

7/11/11



DEPARTMENT OF THE AIR FORCE  
HEADQUARTERS 49TH WING (ACC)  
HOLLOMAN AIR FORCE BASE, NEW MEXICO



A. David Budak  
Deputy Base Civil Engineer  
550 Tabosa Avenue  
Holloman AFB NM 88330-5840

New Mexico Environment Department  
Attn: Mr. John Kieling  
Hazardous Waste Bureau  
2905 Rodeo Park Drive East, Building 1  
Santa Fe NM 87105-6303



Dear New Mexico Environment Department

Holloman AFB is pleased to submit the Basewide Background Study corrected pages to be inserted into document for your review.

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If you have any questions, please contact Mr. David Scruggs of our Asset Management Flight at (575) 572-5395.

Sincerely

  
A. DAVID BUDAK, GS-14, DAFC

Attachment:  
Basewide Background Study corrected pages

cc:  
(w/ Atch)  
Mr. David Strasser  
Hazardous Waste Bureau  
5500 San Antonio Dr. NE  
Albuquerque, NM 87109

(w/o Atch)  
Mr. Will Moats  
Hazardous Waste Bureau  
5500 San Antonio Dr. NE  
Albuquerque, NM 87109

(w/o Atch)  
Ms. Laurie King  
USEPA, Region 6 (6PD-F)  
1445 Ross Ave., Ste 1200  
Dallas, TX 75202-2733

**FINAL  
BASEWIDE BACKGROUND STUDY REPORT  
HOLLOMAN AIR FORCE BASE,  
NEW MEXICO**

Prepared for:

**49 CES/CEA  
Holloman Air Force Base  
New Mexico**

Under Contract To:

**U.S. Army Corps of Engineers  
Omaha District  
Omaha, Nebraska**

**Contract No. W9128F-07-D-0022  
Task Order No. 0003**

**July 2011  
Revision 03**

Prepared by:

**NationViewIBhate JV III, LLC  
1608 13<sup>th</sup> Avenue South, Suite 300  
Birmingham, Alabama 35205**

**NationViewIBhate Project No. 9081001**

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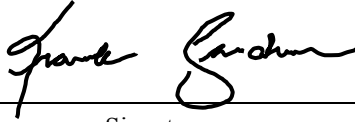
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**REVIEW SHEET**

This Report has been reviewed and approved by:

---

Katherine Thompson Geologist/Field Manager	Signature	Date
J. Mark Stapleton, Ph.D., P.E., AEE Technical Director	Signature	Date
Frank Gardner, P.G. Program Manager	 Signature	Date

---

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**CERTIFICATION**

I certify that I am a qualified groundwater scientist who has received a baccalaureate or postgraduate degree in the natural sciences or engineering, and have sufficient training and experience in groundwater hydrology and related fields, as demonstrated by state registration and completion of accredited university courses, that enables me to make sound professional judgments regarding groundwater monitoring and contaminant fate and transport. I further certify that I am a Professional Engineer for Bhate Environmental Associates, Inc., and this report was prepared by myself or by a subordinate working under my direction and that the information contained in this report is correct and accurate to the best of my knowledge.

---

J. Mark Stapleton, Ph.D., P.E., AEE  
Technical Director  
New Mexico Registered Professional Engineer  
No. 17492  
Expiration Date: December 31, 2012

Signature: \_\_\_\_\_

Date: \_\_\_\_\_



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Appendix D	ProUCL 4.00.04 Technical Guide - Input and Output File (Provided on CD)
Appendix E	Histograms
Appendix F	Box Plots
Appendix G	Normal Probability Plots (Q-Q Plots)
Appendix H	Stiff Diagrams
Appendix I	Piper Diagram

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## **ACRONYMS AND ABBREVIATIONS**

AAF	Army Air Field
AEE	Associate to the American Academy of Environmental Engineering
AF FM	Air Force Form
amsl	Above mean sea level
ASTM	American Society for Testing and Materials
bgs	Below ground surface
Bhate	Bhate Environmental Associates, Inc.
BWBG	Basewide background
CES/CEA	Civil Engineering Squadron/Asset Management Flight
COC	Chain-of-custody
COPC	Chemical of Potential Concern
DL	Detection Limit
DO	Dissolved oxygen
DOE	Department of Energy
DQO	Data Quality Objective
EDD	Electronic data deliverable
ERP	Environmental Restoration Program
ERPIMS	Environmental Restoration Program Information Management System
°F	Degrees Fahrenheit
ft	Feet
GPS	Global positioning system
HAFB	Holloman Air Force Base
HSA	Hollow Stem Auger
IDLs	Instrument detection limits
IDW	Investigation-Derived Waste
LCS	Laboratory control samples
LCSD	Laboratory control sample duplicates
MCL	Maximum Contaminant Level
MDC	Minimum Detectable Concentration
MDL	Method Detection Limit
meq/L	Milli-equivalents per liter
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
µg/L	Micrograms per liter
MS	Matrix spike
MSD	Matrix spike duplicate
NAD	North American Datum
NAPs	Natural Attenuation Parameters
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMWQCC	New Mexico Water Quality Control Commission

## ACRONYMS AND ABBREVIATIONS (CONTINUED)

NTUs	Nephelometric turbidity units
NVB	NationView/Bhate JV III, LLC
ORP	Oxidation reduction potential
OSWER	Office of Solid Waste and Emergency Response
pCi/L	PicoCuries per liter
P.E.	Professional Engineer
P.G.	Professional Geologist
PhD	Doctor of Philosophy
PPE	Personal protective equipment
ppb	Parts per billion
PQL	Practical quantitation limit
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
%R	Percent Recovery
RL	Reporting Limit
RPD	Relative Percent Difference
SOP	Standard Operating Procedure
SWMU	Solid Waste Management Unit
TAL	Target Analyte List
TDS	Total dissolved solids
USACE	United States Army Corps of Engineers
USAF	United States Air Force
USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
UTL	Upper Tolerance Limit
WRCC	Western Regional Climate Center
WSMR	White Sands Missile Range

## **EXECUTIVE SUMMARY**

NationViewIbhatte JV III, LLC (NVB) was retained by the United States Army Corps of Engineers (USACE), to conduct a Basewide Background Study at Holloman Air Force Base (HAFB), New Mexico. The objective of the soil and groundwater Basewide Background Study was to collect data of sufficient quantity and quality to enable statistical evaluation of background soil and groundwater characteristics. Data collection, laboratory analysis, and statistical treatment were performed in accordance with the Work Plan (NVB, August 2008) that was approved by the New Mexico Environment Department (NMED) on July 30, 2008. The objective of this study was achieved.

This report presents a summary of the work conducted at the base and background values based upon the calculated statistical analysis. The following steps were conducted in order to determine the background values:

- An evaluation of the Previous Background Study dataset and existing Environmental Restoration Program Information Management System (ERPIMS) database was conducted to consider combining the historical datasets with the new investigation to generate a more robust background dataset. A combined background dataset would increase the overall accuracy of the statistical evaluation and level of confidence in the resulting Upper Tolerance Limits (UTLs). However, on August 24, 2007, NMED indicated in the disapproval letter of the Previous Background Study that both the sample size and sampling locations were either too small or poorly described and did not provide confidence that the samples were collected at locations that are representative of natural conditions. In order to prevent potential error propagation from the Previous Background Study or incorporation of the ERPIMS datasets which contains limited information regarding natural conditions, HAFB will only use the data set that was collected for the background study.
- Collection and analysis of surface, subsurface, and saturated subsurface soil samples from 42 borings
- Collection and analysis of groundwater samples from 30 existing monitoring wells
- Performance of statistical evaluation of sampling data to establish background values

Based on the statistical analysis, the following conclusions/observations were made:

- Background levels are based on the 95% Upper Tolerance Limit (UTL) which represents an estimate of the upper 95<sup>th</sup> percentile of the true background concentration of the constituent of interest.
- The 95% UTL values were not calculated for antimony, selenium, silver, thallium, and carbon-14 in surface soil, subsurface soil, and saturated subsurface soil; and, 95% UTL values were not calculated for antimony, beryllium, lead, silver, thallium, tin, carbon-14, lead 210, and thorium 232 in groundwater due to the limited number of detections or the fact that all samples were non-detects. It should be noted that, if 1 to 3 of the measurements in the data set were non-detects, the UTL was set at 2 times the maximum detected value. If 100%

of the measurements in the data set were non-detect, the UTL was set to the lowest detection limit in the data set as required by the NMED.

