. Dissolved (fuel constituents in groundwater and pore water in the vadose zone).

Dispersion, diffusion, and other transport mechanisms discussed in the RFI Report have been the factors responsible for the migration of fuel and its constituents (including EDB, benzene, and other fuel constituents) through the vadose zone and subsequently off-Base (USACE, 2017a). A distinct layer of floating LNAPL on the water table has not been consistently measured at the Site since 2012. Interim measures (for example [e.g.], soil removal at the source in 1999, and skimmer system and bioslurping from about 2008 through 2011) were implemented early on and reduced the amount of free product contributing to contamination in the environment. A significant factor impeding measurement of LNAPL has been a rising water table that has been documented from the early 20th century to the end of 2015 (USACE, 2017a; Section 5). Thus, present-day contamination is limited to dissolved constituents in groundwater (e.g., EDB, benzene, and other dissolved fuel constituents; see Figure 1-1), LNAPL that has moved into soil at the boundary of the water table, and soil gas generated from LNAPL, soil, and groundwater which exists at a depth of approximately 500 feet bgs.

The RFI Report describes the nature and extent of each form of contamination in the vadose zone and groundwater (USACE, 2017a). Table 1-1 summarizes the results of the RFI Report (USACE, 2017a) and describes the types of contamination present at the Site, both on-Site and off-Base.

Describing the nature and extent of contamination at the Site requires an understanding of possible chemical and biological transformations of LNAPL constituents, and of the relevant transport processes related to constituent migration. That is, it is important to understand the degradation of organic contaminant(s) through inorganic and biological chemical processes in the environment, and the processes by which contaminant(s) move away from the source area. For example, volatile hydrocarbon (HC) components of LNAPL are biologically degraded in soil pore spaces by indigenous bacteria under both aerobic and anaerobic conditions. This is especially true at the Site, where results of quarterly soil gas monitoring events and the rebound and respiration testing (USACE, 2017a; Section 4) indicate that aerobic biodegradation is active in many areas of the vadose zone. Biodegradation has played a substantial role in remediating fuel constituents at the Site before, during, and after soil vapor extraction (SVE) operation. The SVE systems generally have the effect of oxygenating areas of high soil vapor concentrations to promote aerobic biodegradation. However, the SVE system has also had a drying effect on the vadose zone that might have limited biodegradation in certain areas (USACE, 2017a; Section 4). Microbial analyses performed on groundwater samples at the Site in 2013 and 2015 (USACE, 2017a; Section 6) indicate that microbial-remediated reductive debromination of EDB is occurring in-situ in groundwater, and that benzene is also being microbially degraded in groundwater.

Additionally, as some fuel HCs are metabolized, enzymes are produced that can facilitate the degradation of halogenated HC additives, such as EDB, that are commonly more resistant to biodegradation. This process is known as co-metabolism. The agreement between independent measures of anaerobic EDB degradation (excess bromide and ethene/ethane) at the Site suggest that large quantities of EDB may have degraded at the Site, possibly aided by the co-metabolism of benzene while microorganisms degraded fuel HCs within the source area and just downgradient of the benzene plume. The fate and transport properties of LNAPL and the specific constituents of LNAPL are discussed in more detail in Sections 5 and 7 of the RFI Report (USACE, 2017a).

1.4 Interim Measures

As mentioned earlier and discussed in detail in the RFI Report, Kirtland AFB has completed a number of interim measures in the source area and is continuing to implement interim measures to address COPCs in soil, soil gas, and groundwater (USACE, 2017a). Interim measures as defined in the Permit include, “actions necessary to minimize or prevent the further migration of contaminants and limit actual or potential human and environmental exposure to contaminants while long-term corrective action remedies are evaluated.” These measures are important for the RA because of their role in reducing or eliminating exposure to some of the contaminated media. The following interim measures have been implemented:

- **Soil Removal:** Three separate excavation events removed a total of 4,822 tons (3,027 cubic yards) of contaminated soil to achieve NMED’s residential screening levels (SL; USACE, 2017a; Section 4).

- **Removal of Source Infrastructure:** Removal of the source area pipelines and replacement of fueling infrastructure eliminated the source of the release (USACE, 2017a; Section 2).

- **Soil Vapor Extraction:** SVE systems operated at the Site from 2003 through 2015. These systems disrupted the transport pathway for soil gas by reducing the mass of volatile contaminants. These SVE systems removed approximately 775,000 equivalent-gallons of jet fuel. Subsequent to deactivation of the SVE system in Quarter (Q) 2 2015, vadose zone soil gas HC concentrations have been returning to spatial patterns reflecting non-flow conditions (USACE, 2017a; Section 4).

- **LNAPL Skimmer System and Bioslurping:** The LNAPL skimmer system and bioslurping removed most of the floating LNAPL from the water table. This removal limited LNAPL constituents from volatilizing into soil gas or dissolving into groundwater (USACE, 2017a; Section 5). The skimmer system, used from 2007 to 2008, removed approximately 280-gallons of LNAPL. Bioslurping, used from early 2008 until late 2011, removed 225,000 equivalent-gallons of fuel (this number is included in the total amount removed by SVE).

- **Groundwater Treatment System:** The only interim measure operating at the time of this RA is the groundwater treatment system. This system currently includes three off-Base extraction wells which pump groundwater from the dissolved-phase EDB plume to an on-Site treatment facility. This interim measure is designed to collapse, treat, and hydraulically-control the downgradient dissolved-phase EDB plume (USACE, 2017a: Section 6).

- **Groundwater Monitoring:** Continual monitoring of on-Site and off-Base groundwater monitoring wells, and drinking water supply wells prevents exposure to current receptors. This monitoring includes several different types of wells listed below:

    - ***Groundwater Monitoring Program:*** One-hundred thirty four groundwater monitoring wells are monitored regulary to delineate the nature and extent of contaminants in groundwater as described in the RFI Report (USACE, 2017a). Shallow and deep sentinel groundwater monitoring wells on-Site and off-Base are sampled quarterly to ensure early detection of potential dissolved COPCs prior to reaching drinking water supply wells. The majority of off-Base public drinking water supply wells are operated by the Water Authority. The two Water Authority wells closest to the dissolved-phase EDB plume are Ridgecrest-3 and Ridgecrest-5 (Figure 1-1). In addition, the United States Geological Survey (USGS) performs monitoring of sentinel wells on a quarterly basis (Figure 1-1).

    - ***Kirtland AFB Water Supply Wells:*** There are three Kirtland AFB drinking water supply wells AFB (KAFB-003, KAFB-015, and KAFB-016) near the EDB plume, which are monitored monthly when operational to ensure COPCs have not reached the on-Site drinking water supply system (Figure 1-1). All analytical results have been below project SLs. In addition, sentinel groundwater monitoring wells are located between the groundwater contaminant plume and the Kirtland AFB supply wells to provide early detection of contaminants.

    - ***VA Medical Center Supply Well:*** The VA Medical Center abuts Kirtland AFB to the north and has one drinking water supply well, which is sampled monthly (Figure 1-1). Analytical results at this location have historically been nondetect or below project SLs for project COPCs. Additionally, there are sentinel groundwater monitoring wells located between the groundwater contaminant plume and the VA Medical center supply well to provide early detection of contaminants.

    - ***Privately-owned Irrigation Wells:*** There are two privately-owned water supply wells in the vicinity of the plume, which are used primarily for irrigation (Figure 1-1). One of these is sampled quarterly, and results are reported to NMED. All analytical results have been below project SLs. In addition, groundwater monitoring wells are located between these irrigation wells and the EDB plume to provide early detection of contaminants.

- **Land Use Controls:** Current land use controls (LUC) include general access restrictions for Kirtland AFB and the BFF, and restrictions on intrusive activities within the Site in accordance with the Air Force Work Clearance Request review process. At the direction of NMED, the Office of the State Engineer has restricted the installation of private water supply wells within a 500-foot buffer around the footprint of the dissolved-phase EDB plume. LUCs considered in this RA are discussed in more detail in Section 4.2.

1.5 Organization of this Document

The remainder of this document includes the following:

- **Section 2 Overview of the Risk Assessment Process**
  A description of NMED's HHRA and ERA methodologies, including information related to the human health and ecological SLs applied in the RA.

- **Section 3 Environmental Data and Data Quality**
  A description of the environmental sampling by which the soil, soil gas, and groundwater data used in the RA were acquired, and how the data were incorporated in the RA.

- **Section 4 Human Health Risk Assessment Exposure Assessment**
  This section provides includes identification of potentially complete exposure pathways for soil, soil gas, and groundwater for on-Site and off-Base locations.

- **Section 5 Human Health Risk Assessment Risk Characterization**
  This section includes a detailed risk characterization and uncertainty analysis, and presents the conclusions and recommendations of the HHRA.

- **Section 6 Ecological Risk Assessment**
  This section provides the results of the ERA, consisting of Phase I, Phase II Tier 1, and Phase II Tier 2 assessments.

2 OVERVIEW OF THE RISK ASSESSMENT PROCESS

The HHRA and ERA are conducted in accordance with NMED's *Risk Assessment Guidance for Site Investigations and Remediation* (NMED, 2017). NMED's Guidance incorporates readily obtainable Site data and utilizes methods from various EPA RA Guidances. The NMED Guidance is divided into two volumes:

- "Volume 1—Tier I Soil Screening Guidance Technical Background Document" discusses the methodology used to derive chemical-specific soil SLs (SSLs), tapwater SLs (TSLs), and vapor intrusion SLs (VISLs). In addition, guidance is provided to assist in identifying and evaluating appropriate exposure pathways and human or ecological receptors. Finally, it provides generic SSLs, TSLs, and VISLs for chemicals commonly found at contaminated sites based on default exposure parameters under residential and non-residential land use scenarios.

- "Volume 2—Screening Level Ecological Risk Assessments" describes NMED's procedure for the evaluation of ecological risk.

This RA is a screening level RA (SLRA) for both human and ecological receptors. As such, the focus of this SLRA is to evaluate whether 1) potentially complete exposure pathways could exist now or in the future for human or ecological receptors, and 2) to determine whether concentrations of analytes measured in environmental media present a risk to those receptors by comparison to NMED SLs and target risk values (NMED, 2017). SLs are media-specific and scenario-specific contaminant concentrations at or below which exposure would not be expected to result in an unacceptable risk. This SLRA answers the following questions:

- What are the sources, distribution, and concentrations of contaminants in soil, soil gas, and groundwater?

- Who could potentially come in contact with the contaminated soil, water, or air?

- Are the contaminant concentrations high enough to potentially cause an unacceptable risk to humans or ecological receptors (e.g., plants and wildlife)?

- Is further action needed to prevent exposure or cleanup the contamination?

As stated previously, this SLRA has been performed near the end of the investigation stage and while interim measures are being implemented. The objective of a SLRA is simply to indicate whether further evaluation, sampling, or other actions may be necessary (e.g., use of institutional or engineering controls to prevent exposure).

The Permit cites NMED Guidance, which specifies the steps that must be followed to perform a SLRA for both human and ecological receptors. These steps and their location in this RA include:

- Data quality assessment for SLRA (see Section 3)

- Development of human and ecological Conceptual Site Exposure Models (CSEM) to determine complete and incomplete exposure pathways (see Sections 4 and 6)

- Comparison of Site data with SLs and calculation of cumulative risk estimates to determine whether an unacceptable risk to human or ecological receptors from complete or potentially complete exposure pathways exists (see Sections 5 and 6)

- Assessment of uncertainties (see Sections 5.2 and 6.4).

NMED SLs incorporate a number of assumptions. Therefore, it is important to understand how the SLs are used in the SLRA, how they were developed, and why they are protective of human health and the environment. These topics are discussed in the following sections.

2.1 Human Health Risk Assessment

NMED uses a two-step approach for a HHRA. Step 1 involves comparing maximum COPC concentrations to the appropriate NMED-developed SLs. NMED SLs for soil, soil gas, and groundwater have been developed using conservative exposure assumptions. The exposure assumptions used in SL development are more likely to overestimate than underestimate potential risk (NMED, 2017). NMED SLs were derived from equations combining exposure assumptions with toxicity criteria following EPA's preferred hierarchy of toxicological data. NMED also considered different exposure scenarios, such as residential and commercial/industrial, and developed receptor-specific SLs for the different exposure scenarios. Figure 2-1 summarizes NMED's overall HHRA process. Step 1 of the NMED HHRA process uses maximum COPC concentrations and the appropriate media- and receptor-specific SL to calculate cumulative risks to human receptors. These cumulative risk estimates are compared to NMED target risk levels for carcinogenic and non-carcinogenic risks.

