EXECUTIVE SUMMARY

This Phase I Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Report was prepared by Kirtland Air Force Base (AFB) to summarize the investigation of fuel releases discovered at the Bulk Fuels Facility (BFF) in November 1999. This Phase I RFI Report (Report) summarizes all investigation activities and interim measures performed between 2000 and December 31, 2015. Investigations and interim measures conducted after December 31, 2015, will be included in a Phase II RFI Report. Potential human health and environmental impacts are evaluated in the Risk Assessment report, which was submitted as a separate document (U.S. Army Corps of Engineers [USACE], 2017).

Solid Waste Management Unit (SWMU) ST-106/SS-111 is the location of jet fuel leaks that occurred over an unknown period at Kirtland AFB. The leaks originated from fuel-delivery infrastructure at the BFF and were identified by Kirtland AFB personnel in November 1999. This Executive Summary is a stand-alone document briefly summarizing the results and conclusions of this Report. The methods, results, and conclusions included here are discussed in detail within this Report. The “Site” is comprised of the nine areas of interest (AOIs) used in this Report to divide the investigation of the fuel release.

ES-1 RFI Report Objectives

The purpose of this Report, and the future Phase II RFI Report, is to determine the nature and extent of fuel-related analytes (FRAs) at the Site. This Report condenses information generated from investigations and interim measures conducted at the Site and compares results to applicable cleanup requirements by media administered by the Hazardous Waste Treatment Facility Operating Permit, U.S. Environmental Protection Agency (EPA) identification number NM9570024423 (RCRA Permit). Information presented in the Phase I and Phase II RFI reports will be used to evaluate Site cleanup requirements under applicable regulations. Objectives of the Phase I and Phase II RFI reports include the following.

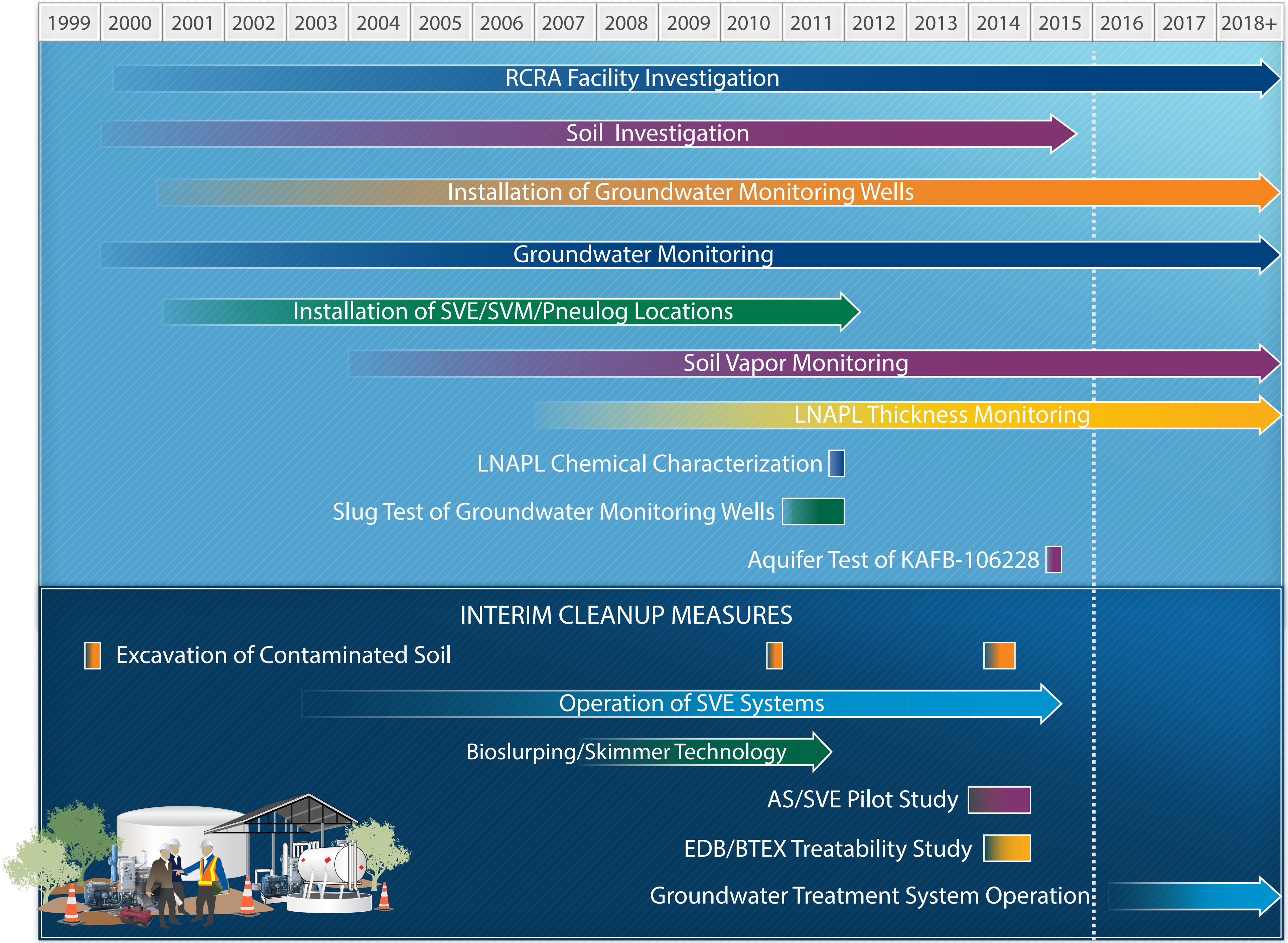
- Characterize the nature and extent of fuel-related contamination in the vadose zone (soil and soil vapor), light non-aqueous phase liquid (LNAPL), and groundwater within the Site.
- Adequately characterize the Site to evaluate and select the applicable corrective measures required to address soil, soil vapor, and groundwater fuel-related contamination as necessary. Corrective measures will be chosen during a corrective measures evaluation (CME) phase as outlined in Section 6.2.4.7. of the RCRA Permit (NMED, 2010a).

The RFI is a step in the RCRA process. Enacted in 1976, RCRA is the U.S. law that oversees the disposal of solid waste and hazardous waste. In New Mexico, EPA holds the New Mexico Environment Department (NMED) responsible for enforcing the RCRA process. At Kirtland AFB, that is accomplished by administering the RCRA Permit (NMED, 2010a).

The RCRA Permit specifies the process that environmental cleanup sites at Kirtland AFB must follow. These sites are referred to as AOIs in this Report. First designated as SWMU ST-106 and SS-111, the nine AOIs compose the area investigated and reported in this Phase I RFI Report.

The process established by RCRA and set forth in the RCRA Permit includes several common steps or phases that must be performed at all cleanup sites (Figure ES-1). Broadly, these steps begin with an initial investigation to determine the nature and extent of contamination. Once the investigation phase is adequately completed, the Site may move into the CME. The CME phase evaluates all possible remedies, or cleanup methods, and chooses the best option, or multiple options. This Report provides the results of Site investigations that have been performed during the past 16 years.

Figure ES-1. Site Activity Timeline



AS - Air Sparge • BTEX - Benzene, Toluene, Ethylbenzene and Xylenes • EDB - Ethylene Dibromide • LNAPL - Light Non-Aqueous Phase Liquid • RFI - RCRA Facility Investigation Report • SVE - Soil Vapor Extraction • SVM - Soil Vapor Monitoring

Many sites have contamination that poses an immediate threat to human health or the environment. The investigation phase can often take years to complete. For this reason, interim measures may be put in place to mitigate the risk to human health and the environment while the investigation is performed. Many interim measures have been performed at the Site during the course of the investigation and include excavating contaminated soil, extracting contaminated soil vapor, and extracting and treating contaminated groundwater. These interim measures are discussed further in this Executive Summary, and in detail within this Report.

ES-2 Site Overview

The BFF at Kirtland AFB became operational in 1953 and has been used over time to store aviation gasoline (AvGas), jet propellant 4 (JP-4), jet propellant 8 (JP-8), and smaller amounts of diesel fuel and unleaded gasoline (Tetra Tech, 2004; Figure ES-2). Jet fuel was initially delivered to the BFF via railroad until deliveries were transitioned to tanker truck sometime between 1986 and 1991. Jet fuel was offloaded from railcars or tanker trucks to the Former Fuel Offloading Rack (FFOR), pumped through underground pipelines to the pump house, and then to large fuel storage tanks at the BFF. The leaks were discovered in November 1999 when a BFF worker noticed fuel staining the ground surface at the FFOR. To investigate the stained soil, workers at the BFF pressure tested the two underground pipelines between the FFOR and pump house. Both pipelines failed pressure testing.

It is unknown how long the pipelines had been in a state of failure, but the types of contaminants at the Site may be used to develop an estimate. From 1953 to late 1975, the primary fuel stored and used at the BFF was AvGas. In 1975, the BFF transitioned from AvGas to the less volatile fuel JP-4 (USACE 2011a), and from JP-4 to JP-8 starting in 1993 (Air Force Center for Engineering and the Environment 2001). Ethylene dibromide (EDB) is an additive only in AvGas; EDB use as a fuel additive was discontinued in 1975. EDB has been found in soil, soil vapor, and groundwater, so the releases must have begun before 1975.

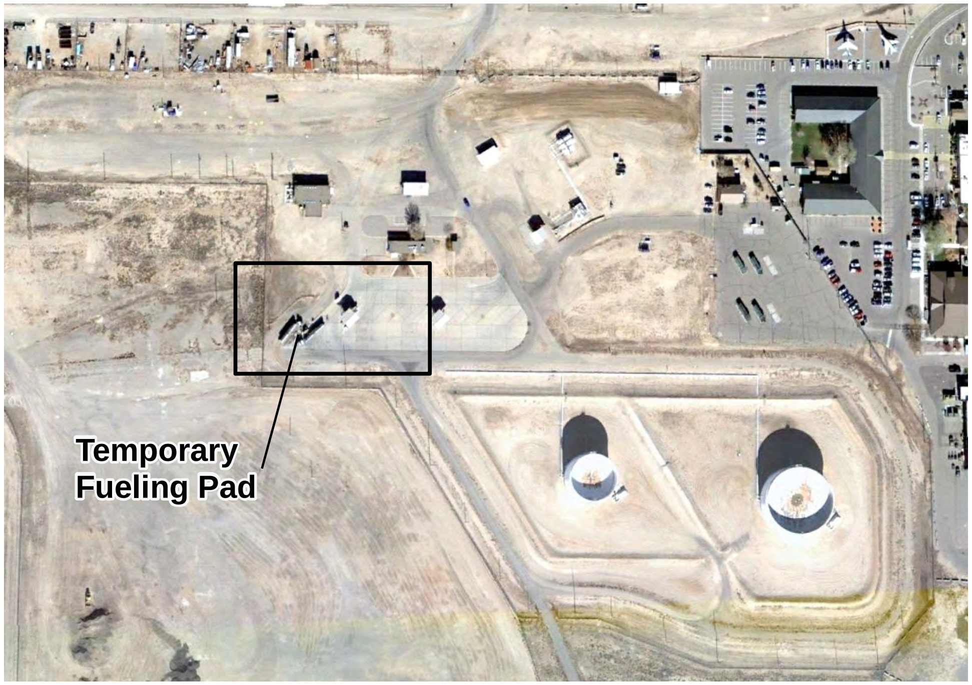
The duration of the releases is unknown. As a result, it is also unknown exactly how much fuel was released. When the release was discovered it was estimated that the yearly throughput was 20 million to 25 million gallons. Fuel gain and loss records are available from 1996 through 1999 (the facility was only required to keep records for the previous 3 years). This record documents whether more or less fuel was accounted for than the known volume transferred through the lines during BFF operation, and documented a total loss for 1999, but a total gain for the years 1996 and 1998, which indicates a large margin of error due to imprecise measurements. Estimates of the total fuel loss in the 12 months before the discovery of the release ranged from 97,171 gallons to 162,759 gallons. The variation in gain and loss totals from 1996 through 1999, the uncertainty in metering the original fueling infrastructure, and the uncertainty about the year that the releases began, make it challenging to develop an estimate of the total fuel released.

When the fuel release was discovered in November 1999, the FFOR was closed and a temporary fuel offloading area was constructed and used until the faulty FFOR infrastructure could be replaced. This included replacing the jet fuel offloading pad, transfer pipelines, and storage tanks. All underground pipelines related to the FFOR were either removed or grouted in place, and all pipelines and aboveground storage tanks were replaced with an aboveground infrastructure with leak-detection and leak-containment measures. Infrastructure replacement was finished March 18, 2011.