- One UTL was developed for all three soil horizons (surface, subsurface, and saturated subsurface) although samples were collected from various depths
- One UTL for the combined soil (arsenic) exceeded the NMED Soil Screening Level.
- Twelve UTLs for groundwater (total) exceeded their respective federal Maximum Contaminant Levels (MCLs) and eight UTLs exceed the New Mexico Water Quality Control Commission (NMWQCC) Regulations (New Mexico Administrative Code [NMAC] 20.6.2).
- Four UTLs for groundwater (dissolved metals) exceeded their respective federal MCLs and no UTL exceeded the NMWQCC regulations in NMAC 20.6.2.

## **1 INTRODUCTION**

NationView|Bhate JV III, LLC (NVB) has been retained by the United States Army Corps of Engineers (USACE), under contract W9128F-07-D-0022, Task Order No. 0003, to conduct a Basewide Background Study at Holloman Air Force Base (HAFB), New Mexico (Figures 1-1 and 1-2). On August 24, 2007, the New Mexico Environment Department (NMED) notified the 49th Civil Engineering Squadron/Asset Management Flight (CES/CEA) at HAFB that it had completed its review of the document entitled *Base-wide Background Study, Sewage Lagoons and Lakes Investigation*, submitted in December 1993 by Radian Corporation (hereinafter referred to as the "Previous Background Study") and disapproved the Previous Background Study for several technical reasons. NMED indicated that the Previous Background Study was inadequate from a technical and statistical perspective and indicated that it must be completely redone. A copy of the NMED Disapproval letter is provided as Attachment 1 of this report. Following is a chronology of events following receipt of the disapproval letter:

- In November 2007 HAFB met with NMED to formulate the conceptual design for the new background study.
- In February 2008, HAFB submitted a Work Plan to conduct the necessary investigation to support a background study which included: identification of clean background soil boring locations (42); identification of existing wells appropriate for background study (30); development of statistical methodology; collection and analysis of surface soil, subsurface soil, and saturated subsurface soil samples from 42 soil borings located across HAFB for metals and radionuclides; collection of groundwater samples from 30 existing monitoring wells for metals, radionuclides, and natural attenuation parameters; and finally perform the statistical evaluation of sampling data to establish background values.
- On July 2, 2008, HAFB received comments from NMED on the Work Plan.
- On July 14, 2008, HAFB responded to NMED comments and began revising the Work Plan following verbal concurrence.
- In August 2008, the Final Work Plan was submitted and field activities commenced.
- In January 2009, the Basewide Background Study Report was submitted to NMED.
- On May 4, 2009, NMED provided comments (Notice of Disapproval) regarding the Basewide Background Study Report (provided in Attachment 2 of this report).
- On June 1, 2009, HAFB submitted responses to comments regarding the Basewide Background Study Report and requested a meeting for clarification.
- On June 3, 2009, HAFB and NMED personnel met in Albuquerque, New Mexico to discuss the response to comments regarding the Basewide Background Study Report.
- On August 11, 2009, HAFB and NMED met in Albuquerque, New Mexico to discuss the response to comments and additional verbal comments received during the June 3 meeting. NMED solicited graphic representation of the revised groundwater data using 24 wells instead of 30.



- On August 28, 2009, HAFB provided NMED a conceptual write up of groundwater geochemistry and revised groundwater concentration maps for the 24 wells as requested by NMED so that guidance on the revised data set could be provided to HAFB.
- On September 4, 2009, NMED replied via e-mail that additional guidance could not be provided until the entire document was re-submitted as a complete re-analysis of the data could not be performed.
- On November 3, 2009, HAFB submitted the Basewide Background Study to Air Force Center for Engineering and the Environment (AFCEE).
- On November 18, 2009, AFCEE provided comments regarding the Basewide Background Study Report and indicated that they concur with the technical approach used to develop the document.
- On December 7, 2009, the Revised Basewide Background Study Report was submitted to NMED.
- On October 28, 2010, NMED provided a second set of comments (Notice of Disapproval) regarding the Basewide Background Study Report (provided in Attachment 2 of this report).
- On December 17, 2010, HAFB submitted responses to comments regarding the Basewide Background Study Report and requested a meeting for clarification.
- On January 3, 2011, HAFB and NMED met in Albuquerque, New Mexico to discuss the response to comments received on October 28<sup>th</sup>, 2010.
- On July 13, 2011, NMED indicated via email that they were prepared to provide partial approval with respect to metals.

This document is the third revision of the Basewide Background Study Report which was submitted to the NMED in January 2009, and incorporates the comments made in the NOD letter. This document includes a Response to Comments table (included in Attachment 2 of this report following the NOD letters) which provides a response to how each line item was addressed within this document.

## **1.1 Objectives**

The primary objective of this report is to fulfill the requirements identified by the NMED in order to establish background values for the occurrence of certain naturally occurring inorganic constituents in both groundwater and soil. This report presents a summary of the work conducted at the base and background values developed based upon the calculated statistical analysis.

### **1.1.1 Purpose of the Basewide Background Study**

The purpose of this study is to establish background values for the occurrence of certain naturally occurring inorganic constituents in soil (surface, subsurface, and saturated subsurface) and groundwater.

### 1.1.2 Scope of Work

The scope of work and evaluation methods presented in this report were developed based on the previous background study report in concurrence with NMED. Additionally, the work plan which met scope requirements, was approved by NMED. The following list is a summary of the work performed in order to complete this Basewide Background Study.

- Held a scoping meeting at NMED in November 15, 2007, to frame the scope of work to be performed and discuss technical and statistical approaches
- Prepared and submitted a work plan
- Implemented the work plan which included the following:
  - identification of clean background soil boring locations (42)
  - identification of existing wells appropriate for background study (30) (see Figure 1-3)
  - development of statistical methodology
  - collection and analysis of surface soil, subsurface soil, and saturated subsurface soil samples from 42 soil borings located across HAFB (see Figure 1-4)
  - collection of groundwater samples from 30 existing monitoring wells
  - performance of statistical evaluation of sampling data to establish background values
- Prepared and submitted sampling data in the appropriate format for inclusion in the Environmental Restoration Program Information Management System (ERPIMS)
- Prepared and submitted this Basewide Background Study Report

### 1.2 Site Description

HAFB is situated in south central New Mexico, in the northwest central part of Otero County, approximately 75 miles north-northeast of El Paso, Texas (Figure 1-1). HAFB has a population of 6,000 and occupies 59,600 acres in the northeast quarter of Section 1, Township 17 South, Range 8 East. The White Sands Missile Range (WSMR) testing facilities occupy additional land extending northward from the Base. Private and public owned lands border the remainder of HAFB. The major highway servicing HAFB is Highway 70, which runs southwest from the town of Alamogordo and separates HAFB from publicly owned lands to the south. Alamogordo which has a population of approximately 35,000 is located approximately 7 miles east of the base.

HAFB was first established in 1942 as Alamogordo Army Air Field (AAF). From 1942 through 1945, Alamogordo AAF served as the training grounds for over 20 different flight groups, flying primarily B-17s, B-24s, and B-29s. After World War II, most operations had ceased at the base. In 1947, Air Material Command announced the air field would be its primary site for the testing and development of un-manned aircraft, guided missiles, and other research programs. On January 13, 1948, the Alamogordo installation was renamed Holloman Air Force Base, in honor of the late Col. George V. Holloman; a pioneer in guided missile research. In 1968, the 49th Tactical Fighter Wing arrived at HAFB and has remained since. Today, HAFB also serves as the training center for the German Air Force's Tactical Training Center.