If the risk calculations performed using maximum concentrations of each COPC exceed NMED's target risk levels, the next step (Step 2) in the risk evaluation involves development of statistical estimates of average exposure point concentrations (EPCs). Section 3 includes a detailed analysis of the Site data to support calculation of EPCs.

The chemical-specific NMED SLs are based on a 1×10^{-5} target risk for carcinogens (risk of cancer occurrence is 1 in 100,000), or a hazard quotient (HQ) of 1.0 for non-carcinogens. A HQ is the ratio between an estimated exposure concentration (based on site data and exposure assumptions) and a concentration that is not expected to result in an adverse health effect.

2.1.1 Summary of NMED Human Health Screening Levels

NMED SLs are developed for residential, commercial/industrial, and construction exposure scenarios. Routes of exposure include dermal (absorption through skin contact with contaminants in soil or water), inhalation (absorption through the lungs from breathing), and ingestion (absorption through the gastrointestinal tract) exposures as appropriate to the exposure scenario (NMED, 2017). The assumptions NMED used to develop SLs for various exposure scenarios are described below. Section 2 in NMED's Guidance (NMED, 2017) has more detailed descriptions of the methods used to develop NMED SLs. NMED has also developed SSLs related to protection of groundwater from residual contamination in soil. Because near-surface soil remediation is complete and groundwater contamination from historical releases is directly evaluated in the HHRA, the groundwater protection SLs are not employed in the HHRA.

2.1.1.1 Soil Screening Levels for Residential Exposure Scenarios

Residential exposures are assessed with SSLs based on child and adult human receptors. The child receptor is used as the basis for calculating SSLs for non-carcinogenic effects, and both child and adult exposures are used to assess cancer risk over an individual's lifetime. Residential exposure includes three soil exposure pathways: direct ingestion, dermal absorption, and inhalation of volatiles and dust at soil depths ranging from ground surface to 10 feet bgs. A resident is assumed to occupy a home at a site 24 hours per day for 350 days per year for 26 years (NMED, 2017; Section 2). Residential SSLs are incorporated in this HHRA to evaluate exposure to future hypothetical on-site residents and assess the unrestricted use scenario.

2.1.1.2 Soil Screening Levels for Commercial/Industrial and Construction Exposure Scenarios

Non-residential land use exposures include all industrial and commercial land uses and focuses on two types of human receptors: a commercial/industrial worker and a construction worker. These types of workers are representative of on-Site workers. These SSLs are based on adult exposure only. The commercial/industrial worker is assumed to be a long-term (i.e., 25 years) receptor exposed to surface soil (0 to 1 foot bgs) on a regular basis during the work week. The construction worker is assumed to perform instrusive operations (i.e., excavation, trenching, etcetera [etc.]) and be exposed to surface and subsurface soil (i.e., 0 to 10 feet bgs) during the entire workday for a single project of one year's duration (NMED, 2017; Section 2). The application of commercial/industrial and construction scenarios allows for appropriate screening of potential soil exposures for both surface and subsurface soils, respectively, consistent with NMED's Guidance (NMED, 2017).

2.1.1.3 Tapwater Screening Levels

NMED TSLs are used in this HHRA to evaluate risk from exposure to contaminated groundwater. The TSLs are for domestic use (as tapwater) and assume ingestion and dermal contact with contaminants in domestic/household water and inhalation of volatiles through showering or dish washing (NMED, 2017; Section 2). TSLs are used in this HHRA because the fuel contamination is in an aquifer that is currently used by public drinking water systems, although any public supply wells and privately-owned irrigation wells are located outside the impacted area of the aquifer.

2.1.1.4 Vapor Intrusion Screening Levels

Vapor intrusion occurs when soil gas migrates from subsurface media (i.e., soil and/or groundwater) through pore spaces in the vadose zone and building foundations into indoor air, potentially exposing residential and commercial/industrial receptors to volatile COPCs. VISLs have been developed by NMED to address areas where buildings may exist above contaminated soil gas. The VISLs were developed for both soil gas (when the vapor is still in the ground beneath a building) and indoor air (vapor in a building). VISLs are evaluated if 1) there are compounds present in subsurface media that are sufficiently volatile and toxic, and 2) there are existing or planned buildings where exposure could occur. A chemical is considered to be sufficiently volatile if its Henry's Law Constant is 1×10^{-5} units of moles per cubic meter for air to moles per cubic meter for water or greater and its molecular weight is approximately 200 grams per mole or less. Section 7 of the RFI Report lists the physical properties of contaminants evaluated in the RFI Report and shows that most of the COPCs evaluated in this HHRA are sufficiently volatile (USACE, 2017a). Commercial/industrial and residential soil gas VISLs are used in this HHRA to evaluate exposure to COPCs in soil gas.

2.1.2 Ecological Risk Assessment

Part 6.2.3.7 of the RCRA Permit requires the evaluation of potential ecological risk for any SWMU or AOC where there has been a release of contaminants. As required by the Permit, the ERA follows Volume 2 of NMED's Guidance (NMED, 2017), with additional documents as cited in Section 6. The purpose of the ERA is to evaluate the potential adverse effects that chemical contamination could have on plants and animals on or near the site. Furthermore, it provides a means to organize and present scientific information in a logical format for risk managers (NMED, 2017).

NMED's ERA process includes a Phase I Qualitative Assessment, and a Phase II Quantitative Assessment. Phase II consists of Tier 1 and Tier 2 screening level ERA (SLERA). The Tier 1 SLERA determines whether the site needs to have the toxicity data and risk characterization assessed in more detail. The Tier 2 SLERA findings are used to determine whether the site requires a Quantitative Site-specific Risk Assessment (NMED, 2017).

The Phase I Qualitative Assessment begins with a scoping assessment that reviews the biological and physical properties of the site, including environmental setting, land use, contaminant fate and transport mechanisms, and the area's habitats, ecological receptors, and exposure pathways. This information is used to support development of a preliminary CSEM to determine if ecological risk is possible. If it is, then a Phase II, Tier 1 SLERA is implemented by selecting representative screening ecological receptors and exposure pathways to determine exposure estimates for effects assessment and risk characterization. If warranted, a Phase II, Tier 2 SLERA is implemented, which refines the toxicity assessment using more realistic estimates of exposure, such as maximum, mean and median concentration values, as well as using area use factors to provide a refined risk characterization.

3 ENVIRONMENTAL DATA AND DATA QUALITY

The foundation for any RA is the quality and quantity of data available to determine potential risk. The specific analytes evaluated in this RA are identified in Section 3.1. The data used in the RA include soil data collected on-Site and groundwater and soil gas data collected both on-Site and off-Base; these data are discussed in Section 3.2. Data quality attributes are discussed in Section 3.3, Data Evaluation.

3.1 Selection of Contaminants of Potential Concern

Section 3 of the RFI Report examined the list of sampled analytes throughout the history of Site investigations. NMED's RA Guidance states, "…*identification of contaminants of potential concern should begin with existing knowledge of the process, product, or waste from which the release originated*" (NMED, 2017). Since the sources of contamination at the Site are AvGas, JP-4, and JP-8; the list of fuel-related constituents is known. For the purposes of the RFI Report, a list of fuel-related analytes was developed for soil, soil gas, and groundwater, and referred to in this RA as COPCs (see Table 3-1). It should be noted that not all COPCs were sampled in every medium (e.g., lead is not volatile within the expected temperature and pressure ranges at the Site, and was not analyzed in soil gas samples). In total, there are 20 COPCs across all three media. The list of COPCs differs slightly for soil, soil gas, and groundwater; however, EDB; benzene, toluene, ethylbenzene, and xylenes; naphthalene; 1,2,4-trimethylbenzene (1,2,4-TMB); and 1,2-dichloroethane (1,2-DCA) are common to all three media. Analytes previously removed from sampling suites during optimization of the groundwater monitoring program were not included as COPCs (e.g., the 97 analytes removed from the groundwater monitoring program in 2015 [USACE, 2017a]).These analytes were nondetect and/or below SLs for the previous eight quarters of analysis.

3.2 Environmental Data Evaluated in the Risk Assessment

The following sections describes the environmental data in each media that were evaluated as part of this RA.

3.2.1 Soil

Several separate on-Site soil investigations have been conducted between 2000 and 2014, as described in Section 4 of the RFI Report (USACE, 2017a). Of the different soil samples acquired during this period, two sets of soil data are relevant for assessing potential risk from present-day exposure to soil on-Site: 1) soil data from unexcavated (non-removal) areas proximal to the release area, and 2) post-excavation soil confirmation data collected after the 2014 soil removal (USACE, 2017a). The 2014 post-excavation soil data are particularly relevant to the RA because they provide the most recent shallow soil data within 20 feet of the ground surface. Soil samples collected as part of well installation were not included in this RA because they were collected from soil at depths not relevant for RA, or were part of earlier sample events and represent soil that has been removed.

The soil dataset includes samples from 14 soil boring locations that contained exceedances of the NMED 2012 SSLs, but were not excavated or were only partially excavated during the 2014 excavation activities (USACE, 2017a) and post-excavation confirmation samples collected between 0 to 10 feet bgs. Figures 3-1 and 3-2 illustrate the 14 soil sample locations where excavation was not possible due to existing underground utilities and infrastructure. Sixty-three samples were collected from the sidewalls and floor of the excavation. Twelve additional step-out confirmation samples were collected for semi-volatile organic compounds, 2-methylnaphthalene and naphthalene, when concentrations exceeded the NMED 2012 SSLs (75 samples total were analyzed for 2-methylnaphthalene and naphthalene). 1-Methylnaphthalene was not included in the analysis for the original 63 confirmation samples, but was included in the method used to analyze the step-out confirmation samples (12 samples total analyzed for 1-methylnaphthalene). The post-excavation sample locations are presented in Figures 3-1 and 3-2 and sample results are summarized in Table 3-4.

Concentrations of COPCs in surface soil collected from 0 to 1 foot bgs are summarized in Table 3-2 and are compared to commercial/industrial worker SSLs in Section 5 per NMED RA Guidance (NMED, 2017).

Concentrations of COPCs in mixed zone soil (i.e., 0 to 10 feet bgs) are summarized in Table 3-3 and were compared to the residential or construction worker SSLs in Section 5 per NMED RA Guidance (NMED, 2017).

3.2.2 Soil Gas

Soil gas data from Q1 through Q3 2016 were used to evaluate the potential risk on-Site and off-Base from exposure to COPCs in soil gas. Soil gas data from three quarters were used in this RA to minimize the effect of the vadose zone stabilizing to natural flow conditions after the shutdown of the approximately 1,800 standard cubic feet per minute catalytic oxidizer SVE system, which occurred in Q2 2015 (USACE, 2017a). Analytical data for Q1 through Q3 2016 is included in the Q4 2016 monitoring report (USACE, 2017b).

Currently, there are 51 soil vapor monitoring (SVM) locations on-Site and five off-Base, as illustrated in Figure 3-3. Sample depth intervals at each location commonly range from a shallow interval with a well screen at 15 to 25 feet bgs to intervals at a depth of approximately 450 feet bgs. Soil gas data from all depth intervals are presented in the RFI Report (USACE, 2017a). However, for the RA, the most relevant data are the on-Site and off-Base shallow soil gas data collected at 15 to 25 feet bgs because these data best represent a potential source term for vapor intrusion into a building.

Of the 56 total locations, 35 have sample intervals at the 15 to 25-foot interval, 31 on-Site and four off-Base. Table 3-4 summarizes on-Site samples evaluated from Q1 through Q3 2016 (93 samples). Table 3-5 summarizes off-Base samples collected from Q1 through Q3 2016 (12 samples). Note that the RFI Report presents soil gas data with units of parts per million by volume, while the RA employs the units used by NMED for VISLs (i.e., micrograms per cubic meter [$\mu g/m^3$]). Soil gas data were converted to $\mu g/m^3$ from parts per billion by volume using the molecular weight of each chemical and a conversion factor of 24.45, which assumes a standard atmospheric pressure of 1 atmosphere and a standard temperature of 25 degrees Celsius. This conversion was performed to facilitate the HHRA by matching NMED soil gas VISL units.