Once leaked jet fuel enters the ground, it is called LNAPL. LNAPL includes liquid compounds that are not water, do not dissolve in water, and are less dense than water. Aromatic compounds present in

Figure ES- 2. BFF Infrastructure Time Series

1) October 1996, former fueling infrastructure.



2) November 2009, temporary fueling pad installed in1999 after decommissioning of former fuel offloading rack.

3) February 2011, construction of new infrastructure including new offloading pad and new jet fuel aboveground storage tanks.

4) November 2015, current infrastructure. Former jet fuel aboveground storage tanks have been removed.

Not to Scale

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hydrocarbon fuels—including benzene, toluene, ethylbenzene, and xylenes (BTEX)—and short-chain aliphatic compounds dissolve in groundwater and soil porewater at varying concentrations, which is controlled by their molecular weight, compound geometry, vapor pressure, and aqueous solubility. Many of the LNAPL compounds, over time, will dissolve into soil moisture and groundwater. As the LNAPL was released from the underground pipelines over time, it traveled downward due to the force of gravity through different parts of the subsurface. Activities performed as part of the investigation are divided into different areas of the subsurface that were contaminated by LNAPL.

LNAPL traveled downward through soil in the vadose zone. The vadose zone is the part of the earth between the ground surface and the water table. The vadose zone is also referred to in this Report as the unsaturated zone, because this area is generally not saturated with water. The capillary fringe—where groundwater seeps up from the water table by capillary action—is also included in the vadose zone. At the Site, the vadose zone reaches to a depth of approximately 480 feet below ground surface (bgs). LNAPL traveled through the vadose zone to groundwater.

As LNAPL traveled through the subsurface, constituents in the LNAPL partitioned to different phases. In the vadose zone, LNAPL constituents volatilized and contributed to soil vapor contamination in the spaces between sand grains. LNAPL also sorbed to materials in soil, or dissolved into water between sand grains, and was retained in the spaces between grains in the vadose zone due to viscosity and capillary forces (Section 7). When LNAPL reached the water table it spread laterally in response to buoyancy forces, selectively displaced groundwater from the interior of the larger pores in the aquifer media, and began to dissolve into groundwater. Some constituents of LNAPL dissolved into groundwater—also known as the dissolved-phase fuel-related contamination—and followed the flow of groundwater in a north–northeast direction. A more detailed discussion of the conceptual site model (CSM) can be found in Section 7 of this Report and Section ES-5.

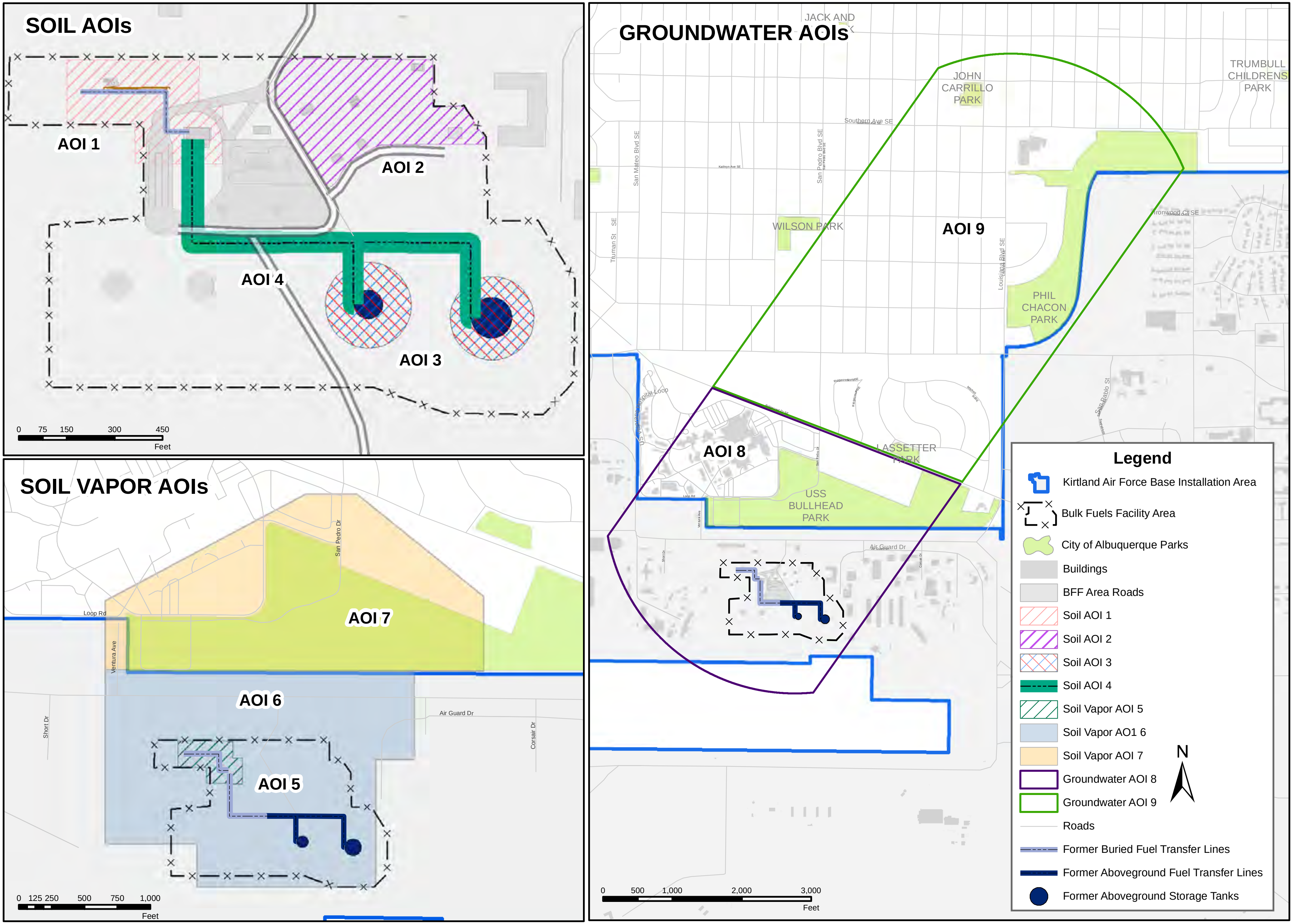
ES-3 Scope of Activities

Activities were performed to characterize contamination in the vadose zone and in groundwater, and to characterize LNAPL itself. Each of these activities is described in detail within the Report. The general scope of these activities is summarized in Figure ES-1. For a more detailed summary of vadose zone activities, refer to Section 4 of this Report; for LNAPL characterization activities, refer to Section 5; and for groundwater activities, refer to Section 6. Starting in 2014, technical working group meetings including USACE, Air Force Civil Engineer Center (AFCEC), NMED, EPA, the Albuquerque Bernalillo County Water Utility Authority (Water Authority), and the city of Albuquerque were held periodically to reach key decisions on project tasks. Technical working group decisions that directed project activities are discussed in the applicable sections of this Report.

This Report uses AOIs to subdivide the Site by method of investigation. The specific location of each AOI is depicted in Figure ES-3. AOI 1 through AOI 6 are located on base. The AOIs were assigned based on which Site medium was being analyzed for fuel-related contamination: AOI 1 through AOI 4 involve soil; AOI 5 through AOI 7 involve soil vapor; and AOI 8 and AOI 9 involve groundwater. Because LNAPL remains in both the vadose zone and the saturated zone at the Site, information from all AOIs may provide information about the nature and extent of LNAPL at the Site.

Vadose zone investigation activities included collecting 2,307 soil matrix grab samples at the Site. This included samples collected from both shallow and deep soil borings, as well as excavation confirmation samples. Soil samples were collected throughout the BFF to determine the source of the releases and the nature and extent of soil contamination. Fifty-six soil vapor monitoring (SVM) locations (consisting of

Figure ES-3. Areas of Interest (AOIs)



284 soil vapor monitoring points [SVMPs]) were installed to measure soil vapor contamination quarterly at the Site. Permeability testing was performed to create air permeability profiles in the vadose zone. Vadose zone interim measures included excavating contaminated soil and installing soil vapor extraction (SVE) locations to extract contaminated soil vapor.

LNAPL investigation activities included measuring LNAPL thickness quarterly, performing baildown testing, collecting LNAPL samples, and collecting soil cores saturated with LNAPL. LNAPL interim measures included using a skimmer pump to skim LNAPL off the water table, and modified bioslurping (as defined in Section 5.4.2) to volatilize LNAPL from the water table.

Groundwater investigation activities included installing and sampling 134 groundwater monitoring (GWM) wells between 2000 and December 31, 2015. Sampling events included both chemical and biological parameters to evaluate the nature and extent of contamination, as well as the effects of degradation. Soil samples and soil cores were collected to determine aquifer properties. Aquifer tests were performed at GWM wells. Groundwater interim measures included installing a groundwater treatment system (GWTS) and a pilot air sparge/SVE system to extract and treat contaminated groundwater and begin a bench-scale treatability study to evaluate EDB degradation in groundwater.

ES-4 Nature and Extent of Contamination

The investigations and interim measures described above helped to delineate the nature and extent of FRAs in soil, soil vapor, LNAPL, and groundwater. The results of the characterization of the nature and extent of fuel-related contamination in each area are discussed in the following sections.

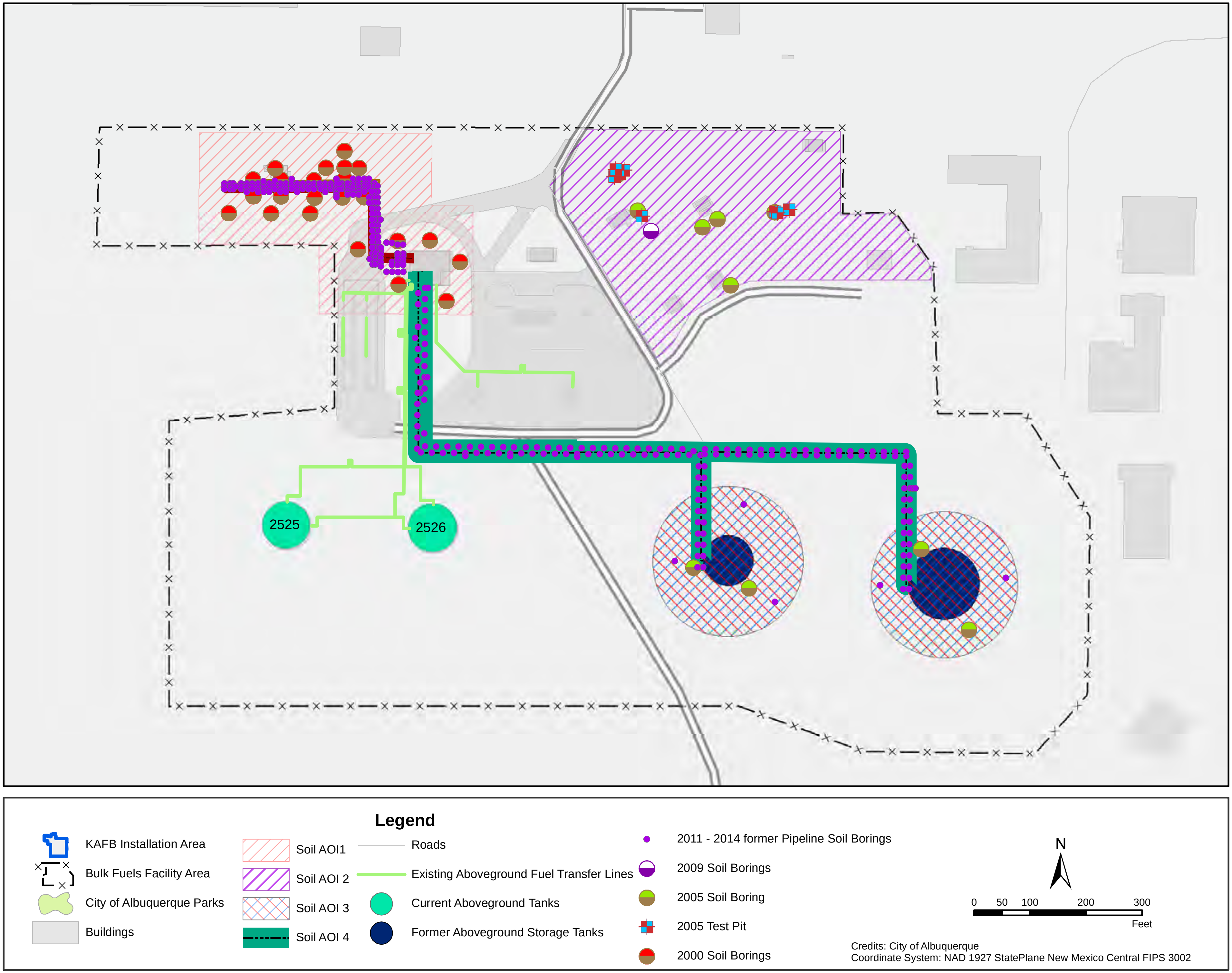
ES-4.1 Vadose Zone Investigation Results

Four source area investigations performed between 2000 and 2014 confirmed that the fuel releases originated from the pipelines in AOI 1 from the FFOR to the pump house (Figure ES-4). In total, more than 2,200 soil samples were collected at the Site. There is no evidence that other fueling infrastructure contributed to the release; both shallow and deep soil investigation results identified that the highest concentrations of FRAs in soil are located in AOI 1 to approximately 270 feet bgs. The soil investigations also confirmed a laterally continuous clay layer below the FFOR at approximately 270 feet bgs that may have slowed the migration of LNAPL at this depth.