### 1.3 Document Organization

The report is organized into the following chapters and appendices:

- **Chapter 1 – Introduction.** This chapter discusses the objectives of the Basewide Background Study and provides a site description.
- **Chapter 2 – Environmental Setting.** This chapter provides a description of the physiography and topography, surface water and hydrology, regional geology and soils, regional hydrogeology, climate, and current and future land and water use at the site.
- **Chapter 3 – Investigation Activities.** This chapter provides a description of all field activities conducted for the Basewide Background Study and a summary of the data quality objectives, standard operating procedures, sample identification, and project documentation.
- **Chapter 4 – Conceptual Site Model.** This chapter provides a description of the hydrogeologic framework and depositional environments that affect soil and groundwater chemistry.
- **Chapter 5 – Technical Approach.** This chapter provides a description of how the data collected for the Basewide Background Study was graphically and statistically analyzed.
- **Chapter 6 – Summary of Results and Observations.** This chapter provides a summary of the results and observations associated with the statistical analysis of the Basewide Background Study.
- **Chapter 7 – References.** This chapter provides references used in this Basewide Background Study Report.

The *Tables* and *Figures* referenced throughout this Basewide Background Study Report are included following the text (after Chapter 7). In addition, the following Attachments and Appendices are included:

- **Attachment 1** – NMED Disapproval Letter dated August 24, 2007
- **Attachment 2** - – NMED Disapproval Letter dated May 4, 2009, regarding the Basewide Background Study and Response to Comments
- **Appendix A** – HTW Drilling Logs
- **Appendix B** – Monitoring Well Sample Collection Forms
- **Appendix C** – Data Validation (provided in Hard Copy) and Laboratory Analytical Results (Provided on CD)
- **Appendix D** – ProUCL 4.00.04 Technical Guide (Provided on CD)
- **Appendix E** – Histograms
- **Appendix F** – Box Plots
- **Appendix G** – Normal Probability Plots (Q-Q Plots)
- **Appendix H** – Stiff Diagrams
- **Appendix I** – Piper Diagram



## **2 ENVIRONMENTAL SETTING**

### **2.1 Physiography and Topography**

HAFB is located within the Sacramento Mountains Physiographic Province on the western edge of the Sacramento Mountains (Figure 1-1). HAFB is approximately 59,600 acres in area, and is located at a mean elevation of 4,093 feet above mean sea level (amsl) (Figure 1-2). The region is characterized by high tablelands with rolling summit plains; cuesta-formed mountains dipping eastward and of west-facing escarpments with the wide bracketed basin forming the basin and range complex. The Base is located in the Tularosa Sub-basin which is part of the Central Closed Basins. The bordering mountains rise abruptly to altitudes of 7,000 to 12,000 feet amsl. The San Andres Mountains bound the basin to the west (about 30 miles) with the Sacramento Mountains approximately 10 miles to the east. At its widest, the basin is about 60 miles east to west and stretches approximately 150 miles north to south.

### **2.2 Surface Water and Hydrology**

The Tularosa Basin contains all of the surface flow in its boundaries. The nearest inflow of surface waters to the Base comes from the Lost River, located in the north-central region of the Base. The upper reaches of the Three Rivers and the Sacramento River are perennial in the basin. HAFB is dissected by several southwest trending arroyos that control the surface drainage. Hay Draw arroyo is located in the far north. Malone and Rita's Draw, which drain into the Lost River, and Dillard Draw arroyos are located along the eastern perimeter of the Base. Approximately 10,000 years ago, indications are of a much wetter climate. The present day Lake Otero encompassed a much larger area, possibly upwards of several hundred square miles. Its remains are the Alkali Flat and Lake Lucero. Lake Lucero is a temporary feature of merely a few inches in depth during the rainy season.

Ancient lakes and streams deposited water bearing deposits over the older bedrock basement material. Fractures, cracks, and fissures in the Permian and Pennsylvanian bedrock yield small quantities of relatively good quality water in the deeper peripheral. Potable water is only found from a handful of wells near the edges of the basin with more saline water towards the center. Two of the principal sources of potable water are a long narrow north-south trending area east of Tularosa and Alamogordo and in the far southwestern part of the basin. Alamogordo's water, as well as the Base's, is supplied from Lake Bonito (which is in the Pecos River Basin).

### **2.3 Regional Geology and Soils**

#### **2.3.1 Geology**

The sedimentary rocks which make up the adjacent mountain ranges are between 500 and 250 million years old (WSMR, 2003a). During the period when the area was submerged under the shallow intra-continental sea, the layers of limestone, shale, gypsum, and sandstone were deposited. In time, these layers were pushed upward through various tectonic forces forming a large bulge on the surface. Approximately 10 million years ago the center began to subside resulting in a vertical drop of thousands of feet leaving the edges still standing (the present day

Sacramento and San Andres mountain ranges). In the millions of years following, rainfall, snowmelt, and wind eroded the mountain sediments depositing them in the valley (i.e. Tularosa Basin). Water carrying eroded limestone, dolomite, gravel, and other matter continue to flow into the basin.

As the Tularosa Basin is a bolson, which is a basin with no surface drainage outlet, sediments carried by surface water into a closed basin are bolson deposits. The overlying alluvium generally consists of unconsolidated gravels, sands, and clays. Soils in the basin are derived from the adjacent ranges as erosional deposits of limestone, dolomite, and gypsum. A fining sequence from the ranges towards the basin's center characterizes the area with the near surface soils as alluvial, eolian, and lacustrine deposits. The alluvial fan deposits are laterally discontinuous units of interbedded sand, silt, and clay while the eolian deposits consist primarily of gypsum sands. The eolian and alluvial deposits are usually indistinguishable due to the reworking of the alluvial sediment by eolian processes. The playa, or lacustrine deposits, consist of clay containing gypsum and are contiguous with the alluvial fan and eolian deposits throughout HAFB. There has been the identification of stiff caliche layers, varying in thickness, at different areas of the Base.

### **2.3.2 Soils**

The United States Department of Agriculture (USDA) Soil Conservation Service has identified two soil associations in the vicinity of HAFB; the Holloman-Gypsum Land-Yesum complex, and the Mead silty clay loam. The permeability of these horizons ranges from  $4 \times 10^{-4}$  to  $1 \times 10^{-3}$  centimeters per second.

The Holloman-Gypsum land-Yesum complex, 0 to 5 percent slopes soil consists of large areas of shallow and deep, well drained soils and areas of exposed gypsum. The Holloman soil makes up about 35 percent of the complex. Typically, the surface layer is light brown very fine sandy loam about 3 inches thick. The upper 13 inches of the substratum is pink very fine sandy loam that is very high in gypsum. Below that, the substratum is white gypsum to a depth of more than 60 inches. This soil is calcareous and mildly alkaline to moderately alkaline throughout. Permeability is moderate, and available water capacity is very low.

Gypsum land makes up about 30 percent of the Holloman-Gypsum land-Yesum complex, 0 to 5 percent slopes. Typically, less than 1 inch of very fine sandy loam overlies soft to hard, white gypsum. The deep Yesum very fine sandy loam makes up about 20 percent of the complex. Typically, the surface layer is light brown very fine sandy loam about 3 inches thick. The upper 9 inches of the substratum is light brown fine sandy loam that is very high in gypsum. Below that, the substratum is pink very fine sandy loam to a depth of more than 60 inches. The soil is calcareous throughout and is mildly alkaline. Permeability is moderate, and available water capacity is moderate. Many fine gypsum crystals are found throughout the profile.