3.2.3 Groundwater

Groundwater data from Q3 and Q4 2015, as presented in the RFI Report, were used to evaluate potential on-Site and off-Base risks from exposure to groundwater (USACE, 2017a). Section 6 of the RFI Report presents the details of the groundwater monitoring program along with the results from the beginning of monitoring in 2000 to the end of 2015 (USACE, 2017a). Tables 3-6 and 3-7 summarize the on-Base and off-Base groundwater datasets used in the HHRA. Thirty-four on-Site wells were sampled in Q3 and Q4 2015 (68 samples). Ninety-seven off-Base wells were sampled in Q3 and Q4 2015 with an additional three off-Site wells installed and sampled in Q4 2015 (197 samples; Figure 1-1).

3.3 Data Quality Evaluation

Data validation reports for soil data collected between Q1 2011 and Q4 2015, soil gas data collected from Q3 2015 through Q3 2016, and groundwater data collected from Q3 through Q4 2015 were completed in accordance with the *Quality Assurance Project Plan (QAPjP) for the Vadose Zone Investigation and Groundwater Investigation Work Plans* (USACE, 2011), and the *Soil Vapor and Drinking Water Monitoring Work Plan* (USACE, 2016), and have been presented in the associated Quarterly Pre-remedy Monitoring Reports. The requirements for data quality, quantity, and usability for the analytical data used in the RFI Report and this RA were specified in the QAPjP associated with each Work Plan. Therefore, these data have been determined to meet the data quality objectives (DQO) requirements in NMED's RA Guidance (NMED, 2017). The foundation for any RA is the quality of data available to determine potential risk. The RFI Report, which was submitted to NMED on January 31, 2017, summarizes all investigation activities and interim measures performed between November 11, 1999 and December 31, 2015. These data were collected during the multiple project investigations, which were performed in accordance with Site-specific Work Plans for each separate sampling event.

This RA uses validated data for the identified COPCs that was collected to support the RFI. Laboratory data flags are included in the project database, and no rejected data were used to evaluate the nature and extent of fuel-related contamination in the RFI Report or in this RA. The inclusion or exclusion of data within the RA, on the basis of analytical qualifiers, was performed in accordance with NMED Guidance (NMED, 2017). Data without qualifiers were retained at the reported concentration. The following procedures were followed if qualifiers were present:

- Analytical results bearing the U-qualifier (indicating that the analyte was not detected at the given reporting limit [RL]) were retained in the dataset and considered nondetects at the given RL.

- Analytical results bearing the J-qualifier (indicating that the reported value was estimated because the analyte was detected at a concentration below the RL or for other reasons), "+" qualifiers (indicating the inorganic reported value may be biased high), and "-" qualifier indicating the reported value may be biased low) were retained at the reported concentration.

If duplicate samples were collected, the following guidelines were employed to select the appropriate sample measurement:

- If both samples show that the analyte was present, the two results were averaged.

- If both samples show nondetect values, the two nondetect RLs were averaged.

- If only one sample indicated that the analyte was present, it was retained in the dataset and the nondetect value was discarded.

If all results for a COPC were nondetect, the COPC was not carried forward for risk characterization in Sections 5 or 6 (See Tables 3-2 through 3-7).

3.3.1 Soil Gas Data Quality Evaluation

The following issues were identified for soil gas data collected from the SVM locations:

- EDB was measured by two analytical methods (EPA method TO-15 and method California Air Resources Board [CARB] 422) and the results were not in agreement.
- Elevated concentrations of acetone and methyl ethyl ketone (MEK) were found in a number of samples.

To ensure the soil gas data used to assess risk met DQOs, each of these potential issues was evaluated further and the results of this evaluation are provided below. Detailed data evaluation reports are included in quarterly data quality evaluation reports. As summarized below and detailed in Attachment 1, these issues were evaluated and the analytical data were determined to be acceptable relative to the data quality indicators.

3.3.1.1 Evaluation of Soil Gas Analytical Methods for EDB

EDB in soil gas was measured in samples collected during SVM by two analytical methods: EPA method TO-15, which is a mass spectrometry detection method, and method CARB 422, which is an electron capture detection method. The TO-15 method has been used for SVM since 2010. The CARB 422 method was added in 2014 with the goal of having a method with a lower EDB detection limit in soil gas than the TO-15 method. However, a detailed assessment of soil gas data by both methods indicates the CARB 422 EDB results are not accurate; therefore, only TO-15 EDB results are used in this RA.

An investigation into the two soil gas methods for EDB is described in Attachment 1. Comparisons of the detection limits for EDB in soil gas by TO-15 and by CARB 422 are documented in a summary memo submitted to NMED in April 2017 (Kirtland AFB [KAFB], 2017). Level IV soil gas data packages and data analyses for EDB revealed a systematic difference in the magnitude of the detected values between the two methods, as well as an increase in the analytical detection limit by CARB 422 method. The following lines of evidence provide the basis for using the TO-15 EDB data in the RA rather than the CARB 422 EDB data:

- Comparison of 408 sample pairs of detected EDB results by CARB 422 and TO-15 showed a very consistent pattern of CARB 422 results two to five times higher than TO-15 results.
- Based on two laboratory control sample analyses performed by the laboratory, it appears the CARB 422 EDB results are biased approximately 1.7 times higher than the TO-15 results.
- Results of an investigation by the analytical laboratory indicate that this bias is at least partly due to improper preparation of the CARB 422 calibration standard prepared in March 2015 and used through November 2016.
- Review of 16 TO-15 analytical data packages confirms the ability of the TO-15 method to detect EDB in the presence of high concentration of other COPCs. TO-15 mass spectra with straight-chain HC mass up to 1,000 times larger than EDB mass were reviewed and determined not to impact EDB identification and quantitation.

- Mass spectrometry (i.e., TO-15) is considered a more definitive identification technique than electron capture detection (i.e., CARB 422) because the generally unique mass fragmentation patterns evaluated by mass spectrometry greatly reduce the chances for misidentification of an analyte and TO-15 is not affected by interference from other halogenated compounds.

- Review of detection limits for EDB in soil gas by TO-15 and CARB 422 indicate that approximately 70 percent (%) of the time, the detection limit (DL) for EDB by TO-15 is lower than that of CARB 422, demonstrating that for most sample locations, TO-15 is the more effective method (KAFB, 2017).

3.3.1.2 Evaluation of Acetone and MEK in Soil Gas

High levels of acetone and MEK were observed in some of the soil gas samples. The presence of these analytes is believed to be related to two sources 1) the polyvinyl chloride (PVC) glue (i.e., Oatey low volatile organic compound [VOC] purple primer) that was used to seal the SVM ports during Q1 2015 and 2) as a byproduct of biodegradation of fuel-related constituents. Acetone and MEK were not evaluated in the RA due to their relationship with these sources.

In the source area (e.g., SVMW-10-250), acetone, and MEK concentrations are similar in pattern to COPCs such as EDB and benzene. Transient production of acetone is generally correlative to sub-oxic, methanogenic environments. It is assumed that acetone production happens before the system becomes fully anaerobic (Mueller, 2011). The Q4 2016 Report (USACE, 2017b), indicates that this process may be occurring in groundwater. Thus, the report concludes persistence of the compound would indicate an active, continuing bioremediation signature. Concentrations of acetone and MEK in anaerobic areas of the vadose zone indicate this process may also be ongoing in the source area of the vadose zone.

In locations outside of the source area (e.g., KAFB-106141-250), the presence of acetone is consistent with the use of a PVC glue used to seal the sample ports in Q1 2015. This conclusion is supported by the presence of acetone and MEK in the primer and the temporal patterns of these constituents in the soil vapor monitoring points (SVMPs) data from this period. The highest concentrations of acetone and MEK were detected in the Q3 2015 soil gas data, which was the first quarter of data collected after the SVM locations were sealed. Review of chromatograms provided by the analytical laboratory demonstrates identification and quantification of the COPCs by EPA Method TO-15 was not otherwise affected by high concentrations of acetone and MEK. Soil gas data from Q1 through Q3 2016 were used in this RA.

4 HUMAN HEALTH EXPOSURE ASSESSMENT

The exposure assessment evaluates the magnitude, frequency, and duration of exposure of human receptors to contaminated media affected by site activities. A key component of the exposure assessment is the CSEM, which is based on the CSM (Section 7) described in the RFI Report (USACE, 2017a). The HHRA CSEM illustrates the potential exposure pathways by which humans could be exposed to contaminants at a site. As discussed in Section 3.1, this exposure assessment focuses on COPCs identified in the RFI Report that are related to the fuel released at the Site (USACE, 2017a).

Exposure pathways begin at source areas and progress through the environment via various fate and transport processes to potential human receptors. Schematic renderings of the on-Site and off-Base human health CSEMs are shown in Figures 4-1 and 4-2, respectively. The RFI CSM (USACE, 2017a; Section 7) sets forth the potential source areas and contaminant migration pathways. The following section details the site exposure setting and potential human receptors. A completed exposure pathway requires the following four components:

- Source and mechanism of chemical release to the environment
- Environmental transport medium for the released chemical
- Point of potential human contact with the contaminated medium
- Human uptake route at the point of exposure.

All four components must exist for an exposure pathway to be complete (or potentially complete in the future) and for exposure to occur. Incomplete exposure pathways do not result in actual exposure and are not evaluated in the risk characterization. If the exposure pathway is incomplete, there is no risk to human receptors. Complete and potentially complete exposure pathways are carried forward and evaluated in the HHRA (Section 5, Human Health Risk Characterization) to determine whether there is a potential unacceptable risk to human health.

4.1 Land Use

NMED Guidance (NMED, 2017) requires plausible exposure under both current and future land use be evaluated in the HHRA. Therefore, an understanding of current and future land use is important to accurately determine the human receptors that may be present at the Site currently or in the future. Both on-Site and off-Base land use are evaluated in the vicinity of the BFF. Human receptors are discussed in Sections 4.3 and 4.4.

4.1.1 On-Site Land Use

Kirtland AFB is an active military installation, and is expected to remain active for the foreseeable future. According to the current Kirtland AFB's Installation Development Plan, the Site is located within the "Flightline District." The Flightline District is primarily industrial, with facilities and land use dedicated to the support of airfield operations. This includes the BFF, which is where the Site source area is located on-Site. As a result, current and anticipated future land use is primarily industrial for the Site, with limited, restricted administrative use (KAFB, 2016). No transfer of military property to the public is anticipated near the Site. Twelve buildings have been identified within and adjacent to the BFF (Table 4-1). Of these 12, only four are occupied on a regular basis. Only three of those four (Buildings 1044, 1049, and 1055) are occupied full time, and consistent with the NMED commercial/industrial exposure scenario, which assumes exposure to workers eight hours a day, five days a week, 45 weeks a year for 25 years (NMED, 2017).

4.1.2 Off-Base Land Use

Figure 1-1 shows the delineation of the benzene and EDB groundwater plumes off-Base. Current land use and expected future land use above the impacted groundwater plume north of the Kirtland AFB property line (Figure 1-1) is zoned majority residential with limited commercial zoning (City of Albuquerque, 2017a).

Off-Base soil gas contamination has been measured in a smaller area than the footprint of the off-Base groundwater plume, and includes the area of Bullhead Park, the VA Medical Center parking lot, and the Air Force-owned open space. Land use in the off-Base area adjacent to the Site and overlying the vapor plume is not expected to change in the future. Land use above the area of the off-Base soil gas plume includes areas zoned as residential. It is important to note there are currently no residential or industrial buildings in the area of the off-Base soil gas plume; the majority of the area is comprised of Bullhead Park. Since the area adjacent to Bullhead Park is already established and densely developed, it is unlikely land use will change significantly in the foreseeable future. Per the City of Albuquerque, the area is zoned RA-1, which requires a minimum of 20,000 square feet of open space per dwelling unit (City of Albuquerque, 2017a). In addition, although the City of Albuquerque websites show plans for redevelopment of commercial areas north of Bullhead Park, there are no planned changes to Bullhead Park or to the residential areas (City of Albuquerque, 2017b). The large open area to the northeast, between Bullhead Park and the residential areas (Figure 3-3), is owned by the Air Force and the Air National Guard.