This Report evaluates soil vapor data from 2015, following the SVMP retrofit to reduce the influence of barometric pumping in quarter (Q)1 2015. Soil vapor data from Q3 and Q4 2015 were collected after the soil vapor extraction interim measure was shut down. The maximum soil vapor concentrations both historically and as of Q4 2015 are found within AOI 5 (on base in the source area) from 50 feet to approximately 300 feet bgs. In Q4 2015, 11 SVMPs in AOI 5 (34%) had EDB concentrations greater than 0.5 part per million by volume (ppmv), and 27 SVMPs in AOI 5 (84%) had benzene concentrations greater than 1 ppmv. The maximum benzene concentration at the Site in 2015 was measured in AOI 5 in Q4 2015 and was 840 ppmv at soil vapor monitoring well (SVMW)-11-100.

The maximum EDB concentration in 2015 was measured in AOI 5 in Q1 2015 and was 8.3 ppmv at SVMW-11-100. Soil vapor rebound and respiration testing identified that this area of AOI 5 contained residual LNAPL contamination that is a contributing source of soil vapor. Permeability testing further identified a low permeability, high hydrocarbon (HC) zone from 240 feet to 280 feet bgs that most likely contains residual fuel contamination in AOI 5.

Figure ES-4. Soil Investigation Locations



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The maximum soil vapor concentrations in AOI 6 (on base outside of the source area) are located between 300 feet and 450 feet bgs. In Q4 2015, EDB was not detected higher than 0.5 ppmv at any SVMPs in AOI 6. Benzene results at 21 SVMPs in AOI 6 (9%) were detected at concentrations higher than 1 ppmv, 15 of which were located at the 350-foot or 450-foot horizons. Rebound and respiration testing identified this depth horizon in AOI 6 as an area containing residual fuel contamination. Selected locations in AOI 6 have maximum measured soil vapor concentrations at 250 feet bgs. This is most likely due to the presence of the low permeability, high HC zone from 240 feet to 280 feet bgs identified in AOI 5 and AOI 6 by permeability testing.

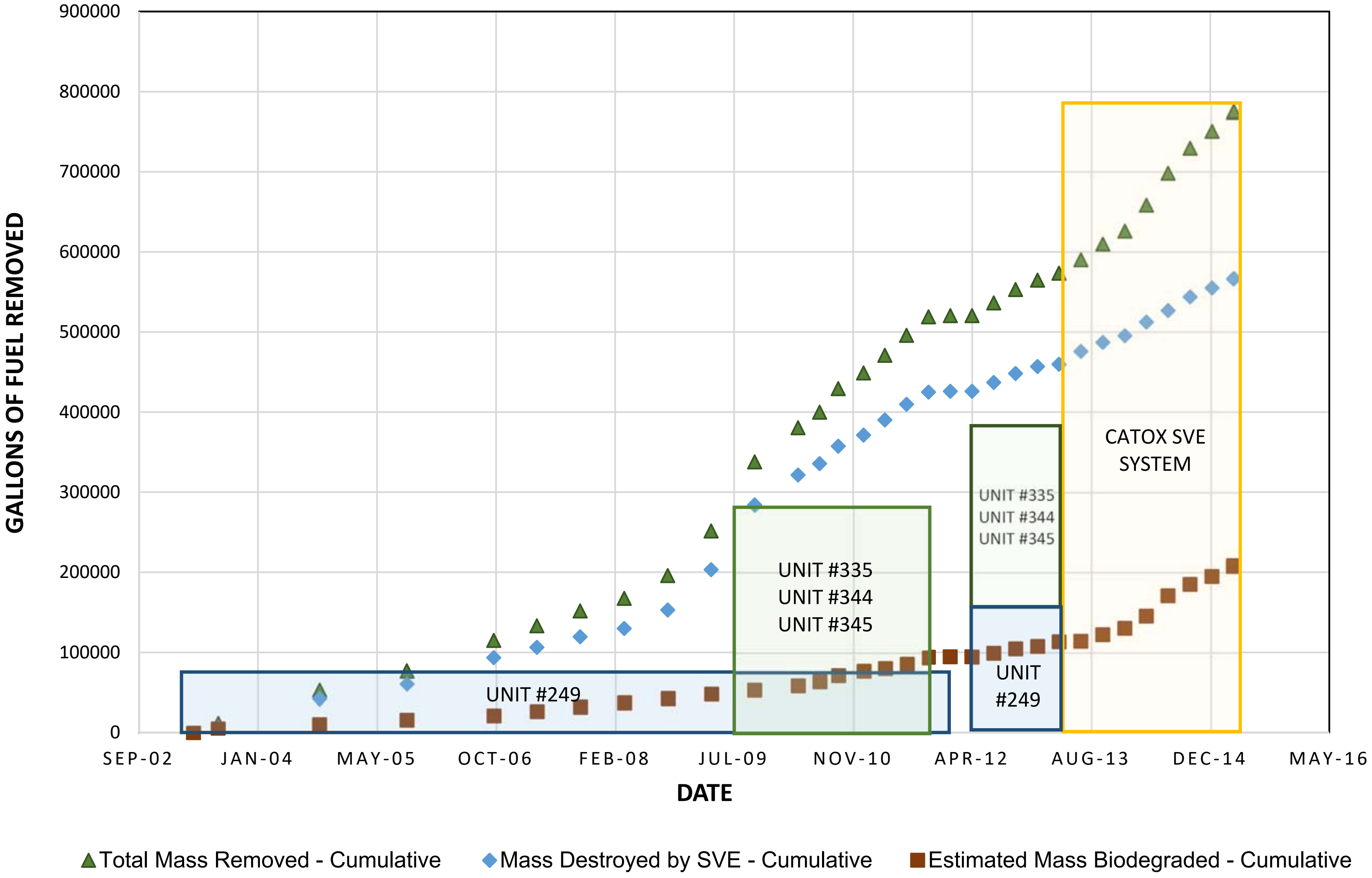
Oxygen (O_2) consumption rates were also measured in the on-base source area to determine if biodegradation is occurring. The data show that biodegradation is occurring in AOI 5 and AOI 6 based on O_2 consumption rates and that some areas in AOI 5 are low in O_2. This suggests that aerobic biodegradation is rate-limited in these areas due to low O_2 and low soil moisture, and optimal biodegradation is no longer occurring. Constant SVE operation from 2003 through Q2 2015 has limited the available moisture in the vadose zone, which in turn limits biodegradation rates.

Soil vapor FRAs in AOI 7 (off base) are detected at much lower concentrations than in the on-base AOIs. In Q4 2015, 27 out of 28 SVMPs in AOI 7 (96%) were non-detect for EDB, and six SVMPs (21%) were non-detect for benzene. There were no SVMPs in AOI 7 in Q4 2015 with EDB concentrations greater than 0.5 ppmv or benzene concentrations greater than 1 ppmv. Low but detectable concentrations of FRAs in AOI 7 indicate that there may be two sources contributing to soil vapor concentrations in AOI 7. Shallow groundwater and the smear zone directly above the water table contribute to deep soil vapor concentrations while shallower soil vapor (e.g., the 250-foot depth horizon) may be attributable to lenses of permeable sediments facilitating soil vapor transport. However, the three most distal SVM locations in AOI 7 were non-detect for EDB in Q3 2015 and Q4 2015 indicating that soil vapor contamination is not significant north of AOI 7.

Interim measures performed to remediate contamination in the vadose zone include excavating contaminated soil and performing SVE. Approximately 3,000 cubic yards of contaminated soil was excavated from the Site throughout the course of the investigation from 1999 to 2015. Impacted soil was primarily removed from the source area except for a few local areas associated with existing underground infrastructure (e.g., SVMPs or underground electric utility lines) or the presence of existing high-use roads associated with delivering fuel to the BFF. Soil was primarily removed from the surface to 20 feet bgs.

SVE systems operated at the Site from 2003 through 2015 created a vacuum below the ground surface to remove fuel-related contamination in soil vapor. The vacuum pulled the contaminants to the ground surface where they were treated. Two types of systems were used to treat the contaminants at the ground surface. The first used an internal combustion engine to destroy contaminants, and the second used a catalytic oxidizer to destroy contaminants by a catalyst similar to the catalytic converter in a car. The SVE systems moved air through the subsurface, which delivered HC vapor and O_2 to microbes that perform aerobic biodegradation of fuel constituents. Approximately 775,000 equivalent gallons of jet fuel have been removed from the subsurface by vacuum extraction (Figure ES-5). These calculated volumes include the combined total removed by SVE and the total biodegraded. Soil vapor contaminant concentrations have decreased over time in the area where SVE was performed at the Site.

Figure ES-5. Cumulative Hydrocarbon Removal by SVE



Gallons Removed 2003 - 2012 = 456,814 Gallons Removed 2013 - 2015 = 110,233

ES-4.2 LNAPL Investigation Results

LNAPL was discovered as an immiscible layer on the water table in 2007 and has been under investigation since that time. Figure ES-6 illustrates the 11 GWM wells where LNAPL has historically been detected at the Site. Measurable LNAPL was detected in multiple wells each quarter from Q1 2007 until Q1 2012, when the thicknesses and detections of LNAPL dropped. The maximum thicknesses measured at KAFB-1065, KAFB-1066, and KAFB-1068 were recorded in Q3 2010 at 4.04 feet, Q2 2010 at 2.45 feet, and Q3 2010 at 2.83 feet, respectively. From Q1 2009 to Q4 2011, the number of GWM wells with detectable LNAPL fluctuated between five and seven. Following cessation of modified bioslurping in Q3 2011, and concurrent with rising water levels, the number of wells with measurable LNAPL decreased. In Q1 2012, only KAFB-106059 and KAFB-106076 had measurable LNAPL thickness of 0.72 foot and 0.46 foot, respectively.

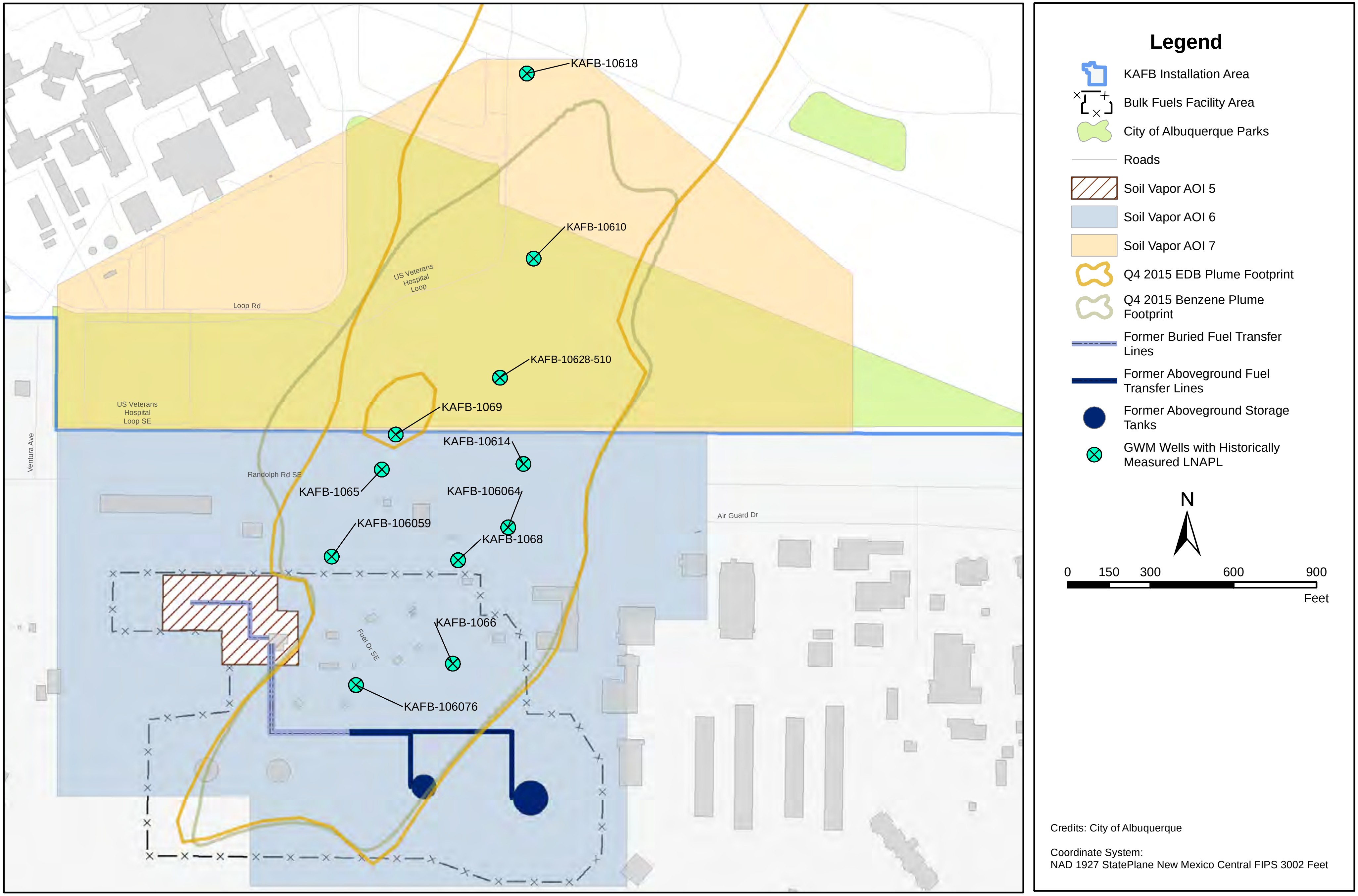
An effective solubility for benzene was calculated based on LNAPL samples collected at the Site in 2011. Locations where benzene concentrations exceeded the calculated effective solubility may indicate residual LNAPL in the saturated zone. Locations where benzene exceeded effective solubility at the Site are within the footprint of historical LNAPL measurements, indicating that the horizontal extent of residual LNAPL is understood.