The soil type located across the main drainage area for the installation is Mead silty clay loam, 0 to 1 percent slopes. This deep, poorly drained, nearly level soil is on outer fringes of alluvial fans. This soil formed in fine textured alluvium over lacustrine lake sediment. It is very high in salt content because of periodic flooding and poor drainage. Slopes are smooth and concave.

Typically, the surface layer is reddish brown silty clay loam and clay loam about 5 inches thick. The substratum, to a depth of 48 inches, is light reddish brown clay that has a high content of salts. Below that, the substratum is lacustrine material of variable texture and color to a depth of more than 60 inches. Included with this soil are areas of Holloman soils and Gypsum land along the margins of the unit of steep, short gully sides and knolls. These inclusions make up about 15 percent of the map unit for this soil type. Individual areas are generally smaller than 10 acres. This soil is moderately calcareous throughout and is moderately to strongly alkaline. It has a layer of salt that is more soluble than gypsum. Permeability is very slow, and available water capacity is low.

### **2.3.3 Site Specific Geology**

Drilling activities were conducted from September 3 through September 20, 2008, using Hollow Stem Auger (HSA) technology and soil boring locations are shown on Figure 1-4. During drilling activities, soils were logged continuously down to the deepest sample collected (64 feet below ground surface [bgs] from sample BWBG-SB23). HTW Drilling Logs are provided in Appendix A of this report.

The overall geology of these soil borings consisted primarily of silts and sands (mostly silty sand) with higher gypsum content with increasing depth. Some borings consisted of clay lenses or mixtures of clayey sand and clayey silt. Samples were collected from the surface, subsurface, and the saturated subsurface zones and are discussed in further detail below. A cross-section is provided as Figure 2-1.

#### **2.3.3.1 Surface Soil**

Surficial soil samples were collected from the ground surface to 0.5 feet (ft) bgs. Surface soils consisted primarily of well sorted, very fine-grained silty sands.

#### **2.3.3.2 Subsurface Soil**

Subsurface soil samples were collected mid-way between the surface and the saturated zone. These samples were collected from depths ranging from 7 ft bgs to 30 ft bgs. These samples consisted primarily of silty sand. Some samples were collected in zones with higher sand content or higher silt content and only a few samples were collected in zones with clay contents. The subsurface geology generally consisted of silty sands near the surface and increased in both sand and clay content with depth, however, mixtures of silt and sand were predominate throughout the base.

#### **2.3.3.3 Saturated Subsurface Soil**

Saturated subsurface soil samples were collected immediately upon encountering groundwater within the saturated zone. These samples were collected from depths ranging from 15 ft bgs to 64 ft bgs. These samples consisted primarily of silty sand and sands. Very few samples were collected in zones containing some clay content.

## **2.4 Hydrogeology**

### **2.4.1 Regional Hydrogeology**

Groundwater occurs as an unconfined aquifer in the unconsolidated deposits of the central basin, with the primary source of recharge as rainfall percolation and minor amounts of stream run-off along the western edge of the Sacramento Mountains. Surface water/rainfall migrates downward into the alluvial sediments at the edge of the shallow aquifer near the ranges, and flows downgradient through progressively finer-grained sediments towards the central basin. Because the Tularosa Basin is a closed system, water that enters the area only leaves either through evaporation or percolation. This elevated amount of percolation results in a fairly high water table. Beneath HAFB, groundwater ranges from 5 to 50 feet bgs. Flow for the Base is generally towards the southwest with localized influences from the variations in the topography of the Base. In the northern and western portions of the Base, groundwater flows more to the west toward the Ritas Draw, Malone Draw, and Lost River drainages. Groundwater flow is affected by local topography in areas immediately adjacent to arroyos, where groundwater flows directly toward the drainages regardless of the regional flow pattern. A groundwater potentiometric surface map from measurements collected in September 2008 is provided as Figure 2-2.

Groundwater quality in the Tularosa Basin is of potable quality at the recharge areas in close proximity to the Sacramento Mountains and becomes increasingly mineralized toward the central portion of the basin and discharge areas. The majority (over 70%) of the Environmental Restoration Program (ERP) Sites/Solid Waste Management Units (SWMUs) located across HAFB have groundwater monitoring wells containing water with an average total dissolved solids (TDS) concentration greater than 10,000 milligrams per liter (mg/L). This TDS data supports the hypothesis that TDS concentrations below 10,000 mg/L at HAFB are caused by dilution of natural groundwater from leaking water lines and surface irrigation from the domestic water supply. TDS concentrations greater than 10,000 mg/L exceed the New Mexico Water Quality Control Commission (NMWQCC) limit as potable water and thus, the groundwater beneath HAFB has been designated as unfit for human consumption. Likewise, the United States Environmental Protection Agency (USEPA) guidelines have identified the groundwater as a Class IIIB water source, characterized by TDS concentrations exceeding 10,000 mg/L. Class IIIB groundwater is also characterized by a low degree of interconnection with adjacent surface waters or groundwater of a higher class. Groundwater does not discharge or connect to any adjacent aquifers because the Tularosa Basin is a closed basin. Adjacent surface waters include Lost River and Lake Holloman, which also have high concentrations of TDS, and are not considered potential drinking water sources.

### **2.4.2 Site-Specific Hydrogeology**

During field activities associated with this Basewide Background Study, 30 existing monitoring wells were measured and sampled (Figure 1-3). Depth to groundwater was measured prior to sampling and groundwater elevations were calculated based on the top-of-casing elevation. Groundwater elevations ranged from 4,031.21 ft amsl to 4,112.59 ft amsl. Based on the measurements collected in September 2008, groundwater generally appears to be flowing



towards the southwest. A groundwater potentiometric surface map is provided as Figure 2-2. Monitoring Well Sample Collection Forms are provided in Appendix B of this report.

## **2.5 Climate**

As a whole, New Mexico has a mild, arid to semi-arid continental climate characterized by light precipitation totals, abundant sunshine, relatively low humidity, and relatively large annual and diurnal temperature range (Western Regional Climate Center [WRCC], 2003). The climate of the Central Closed Basins varies with elevation. The Base is found in the low areas and is characterized by warm temperatures and dry air. Daytime temperatures often exceed 100 degrees Fahrenheit (°F) in the summer months and are in the middle 50s in the winter. A preponderance of clear skies and relatively low humidity permits rapid night time cooling resulting in average diurnal temperature ranges of 25 to 35°F. Potential evapotranspiration, at 67 inches per year, significantly exceeds annual precipitation, usually less than 10 inches. The very low rainfall amounts resulting in the arid conditions, which with the topographically induced wind patterns combining with the sparse vegetation, tend to cause localized “dust devils”. The annual rainfall for Alamogordo is 12 inches per year<sup>1</sup>. Much of the precipitation falls during the mid-summer monsoonal period (July and August) as brief, yet frequent, intense thunderstorms culminating to 30 – 40% of the annual total rainfall.

## **2.6 Current and Future Land Use**

The land surrounding HAFB consists of residential areas to the east and northeast (City of Alamogordo), rangeland to the south, the White Sands National Monument to the west, and areas where military activities are conducted to the north. The desert terrain of the area immediately surrounding HAFB has limited development, and there are no agricultural operations, residential communities, or large industrial operations located adjacent to the Base. HAFB is an active military installation and is expected to remain active for the foreseeable future. No transfer of military property to the public is anticipated, and public access to the Base is restricted (Foster Wheeler, 2002).

Residential development on the Base is limited by environmental and operational constraints imposed by the 100-year floodplain, historic sites, and areas identified under the Installation Restoration Program. Safety and noise zones also limit residential development on HAFB. Future plans for residential development on the Base include renovation of existing structures, replacement of inefficient buildings, and expansion into open areas in the southeast corner of the Base (HAFB, 2000). Future land use is not expected to differ significantly from current land use practices (Foster Wheeler, 2002).