4.1.3 Groundwater Use

Groundwater used by on-Site workers, and on-Site residents originates from two sources as discussed in the RFI Reprt (USACE, 2017). Kirtland AFB groundwater drinking water supply wells are used for offices, irrigation, and industrial purposes, and 2) the Water Authority supplies potable water for on-Site residential housing (USACE, 2017a). There are seven Kirtland AFB drinking water supply wells in the Albuquerque Basin screened at depths of 450 to 1,000 feet bgs. The three Kirtland AFB drinking water supply wells (KAFB-003, KAFB-015, and KAFB-016) closest to the groundwater plume are monitored monthly for potential groundwater contamination. KAFB-016 has not been operational for the last few years due to ongoing repairs; however, it is scheduled to resume operation in the summer of 2017. All analytical results have been below project SLs. In addition, sentinel groundwater monitoring wells are located between the groundwater contaminant plume and the Kirtland AFB supply wells to provide early detection of contaminants.

Off-Base groundwater in the vicinity of the Site originates from three sources: Water Authority supply wells, one VA Medical Center water supply well, and two privately-owned irrigation wells. The majority of off-Base public drinking water supply wells are operated by the Water Authority. The two Water Authority wells closest to the dissolved-phase EDB plume are Ridgecrest-3 and Ridgecrest-5 (Figure 1-1). Drinking water wells used by the Water Authority for its customers are screened at a depth of approximately 1,000 feet, which is significantly deeper in the aquifer than the contaminant plume. Shallow and deep sentinel groundwater monitoring wells on-Site and off-Base, and USGS sentinel wells are sampled quarterly to ensure early detection of potential dissolved COPCs prior to reaching drinking water supply wells (Figure 1-1).

The VA Medical Center drinking water well, located approximately 750 feet west of the estimated plume boundary, is also screened at a depth of approximately 1,000 feet bgs. This VA Medical Center drinking water well has not had any contaminant detections above SLs to-date and is sampled monthly. Additionally, there are sentinel groundwater monitoring wells located between the groundwater contaminant plume and the VA Medical Center supply well to provide early detection of contaminants.

The two privately-owned water supply wells in the vicinity of the plume are used primarily for irrigation (Figure 1-1). One of these wells is sampled quarterly, and concentrations of all analytes have been below SLs since sampling began in 2008. Results of the sampling events are reported quarterly to NMED.

4.2 Land Use Controls

Knowledge of the existing LUCs is important to develop the CSEM because LUCs can limit exposure of current human receptors to contamination. LUCs include physical, legal, or administrative mechanisms restricting the use of, or limiting access to, real property to prevent or reduce risks to human health and the environment. This HHRA incorporates current LUCs to evaluate current/future industrial exposure; however future residential scenarios assume an unrestricted scenario, to include the removal of all LUCs.

Access to Kirtland AFB (and the Site) is restricted by control gates manned by security forces 24 hours per day. All qualifying unescorted personnel are required to be registered in the defense identification system using REAL ID (REAL ID Act of 2005) criteria. In addition, the BFF itself has limited access and egress. The Kirtland AFB BFF enclosure includes a fenced area with signage and an automated gate, which limits access to authorized personnel with an appropriate code. Personnel must have approval from the Base Wing Commander to work inside the BFF. Additionally, there is on-Site signage, and utilities in the BFF are marked to prevent potential damage during digging and subsurface access is limited.

Administrative procedures are in place to manage activities to prevent exposure to contaminants. All work performed on-Site, including within the BFF, must have prior approval on an Air Force Form 332. If the proposed work requires digging or other land disturbance, it must be further reviewed through the Air Force Form 103, Base Civil Engineering Work Clearance Request. As part of this land disturbance review process, the location of buried utility lines and areas of contamination are identified and steps are outlined to control the disturbance of contaminated soils.

Off-Base institutional controls include City of Albuquerque zoning as discussed in Section 4.1. In addition, at the direction of NMED, the Office of the State Engineer has restricted the installation of private water supply wells within a 500-foot buffer around the footprint of the dissolved-phase EDB plume. This restriction ensures contaminated groundwater exposure pathways to private well owners remain incomplete.

4.3 On-Site CSEM

The on-Site CSEM is shown in Figure 4-1. The LUCs discussed in Section 4.2 are incorporated in the CSEM to determine whether exposure pathways are complete or potentially complete under the current/future commercial/industrial and construction worker scenarios. The future hypothetical residential scenario, although unlikely, assumes no action (to include any LUCs) will be performed to reduce exposure.

4.3.1 On-Site Human Receptors

Based on the Kirtland AFB land uses discussed in Section 4.1, the following receptors were identified on-Site who may be exposed to contaminated media:

- Current/future commercial/industrial workers who support daily activities at the BFF. Since the replacement and automation of the fueling infrastructure in 2011, operational activities at the BFF are greatly reduced.

- Future construction workers who may engage in intrusive construction or excavation activities at the BFF. Although there is no current active construction at the BFF, construction may occur in the future to repair or replace existing infrastructure.

- Future hypothetical residents within the BFF. Although unlikely, this scenario addresses changes in on-Site land use at the BFF to include future on-Site housing. This scenario informs risk management decisions for consideration of unrestricted use and assumes no actions (to include LUCs) will be taken to reduce exposure.

4.3.2 On-Site Exposure Pathways

The following sections describe the complete, potentially complete, and incomplete exposure pathways to contaminated media on-Site for receptors evaluated quantitatively in the HHRA. As illustrated in Figure 4-1, exposure pathways to both current and future human receptors are evaluated. The current LUCs in place on-Site restrict or reduce exposure to contaminated media in some cases.

4.3.2.1 On-Site Soil Exposure Pathways

As discussed in Section 3, contaminated soil was removed to 20 feet bgs during the 2014 excavation event. Contaminated soil deeper than 20 feet bgs is considered inaccessible to human receptors. However, contaminated soil at 14 locations in the BFF was not removed due to existing infrastructure and utilities.

Runoff and erosion from contaminated surface soil to surface water is not expected to result in any complete exposure pathways for human receptors. It is highly unlikely surface water is introducing appreciable amounts of contaminated surface soil into the storm water system because 1) topography at the Site is relatively flat and 2) the majority of surface water at the Site either evaporates or infiltrates into the soil (USACE, 2017a). The amount of unexcavated surface soil (approximately 700 square feet) would have a negligible contribution to surface water runoff at the BFF.

Current/Future Commercial/Industrial Worker – Surface Soil (0 to 1 foot bgs): A complete exposure pathway exists for surface soil and dust to both current and future commercial/industrial workers at the BFF (Figure 4-1). As discussed in Section 2, the commercial/industrial worker is assumed to be a long-term receptor exposed to surface soil (0 to 1 feet bgs) on a regular basis during the work week. A limited amount of impacted surface soil was left in place following the 2014 excavation. The commercial/industrial worker is not expected to perform intrusive activities in these areas but may visit these areas during regular work activities. Currently, there are no LUCs in place to prevent commercial/industrial workers from encountering contaminated surface soil, or dust blown from surface soil by wind, therefore, direct contact with surface soil for the commercial/industrial worker is considered a complete exposure pathway. The current/future commercial/industrial worker was evaluated for exposure to surface soil via ingestion, dermal contact, and inhalation of volatiles and particulates in dust.

Future Construction Worker – Mixed Zone Soil (0 to 10 feet bgs): The construction worker is assumed to be exposed to mixed zone soil (0 to 10 feet bgs) during the entire workday for a single project of one year's duration (NMED, 2017; Section 2). As described in Section 4.2, LUCs at Kirtland AFB currently prevent intrusive work without prior review and approval. However, under a future unrestricted use scenario, construction activities may be performed to repair or replace existing infrastructure or for redevelopment. Therefore, exposure pathways from mixed zone soil and dust to future construction workers are potentially complete. The future construction worker was evaluated for exposure to mixed zone soil via ingestion, dermal contact, and inhalation of volatiles and particulates in dust.

Future Hypothetical Residents – Mixed Zone Soil (0 to 10 feet bgs): There are currently no residential homes on-Site. However, the future on-Site residential scenario is evaluated to inform risk management decisions and assumes unrestricted use. The future residents are assumed to be adults and children in contact with soil at depths from 0 to 10 feet bgs. A resident is assumed to occupy a home on-Site 24 hours per day for 350 days per year for 26 years (Section 2). Under this scenario, exposure pathways from mixed zone soil and dust to future residential homeowners are potentially complete (Figure 4-1). The future hypothetical resident was evaluated for exposure to mixed zone soil via ingestion, dermal contact, and inhalation of volatiles and particulates in dust.

Concentrations of COPCs in on-Site soil are evaluated in Section 5 to determine whether there is an unacceptable risk to current or future receptors at the BFF from complete or potentially complete exposure pathways.

4.3.2.2 On-Site Soil Gas (Vapor Intrusion) Exposure Pathways

COPCs can volatilize from on-Site contaminated soil or groundwater into soil gas, which can migrate into indoor air spaces if buildings are present. The migration of vapors from subsurface sources to indoor air within buildings is defined as vapor intrusion. As shown in Figure 4-1, COPCs could volatilize from contaminated groundwater or subsurface soil. However, the water table is located at 480 feet bgs and vapors from groundwater are not expected to migrate from the top of the water table upwards to ground surface (EPA, 2012). The primary soil gas exposure pathway is the volatilization of COPCs in impacted subsurface soil to indoor air vai vapor intrusion.

Inhalation of VOCs released from soil gas to ambient (outdoor) air was considered a potentially complete but insignificant exposure pathway for all human receptors. It is unlikely appreciable amounts of contaminated soil gas are being released into the ambient air from subsurface soil on-Site because 1) almost no contaminated soil remains near the ground surface (i.e., within 20 feet of ground surface) to provide a continual source and 2) any such releases would be immediately diluted. The leaking underground pipes were decommissioned in 1999 and removed in 2010; the majority of the impacted soil has been excavated to 20 feet bgs. Volatile COPCs in soil at 0 to 10 feet were addressed as a soil exposure pathway as described in Section 4.3.2.1.

Soil gas exposure pathways for human receptors evaluated in the RA are discussed below.

Current/Future Commercial/Industrial Worker: A potentially complete vapor intrusion exposure pathway exists from soil gas to indoor air within existing buildings for current/future commercial/industrial workers at the BFF. Although there is a limited number of occupied buildings at and adjacent to the BFF (Section 4.1), there are currently no actions or LUCs in place addressing vapor intrusion specifically. The current/future commercial/industrial worker was evaluated for exposure via inhalation to COPCs in soil gas, which could be present in indoor air due to vapor intrusion.

Future Construction Worker: Because construction workers are assumed to perform all work outside, no complete exposure pathway exists for future construction workers for indoor air via vapor intrusion. Construction workers are assumed to be outdoor workers. A potentially complete exposure pathway may exist for soil gas to outdoor air within a trench. Concerns about construction worker exposure to soil gas within a trench will be captured qualitatively through the evaluation of the vapor intrusion to indoor air pathway for the current/future commercial/industrial workers in Section 5.

Future Hypothetical Resident: There are no current on-Site residential receptors within the BFF. However, should land use change in the future, residential homes could be constructed on-Site. Therefore, a potentially complete vapor intrusion exposure pathway exists from soil gas to indoor air within future residential buildings at the BFF (Figure 4-1). The future hypothetical on-Site resident was evaluated for exposure via inhalation to COPCs in soil gas, which could be present in indoor air due to vapor intrusion.

Concentrations of COPCs in on-Site soil gas are evaluated in Section 5 to determine whether there is an unacceptable risk to current or future receptors at the BFF from complete or potentially complete exposure pathways.

4.3.2.3 On-Site Groundwater Exposure Pathways

As shown in Figure 4-1, released LNAPL migrated through contaminated soil to groundwater underlying the Site. As discussed in Section 1.4, and Section 4.1.3, the active interim measures in place cause the exposure pathway to current groundwater receptors to be incomplete.

Future Users of Groundwater On-Site: To inform risk management decisions the HHRA assumed that a drinking water supply well could be installed within the on-Site portion of the contaminant plume. Therefore, direct contact pathways for groundwater were considered potentially complete, to include ingestion, dermal contact, and inhalation of volatiles during household use (such as showering or dishwashing). A second hypothetical future scenario is a future industrial worker. However, the NMED TSLs are developed to evaluate residential receptors, and assume higher exposure than that of a worker. Thus the TSLs are suffiently protective of workers.

Concentrations of COPCs in groundwater are evaluated in Section 5 to determine whether there is an unacceptable risk to future receptors should water supply wells be installed in the contaminated portion of the aquifer based on complete or potentially complete exposure pathways.

4.4 Off-Base CSEM

The off-Base CSEM is shown in Figure 4-2. The land use and LUCs discussed in Sections 4.1 and 4.2 are incorporated in the CSEM to determine where exposure pathways are complete, potentially complete, or incomplete for the identified human receptors.