Two variables have complicated the ability to quantitatively determine the fate and transport of LNAPL at the Site: changes in groundwater elevations and operating modified bioslurping systems. The modified bioslurping systems used at the Site are similar to SVE in that they create a vacuum and treat fuel-related contamination from the subsurface, but include a drop pipe that is extended from the ground surface to just above the air-LNAPL interface. A vacuum system is attached to the pipe and induces a vacuum, which volatilizes contaminants off the water table and treats them at the surface. Modified bioslurping was employed at the Site until Q3 2011 and removed 225,000 equivalent gallons of fuel. Another interim measure to recover LNAPL involved SVE at or above the water table. The vacuum created by modified bioslurping and SVE at the water table likely artificially inflated LNAPL thicknesses where it was implemented. Changes in LNAPL thickness also may have been caused by water table fluctuation as discussed below, and it is not possible to determine the exact amount of thickness increase caused by modified bioslurping and SVE at or above the water table. However, the seven greatest historical LNAPL thicknesses measured at the Site were during the time of modified bioslurping operation at three GWM wells between Q1 2008 and Q3 2011.

In addition to modified bioslurping, fluctuating groundwater elevations influence LNAPL thicknesses. In unconfined aquifers, LNAPL thickness in wells tends to decrease with water table rise and increase with water table fall, indicating an inverse relationship between LNAPL thickness and groundwater elevation (Tomlinson et al., 2014). Groundwater elevations at the Site decreased approximately 142 feet between 1949 and 2009. As Water Authority water usage changed in 2009 to make better use of surface water and implement conservation practices, the water table began to rise. LNAPL thicknesses decreased as groundwater elevations rose. Except for limited sheens of LNAPL, immiscible LNAPL on the water table was no longer detected at the Site before GWM well screens were submerged by the rising water table. This suggests that in addition to the rising water table, active interim measures may have contributed to the decrease in measurable LNAPL at the Site.

Although the horizontal extent of LNAPL at the Site is understood, the full vertical extent of residual LNAPL in the saturated zones remains unknown. The changes in groundwater elevations at the Site have created a smear zone. The highest elevation of the smear zone is equal to the groundwater elevation at the time that LNAPL reached the water table, which is unknown, but may be on the order of 100 feet higher

Figure ES-6. Historic LNAPL Detections



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than current water levels. The lowest elevation of the smear zone corresponds with the lowest groundwater elevations at the Site, about 15 feet lower than December 2015 water levels.

ES-4.3 Groundwater Investigation Results

Dissolved-phase contamination exceeding standards in groundwater was discovered in 2001. Since that time, groundwater monitoring has been ongoing, with 134 GWM wells installed as of December 2015. Objectives of the Phase II RFI will be to delineate dissolved-phase fuel-related contamination and evaluate the effects of the rising water table. Changes in water levels at the site are discussed below and in Section 6. In Q4 2015, the Shallow Zone EDB plume was approximately 6,850 feet long and ranged from 500 feet to 1,150 feet wide. The maximum EDB concentration was 93 micrograms per liter (µg/L) at KAFB-10614, which is in AOI 8. Concentrations greater than 1 µg/L were not found in AOI 9.

Average concentrations were calculated for EDB and benzene results. Average concentrations are arithmetic means from all sampled wells within the GWM network for each quarter evaluated. Between Q4 2012 and Q4 2015, the average EDB concentration decreased from 9.6 µg/L to 1.1 µg/L. Average EDB concentrations and maximum EDB detections in AOI 8 and AOI 9 decreased. Although the interpreted length of the plume remained fairly constant throughout the 4-year time period, as additional GWM wells were installed the interpreted width of the plume decreased from a maximum of 1,800 feet to 1,300 feet in the Shallow Zone (Figure ES-7).

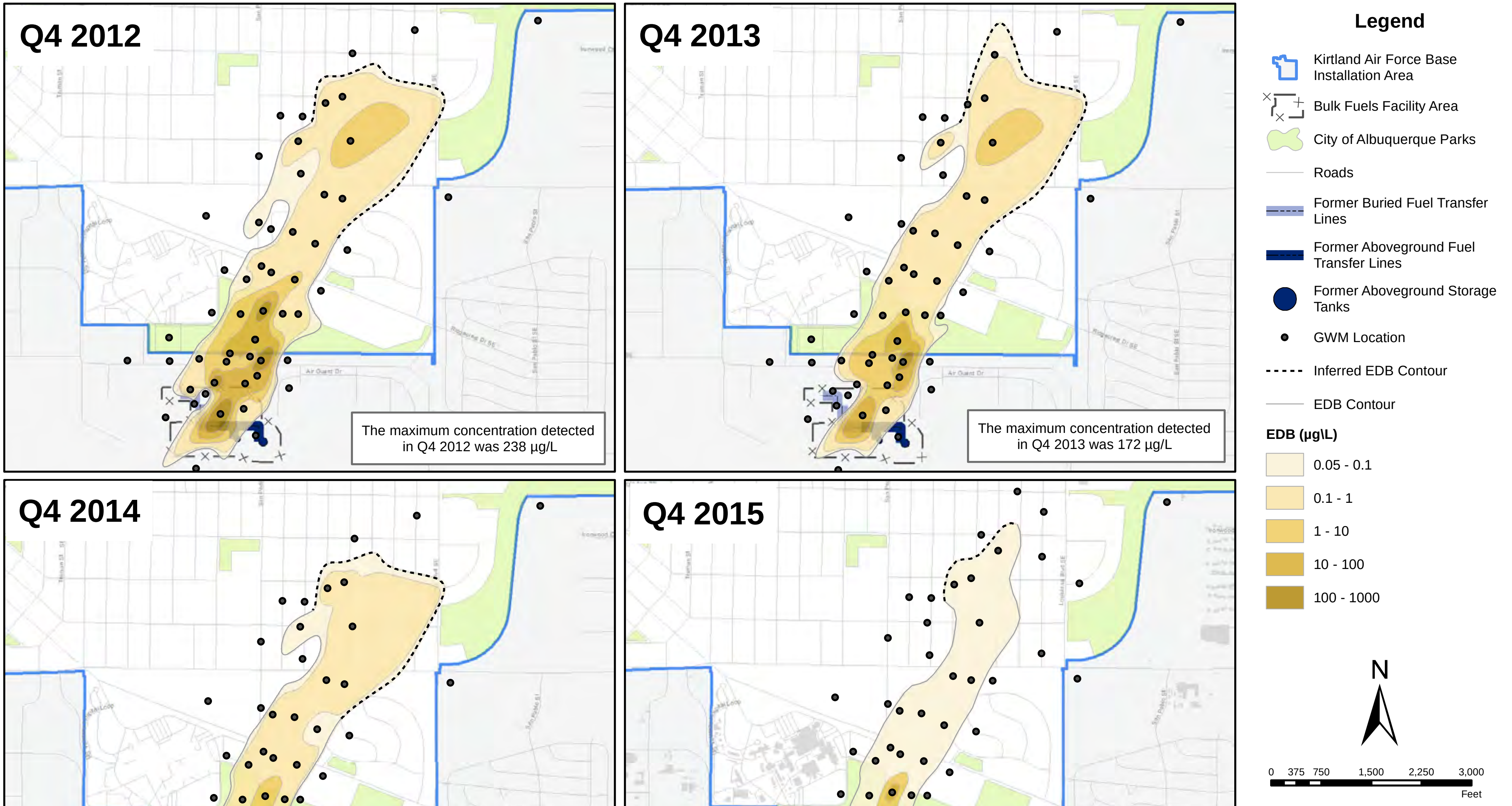
The average benzene concentration decreased between Q4 2012 and Q4 2015 from 580 µg/L to 175 µg/L. The maximum detected concentration also decreased from 12,700 µg/L to 8,940 µg/L. The length and width of the plume were stable to slightly decreasing, with the maximum length ranging from 3,000 feet to 2,800 feet in length, and the width ranging from a maximum of approximately 1,300 feet to a minimum of approximately 1,100 feet (Figure ES-8).

All other FRAs in groundwater are found in AOI 8, within the footprint of the shallow benzene plume. Changes in dissolved-phase concentrations and apparent plume configuration could also be influenced by the rising water table. The effects of the rising water table will be evaluated in the Phase II RFI Report.

Concentrations of microbial degradation indicators dissolved oxygen (DO), nitrate/nitrite, iron, manganese, sulfate, bromide, excess bromide, bicarbonate alkalinity, oxidation-reduction potential, and methane indicate that microbial degradation has been occurring within and just downgradient of the footprint of the benzene plume (Figure ES-9 and Figure ES-10). Indigenous microorganisms consume dissolved fuel constituents under aerobic (such as with O_2 present) or anaerobic (such as O_2 deficient) conditions (USACE, 2016b). As the microorganisms degrade the fuel constituents, they consume O_2, causing the DO to decrease. Once the DO concentration becomes limiting, nitrate/nitrite becomes the preferred electron acceptor, and its concentration will decrease as more fuel constituents are degraded. The next alternative electron acceptor is manganese. During fuel constituent degradation, manganese will be reduced to a lower oxidation state and more soluble form, thus resulting in an increase in dissolved manganese. The tertiary electron acceptor is iron and is similar to manganese in that it becomes more soluble as its oxidation state is reduced during fuel constituent degradation, resulting in increased dissolved concentrations.