## **2.7 Current and Future Water Use**

At present, the primary fresh water resource for the City of Alamogordo and HAFB is Lake Bonita, 60 miles northeast of the Tularosa Basin. Currently, there are no potable supplies of

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<sup>1</sup> <http://countrystudies.us/united-states/weather/new-mexico/>

groundwater or surface water located on the Base. HAFB obtains its water supply from the City of Alamogordo and the HAFB wells in the Boles, San Andres, and Douglas well fields at the base of the Sacramento Mountains. No water supply wells are located on or near the Base because of poor groundwater quality (TDS greater than 10,000 mg/L). The nearest production well downgradient from HAFB is a livestock well located 13 miles southwest of DP-63. There are no potable or irrigation wells near to or immediately downgradient of the Base (Foster Wheeler, 2002).

### **3 SAMPLING ACTIVITIES**

The purpose of this section is to describe the sampling activities associated with surface soil, subsurface soil, saturated subsurface soil (capillary fringe), and groundwater data collection used in order to establish background values for the occurrence of certain naturally occurring inorganic constituents. To meet the sampling objectives the following field activities were performed:

- Advancement of 42 soil borings,
- Collection of three soil samples per boring,
- Collection of groundwater samples from 30 existing monitoring wells with historically non-detect laboratory analyses, and
- Laboratory analysis of soil and groundwater samples.

Prior to sampling activities, an Air Force Form (AF FM) 332 and dig permit were submitted to the proper offices. All sampling activities were completed following the *Basewide Background Study Work Plan, Holloman Air Force Base, New Mexico* (NVB, August 2008) and standard industry practices.

#### **3.1 Field Activities**

##### **3.1.1 Sampling Requirements**

Field activities were performed in accordance with the *Site-Specific Addendum to the Basewide Health and Safety Plan* (Appendix A of the Work Plan), the *Quality Assurance Project Plan [QAPP] Addendum* (Appendix B of the Work Plan), as well as other USACE mandated procedures for laboratories. The field work for sampling activities was conducted in accordance with HAFB Standard Operating Procedures (SOPs) provided in the *Basewide Quality Assurance Project Plan* (Bhate, 2003a) and the *Bhate Standard Operating Procedures* (Bhate, 2002). These SOPs outline methodologies for soil boring advancement, soil sampling, soil sample description, groundwater sampling, sample management, equipment decontamination, and chain-of-custody procedures. Sample nomenclature followed the ERPIMS format. The specific HAFB SOPs used for the associated sampling are listed below:

- HAFB SOP-1, Documentation, Sample Handling, Chain-of Custody, and Shipping
- HAFB SOP-2, Sampling Equipment Documentation
- HAFB SOP-3, Staking, Utility Clearance, and Permitting
- HAFB SOP-5, Soil Sampling for Chemical Analysis
- HAFB SOP-6, Procedure for Field Screening of Volatile Organics
- HAFB SOP-7, Lithologic Description and Geotechnical Sampling
- HAFB SOP-8, Groundwater Sampling for Chemical Analysis
- HAFB SOP-10, Borehole Abandonment and Site Restoration

The following sections describe the procedures for soil sampling, groundwater sampling, and the analyses performed.

### **3.1.2 Soil Sampling**

Soil samples were collected from 42 borings located across the base which are shown on Figure 1-4. A total of three samples (surface, subsurface, and saturated) were collected from each boring using hollow stem auger technology. The samples were collected continuously with a 5-foot interval stainless steel sampler.

#### **3.1.2.1 Laboratory Analyses for Soil Sampling**

The analysis of soil samples collected for the Basewide Background Study followed the USEPA SW-846 protocol. The soil samples were analyzed for the following:

- Target Analyte List (TAL) Metals by USEPA Methods 6010B and 7471A
- Radionuclides by Methods C-01-1/E903.0/E904.0/STL-RC-0211/A-01-R

Samples submitted for laboratory analysis were labeled, handled, and prepared for shipment in accordance with HAFB SOP-1. The samples were placed on ice and shipped under strict chain-of-custody to TestAmerica Laboratories, Inc., in Arvada, Colorado and St. Louis, Missouri.

Tables 3-1, 3-2, 3-3, 3-4, 3-5, and 3-6 provide a summary of the soil and radiological analytical sampling results for the surface, subsurface, and saturated subsurface soils, respectively. Data Validation Reports and Laboratory Analytical Results for soil are provided in Appendix C of this report.

#### **3.1.2.2 Quality Control Samples**

Field duplicate samples were collected at a frequency of 10 percent and matrix spike and matrix spike duplicate (MS/MSD) samples were collected at a frequency of 5 percent. Homogenous quality control samples were collected from the same interval as the discrete sample. This method was used in order to achieve consistency between the discrete samples and their associated quality control samples.

The detection reporting limits for all analytical parameters and the quality assurance sampling requirements (duplicate and MS/MSD) are summarized in the QAPP Addendum previously provided in Appendix B of the Work Plan.

#### **3.1.2.3 Sampling Depths**

At each boring location, three discrete soil samples were collected from the surface (0-6 inches bgs), the subsurface (mid-point between the surface sample and the saturated zone), and the saturated zone. Samples depths for subsurface soil samples ranged from 7 to 30 feet bgs, and sample depths for saturated subsurface soil samples ranged from 15 to 64 feet bgs. The depths of the saturated subsurface sample locations were dependent upon the localized water table.

#### **3.1.2.4 Soil Description and Classification**

Each boring was visually classified and lithology described in the field according to HAFB SOP - 7 and the Unified Soil Classification System (USCS) (American Society for Testing and Materials [ASTM] D 2487-06 and ASTM D 2488-06) by a qualified geologist. HTW Drilling logs were completed in the field and are presented in Appendix A of this report to validate that the sampling locations demonstrated mineralogical uniformity across the base.

#### **3.1.2.5 Sampling Procedures**

All sampling equipment was decontaminated prior to sample collection using appropriate decontamination procedures. Before and during sampling, all decontaminated sampling equipment and bottles were placed on clean plastic sheeting to avoid contamination. Soil from the sampler was placed into the sampling jars provided by the laboratory. Excess soil around the top of the sample jars was wiped away with a clean cloth or paper towel to ensure the cap fit tightly. When all required sample jars were filled, excess soil was returned to the sampling site. New, disposable gloves were worn to collect each soil sample. Residual soil from the soil sampling was discarded in accordance with the waste management procedures established in Section 4.3 of the Work Plan, Investigation-Derived Waste (IDW) Management (NVB, August 2008).

#### **3.1.2.6 Identification System**

Each sample collected was identified on the sample label and chain-of-custody (COC) records, regardless of type. Sample documentation, handling, and shipping was conducted in accordance with HAFB SOP-1. Sample collection information inclusive of the container type and quantity for the soil samples collected during this background study was performed in accordance with the QAPP Addendum of the previously submitted Work Plan. An example of the sample identification nomenclature used for soil samples collected from the boreholes was as follows:

BWBG-SB01-5-a

Investigation identifier: BWBG = Basewide Background

Sample type identifier: SB = soil boring

Sequential soil boring number: 01, 02, etc.

Ending depth of sample interval: 5

Reserved for quality assurance (QA) sample identifiers: a = field duplicate, TB = trip blank, MS = matrix spike, MSD = matrix spike duplicate

#### **3.1.2.7 Survey**

Prior to leaving the sample location, a qualified surveyor located the boreholes using a global positioning system (GPS). All horizontal coordinates are referenced to the State Plane Coordinate System, New Mexico Central and surveyed to an accuracy of +/- 1.0 foot.

### **3.1.3 Groundwater Sampling**

Groundwater samples were collected from 30 existing monitoring wells located across the base which are shown on Figure 1-3.