4.4.1 Off-Base Human Receptors

Based on the off-Base land uses discussed in Section 4.1, there are three types of human receptors that may be exposed to contaminated media:

1. Current/future recreational users at Bullhead Park or the Air Force-owned open space.

2. Future hypothetical off-Base residents in the footprint of Bullhead Park or the Air Force-owned open space, should land use change in the future. The City of Albuquerque has no plans to change the use of Bullhead Park, and there are currently no residential buildings present, however consideration of a future residential scenario provides information for consideration of unrestricted use.

3. Future users of groundwater Off-Base: Although interim measures are in place to prevent exposure to contaminated groundwater, the HHRA assumed a a drinking water supply well could be installed within the off-Base portion of the contaminant plume. Therefore, direct contact pathways for groundwater were considered potentially complete, to include ingestion, dermal contact, and inhalation of volatiles during household use (such as showering or dishwashing).

Although current/future residents north of Ridgecrest and current/future commercial/industrial workers (i.e., VA complex) were not evaluated quantitatively in the RA, consideration of the future hypothetical residents at Bullhead Park conservatively assesses these scenarios. Bullhead Park is located nearest to the contamination and is expected to have higher concentrations compared to the Ridgecrest area or the VA complex, thus estimated exposure is maximized with consideration of the future hypothetical resident at Bullhead Park.

4.4.2 Off-Base Exposure Pathways

The following sections describe the complete, potentially complete, and incomplete exposure pathways to contaminated media off-Base for receptors evaluated quantitatively in the HHRA. As illustrated in Figure 4-2, the exposure media present off-Base are limited in comparison to the on-Site exposure media. There is no contaminated surface (0 to 1 feet bgs) or mixed zone (0 to 10 feet bgs) soil off-Base. All soil exposure pathways were considered incomplete for off-Base receptors.

4.4.2.1 Off-Base Soil Gas (Vapor Intrusion) Exposure Pathways

Contaminated groundwater has migrated off-B. COPCs in groundwater could volatilize and migrate upward through the subsurface to indoor air if buildings are present. However, the water table is located at 480 feet bgs, therefore vapors from groundwater are not expected to migrate from the top of the water table upwards to the ground surface over this distance (EPA, 2012). The primary vapor intrusion exposure pathway is the volatilization of COPCs from impacted subsurface soil remaining on-Site in the area adjacent to the Base (i.e., Bullhead Park).

Current/Future Recreational Users: There are no occupied buildings in Bullhead Park or in the Air Force-owned open space. The vapor intrusion pathway from soil gas to indoor air is incomplete for current/future recreational users.

Future Hypothetical Off-Base Residents: While the City of Albuquerque has no plans to change the use of Bullhead Park, it is possible that this area could become residential in the future. If Bullhead Park was converted to residential use in the future, the exposure pathway from soil gas to indoor air could be potentially complete due to horizontal soil gas migration. The future hypothetical resident at Bullhead Park was evaluated for exposure via inhalation to COPCs in soil gas, which could be present in indoor air due to vapor intrusion. The amount of soil gas at the shallow depths where garden plant roots would be found is negligible, therefore uptake of COPCs in soil gas via plant was considered an incomplete pathway.

The concentrations of COPCs in off-Base soil gas are evaluated in Section 5 to determine whether there is an unacceptable risk to future residents from this potentially complete exposure pathway.

4.4.2.2 Off-Base Groundwater Exposure Pathways

As shown in Figure 1-1, contaminated groundwater has migrated off-Base in the direction of groundwater flow resulting in a plume that extends off-Base. Figure 4-2 illustrates the complete, potentially complete, and incomplete exposure pathways for groundwater for each human receptor.

Current/Future Recreational Users: The depth to groundwater is approximately 480 feet bgs, therefore, there is no potential for contact with groundwater at Bullhead Park. Water for drinking fountains and landscape irrigation at the park is provided by the Water Authority (City of Albuquerque, 2015). As a result, the exposure pathways for a current/future recreational user at Bullhead Park is considered incomplete for groundwater.

Future Users of Groundwater Off-Base: Although interim measures are in place to prevent exposure to contaminated groundwater, the HHRA assumed a a drinking water supply well could be installed within the off-Base portion of the contaminant plume. Therefore, direct contact pathways for groundwater were considered potentially complete, to include ingestion, dermal contact, and inhalation of volatiles during household use (such as showering or dishwashing).

There are no Water Authority drinking water supply wells installed in the impacted portion of the off-Base groundwater plume. Therefore, groundwater exposure pathways are incomplete for current off-Base receptors.

Concentrations of COPCs in groundwater are evaluated in Section 5 to determine whether there is an unacceptable risk to future receptors should water supply wells be installed in the contaminated portion of the aquifer based on complete or potentially complete exposure pathways.

5 HUMAN HEALTH RISK CHARACTERIZATION

Risk characterization evaluates information pertaining to potential exposures of human receptors to contamination and the health effects for the COPCs identified in soil, soil gas, and groundwater (Section 3.1). Exposure pathways for these media are described in Section 4; complete or potentially complete exposure pathways for current and future human receptors were evaluated quantitatively. The risk characterization for the complete and potentially complete exposure pathways is provided in Section 5.1. Key uncertainties related to the risk characterization are discussed in Section 5.2. Conclusions of the human health risk characterization are discussed in Section 5.3.

5.1 Human Health Risk Assessment

Human health risks were estimated for the receptors and exposure pathways identified as complete or potentially complete in Section 4. Risk characterization was performed using the following steps:

1. Appropriate NMED SLs based on exposure media (e.g., soil, soil gas, groundwater) and appropriate receptor (e.g., residential, commercial/industrial, or construction worker) were identified:

    - On-site soil concentrations for COPCs were compared to commercial/industrial, construction worker, and residential SSLs.

    - On-Site soil gas concentrations for COPCs were compared to commercial/industrial and residential soil gas VISLs.

    - Off-Base soil gas concentrations were compared to residential soil gas VISLs.

    - Both On-Site and Off-Base groundwater concentrations were compared to residential TSLs.

    If NMED screening levels were not available, EPA regional screening levels (RSLs; EPA, 2016) were used. Carcinogenic RSLs were adjusted to NMED's target cancer risk of one in 100,000 (10^{-5}). As noted in Section 2, NMED SLs represent environmental concentrations at or below which further action is not warranted under the indicated land use.

    Maximum detected concentrations in each media were screened against the appropriate COPCs.

2. COPC-specific and cumulative cancer risks and hazard indices (HI) were calculated using the maximum concentration of each COPC as described in NMED, 2017.

    - For carcinogenic COPCs, the maximum concentration was divided by the appropriate SL and multiplied by 1×10^{-5} to derive a COPC-specific cancer risk. The cancer risks for each COPC in an exposure media were then summed for each receptor to provide the total estimated cancer risk. The sum was compared to the NMED target cancer risk level of 1×10^{-5} (NMED, 2017).

- For a non-carcinogenic COPC, a COPC-specific HQ was calculated by dividing the maximum concentration by the appropriate SL. The HQs for each COPC in an exposure media were summed for each receptor to obtain a total estimated HI. The HI was compared with the NMED target HI of 1 (NMED, 2017).

- If a COPC had both carcinogenic and non-carcinogenic effects, it was included in both the carcinogenic and non-carcinogenic risk calculations.

3. If the total cancer risk estimate or the total HI calculated using the maximum concentrations in an exposure medium the NMED target values, then further risk characterization was performed. In accordance with NMED Guidance (2017), EPCs were calculated in these cases. The total cancer risk and the total HI were then recalculated using the EPCs in place of the maximum concentration as described in Step 2 above.

   Statistic-based EPCs were derived to quantify concentrations of COPCs in media. For the HHRA, the EPC represents the COPC concentration in a media that a potential receptor is expected to contact over a designated exposure period (NMED, 2017). COPCs concentrations, as discussed in Section 3.3, were used to calculate the 95th percentile upper confidence limit of the mean (95UCL) when the total cancer risk and HI for an exposure medium exceeded the NMED target levels.

   In accordance with NMED Guidance (2017) EPCs were only calculated if the dataset for a COPC contained at least eight results with at least five detections. If a dataset contained nondetects, each nondetect was assigned a numerical value equal to its reporting limit. If an analyte was not detected in any samples, then it was not carried forward in the risk calculations. 95UCLs were calculated using the EPA's ProUCL 5.1 software. ProUCL performs distributional tests on the dataset for each COPC and calculates the most appropriate UCL based on the distribution of the dataset. The ProUCL program recommends a distribution and a value for the 95UCL, or the 99UCL as appropriate. The input and output data files for ProUCL calculations for each site are provided as Attachment 2.

5.1.1 Soil

Complete or potentially complete soil exposure pathways were identified in Section 4 for current/future on-Site industrial workers, future construction workers, and future hypothetical on-Site residents. No complete or potentially complete exposure pathways were identified for off-Base receptors for soil, as no contaminated soil exists off-Base at 0 to 10 feet bgs.

5.1.1.1 On-Site Soil Risks

As discussed in Section 3, both surface (0 to 1 foot bgs) and mixed zone soil (0 to 10 feet bgs) datasets were evaluated in this RA. The maximum detected concentrations of COPCs in surface soil and subsurface soil did not exceed NMED commercial/industrial, construction worker, or residential SSLs. Benzene and ethylbenzene were the only carcinogenic COPCs detected in soil samples collected from 0 to 10 feet bgs.

The maximum detected concentration of lead in soil at 0 to 10 feet bgs was 71 milligrams per kilogram (mg/kg), which is below the NMED SSL of 400 mg/kg.

Current/Future Commercial/Industrial Worker - Surface Soil (0 to 1 foot bgs): The total cancer risk and HI was calculated using the maximum concentrations for each COPC as shown in Tables 5-1 and 5-2, respectively. The total cancer risk was 2 x 10^{-10}, which is below NMED's target cancer risk level of 1 x 10^{-5} (Table 5-1). The total non-carcinogenic HI was 4 x 10^{-5}, which is below NMED's target HI of 1 (Table 5-2). The risk estimates indicate there is no unacceptable risk to current/future commercial/industrial workers at the BFF based on exposure to surface soil. No further risk evaluation was performed.

Future Hypothetical On-Site Resident – Mixed Zone Soil (0 to 10 feet bgs): Currently no residential homes exist at the BFF, and there are no plans to change land use from industrial to residential. However, should land use change in the future, a residential scenario was considered to inform the risk management process (Section 4). The total cancer risk and HI was calculated using the maximum concentrations for each COPC as shown in Tables 5-3 and Table 5-4, respectively. The total cancer risk was 8 x 10^{-8}, which is below NMED's target cancer risk level of 1 x 10^{-5} (Table 5-3). The total non-carcinogenic HI was 0.2, which is below NMED's target HI of 1 (Table 5-4). The risk estimates indicate there is no unacceptable risk to future hypothetical on-Site residents at the BFF based on exposure to mixed zone soil at 0 to 10 feet bgs. No further risk evaluation was performed.

Future Construction Worker – Mixed Zone Soil (0 to 10 feet bgs): Current LUCs prevent intrusive work at the BFF without prior review and approval. The future construction worker scenario evaluates the case where the existing LUCs are removed. The total cancer risk and HI was calculated using the maximum concentrations for each COPC as shown in Tables 5-5 and Table 5-6, respectively. The total cancer risk was 3 x 10^{-9}, which is below NMED's target cancer risk level of 1 x 10^{-5} (Table 5-5). The total non-carcinogenic HI was 0.04, which is below NMED's target HI of 1 (Table 5-6). The risk estimates indicate there is no unacceptable risk to future construction workers at the BFF based on exposure to mixed zone soil at 0 to 10 feet bgs. No further risk evaluation was performed.

5.1.1.2 Off-Base Soil Risk

No contaminated soil is present off-Base at depths of 0 to 10 feet bgs. Contaminated soil is confimed to the on-Site portion of the BFF. There are no complete exposure pathways for soil for any off-Base receptor.

5.1.2 Soil Gas

Complete and potentially complete soil gas exposure pathways via vapor intrusion to indoor air were identified in Section 4 for current/future on-Site commercial/industrial workers and future hypothetical on-Site residents - via vapor intrusion to indoor air.