Sulfate will also be consumed as fuel constituents continue to degrade, resulting in decreased concentrations. Incomplete degradation of EDB may be occurring under sulfate-reducing conditions within the dissolved portion of the plume near the LNAPL source. Additionally, data indicate that methanogenesis is occurring within the footprint of the shallow benzene plume in the zone with the highest residual HCs. Alkalinity is increased directly or indirectly through several processes including the

Figure ES-7. Shallow EDB Plume Q4 2012 - Q4 2015



Q4 2012

The maximum concentration detected in Q4 2012 was 238 µg/L

Q4 2013

The maximum concentration detected in Q4 2013 was 172 µg/L

Q4 2014

The maximum concentration detected in Q4 2014 was 192 µg/L

Q4 2015

The maximum concentration detected in Q4 2015 was 93 µg/L

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Coordinate System:
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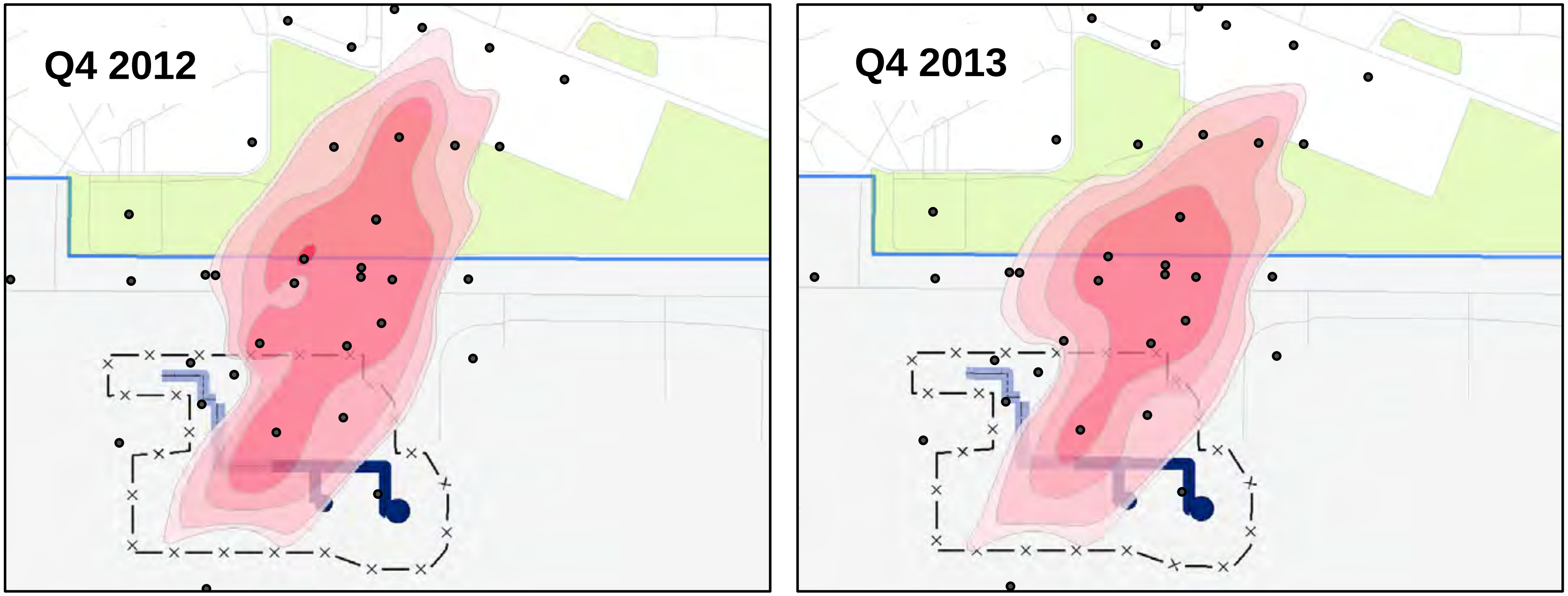
Figure ES-8. Shallow Benzene Plume Q4 2012 - Q4 2015



The maximum concentration detected in Q4 2012 was 12,700 µg/L.

The maximum concentration detected in Q4 2103 was 11,600 µg/L

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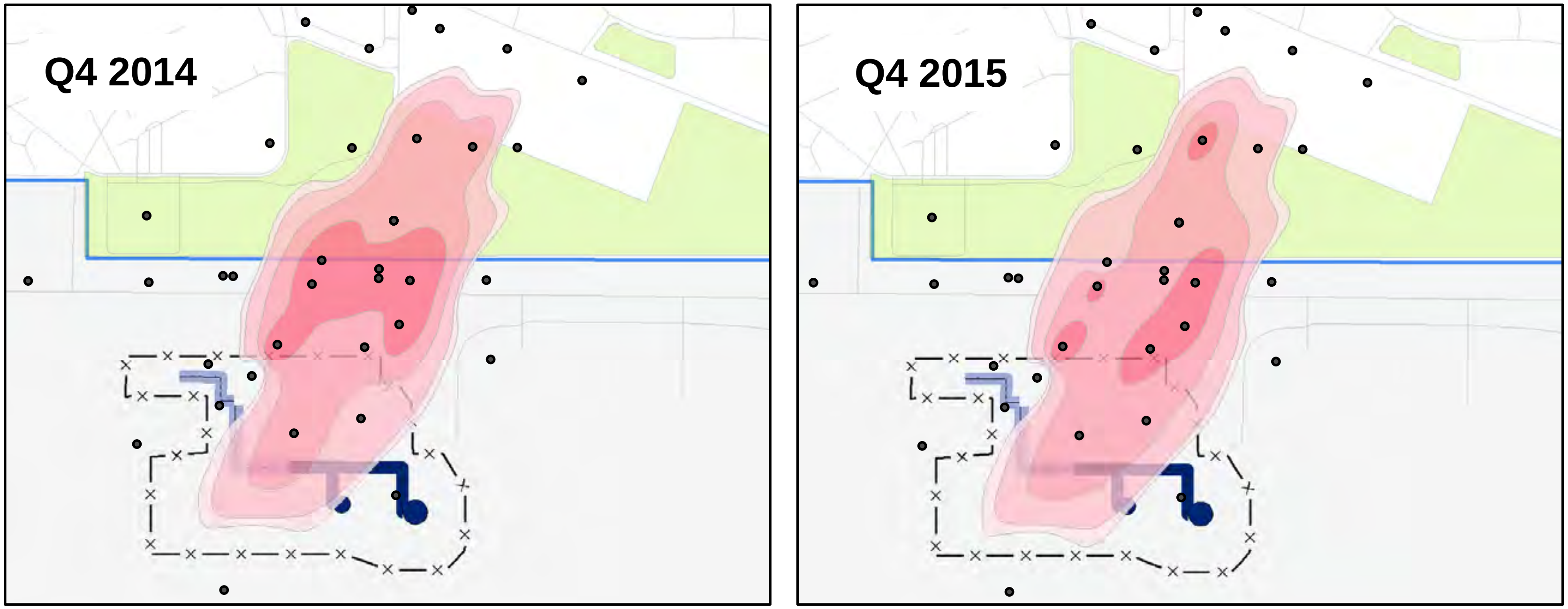

The maximum concentraiont detected in Q4 2014 was 11,800 µg/L

The maximum concentration detected in Q4 2015 was 8,940 µg/L

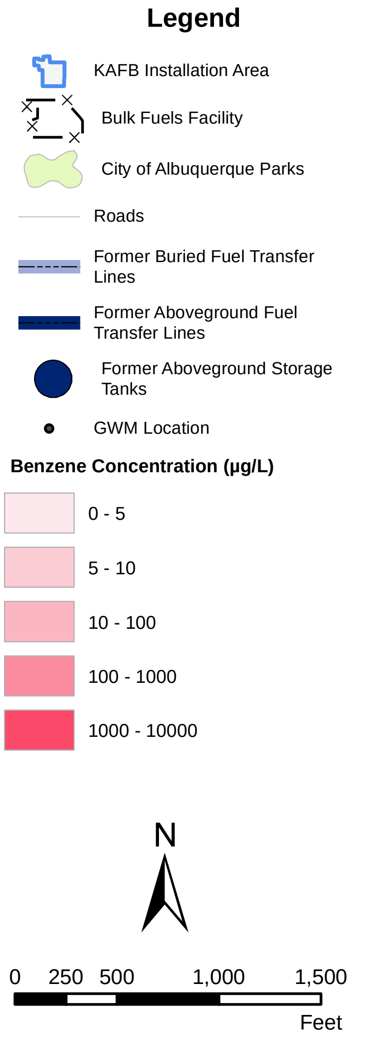

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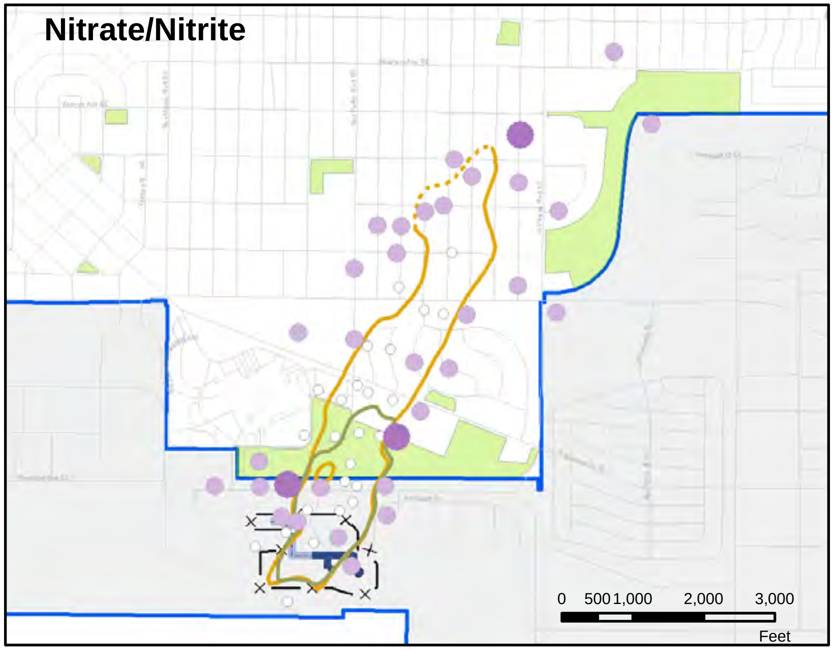
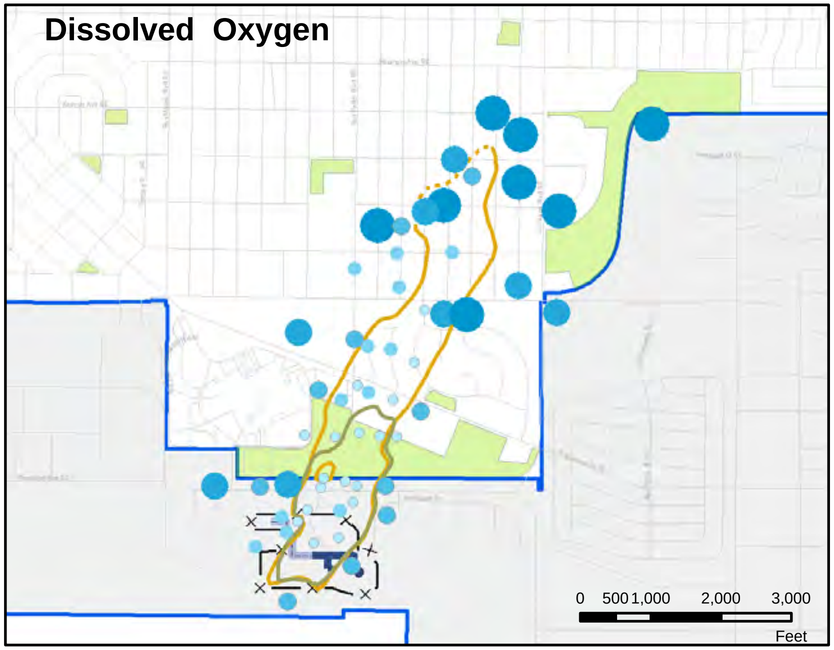
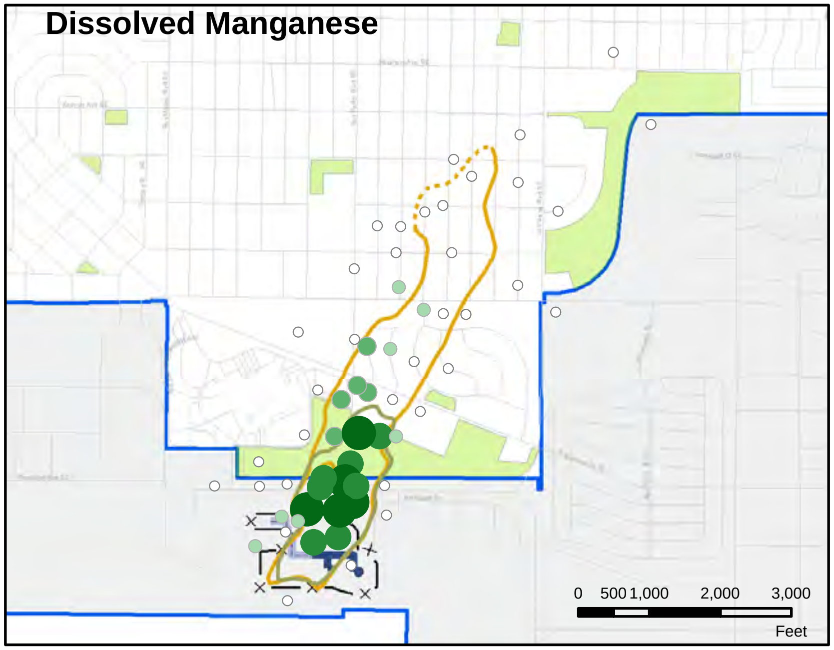
Figure ES-9. Q4 2015 Dissolved Oxygen, Dissolved Magnesium, Dissolved Iron and Nitrate/Nitrite Concentrations



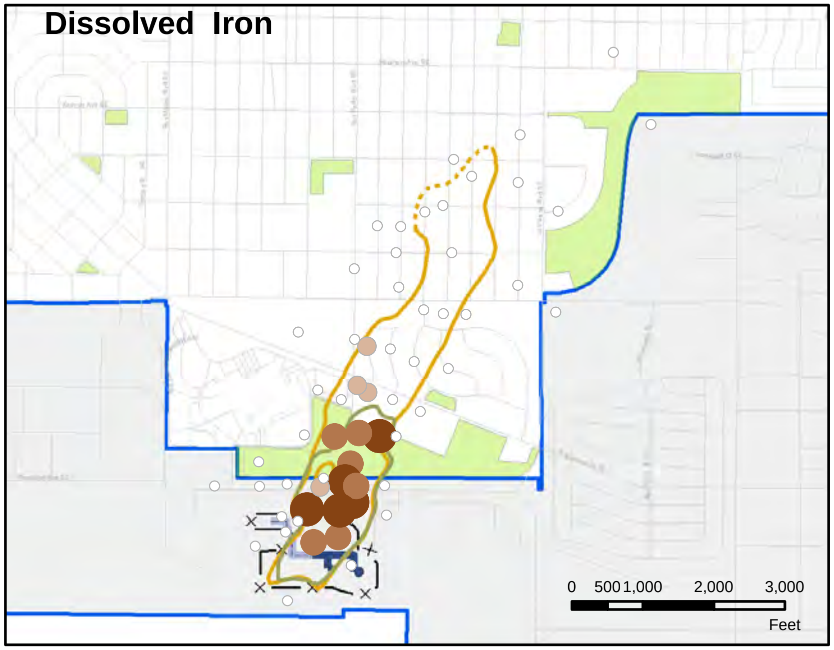
The maximum concentration detected in Q4 2015 was 16.3 mg/L.