#### **3.1.3.1 Laboratory Analyses for Groundwater Sampling**

The analysis of groundwater samples collected for the Basewide Background Study followed the USEPA SW-846 protocol. The groundwater samples were analyzed for the following:

- TAL Metals by USEPA Method 6010B and 7470A (filtered and unfiltered)
- Radionuclides by Methods C-01-1/E903.0/E904.0/STL-RC-0211/A-01-R
- Natural Attenuation Parameters (NAPs) by Methods SM18 2320B (alkalinity), SW846 4500-CL-C (chloride), 353.2 (nitrate), SM20-4500-NO2-B (nitrite), SM20-4500S-F (sulfide), SW846 9056 (sulfate), and E350.1 (ammonia)
- TDS by Method SM18 2540C

Samples submitted for laboratory analysis were labeled, handled, and prepared for shipment in accordance with HAFB SOP-1. The samples were placed on ice and shipped under strict chain-of-custody to TestAmerica Laboratories, Inc., in Arvada, Colorado and St. Louis, Missouri.

Table 3-7 and Table 3-8 provide a summary of the groundwater total metals (unfiltered) and dissolved metals (filtered) analytical results, respectively. Data Validation Reports and Laboratory Analytical Results for groundwater are provided in Appendix C of this report.

#### **3.1.3.2 Quality Control Samples**

Field duplicate samples were collected at a frequency of 10 percent and MS/MSD samples were collected at a frequency of 5 percent.

The detection reporting limits for all analytical parameters and the quality assurance sampling requirements (duplicate and MS/MSD) are summarized in the QAPP Addendum previously provided in Appendix B of the Work Plan.

#### **3.1.3.3 Sampling Procedures**

Prior to the collection of groundwater samples, depth-to-water and total well depth measurements were collected from each well using an electronic water level indicator. Field measurements of pH, temperature, dissolved oxygen (DO), oxidation reduction potential (ORP), conductivity, turbidity, and groundwater level were also recorded. Groundwater sampling activities were conducted in accordance with HAFB SOP-8. Monitoring Well Sample Collection Forms for the 30 wells sampled are provided in Appendix B of this report.

Monitoring wells were purged by pumping each well until the water level, pH, temperature, DO, ORP, conductivity, and turbidity stabilized by +/- 10 percent for at least three consecutive readings. It should be noted that turbidity readings ranged from 0.27 nephelometric turbidity units (NTUs) to 22.6 NTUs. High turbidity readings can indicate high metals concentrations,

however, based on the range of turbidity readings collected during sampling, turbidity is not expected to impact the laboratory analytical data for groundwater.

Groundwater samples were labeled, handled, and prepared for shipment in accordance with HAFB SOP-1. The samples were analyzed for TAL Metals, Radionuclides, NAPs (including alkalinity, ammonia, chloride, nitrate, nitrite, sulfate, and sulfide), and TDS. Samples collected for metals analysis were collected both filtered (using a 0.45 micron filter in the field) and unfiltered.

#### **3.1.3.4 Identification System**

Each sample collected was identified on the sample label and COC records, regardless of type. Sample documentation, handling, and shipping were in accordance with HAFB SOP-1. Sample collection information inclusive of the container type and quantity for the groundwater samples collected during this background study was performed in accordance with the QAPP Addendum in the previously submitted Work Plan.

The sample identification nomenclature for groundwater samples collected from the existing monitoring wells was based on the existing well identification number (i.e. SS61-MW11). QA sample identifiers were denoted after the well identification, as necessary (i.e. SS-61-MW11-a).

#### **3.1.3.5 Groundwater Elevations**

During the sampling of monitoring wells, groundwater elevations were determined. Elevations were measured for the 30 existing wells selected for the Basewide Background Study by using the top of casing elevation and the depth-to-water measurement. All horizontal coordinates are referenced to the State Plane Coordinate System, New Mexico Central and surveyed to an accuracy of +/- 1.0 foot. Vertical elevations are referenced to North American Datum (NAD) 1983 coordinates. A groundwater potentiometric map is provided as Figure 2-2 for the data collected in September 2008.

### **3.2 Data Quality Objectives Process**

To support the overall investigation objectives, Data Quality Objectives (DQOs) were established. The DQOs were qualitative and quantitative statements that specified the quality of data required to meet the goals of the basewide background study. The DQOs were expressed in terms of precision, accuracy, representativeness, comparability, completeness, and sensitivity. Data developed during this basewide background study will be used to support site-specific studies of existing and/or potential solid waste management units in the area.

DQOs were used to:

- Ensure data comparability through the use of standard methods and controlled systems to collect and analyze samples;
- Provide analytical results of known and acceptable precision and accuracy; and to provide a minimum of 95 percent data completeness for analytical results representing each matrix-method combination.

The level of analytical support utilized to meet these goals was both screening (pH, temperature, dissolved oxygen, oxidation reduction potential, and turbidity) and definitive data. As part of the analytical reporting requirements for the definitive data, both reporting laboratories provided the following data, in addition to the data deliverables, as described in the QAPP Addendum found in Appendix B of the previously submitted Work Plan:

- Sample identification numbers cross-referenced with laboratory identification numbers and quality control (QC) sample numbers,
- Problems with arriving samples noted on chain-of-custody,
- Analytes reported as an actual value or less than a specified detection limit, and
- Dilution factors, preparation dates, and analysis dates.

QC sample results for laboratory blanks, MS, laboratory control samples (LCS), and field duplicates were used to evaluate the reliability of the data. The data quality objectives expressed in terms of precision, accuracy, representativeness, completeness, comparability, and sensitivity, are discussed below.

### 3.2.1 Precision

Precision is a measure of the degree of reproducibility of an analytical value and was used as a check on the quality of the sampling and analytical procedures. Laboratory replicates, field duplicates, and duplicate analysis (such as MS/MSD and LCS/LCS duplicates [LCSD]) were used to quantify precision. Laboratory replicates measured the analytical method precision, whereas field duplicate analysis provided a precision measurement that included the sampling procedures and the potential variability of the sample matrix.

Precision of the analytical method, at each stage was expressed in terms of a relative percent difference (RPD) between duplicate determinations. A detailed calculation of the RPD is presented in the *Basewide QAPP*. Soil sample measurements were usually less precise than water sample measurements because it was more difficult to achieve a homogeneous, representative sample. Based on this, the precision targets for soil field duplicates were an RPD of 50 or less, while the target water matrix RPD was 35 or less. The laboratory RPDs are presented in the QAPP Addendum in Appendix B of the previously submitted Work Plan.

Field duplicates were collected at the frequency of one in 10 field samples collected. MS/MSD samples were collected at a frequency of one set per 20 samples. Precision calculations are presented in the Data Validation Reports provided in Appendix C of this report.

### 3.2.2 Accuracy

Accuracy is the degree to which a measurement agrees with the actual value, i.e., the amount of measurement bias. Accuracy was expressed as a percent recovery (%R) of a known concentration of reference material. For this background study at HAFB, MS/MSDs were used to determine the accuracy for a given method and sample matrix. An aliquot of a normal sample was designated as the MS/MSD. The laboratory spiked the MS/MSD sample set as described below.



The spiked compounds included representative compounds that were quantified during the method, and spiked during sample preparation, on a specially prepared aliquot of the sample matrix. Results of those spiked aliquots were then compared to the original concentrations of the analytes spiked, and a %R was calculated. The %R of the spiked compound was used as an assessment of analytical accuracy on the sample matrix analyzed, which was essential in identifying sample matrix interferences. The %Rs were between 48 and 203 percent with some exceptions. See the individual Data Validation Reports provided in Appendix C of this report for these exceptions.

### 3.2.3 **Completeness**

Data completeness represented the percentage of valid data collected from a sampling/analytical program or measurement system compared to the amount expected to be obtained under optimal conditions. The completeness goal for the definitive water matrix samples was 95% while the definitive soil matrix goal was 90%. The completeness results were calculated following data validation and review. The 95% goal was met as the data was 100% complete.