No occupied buildings exist off-Base in the area of soil gas contamination, therefore there are currently no complete exposure pathways for soil gas. Although no residences are located in the area of soil gas contamination, in order to address potential changes in land use in the future, vapor intrusion to indoor air was considered a potentially complete pathway for a future hypothetical off-Base resident at Bullhead Park.

5.1.2.1 On-Site Soil Gas

Maximum detected concentrations in soil gas were compared to the NMED commercial/industrial or residential soil gas VISLs as appropriate. The cancer risk and noncancer HI were calculated using maximum detected concentrations and EPCs based on 95UCLs for the current/future commercial/industrial worker and the future hypothetical on-Site resident as described below.

Current/Future Commercial/Industrial Worker: The total cancer risk was calculated using the maximum detected concentrations for each COPC as shown in Table 5-7. The calculated total cancer risk was 6 x 10^{-5}, which exceeds NMED's target cancer risk level of 1 x 10^{-5}. Primary contributors to the total cancer risk were EDB and naphthalene, which had maximum detected concentrations that exceeded the commercial/industrial soil gas VISLs. Based on the exceedance of the NMED target cancer risk level, total cancer risk was further evaluated using EPCs based on the 95UCL. As shown in Table 5-8, the calculated total cancer risk based on the EPCs is 4 x 10^{-6}, which is below NMED's target cancer risk level of 1 x 10^{-5}.

The EPC represents the COPC concentration in a media that a potential receptor is expected to contact over a designated exposure period (NMED, 2017). To ensure that the calculated EPC was appropriately conservative,concentrations of EDB and naphthalene were evaluated in comparison to the commercial/industrial soil gas VISLs and occupied buildings. Figure 5-1 illustrates EDB concentrations in soil gas at 25 feet bgs in 2016. Only one detection from Q1 through Q3 2016 exceeded the EDB commercial/industrial soil gas VISL of 7.65 μg/m^3. This was a detection of 24 μg/m^3 at KAFB-106119-25 in Q2 2016. All other detected concentrations were below the SL. Figure 5-2 illustrates naphthalene concentrations in soil gas at 25 feet bgs in 2016. Similarly to EDB, only one detected concentration from Q1 through Q3 2016 exceeded the commercial/industrial soil gas VISL of 135 μg/m^3. This was a detection of 257 μg/m^3 at KAFB-106128-25 in Q2 2016. Neither of the detections exceeding screening criteria were located within 100 feet of occupied buildings. The soil gas results indicate that employing the EPCs is appropriately conservative to evaluate potential risk from on-Site soil gas.

As shown on Table 5-9, the calculated HI based on the maximum detected COPC concentrations was 0.2, which is below NMED's target HI of 1.

Based on the total cancer risk estimate and HI, there is no unacceptable risk for current/future on-Site commercial/industrial workers due to exposure to soil gas via vapor intrusion to indoor air.

Future Hypothetical On-Site Resident: The total cancer risk was calculated using the maximum detected concentrations for each COPC as shown in Table 5-10. The calculated total cancer risk was 3 x 10^{-4}, which exceeds NMED's target cancer risk of 1 x 10^{-5}. Primary contributors to the total cancer risk were EDB, benzene, and naphthalene, which had maximum detected concentrations that exceeded the residental soil gas VISLs. Based on the exceedance of the NMED target cancer risk level, total cancer risk was further evaluated using EPCs based on the 95UCL. As shown in Table 5-11, the calculated total cancer risk based on the EPC is 2 x 10^{-5}, which slightly exceeds NMED's target cancer risk level of 1 x 10^{-5}.

As shown in Table 5-12, the calculated HI based on the maxium detected COPC concentrations was 0.9, which is below NMED's target HI of 1.

No residents are located on-Site at the BFF and land use is not expected to change from industrial in the foreseeable future. Estimated cancer risks for a future hypothetical resident exceed the NMED cancer risk target level.

5.1.2.2 Off-Base Soil Gas

Currently no residences are located near the off-Base soil gas contamination, which mainly underlies Bullhead Park, the VA Medical Center parking lot, and the Air Force-owned open space. However, if future land use were to change, consideration of a residential scenario provides information for risk management decisions and unrestricted use considerations. Maximum detected concentrations of COPCs in off-Base soil gas were compared to residential soil gas VISLs. The maximum detected concentrations of COPCs in off-Base soil gas did not exceed residential soil gas VISLs.

Future Hypothetical Off-Base Resident (Bullhead Park): The total cancer risk and HI was calculated using the maximum concentrations for each COPC as shown in Tables 5-13 and 5-14, respectively. The calculated total cancer risk based on the maximum detected concentrations was 2 x 10^{-6}, which is below NMED's target cancer risk level of 1 x 10^{-5}. The calculated total HI from the maximum COPC concentrations was 0.04, which is below NMED's target HI of 1.

Therefore, there is no unacceptable risk to a future hypothetical off-Base resident at Bullhead Park from the vapor intrusion pathway (soil gas to indoor air). Consideration of a residential scenario is conservative and protective of current receptors located farther from the areas of contamination, such as residents north of Ridgecrest, and visitors and workers at the VA Complex. Under the residential scenario, exposure is assumed to be 24 hours per day at the site, 350 days per year, for 26 years.

5.1.3 Groundwater

As discussed in Section 4, there are no current complete exposure pathways for contaminated groundwater. The Kirtland AFB water supply wells, Water Authority wells, VA Complex well,and private irrigation wells are located in areas outside the affected portion of the aquifer. LUCs are in place to prevent installation of new wells within the affected portion of the aquifer. However, in order to inform risk management decisions, a future on-Site and off-Base residential scenario was evaluated which assumes a drinking water well was installed in the affected portion of the aquifer.

Maximum detected concentrations in groundwater were compared to the NMED TSLs for residential use. The cancer risk and noncancer HI were calculated using maximum detected concentrations and EPCs based on 95UCLs for the future hypothetical on-Site and off-Base residents as described below.

The maximum detected concentration of lead in groundwater was 5.3 micrograms per Liter (µg/L), which is below the EPA non-carcinogenic residential RSL of 15 µg/L.

5.1.3.1 On-Site Groundwater

The total cancer risk was calculated using the maximum detected concentrations in on-Site groundwater for each carcinogenic COPC as shown in Table 5-15. The calculated total cancer risk was 5 x 10^{-2}, which exceeds NMED's target cancer risk level of 1 x 10^{-5}. Based on the exceedance of the NMED target cancer risk level, total cancer risk was further evaluated using EPCs based on the 95UCL. As shown in Table 5-16, the calculated total cancer risk based on the EPC is 5 x 10^{-3}, which exceeds NMED's target cancer risk level of 1 x 10^{-5}. Primary contributors to the cancer risk were EDB, benzene, ethylbenzene, and naphthalene.

The total HI was calculated using the maximum detected concentrations for each non-carcinogenic COPC as shown on Table 5-17. The calculated total HI was 600, which exceeds NMED's target HI of 1. Based on the exceedance of the NMED target HI, the total HI was further evaluated using EPCs based on the 95UCL. As shown in Table 5-18, the calculated total cancer risk based on the EPC is 60, which exceeds NMED's target HI of 1. The primary contributors to the HI were benzene, naphthalene, toluene, and xylenes, which each had HQs exceeding 1.

Based on the calculated total cancer risk and HI, exposure to on-Site groundwater for domestic purposes under the hypothetical future residential scenario results in an unacceptable risk.

5.1.3.2 Off-Base Groundwater

The total cancer risk was calculated using the maximum detected concentrations in off-Base groundwater for each carcinogenic COPC as shown in Table 5-19. The calculated total cancer risk was 8×10^{-3}, which exceeds NMED's target cancer risk level of 1×10^{-5}. Based on the exceedance of the NMED target cancer risk level, total cancer risk was futher evaluated using EPCs based on the 95UCL. As shown in Table 5-20, the calculated total cancer risk based on the EPC is 1×10^{-4}, which exceeds NMED's target cancer risk level. Primary contributors to the cancer risk were EDB and ethylbenzene.

The total HI was calculated using the maximum detected concentrations for each non-carcinogenic COPCs as shown on Table 5-21. The calculated total HI was 80, which exceeds NMED's target HI of 1. Primary contributors to the total HI were benzene, naphthalene, toluene, xylenes, and 1,2,4-TMB. Based on the exceedance of the NMED target HI of 1, the total HI was further evaluated using EPCs based on the 95UCL. As shown in Table 5-22 the calculated total HI based on the EPC is 0.8, which is less than the NMED target HI of 1.

Based on the calculated total cancer risk, exposure to off-Base groundwater for domestic purposes under the hypothetical future residential scenario results in an unacceptable risk.

5.2 Uncertainty Analysis

The human health risk-screening assessments are subject to varying degrees and types of uncertainty.

Aspects of data evaluation and COPC identification, exposure assessment, toxicity assessment, and the additive approach for risk characterization contribute to uncertainties in the RA process. Each or all of these uncertainties may affect the evaluation results. Specific uncertainties related to this RA are discussed in the following sections.

5.2.1 Uncertainty Related to Analytical Data Quality

The analytical data quality was evaluated for uncertainties related to the quantitation limits and it was determined that the sensitivity of DLs for COPCs in all environmental media with a low or no detection frequency (majority of samples were nondetect) were less than the analyte-specific SLs, except for three analytes in groundwater (1-methylnaphthalene; 2-methylnaphthalene; and 1,2-DCA) and one analyte in soil gas (EDB). For the three groundwater analytes (as compared to the TSL) and for EDB in soil gas
(as compared to commercial/industrial soil gas VISL), the majority (over 80%) of the nondetect samples had DLs lower than the analyte-specific SLs. With respect to DLs for EDB in soil gas compared to the residential soil gas VISL of 1.56 $\mu g/m^3$, the DLs ranged from 1.23 to 10.76 $\mu g/m^3$).

However, all four of the analytes were identified as COPCs, and were included in the RA with risk estimated using maximum detected concentrations. There is a low potential for underestimation of risk for these analytes.

Other uncertainties in analytical data quality may include errors in sampling, laboratory analysis, and data analysis. However, using both maximum detected concentrations and statisticallybased EPCs is intended to provide upper-bound estimates of exposure and risks.

5.2.2 Uncertainty in Risks Related to Soil Gas Exposure

An uncertainty related to soil gas exposure was identified in the RA. NMED soil gas VISLs were developed to screen soil gas samples collected at shallow depths below a building slab. In this RA, the NMED soil gas VISLs were applied to soil gas data measured from SVMPs at 15 to 25 feet bgs. Even in cases where a COPC is detected above the soil gas VISL at a SVMP located at 15 to 25 feet bgs below a building slab, there is uncertainty whether the COPC will be detected from a shallow sub-slab sample. Fick's First Law of diffusion states that diffusive flux from a source at 25 feet bgs below a building slab will be 15 to 25 times lower than if the source were present at 1 foot from the slab. In principle, concentration gradients are affected by the presence of a slab (EPA, 2012). However, the accumulation of VOCs below a slab based on diffusion from a deep vapor source, as shown by EPA, is only possible if soil gas advection into the building is negligible. The application of soil gas VISLs to the soil gas data collected at 15 to 25 feet bgs most likely results in an overestimation of risks.

5.3 Human Health Risk Assessment Conclusions

The HHRA concludes there are no estimated unacceptable risks to current human receptors from contaminated soil, soil gas, or groundwater either on-Site or off-Base.

The HHRA identified potential unacceptable risks for exposure to on-Site soil gas under a future hypothetical residential scenario, and exposure to groundwater under a future domestic use scenario. However, there are no current complete exposure pathways for groundwater.

Interim measures are in place to prevent exposure to impacted groundwater. An additional LUC may be warranted as part of a final remedy to prevent residential use at the BFF until concentrations of COPCs in soil gas have a level that do not present an unacceptable risk.

5.3.1 Soil

Maximum detected concentations of COPCs in soil at 0 to 10 feet bgs were below NMED SSLs. The total cancer risk and HI based on maximum detected concentrations were below NMED target levels for all receptors. No impacted soil is located off-Base. No unacceptable risk was identified based on exposure to surface or mixed zone soil for any receptor on-Site at the BFF.

Recommendation: No additional interim measures are recommended for soils at 0 to 10 feet bgs.

5.3.2 Soil Gas

Twelve industrial/administrative buildings are located at the BFF or in close proximity; three of these buildings are continuously occupied. For the current/future on-Site commercial/industrial worker at the BFF, although the total cancer risk based on maximum detected concentrations in soil gas exceeded the

NMED target cancer risk level, the total cancer risk calculated using the EPCs was below 1 x 10^{-5}. The total HI based on the maximum detected concentration was below the NMED target HI of 1. No unacceptable risks were identified for the current/future on-Site commercial/industrial worker at the BFF based on exposure to soil gas via vapor intrusion to indoor air.