The maximum concentration detected in Q4 2105 was 9.54 mg/L.



The maximum concentration detected in Q4 2015 was 4800 µg/L.



The maximum concentration detected in Q4 2015 was 4740 µg/L.

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Legend

- KAFB Installation Area
- City of Albuquerque Parks
- Roads
- Q4 2015 Benzene Plume Footprint
- Q4 2015 Inferred EDB Contour
- Q4 2015 EDB Plume Footprint

Nitrate/Nitrite in Groundwater (mg/L)

- ○ ND
- ● 0.1 - 4.6
- ● 4.6 - 10.0
- ● 10.1 - 16.3

Dissolved Oxygen (mg/L)

- ● 0.0 - 1.0
- ● 1.0- 2.8
- ● 2.8 - 5.5
- ● 5.5 - 8.5
- ● 8.5 - 10.0

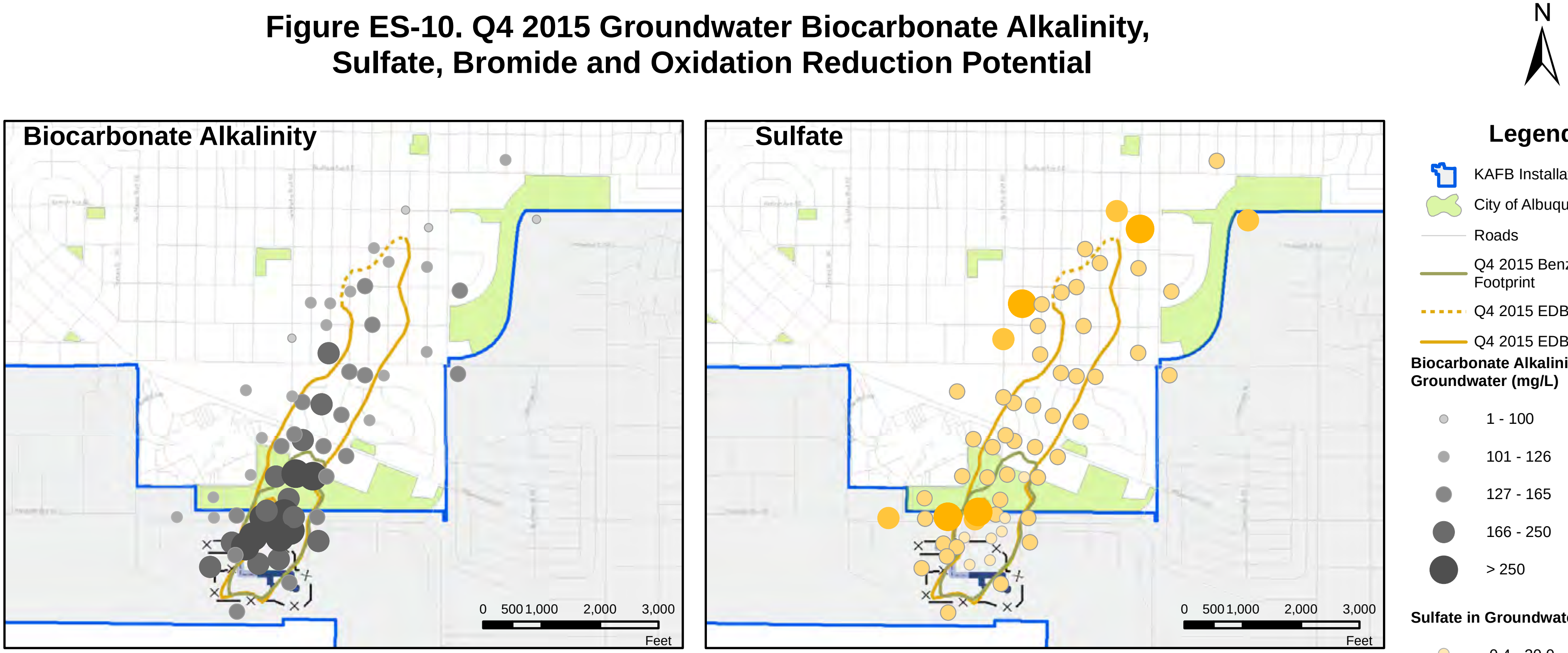
Manganese in Groundwater (µg/L)

- ○ ND
- ● 7.5 - 200
- ● 201 - 1000
- ● 1000 - 2000
- ● 2000 - 4800

Iron in Groundwater (µg/L)

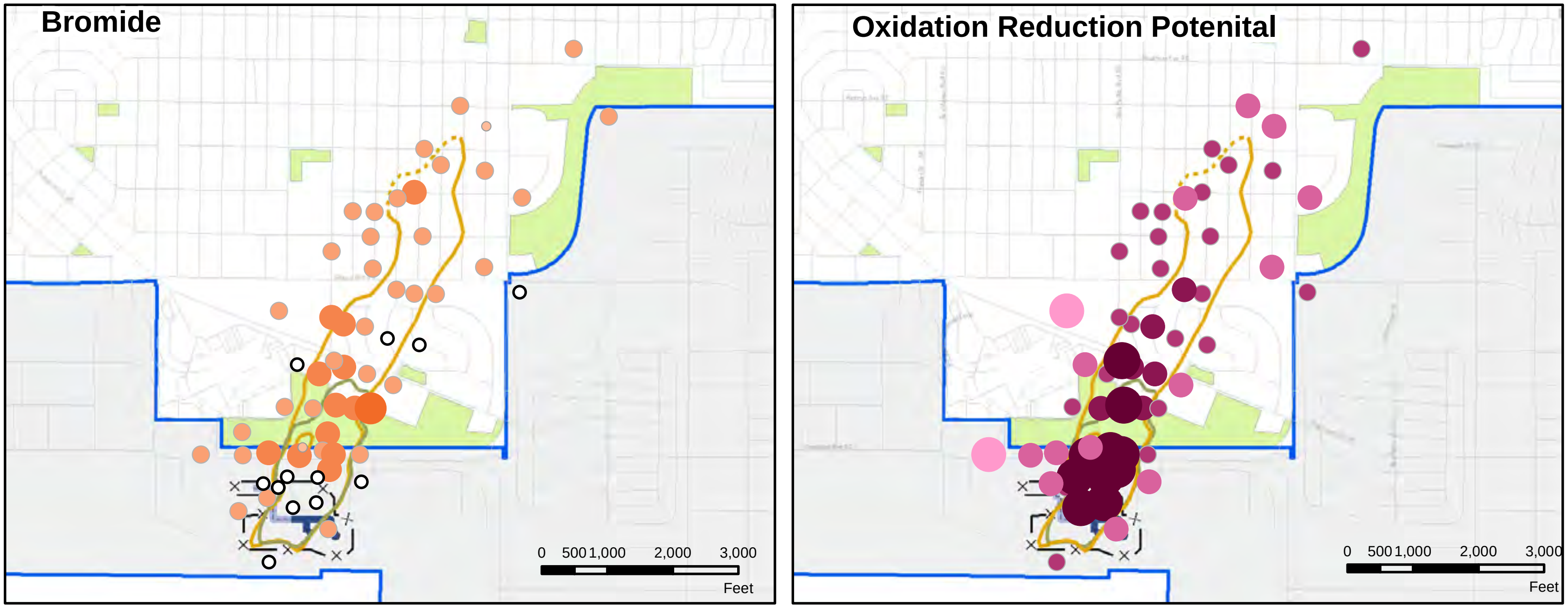
- ○ ND
- ● 50 - 200
- ● 201 - 1000
- ● 1001 - 4740

Figure ES-10. Q4 2015 Groundwater Biocarbonate Alkalinity, Sulfate, Bromide and Oxidation Reduction Potential



The maximum concentration detected in Q4 2015 was 388 mg/L.

The maximum concentration detected in Q4 2105 was 344 mg/L.



The maximum concentration detected in Q4 2015 was 876 µg/L.

The maximum concentration detected in Q4 2015 was 380 mV

Legend

- KAFB Installation Area
- City of Albuquerque Parks
- Roads
- Q4 2015 Benzene Plume Footprint
- Q4 2015 EDB Inferred Contour
- Q4 2015 EDB Plume Footprint

Biocarbonate Alkalinity in Groundwater (mg/L)

- ● 1 - 100
- ● 101 - 126
- ● 127 - 165
- ● 166 - 250
- ● > 250

Sulfate in Groundwater (mg/L)

- ● 0.4 - 20.0
- ● 20.1 - 107.0
- ● 107.1 - 212.0
- ● 212.1 - 344.0

Excess Bromide in Groundwater (µg/L)

- ○ ND
- ● -1217.0 - -910.0
- ● -909.9 - 69.3
- ● 69.4 - 417.9
- ● 418.0 - 876.0

Oxidation Reduction Potential (mV)

- ● < -150
- ● -150 - 0
- ● 1 - 150
- ● 151 - 250
- ● > 250

direct mixing of carbon dioxide (CO_2) with groundwater; the production of CO_2 by the aerobic biodegradation of FRAs; methanogenesis in anaerobic zones, which releases methane and CO_2; and the dissolution of minerals by carbonic acid formed from aqueous CO_2. Elevated bromide and excess bromide concentrations can also indicate that indigenous microorganisms or reactive minerals are degrading EDB and releasing bromide into the groundwater. In addition, the presence of acetone in groundwater at the Site may also indicate degradation of fuels. Transient production of acetone is generally correlative to anoxic to methanogenic environments. It is assumed that acetone production transpires before the system becomes fully anaerobic, or when a carbon source is available (Mueller, 2011).

Results of the microbial communities and compound-specific isotope analysis indicate that EDB is being degraded in the upgradient anaerobic area of the plume by reductive debromination of EDB. Additionally, microorganisms anticipated to be capable of EDB debromination represent a sizeable proportion of all bacteria at the Site (up to 10%). In the downgradient aerobic portion of the plume, data indicate that abiotic processes such as hydrolysis are degrading some amount of EDB.

Water levels at the Site declined approximately 142 feet between 1949 and 2009. Since 2009, water levels have risen between 10 feet and 18 feet at the Site (Figure ES-11). Water levels have increased more rapidly in the northern area of the dissolved-phase EDB plume, due to reduced pumping at the Water Authority’s Ridgecrest well field. The hydraulic gradient has lessened in this area due to the reduced pumping rates.

As a result of technical discussions among USACE, AFCEC, NMED, EPA, the Water Authority, and the city of Albuquerque, in July 2014 it was determined that a GWTS system interim measure would be installed to provide hydraulic control and collapse the EDB plume. A temporary GWTS was constructed and operated until a full-scale GWTS could be built. The full-scale GWTS is has been operational since December 2015.

Additional groundwater interim measures are discussed in Section 6 of this Report. For a more detailed summary of the nature and extent of soil and soil vapor results, refer to Section 4 of this Report; for LNAPL results, refer to Section 5; and for groundwater results, refer to Section 6.