### 3.2.4 **Representativeness**

Representativeness is a qualitative parameter that expresses the degree to which sample data actually represent the matrix conditions. Requirements and procedures for sample collection and handling were designed to maximize sample representativeness. Representativeness was also monitored by reviewing field documentation. The determination of the representativeness of the data was performed by:

- Comparing actual sampling procedures and chain of custody forms to those described in the work plan,
- Identifying and eliminating non-representative data in basewide background study, and
- Evaluating holding times and condition of samples on arrival at the laboratory.

The objective of this element was to eliminate all non-representative data. As collected, the field samples represented the geographical areas that were required to accurately define the Holloman basewide background concentrations.

### 3.2.5 **Comparability**

Comparability is a qualitative measure of the confidence with which one data set can be compared to another. These data sets include data generated by different laboratories, data generated by laboratories in previous investigative phases, data generated by the same laboratory over a period of several years, or data obtained using differing sampling techniques or analytical protocols. The measurement comparability objective for this Background Study was to generate consistent data using standard test methods, standard field data sheets, and uniform concentration units. These data are intended to be accepted and used by other investigators who are considering specific sites within the HAFB.

The data set was generated and will be used as a baseline for the background level concentrations. Future investigations will use this data for background baseline concentrations.

### 3.2.6 Sensitivity

Sensitivity is a general term referring to the calibration sensitivity and the analytical sensitivity of a piece of equipment, used to establish detection/quantitation/reporting limits. Several limits have been established to describe sensitivity requirements (i.e. instrument detection limits [IDLs], method detection limits [MDLs], minimum detectable concentrations [MDCs], and reporting limits [RLs]). Since IDLs and MDLs are normally based on a reagent water matrix or a purified soil matrix, published IDLs and MDLs are presumed not to be consistently achievable for environmental samples. It is because of this inconsistency and the goal to promote the generation of comparable data that the following definitions were used to meet the project DQOs:

- Instrument Detection Limit – The IDL references the absolute limit of detection for a compound or analyte in a media that is free from matrix interferences at a level greater than two times the noise level of the instrument. Certain programs require the laboratory to publish IDLs on an annual basis; however, achievement of these detection levels generally cannot be met during routine analyses.
- Method Detection Limit – The MDL is the minimum concentration of an analyte that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero, and is determined from the analysis of sample in a given matrix containing the analyte. The laboratory is required to perform an MDL study during the initial setup of the analytical procedure and annually thereafter. An MDL study is also performed whenever the basic chemistry of the procedure is changed. When MDLs are reported with analytical data, they should be adjusted for sample weight, moisture content, and volumetric dilution on a per-sample basis. The project specific MDLs were presented in Tables 4-2 and 4-4 of the QAPP Addendum found in Appendix B of the previously submitted Work Plan.
- Minimum Detectable Concentration – The minimum radionuclide concentration that must be present in a sample to give a specified probability of detecting the radionuclide and is expressed in concentration units relative to the sample weight or volume.
- Reporting Limit - The RL is the threshold value below which the laboratory reports a result as non-detected and is established at a level between the laboratory's Practical Quantitation Limit (PQL) and the level needed to meet project requirements. The RL is usually based upon project-specific requirements including risk-based concentrations of concern, or regulatory action levels. RLs should be adjusted based on the sample matrix and any necessary sample dilutions. The RLs for this project were presented in Tables 4-2 and 4-4 of the QAPP Addendum found in Appendix B of the previously submitted Work Plan.

### 3.2.7 Data Validation

Data validation includes the elements of verification, in which a complete accuracy check of the laboratory hardcopies are checked against the electronic data deliverable (EDD), in order to assure agreement; however, the assessment process was designed to result in data that are of "known" accuracy and precision. Individual data that cannot be validated under established criteria for acceptance are flagged to indicate that the results are either estimated, or unusable.

Validation is an alternative to adversarial review and was performed by a qualified chemist who exercised the use of professional judgment during the validation process.

Data validation was performed on 100% of the definitive analytical data and was conducted by the NVB Project Chemist, in order to verify compliance with the QAPP and the specified methodology. Data validation procedures were based on the *USEPA National Functional Guidelines for Inorganic Data Review* (USEPA, 2004) and the *Evaluation of Radiochemical Data Usability* (Department of Energy [DOE], 1997). Upon completion of the data validation process, the usability of the data was determined.

It was determined that 100% of the definitive data was usable based on the data validation reports. Although some data points were qualified as estimated, J, those data points were not rejected and were therefore considered usable.

It should be noted that, in one instance, the EDD did not agree with the hardcopy data report. Sample BWBG-SB-18-18 indicated the incorrect concentration on the EDD for Radium 228. The concentration provided on the EDD was from the same boring but the wrong depth. In such cases, the hard copy always takes precedence over the EDD. This disagreement does not impact the data because the data from the hard copy was used in our summary tables and statistical analysis.

### **3.3 Investigation-Derived Waste Management**

The soil sampling locations and the groundwater monitoring wells were chosen based on previous investigations, therefore, these locations were not considered to be contaminated. All material generated while drilling was used to backfill the borehole and/or spread on the ground at the boring. Purge water was also spread on the ground at the monitoring well location. Personal protective equipment (PPE) and other site non-hazardous debris/waste was disposed of in standard trash receptacles.

### **3.4 Site Restoration**

Upon completion of the sampling activities, the sampling locations were restored to their original condition. Soil sampling locations were backfilled with soil cuttings and bentonite.

## 4 CONCEPTUAL SITE MODEL FOR GROUNDWATER

### 4.1 Background Information

Historical and recent literature document that HAFB is located within a very saline portion of the Tularosa basin where groundwater with TDS greater than 10,000 mg/L is typical (see Figure 4-1 adapted from the New Mexico Water Resources Institute [NMWRRI], June 2002). McLean (1970) also observed the same conditions as presented on Figure 4-2. The literature is further supported by recent groundwater sampling performed for the background study and numerous previous sampling events associated with corrective action investigations at the base where TDS concentrations in excess of 70,000 mg/L have been observed and reported. Observation of TDS concentrations less than 10,000 mg/L have also been observed but only in wells located in developed areas of the base, a condition attributed to the anthropogenic effects of leaking fresh water lines and irrigation activities.

The following documents were used as reference materials for the development of the conceptual model for groundwater at HAFB:

1. Fryberger, S.G. 2009. Geological Overview of White Sands National Monument <http://www.nature.nps.gov/geology/parks/whsa/geows/index.htm>
2. Geo-Marine. 1996. Delineations of Jurisdictional Waters of the United States and Wetlands on Holloman Air Force Base, New Mexico. U.S. Army Corps of Engineers, Fort Worth District, Fort Worth, Texas.
3. Herrick, C.L. 1904. Lake Otero, and ancient salt lake in southeastern New Mexico: *American Geologist*, v. 34, p. 174–189.
4. McLean, J.S. July 1970. “Saline Ground-Water Resources of the Tularosa Basin, New Mexico,” U.S. Department of Interior, Office of Saline Water No. 561.
5. Meinzer, O.E., and Hare, R.F. 1915. Geology and water resources of Tularosa Basin, New Mexico. U.S. Geological Survey Water Supply Paper 343, 317 p.
6. NMWRRI. June 2002. Tularosa, Sacramento River and Great Salt Basin Regional Water Plan.
7. Wilkins, D.W. 1986. Geohydrology of the Southwest Alluvial Basins Regional Aquifer-Systems Analysis, Parts of Colorado, New Mexico, and Texas U.S. Geological Survey Water-Resources Investigations Report 84-4224.

HAFB is located on the northwest corner of a large alkali flat or playa feature measuring approximately 120 miles square that emanates from alluvial fan drainage features along the western flank of the Sacramento Mountains (see Figure 4-3). The sediments underlying the base are comprised of older basin fill (Miocene) which is overlain by lacustrine (gypsiferous lake floor) and fluvial sands and silts (distal piedmont sediments) of Pleistocene to Recent age that are several thousand feet thick (Fryberger, 2009). Fryberger (2009) also noted the younger valley fill has a basin-centered pattern, with rather porous and permeable fluvial sands and gravels from alluvial fans around the edge of the basin, and much less porous and permeable

silty or evaporitic facies in the lower central portions of the basin. The 42 soil borings advanced during the background study encountered gypsiferous lacustrine and fluvial sediments as documented in the lithologic logs presented in Appendix A of this report. The evaluation and analysis of the analytical data concluded that the soils are statistically from the same parent material and cannot be further subdivided.