No residential buildings are located at the BFF and residential use is not planned for the foreable future. However, in order to evaluated an unrestricted use scenario, risk for a hypothetical future on-Site resident was evaluated. Total cancer risks exceeded NMED's target cancer risk level. The total HI based on the maximum detected soil gas concentration was below the NMED target HI of 1.

No occupied buildings are currently located within the area of the off-Base soil gas plume. However, should land use change in the future, a hypothetical future off-Base resident scenario at Bullhead Park was evaluated. Based on the maximum detected concentrations in soil gas, the total cancer risk and HI were below NMED target levels. No unacceptable risk was identified based on exposure to soil gas via vapor intrusion to indoor air. Consideration of a future hypothetical off-Base resident at Bullhead Park is conservative and protective for current/future recreational uses at Bullhead Park. This scenario is also protective for residents north of Ridgecrest and visitors to the VA Complex, which are located farther from the impacted off-Base soil gas area.

Recommendation: Current interim measures prevent residential use at the BFF. A LUC may be needed in a future final remedy to prevent residential reuse in the BFF until concentrations of COPCs in soil gas allow unrestricted use and unlimited exposure. No additional interim measures for off-Base soil gas are recommended.

5.3.3 Groundwater

The calculated total cancer risks and HI for domestic use of on-Site and off-Base groundwater exceed NMED's target cancer risk level of 1 x 10^{-5} and target HI of 1. However, interim measures are in place to prevent exposure to impacted groundwater on and off-Base. There are no current complete exposure pathways to impacted groundwater.

Recommendation: No additional interim measures are recommended to prevent exposure to impacted groundwater on-Site or off-Base.

6 ECOLOGICAL RISK ASSESSMENT

This ERA follows the NMED ERA process described in Section 2.1.2 (NMED, 2017). This process determines whether unacceptable adverse risks are present or might accrue to ecological receptors as a result of hazardous substances released at the Site.

6.1 Phase I Qualitative Assessment

The primary objective of the Phase I Qualitative Assessment is to assess whether enough information is available to determine the potential for unacceptable risks to ecological receptors as a result of hazardous substance releases. Characterizing the ecological communities in the vicinity of the Site (Sections 6.1.1 to 6.1.5), assessing the particular hazardous substances released and likelihood of potential unacceptable risk to identified ecological receptors (Section 6.1.6), identifying potential exposure pathways for ecological receptors (Section 6.1.7), and developing ecological assessment endpoints (Section 6.1.8) meet this objective.

6.1.1 General Site Characteristics

The Site is located in the Arizona/New Mexico Plateau Ecoregion (Omernik, 1986). Based on information contained in the Integrated Natural Resources Management Plan (INRMP) for Kirtland AFB (2007 and 2012 update), no designated or identified critical habitats exist at Kirtland AFB. Surveys and literature indicate important habitats on Kirtland AFB include wetlands that provide water to wildlife in an otherwise arid environment, and are rare in the region. None of these wetlands are near the Site. Other important habitats on Kirtland AFB include prairie dog towns, which provide nesting habitats for the burrowing owl, and open juniper woodlands between 5,900 and 6,600 feet in elevation, which are nesting habitat for the gray vireo. The Site lies between 5,314 and 5,364 feet in elevation. Nesting habitat for gray vireo is primarily on the far eastern side of Kirtland AFB in the foothills of the Manzano Mountains and does not currently exist on the Site. Prairie dog burrows and burrowing owls have been observed on-Site inside the BFF.

6.1.2 Surface Water, Sediment, and Wetlands

No surface water, sediment, or wetlands are located at the Site. Groundwater at the Site is approximately 480 feet bgs, and would not be expressed as surface water.

6.1.3 Vegetative Communities

Vegetation of the Arizona/New Mexico Plateau Ecoregion includes grama/galleta steppe, Great Basin sagebrush, and saltbush/greasewood plants (Omernik, 1986). Before the acquisition of land for what is now Kirtland AFB, the area was rangeland used for livestock grazing and typical ranching as well as mining operations. These operations ceased, for the most part, when Kirtland AFB occupied the land in the mid-1940s. Since then, some of the vegetation has been cleared for operational developments, while the eastern half of the Base has remained primarily undisturbed.

Vegetation on-Site is sparse as shown in on-Site photographs presented in Section 2 of the RFI and in Figure 6-1 (USACE, 2017a). This is primarily due to the generally disturbed nature of the on-Site area, which is largely an industrial area that is kept clear for vehicles and equipment, and characterized by poor soils and low precipitation. From January 2010 to December 2016, the average yearly precipitation ranged from 4.7 to 11.5 inches, with an average of 7.86 inches (National Oceanic and Atmospheric

Administration [NOAA], 2017). Snowfall is not uncommon in winter months, but seldom exceeds 3 inches. The summer monsoon season from July through September accounts for one-half of the annual rainfall.

The following four plant communities on Kirtland AFB constitute the major types of vegetation:

- Grassland (includes sagebrush steppe and juniper woodlands)
- Pinyon-Juniper Woodlands
- Ponderosa Pine Woodlands
- Riparian/Wetland/Arroyo.

The BFF area is industrial, and has been disturbed during construction activities, such as the updates to the fueling infrastructure. However, based on the recorded soil types at the Site (Latene sandy loam and Wink fine sandy loam; USDA, 2013), native vegetation would typically include mesa dropseed, blue grama, broom snakeweed, and sands dropseed (Kirtland AFB, 2007 and 2012 update). These two soil types have poor to very poor potential for supporting habitat elements including grain and seed crops, domestic grasses and legumes, wild herbaceous plants, shrubs, and wetland plants (USDA, 1977). As the on-Site area is primarily industrial, vegetation consists mostly of open sandy and gravel areas with sparsely distributed grasses. The habitat surrounding the on-Site area is also sparsely vegetated with shrub/scrub, grasses, and small trees, which is typical of the Albuquerque, New Mexico area. The very low productivity of the soil is also supported by the finding that the average organic carbon in surface soil is 0.49 mg/kg (based on detected results in soil samples collected on-Site ST105 SB0524 [7]; ST105-SB0525 [7]; and ST105-SB0524 [2]).

6.1.4 Wildlife

The INRMP (Kirtland AFB, 2012) lists 55 species of mammals, 141 species of birds, 34 species of reptiles and amphibians, and three species of fish that may occur on the 52,287-acre Base. Based on the industrial nature and sparse vegetative communities on-Site (Section 6.1.3), few of these bird, mammal, and reptile species would be expected to occur on-Site. However, rabbits, coyotes, and birds, as well as evidence of prairie dogs, have been observed on-Site. No amphibians or fish would be present due to the lack of surface water at on-Site.

6.1.5 Threatened, Rare, and Endangered Species

Threatened, rare, or endangered species in the general area of Kirtland AFB include the following:

- Gray vireo — state-threatened species
- Western burrowing owl — federal species of concern
- Loggerhead shrike — federal species of concern
- Mountain plover — federal species of concern
- Texas-horned lizard — federal species of concern.

Except for the Western burrowing owl, none of these species are expected on-Site. Gray vireo territories have been documented on-Site throughout the juniper woodland community between 5,850 and 6,600 feet elevation on the far eastern side of Kirtland AFB. These species occupy areas with an open canopy (i.e., less than 25%). The Loggerhead shrike has been observed on Base in grassland, pinyon-juniper woodlands, and riparian habitats. Mountain plovers are not known to occur on-Site; however, limited sightings have been documented just south of the Base on the Isleta Pueblo Indian Reservation. Appropriate nesting habitat for the Mountain plover is limited on-Site; however, the southern grasslands on-Site may potentially be used as brood-rearing habitat or during migration. The Texas-horned lizard has not been documented on-Site.

The Western burrowing owl, a federal species of concern, is a common resident at Kirtland AFB and has been monitored on-Site for more than 10 years. The Kirtland AFB INRMP (KAFB, 2012) includes a Burrowing Owl Management Plan (Appendix O). Figure 6-2 illustrates locations of Western burrowing owl nests documented in 2015. Western burrowing owls are very closely associated with the prairie dog colonies on-Site, as they use abandoned prairie dog burrows for nesting. As of 2015 there are no active nests in the vicinity of the BFF; however, prairie dog burrows are present in the BFF, and a burrowing owl was documented at a burrow in the BFF in May of 2017. Thus, the Western burrowing owl is evaluated as an ecological receptor in this RA.

In summary, there are multiple threatened, rare, or endangered species in the general area of Kirtland AFB; however, except for the Western burrowing owl, none of these species are expected on-Site.

6.1.6 Ecological Problem Formulation

The ecological problem formulation for the Site starts with the same list of analytes as the HHRA and compares those analytes to ecological screening values. This formulation process then identifies the exposure pathways, the ecological values (or receptors) to be protected, and the measures of effect used to quantify potential risk to ecological receptors at the Site.

The list of chemicals evaluated in the ERA are listed in Table 3-1 for soil and soil gas. Groundwater was not evaluated as part of the SLERA due to lack of exposure pathways to groundwater.

6.1.7 Conceptual Site Exposure Model

The CSEM identifies complete and potentially complete exposure pathways between physical media affected by Site-related contamination and potential ecological receptors. Identifying relevant exposure pathways is a critical element of the CSEM. Only exposure pathways that are complete or potentially complete are quantitatively evaluated in a Phase II Quantitative Assessment. If, under current and expected future land use scenarios, there are no potential exposure pathways for ecological receptors at the Site, there is no potential for risk, and the exposure pathway is not evaluated in Phase II. A CSEM for ecological receptors is presented in Figure 6-3.

The primary exposure medium on Base for ecological receptors is considered to be surface soil. Mixed zone soil (0 to 10 feet bgs) was considered an exposure medium for the burrowing owl and prairie dogs. NMED Guidance (NMED, 2017) states that, "For all non-burrowing ecological receptors and for shallow-rooted plants, the soil exposure intervals typical of surface conditions and is considered to be between 0 and 1 foot bgs). For all burrowing ecological receptors (and receptors that may use burrows) and deep rooted plants, the soil interval to be evaluated is 0 to 10 feet bgs."

Plants and animals on-Site may be exposed to COPCs in surface soil through direct contact, incidental ingestion of soil, or ingestion of food items that have become contaminated through bioaccumulation. Burrowing animals (i.e., burrowing owls and prairie dogs) may be exposed to mixed zone soil (0 to 10 feet bgs) via these same exposure pathways. Direct contact exposure pathways are considered complete for plants, terrestrial invertebrates, and terrestrial vertebrates, while bioaccumulation exposure pathways are complete for terrestrial invertebrates and vertebrates.

COPCs released to surface soil or mixed zone soil could volatilize into air voids in the soil column such as animal burrows created by burrowing mammals and reptiles. Because several VOCs are listed as COPCs at the Site, inhalation of soil gas in soil burrows is considered a complete exposure pathway for burrowing animals on-Site.

Exposure pathways to surface water and sediment are incomplete for all ecological receptors because there are no permanent surface water features on the Site. In addition, ecological receptors at the Site are not exposed to Site groundwater because groundwater does not reach the surface via any seeps or wetlands. Therefore, groundwater exposure pathways are considered incomplete.

6.1.8 Assessment Endpoints

Assessment endpoints identify the particular ecological resources (e.g., plants and animals, habitats, etc.) to be protected at a site. At the Site, terrestrial fauna potentially includes invertebrates, reptiles, birds, small mammals (e.g., rodents), and larger carnivorous, omnivorous, and/or browsing mammals (e.g., mule deer). The assessment endpoints used for screening are:

1. Protection of terrestrial plant populations and communities
2. Protection of soil invertebrate populations and communities
3. Protection of populations of herbivorous birds
4. Protection of populations of omnivorous birds
5. Protection of populations of insectivorous birds
6. Protection of populations of carnivorous birds
7. Protection of populations of herbivorous mammals
8. Protection of populations of omnivorous mammals
9. Protection of populations of insectivorous mammals
10. Protection of populations of carnivorous mammals.