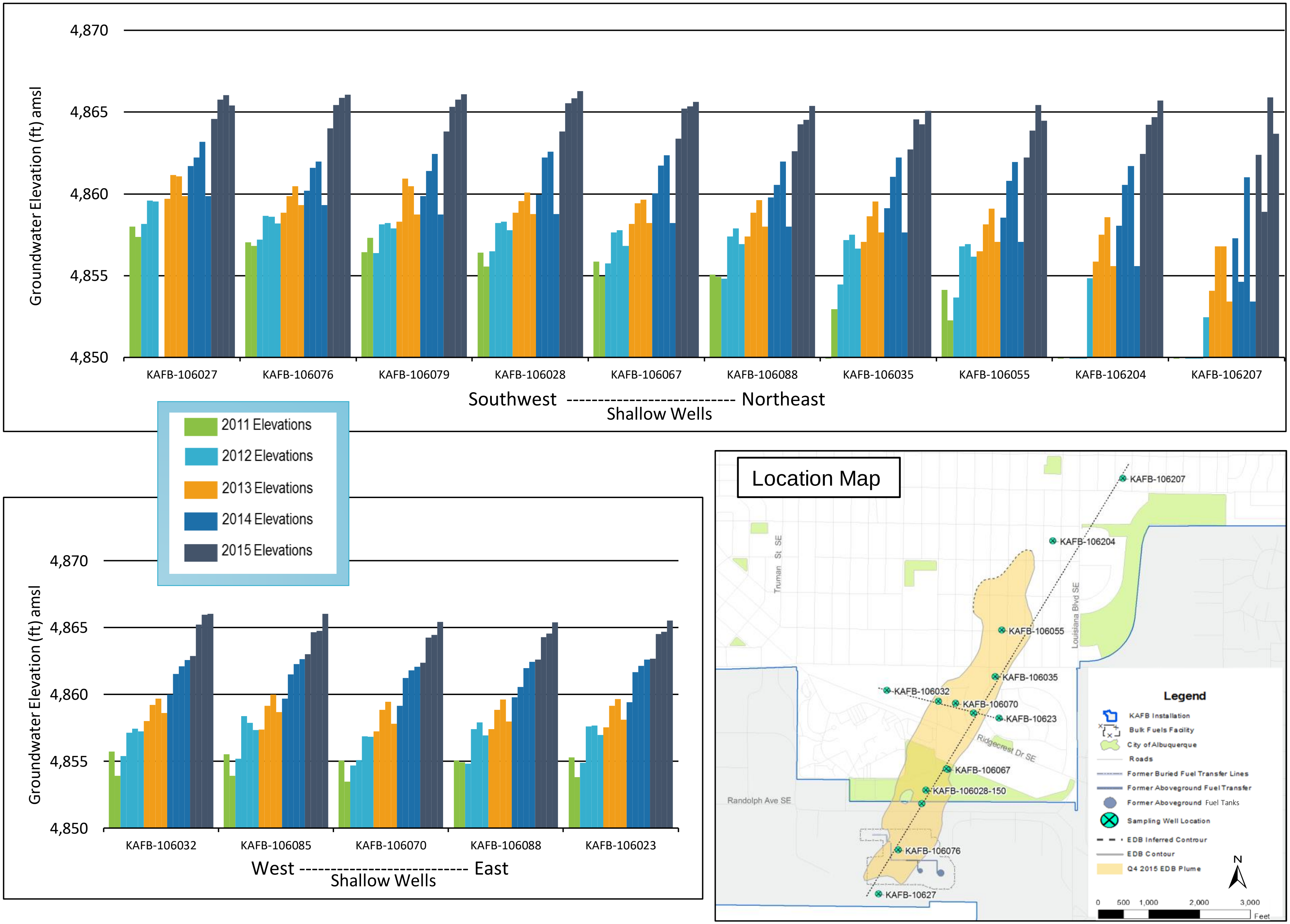
ES-5 Conceptual Site Model

The CSM illustrates the nature and extent of fuel-related contamination across the Site and discusses how the fuel-related analytes originated from the source to their current affected areas.

- The Site is in the Albuquerque Basin of the Rio Grande Rift, which has been filled with sediments of the Santa Fe Group. There are two main types of depositional environments represented by the geology of the Site: east–west-oriented alluvial fan deposits derived of sediments eroded from the Sandia and Manzanita mountains, and north–south-oriented Ancestral Rio Grande deposits. Both the alluvial fan and Ancestral Rio Grande sediments are comprised of both fine-grained (e.g., clays, silts, and fine-grained sands) and coarse-grained (e.g., sands and gravels) deposits.

- Jet fuel was released from the underground pipelines in AOI 1. Although the exact time period of the releases is unknown, it is estimated that leaks began no later than the mid-1970s and continued through 1999. The timeline is constrained by the use of AvGas, which contained EDB (EDB was not a constituent of JP-4 or JP-8). Kirtland AFB transitioned from AvGas to JP-4 in

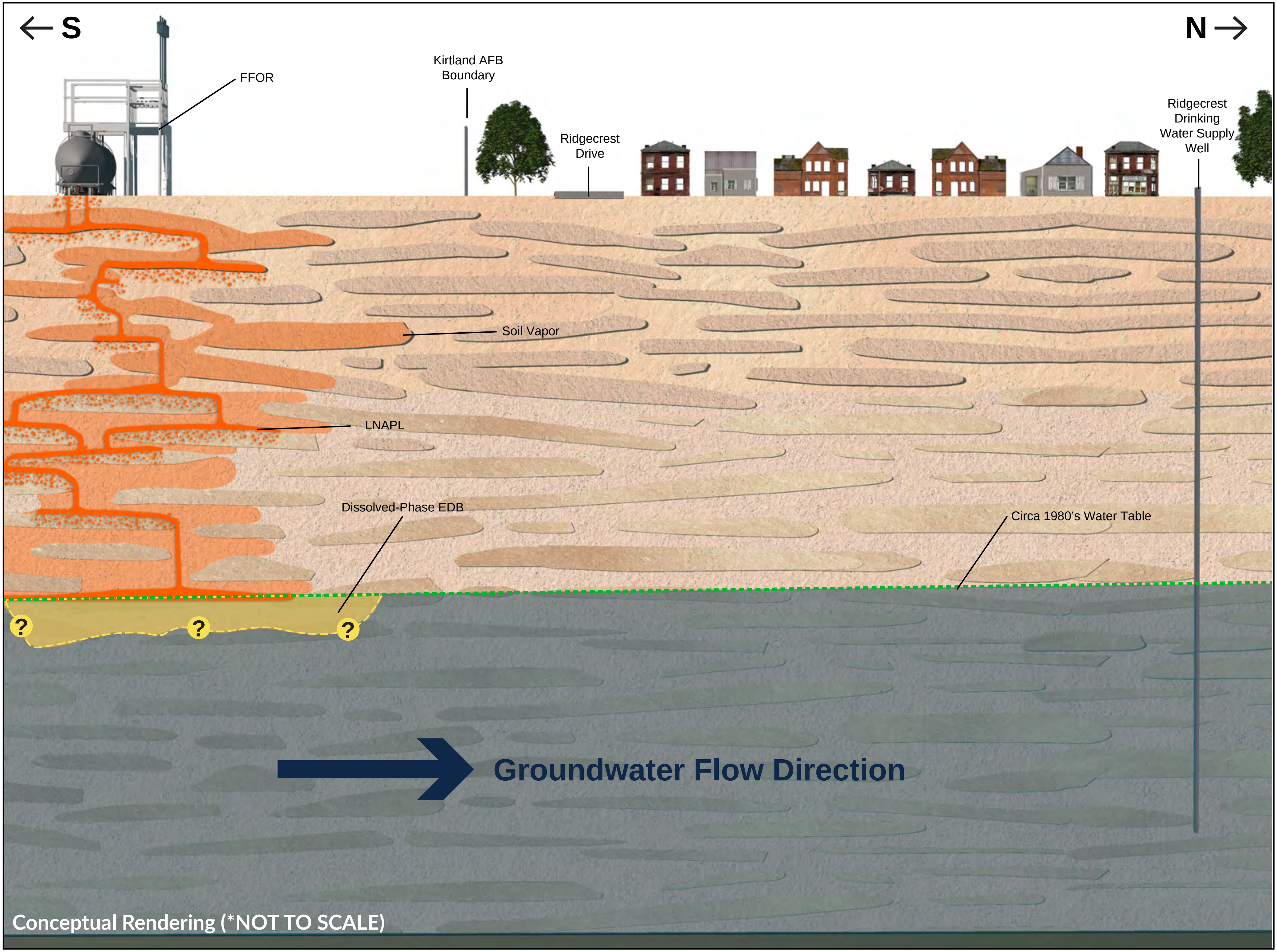
Figure ES-11. Groundwater Elevations 2011 - 2015



1975. Over time, AvGas, JP-4, and JP-8 have been released at the Site, so the LNAPL is a mixture of all three of these fuels.

- The releases at the Site occurred sometime before 1975 through 1999 but were not continuous. As railcars or trucks made deliveries at the BFF, the pipelines were under vacuum. Remaining fuel left in the line would drain into the subsurface through holes in the pipelines after the vacuum was shut off. The pipelines would be empty until the next delivery was made the following day or week. One hole discovered was approximately 1 inch in diameter; however, the dimensions of all the holes are not known.
- The released LNAPL migrated through the vadose zone soil. LNAPL migrated generally downward in AOI 1 and AOI 5 via a complex pathway influenced by the heterogeneous sediments in the alluvial fan and Ancestral Rio Grande deposits. More permeable sands and gravels allowed the LNAPL to migrate more easily, while less permeable silts and clays slowed LNAPL migration. Some LNAPL constituents adsorbed to soils, dissolved in pore water, or were retained within the vadose zone in the LNAPL phase due to capillary forces. As LNAPL migrated through the vadose zone, naturally occurring bacteria degraded some FRAs by oxidizing hydrocarbons and respiring O_2. Residual LNAPL provided a continuous source of soil vapor contamination below the FFOR (Figure ES-12).
- At approximately 240 feet to 300 feet bgs, downward migrating LNAPL encountered discontinuous low-permeability layers of silts and clays. Some LNAPL migrated into this layer and remains a source of ongoing contamination in the vadose zone. Over time, LNAPL continued to release into the subsurface and migrate from the source area. When the LNAPL encountered the saturated low-permeability zone, excess LNAPL that did not adsorb into the layer spread out along it and migrated to the east along the dip direction of the sediments where it encountered a path of least resistance to the water table in AOI 6.
- The leaking LNAPL continued to migrate along this pathway to the water table. When LNAPL reached the water table it spread laterally in response to buoyancy forces, selectively displaced groundwater from the interior of the larger pores in the aquifer media, and began to dissolve into groundwater. It is estimated that LNAPL reached the water table sometime in the 1980s. Constituents of LNAPL at the LNAPL/groundwater interface dissolved into groundwater based on their solubility creating the dissolved-phase groundwater contaminant plumes (Figure ES-12).
- The increased groundwater use by the growing Albuquerque population created not only a decline in water levels, but a cone of depression near the Ridgecrest well field northeast of the Site, causing groundwater to flow to the northeast. Groundwater flow was originally to the southwest but reoriented to the northeast in the late 1970s due to Water Authority pumping regimes. Water levels were decreasing when the LNAPL reached the water table. As the water table dropped, mobile LNAPL continued migrating downward following the receding water table.
- Contaminants dissolving from the LNAPL (EDB and other FRAs) were transported by groundwater that flowed to the northeast. The dissolved-phase groundwater plume moved downgradient following the path of least resistance through the more permeable sediments deposited by river channels of the Ancestral Rio Grande.
- The releases were discovered in 1999. The failed BFF infrastructure from the FFOR to the pump house that was the source of the releases was taken off-line at this time. EDB has high persistence

Figure ES-12. Groundwater Conceptual Model ~1980s



in groundwater and is highly mobile. EDB, a constituent in the dissolved-phase groundwater plume, traveled farther downgradient than the other FRAs, approximately 6,800 feet. The BTEX constituents, which more readily degraded aerobically and more readily adsorbed to soils than EDB, remained primarily in AOI 8, only traveling approximately 3,000 feet downgradient.

- In 2009, the water table began to rise due to a combined effect of water conservation strategies undertaken by the Water Authority as well as the San Juan-Chama Project, which uses surface water from the Rio Grande as a source of drinking water, reducing the pumping of Water Authority supply wells. Rising water levels combined with active interim measures such as modified bioslurping and SVE at or above the water table resulted in reducing free-phase LNAPL (Figure ES-13).

- As the water table continued to rise it encountered and mobilized residual LNAPL in the unsaturated zone, creating discontinuous sheens of LNAPL measured on the water table (Figure ES-14).

- On-base residual LNAPL in the source area from 20 feet bgs to the water table is an ongoing source of soil vapor contamination in the vadose zone. The residual LNAPL in AOI 5 has been removed to 20 feet by excavation but is still present from 20 feet to approximately 300 feet bgs.