In addition, because exposure to volatile chemicals in soil burrows is potentially a complete exposure pathway, the following is an assessment endpoint based on the inhalation exposure pathway:

1. Protection of populations of burrowing mammals.

A lack of toxicity data for Site COPCs precludes adequate quantitative evaluation of risks to reptiles at the Site; therefore, they were not included as ecological receptors for the Phase II Quantitative Assessment. The uncertainties associated with eliminating ecological receptors from quantitative evaluation because of a lack of toxicity (or other) data is considered in the uncertainty discussion in Section 6.4.

6.2 Phase II, Tier 1 Quantitative Assessment

Based on this Phase I Qualitative Assessment, it was determined that a Phase II Quantitative Assessment was warranted because ecological receptors are potentially present at the Site, and Site-related chemicals have been documented in soil and soil gas.

NMED's Phase II Quantitative Assessment starts with a Tier 1 SLERA. The Tier 1 SLERA uses conservative SLs based on concentrations demonstrated to cause no adverse effects in ecological receptors and conservative exposure assumptions based on maximum detected concentrations. The Tier 1 utilizes the initial ecological problem formulation and ecological CSEM, and identifies COPCs for further evaluation in the Tier 2 Quantitative Assessment.

6.2.1 Assessment Endpoints and Measures of Effect

Potential adverse effects to assessment endpoints listed in Section 6.1.8 are inferred from one or more measurement endpoints. The measurement endpoint is a measurable response to a stressor, in this case chemical concentration in soil, that is related to the valued attribute of the chosen assessment endpoint, in this case protection of populations of plants, invertebrates, mammals, and birds. The measurement endpoint serves as a surrogate that can be used to draw a predictive conclusion about the potential for effects of the COPC to the assessment endpoint. For the Tier 1 SLERA, the measurement endpoint for all identified assessment endpoints is comparison of chemical concentrations in soil and soil gas to conservative toxicological benchmarks based on no-observed-adverse-effect levels (NOAEL).

NOAEL toxicity values were obtained from literature sources as indicated below. SLs were obtained for as many of the assessment endpoint ecological receptor categories as possible, and the screening comparisons were conducted using the most sensitive ecological receptor category, i.e., the ecological receptor category with the lowest SL.

For inorganic constituents in soil, ecological screening levels (ESL) derived by NMED (NMED, 2017) were used preferentially over other sources of information for organics. If no SLs were available from NMED, other sources of SLs such as the Los Alamos National Laboratory (LANL; LANL, 2014) ESLs and the National Oceanic and Atmospheric Administration Screening Quick Reference Tables (Buchman, 2008) were used to identify appropriate SLs.

Screening values of soil gas concentrations of COPCs were obtained from the LANL EcoRisk Database V 3.3 (LANL, 2014). If no soil gas SL was available for a constituent in the LANL database, soil gas SLs were obtained from MWH Americas, Inc. (2011).

6.2.2 Exposure Estimation

The Tier 1 SLERA exposure estimation utilizes conservative assumptions, including use of maximum detected values and assumption of 100% bioavailability of COPCs.

The initial screening of COPCs in soil and soil gas was conducted using the maximum measured concentration in the media of interest. For surface soil, the maximum concentration in soil samples collected from 0 to 1 foot bgs were used as the screening EPC for all assessment endpoints. For mixed zone soil, the maximum concentration in soil samples collected from 0 to 10 feet bgs were used as the screening EPC for all assessment endpoints. For soil gas, the maximum measured concentration in the shallowest depth interval (15 to 25 feet bgs) of all on-Site soil gas samples from sampling conducted between Q1 2016 and Q3 2016 were used as the EPC for burrowing mammals. Use of the measured soil gas concentration at 15 to 25 feet bgs is a conservative exposure estimate, because burrowing mammals do not burrow that deeply (typically less than 3 feet bgs), and soil gas concentrations would be lower at 3 feet bgs then 15 to 25 feet bgs.

6.2.3 Ecological Risk Characterization

The Tier 1 SLERA ecological risk characterization compares conservative measures of effect with exposure estimates based on maximum detected concentrations.

6.2.3.1 Surface Soil

Eight of the 12 COPCs analyzed in the surface soil were detected in surface soil (0 to 1 foot bgs). Results of the initial screening of surface soil concentrations are presented in Table 6-1. Maximum detected concentrations of lead exceeded SLs, and therefore the analyte is retained for further evaluation in the Phase II, Tier 2 Quantitative Assessment for surface soil in the suface soil on-Site. In addition to calculating HQs for individual chemical constituents, NMED Guidance requires that the ecological screening assessment calculate a HI for each of the screening ecological receptors evaluated (NMED, 2017). The HI represents the sum of the HQ values across chemical constituents for each ecological receptor, and is intended to account for additive toxicological effects that might be missed if looking solely at individual HQs. The HI calculations for surface soil on-Site are presented in Table 6-2. Three of the 10 ecological receptors had total HIs greater than 1. Table 6-2 shows how each COPC contributes to the total HI for each ecological receptor. Lead was the only COPC that contributed significantly to HI values greater than one.

6.2.3.2 Mixed Zone Soil from Confirmation Samples

Ten of the 13 COPCs analyzed in the mixed zone soil were detected in mixed zone soil (0 to 10 feet bgs). Results of the initial screening of mixed zone soil concentrations on-Site are presented in Table 6-3. Complete exposure pathways exist for mixed zone soil to two ecological receptors evaluated in Table 6-3, prairie dogs and burrowing owls. Maximum detected concentrations of lead in confirmation samples exceeded SLs, and therefore the analyte is retained for further evaluation in the Phase II, Tier 2 Quantitative Assessment for mixed zone soil in the confirmation samples. The HI represents the sum of the HQ values across COPCs for each ecological receptor, and is intended to account for additive toxicological effects that might be missed if looking solely at individual HQs. The HI calculations for mixed zone soil on-Site are presented in Table 6-4. Both ecological receptors had total HIs greater than 1. Table 6-4 shows how each COPC contributes to the total HI for each ecological receptor. Lead was the only constituent that contributed significantly to HI values greater than 1.

6.2.3.3 Soil Gas

Twelve of the 14 potential soil gas COPCs were detected in the shallowest soil gas sampling interval of 15 to 25 feet bgs. Soil gas ESLs were available for eight of the 12 detected constituents. HQs for all eight of these constituents were less than 0.3, indicating no potential unacceptable ecological risk from soil gas concentrations for these COPCs in mammal burrows. Soil gas SLs were not available for 1,2-dibromoethane, cyclohexane, n-heptane, or n-hexane, therefore a quantitative evaluation of risk from these COPCs is not possible. Results of the soil gas are screening are presented in Table 6-5. Potential risk from COPCs without soil gas SLs is discussed further in the uncertainty analysis in Section 6.4.

6.3 Phase II, Tier 2 Quantitative Assessment

A Tier 2 SLERA includes a re-evaluation of the conservative assumptions used in the Tier 1 SLERA. Results of the Tier 2 SLERA indicate that although some detections of lead exceeded the most conservative SLs for a limited number of ecological receptors, no unacceptable risk is posed by any fuel-related constituents at the Site.

For the on-Site surface soil dataset, only lead was carried forward to the Tier 2 assessment. The maximum lead concentration (39.1 mg/kg) exceeded SLs for insectivorous birds, omnivorous birds, and herbivorous birds. Insectivorous, omnivorous, and herbivorous birds forage over defined ranges, and are not exposed to single point concentrations in the way that sessile organisms such as plants are exposed, thus use of an estimator of central tendency exposure is relevant for calculating risk to mammals and birds. Table 6-6 presents summary statistics for lead at the 0 to 1 foot bgs depth. Lead background concentrations at Kirtland AFB are 21.4 mg/kg in surface soil, and 11.8 mg/kg in subsurface soil (NMED, 2007). The lead surface soil background concentration also exceeds the SLs for insectivorous, omnivorous, and herbivorous birds. Mean and median lead concentrations of the on-Site surface soil dataset are 11 mg/kg and 8 mg/kg respectively and the dection frequency is 100%. The mean, median, and detection frequency of lead concentrations support that on-Site surface soils are within the range of background conditions at Kirtland AFB. Thus, potential risk to ecological receptors from lead cannot be differentiated from background conditions.

For mixed zone soil (0 to 10 feet bgs) only lead, based on detections in confirmation samples, was carried forward to the Tier 2 assessment for burrowing owls. The maximum lead concentration in confirmation samples (71 mg/kg) exceed SLs for small omnivorous mammals and carnivorous birds. These receptors forage over defined ranges, and are not exposed to single point concentrations in the way that sessile organisms such as plants are exposed, thus similar to surface soil an estimator of central tendency exposure is relevant to calculating risk to mammals and birds. Table 6-6 present the summary statistics for lead in the confirmation samples from 0 to 10 feet bgs. Mean and median lead concentrations of the on-Site surface soil data are 9.6 mg/kg and 4.1 mg/kg respectively, which is below the SLs for omnivorous mammals and carnivorous birds and the dection frequency is 100%. The mean, median, and detection frequency of lead concentrations support that on-Site mixed zone soils are within the range of background conditions at Kirtland AFB. Thus, potential risk to ecological receptors from lead cannot be differentiated from background conditions in mixed zone soil from 0 to 10 feet bgs.

6.4 Uncertainty Discussion

One uncertainty, which indicates the soil gas evaluation may be overly conservative, is the depth of the soil gas sample intervals. It is important to note that soil gas samples were collected between 15 and 25 feet bgs. Screening soil gas concentrations at these depths is overly conservative when applied to the typical maximum burrowing owl burrow depth of 3 feet (Cornell Lab of Ornithology, 2017). All of the detected chemicals for which soil gas SLs were available had HQ values less than 0.3, suggesting chemical concentrations in the 15 to 25 feet bgs depth interval are relatively low compared to risk levels, and those concentrations are expected to be even lower in the shallower depth interval occupied by burrowing animals.

The ERA is designed to err on the side of conservatism by utilizing NOAEL-based toxicity information and conservative assumptions such as 100% Site use, 100% bioavailability of COPCs, and uptake of COPCs in the Tier 1 SLERA. A key area of uncertainty in the Site is the lack of toxicity information for a number of ecological receptors and chemicals. This is particularly evident in the lack of ecological soil gas SLs for four of the detected chemicals in subsurface soil gas samples. This makes a quantitative evaluation of risk from these chemicals impossible for these ecological receptors.

Another example of the lack of toxicity information is the lack of ESLs for birds for many of the chemicals evaluated in soil (e.g., most polyaromatic HC compounds). Without adequate avian toxicity information, one is left to infer that levels protective of mammals are also protective of birds, which may overestimate or underestimate actual risk to birds.

The lack of available toxicity information also precluded the quantitative evaluation of reptiles at the Site. Therefore, the SLERA presumes that concentrations that are adequately protective of birds and mammals are also adequately protective of reptiles, but the accuracy of that presumption is unknown. However, for the SLERA, this uncertainty is likely not significant in the overall conclusions because of the limited extent of exceedances and the marginal ecological habitat at the Site, which both serve to limit potential ecological exposures.

6.5 Conclusions and Recommendations

This ERA follows the NMED ERA process (NMED, 2017). This process determined there are no unacceptable adverse risks present to ecological receptors as a result of COPCs present at the Site.

Given the limited extent of concentrations exceeding no-effects SLs and the limited ecological exposure potential, no unacceptable ecological risk exists at the Site due to lead in surface or mixed zone soils in the on-Site area. Although maximum detected concentrations of lead exceeded no-effects based SLs, evaluation of other parameters such as mean, median concentrations, and frequency of detects within the on-Site soil datasets suggest exceedances are limited in extent. In addition, the maintenance of the BFF for Site operations limits the amount and quality of ecological habitat present, and ecological exposures are expected to be minimal for this reason.

This ERA concludes that there is no unacceptable ecological risk present when burrowing owls are considered as possible ecological receptors. Concentrations in soil from 0 to 10 feet bgs are below the SLs or are at background concentrations and pose no unacceptable ecological risk. Concentrations of all on-Site soil gas VOCs in the 15 to 25 feet bgs interval were less than available ESLs. Though no SLs were available for four of the detected VOCs, maximum HQs for the eight VOCs with SLs were less than 0.3, indicating that concentrations are low compared to risk levels. In addition, screening soil gas concentrations at the 15 to 25 feet bgs depth interval is overly conservative when compared to the typical maximum burrow depth of the burrowing owl (3 feet bgs). Soil gas concentrations are expected to be even lower at typical burrow depths. Therefore, no further action is proposed for soil gas concentrations in on-Site soils for protection of ecological receptors.

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