- Residual LNAPL is a continuing source of contaminants in the vadose zone and saturated zone. LNAPL measurements and comparison of benzene concentrations to a calculated effective solubility indicate that the horizontal extent of LNAPL at the site is understood. The vertical extent of LNAPL both in the saturated and unsaturated zones represents a data gap at the Site. Both the dissolved-phase EDB and benzene plumes' extent and footprint did not change significantly between 2012 and 2015. However, changes in dissolved-phase concentrations and apparent plume configuration could be influenced by the rising water table.

- Water levels at the Site declined approximately 142 feet between 1949 and 2009. Since 2009, water levels have risen between 10 feet and 18 feet at the Site. Water levels have increased more rapidly in the northern area of the dissolved-phase EDB plume due to reduced pumping at the Ridgecrest well field. The hydraulic gradient has lessened in this area due to the reduced pumping rates. The effects of the rising water table on dissolved-phase groundwater concentrations will be evaluated in the Phase II RFI Report.

- Between Q4 2012 and Q4 2015, the average EDB concentration decreased from 9.6 µg/L to 1.1 µg/L. Average EDB concentrations and maximum EDB detections in both AOI 8 and AOI 9 decreased. Although the interpreted length of the plume remained fairly constant throughout the 4-year time period, as additional GWM wells were installed the interpreted width of the plume decreased from a maximum of 1,800 feet to 1,300 feet in the Shallow Zone. The average benzene concentration decreased between Q4 2012 and Q4 2015 from 580 µg/L to 175 µg/L. The maximum detected concentration also decreased from 12,700 µg/L to 8,940 µg/L. The length and width of the plume were stable to slightly decreasing, with the maximum length ranging from 3,000 feet to 2,800 feet in length, and the width ranging from a maximum of approximately 1,300 feet to a minimum of approximately 1,100 feet. However, changes in dissolved-phase concentrations and apparent plume configuration could be influenced by the rising water table.

- Microbial degradation indicators at the Site and the limited extent of the benzene plume indicate that aerobic degradation has effectively controlled the migration of BTEX constituents from the

Figure ES-13. Groundwater Conceptual Model 2009

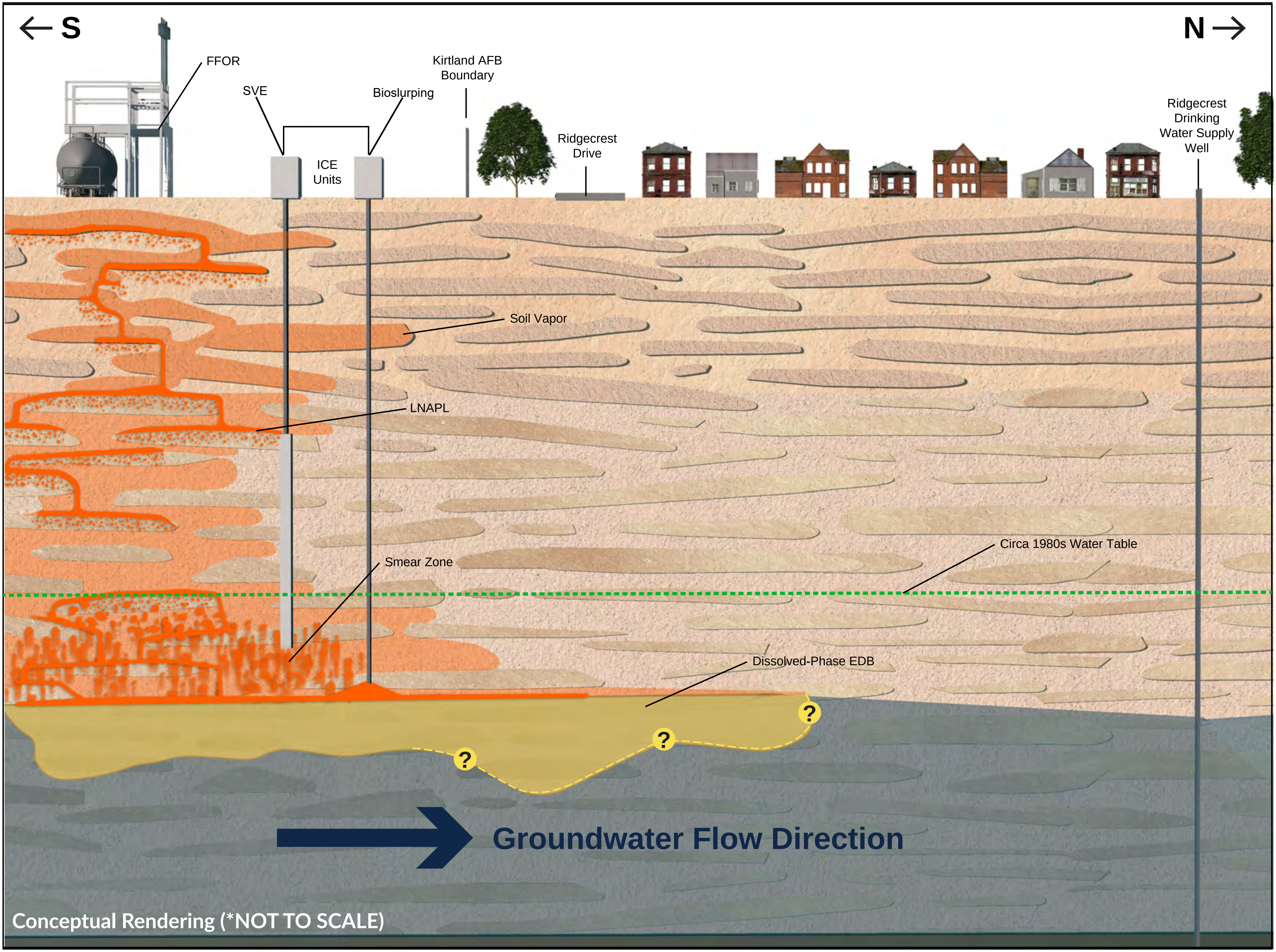
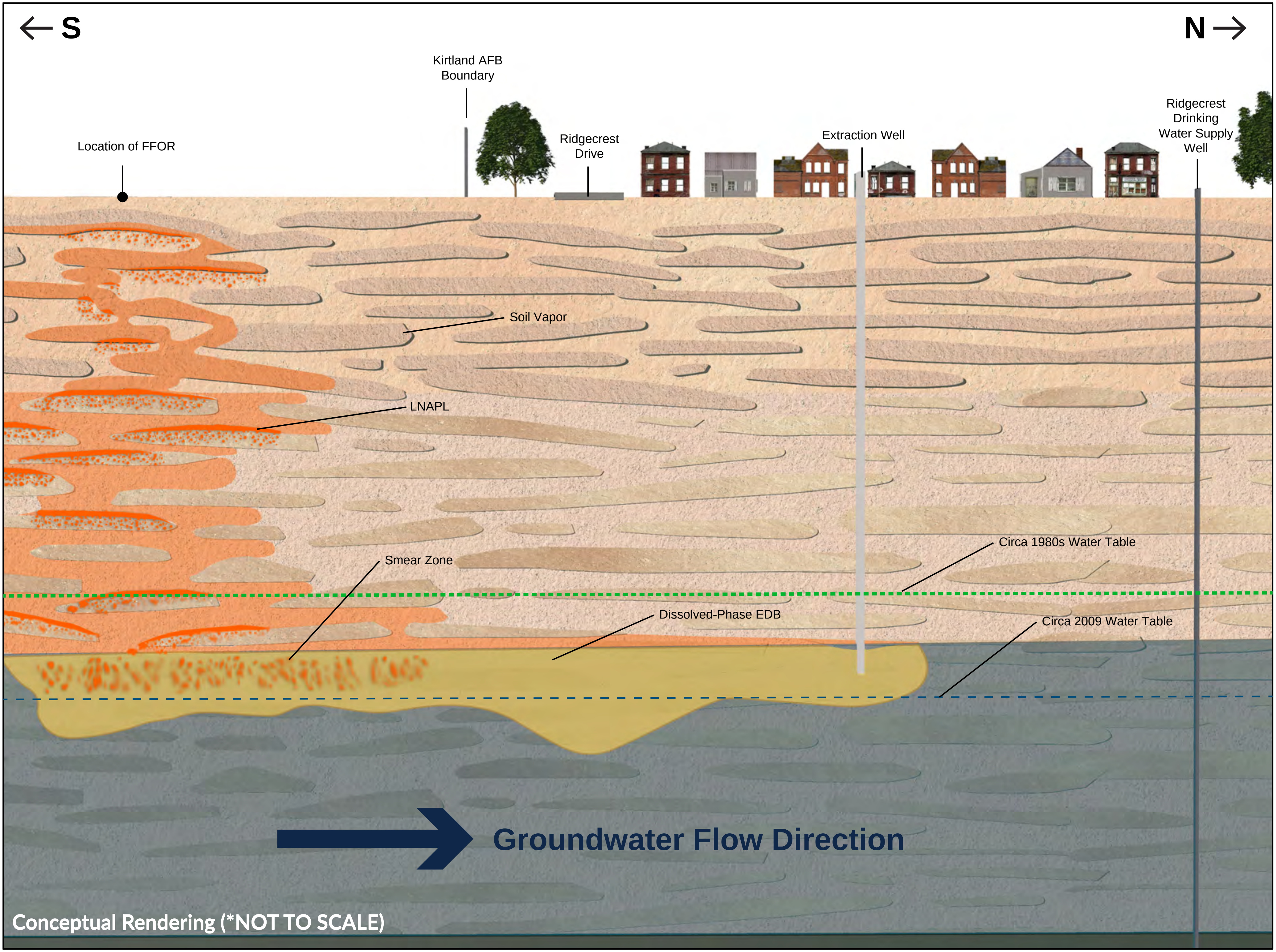


Figure ES-14. Groundwater Conceptual Model 2015



source area in AOI 8 (Section 6). There is evidence that EDB—commingled with the benzene plume in groundwater—is undergoing biological anaerobic reductive debromination. Furthermore, bench-scale microcosm testing results demonstrated that EDB degradation may be enhanced with the addition of amendments to groundwater.

The CSM is discussed in further detail in Section 7 of this Report.

ES-6 Conclusions and Recommendations

As summarized below, the RFI performed for the BFF met the goals for the Phase I investigation.

1. Characterization of the nature and extent of fuel-related contamination at the Site will be completed by Phase II activities.
2. The underground pipeline from the FFOR to the pump house has been removed, preventing further fuel releases at the Site.

Site lithology is a major factor influencing the nature and extent of contamination at the Site. The migration of LNAPL and soil vapor through the vadose zone, and the migration of dissolved contaminants through the saturated zone, are all influenced by the composition and orientation of the alluvial fan deposits and the Ancestral Rio Grande deposits.

Water use in the Albuquerque Basin has had a significant effect on the nature and extent of contamination in groundwater and will continue to influence contaminant transport at the Site into the future. The plume is oriented to the northeast due to the high pumping rates at Water Authority wells through 2009. As pumping rates decreased, the hydraulic gradient began to flatten through 2015, and water levels are projected to continue to rise over the next 50 years. Continued collaboration with the Water Authority and Raymond G. Murphy VA Medical Center will be essential during the CME phase to understand how current and projected use of Water Authority and Raymond G. Murphy VA Medical Center wells will affect groundwater conditions, and thus implementing any proposed remedy at the Site.

The RCRA Permit defines an SWMU as “any discernible unit at which solid wastes have been placed at any time, irrespective of whether the unit was intended for the management of solid or hazardous waste. Such units include any area at the Facility at which solid wastes have been routinely and systematically released.” AOI 1 and AOI 5 have been identified as the source of the released jet fuel at the Site. Therefore, the SWMU boundary is defined as AOI 1 and AOI 5.

Remaining data gaps include the following areas.

- **LNAPL**: Due to the rising groundwater levels, it is unclear how much and where the LNAPL remains vertically smeared beneath the water table, how degraded the existing LNAPL is, and how it may be contributing to the dissolved contamination in the groundwater.
- **Groundwater**: Changes in dissolved-phase concentrations and apparent plume configuration could be influenced by the rising water table. The effects of the rising water table will be evaluated in the Phase II RFI Report.

The recommendations summarized below are necessary to fill these remaining data gaps.

ES-6.1 Recommendations

The following recommendations are made to close the remaining data gaps and continue implementing interim measures at the Site.

- **LNAPL Delineation**: Phase II RFI activities will include continuous coring in the vadose zone at the FFOR area to further characterize and delineate existing LNAPL in the low-permeability sediments and in the saturated zone. It is recommended that any free-phase LNAPL collected be evaluated by laboratory analysis.
- **Groundwater**: The effects of the rising water table will be evaluated in the Phase II RFI Report by installing additional GWM wells.