## **4.2 Groundwater Recharge**

Groundwater recharge in the Tularosa Basin occurs largely from rainfall and snowmelt in the Sacramento and San Andres mountains, where intermittent stream flow infiltrates into the coarse, loosely consolidated alluvial fan material. Although stream flow is greatest during the summer monsoons, most recharge occurs in the winter months (Wilkins, 1986). Recharge for the Tularosa Basin was estimated to be greater than 100,000 acre-feet per year, with the greatest portion accumulating at the base of the Sacramento Mountains (Meinzer and Hare, 1915).

HAFB lies within the ground flow gradient from the Sacramento foothills to the lowest point within the basin, Lake Lucero, to the southwest of the main base. Groundwater at the margins of the basin within the bajada of the Sacramento Mountains grade from fresh water (containing less than 1,000 mg/L TDS) to highly alkaline sources near the center of the basin with more than 100,000 mg/L TDS (Geo-Marine, 1996). The evidence of recharge (and dissolution of evaporates that are in turn carried toward the White Sands) is quite dramatic in the basin, due to the shallow evaporates of either Pliocene or Permian origin that have been dissolved by fresh water. Herrick (1904, p. 187) noted that the sand dunes on the eastern side of White Sands serve as a dam for storm water runoff from the Sacramento mountains (Lost River and Dillard Draw). Infiltration from the ponded water accelerates the solution of the underlying Quaternary lacustrine deposits, forming many sinkholes and caverns and increasing the TDS concentrations in groundwater associated with the drainage networks.

The primary hydrologic processes in this desert ecosystem are summer monsoons and large storm events falling on the rocky slopes of the Sacramento Mountains. Most of the thunderstorm precipitation is absorbed quickly into the gravels and sandy surfaces at the base of the alluvial fans. At the terminus of the alluvial fan channels, ephemeral playa-like depressions can hold water for several weeks, creating hydric soil conditions (Geo-Marine, 1996). A hydric soil is a soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part. Ephemeral flats occur most notably within the low lying area between Lake Holloman and Lagoon G but also are dispersed sporadically throughout the various drainages. These flats are generally not densely vegetated but may have an algal layer on the surface (Geo-Marine, 1996).

## **4.3 Surface Drainage**

There are at least nine prominent east-west drainages on the base that receive intermittent flows during seasonal thunderstorms, including several which are 100-year floodplain zones. These areas are associated with the presence of alluvial floodplain soils and are present within Dillard Draw; Lagoon G; Malone, Ritas, and Allen Draws; and Lost River drainages. The flood-prone areas associated with Allen, Malone, and Ritas Draws and the Lost River are within the more

remote, less densely developed sections of the base. These drainages are broad and deeply entrenched where extensive downcutting has occurred by as much as 50 feet below the basin floor. The largest of these drainages is the Lost River drainage system, including Malone Draw and Ritas Draw.

Ephemeral drainage features bound the southern and southeastern areas of the base. Much of the southern area of the base appears to have been built over the playa feature discussed above and illustrated on Figure 4-4. The most pronounced drainage feature begins along the southeastern boundary of the base where Dillard Draw forms as the result of multiple drainages (six counted on Figure 4-3), emanating from the alluvial fan feature west of the Sacramento Mountains, combine. Prior to extensive management of the surface topography and construction of U.S. Highways 70/54, Dillard Draw emptied into the main base, creating a network of alkali flats and ephemeral playas including what are now Lake Holloman, Stinky Playa, and Lagoon G. Much of the main base was built over this network. Ephemeral flats and vegetated wetlands have developed north of the golf course as a result of the diversion of drainages associated with construction of U.S. Highway 70/54. The remnant ephemeral playas south of U.S. Highway 70/54 are classified as “active sands” associated with the White Sands Geomorphic Map (Fryberger, 2009, Figure 2-17A) which is provided as Figure 4-5. The historic desert wetland ecosystem that existed between Lagoon G and Lake Holloman has been enhanced to form a “constructed” wetland to provide valuable habitat for wildlife. These wetlands contain a network of earthen berms and channels to direct storm water runoff from the cantonment area and treated wastewater effluents into these alkali flats. Flows into the completed constructed wetlands began in November 1997. A synergistic effect of capturing runoff from the cantonment area in addition to the natural drainage area serviced by Dillard Draw has been the concentration in natural abundance of dissolved solids in groundwater in this area of the base.

Dillard Draw continues south across Highway 70 and appears to braid out to the southwest into a prominent playa feature characterized with noticeable alkali deposits paralleling the southern boundary of the base along Highway 70. Several wells sampled during the background study are located within this drainage complex including S1-MW2, S1-MW5, S10-MW4, and MW19-03. The latter well is located within this playa feature and exhibits some of the highest concentrations for TDS, uranium, manganese, potassium, chloride, sodium, and sulfate observed during the background study. Two more drainages truncate the base from east to west to the north of the airfield. The southern most of these drainages ultimately is known as the Lost River but has a southern fork named Ritas Draw where well MW-BG-04 is located. As with other wells located in or adjacent to the historic drainage features, well MW-BG-04 also exhibits some of the highest TDS concentrations observed during the background study. In contrast, well MW-04-01 located approximately 1,000 feet southwest of MW-BG-04, has significantly lower TDS concentrations. The reason for these different concentration profiles is attributed to the fact that MW-BG-04 is located within the drainage area and is representative of shallow saline groundwater affected by ponding, while MW-04-01 is located outside of the drainage network.

#### **4.4 Distribution of Total Dissolved Solids**

The distribution of the highest TDS and ion concentrations in groundwater correlate well with the drainage and playa network previously described. The occurrence of the higher

concentrations in association with the regional drainage features is attributed to episodic runoff events that have concentrated the dissolved solids and ions in the groundwater underlying the playa and drainage networks over time. Fryberger (2009) noted that several factors in the climate and hydrology of the Tularosa basin cause strong seasonal phenomena to occur in the depositional system at White Sands. Primarily these factors are: (1) the presence of widespread shallow groundwater, (2) seasonally high evaporation and evapotranspiration rates due to extreme heat and strong winds, and (3) sudden influxes of fresh water into the saline groundwater system by flash floods and rainstorms. These factors can cause sudden and extreme changes to water table levels and groundwater salinity, sometimes quite locally.

The distribution of the higher concentrations of TDS and ions is typically associated with four monitoring wells (TDS-MW02, MWBG-04, S1-MW2, and MW19-03) shown on Figure 4-6. The TDS concentrations measured during the background study range up to 50,000 mg/L with a mean concentration of approximately 22,000 mg/L. This is in good agreement with the literature for the region suggesting HAFB overlies a saline groundwater unit that is more than 1,000 feet thick with TDS concentrations ranging from 10,000 to 35,000 mg/L. The alignment of high TDS and ionic concentrations associated with wells located near drainage features and ephemeral playas would indicate the distribution of these constituents is consistent with the regional literature.

#### 4.5 Geochemical Evaluation

The geochemical evaluation of the groundwater data using stiff diagrams superimposed on the TDS concentration map (Figure 4-6) provides a useful comparison tool. The wells exhibiting the highest TDS concentrations correspond with the highest sodium/chloride dominated water. In fact, there is a linear relationship between TDS and sodium/chloride dominated groundwater across the map that would suggest the variability in ion concentrations is proportional to TDS concentration. It should be noted, however, this variability is to be expected given the diverse physiography of the Tularosa Basin that led to a complex drainage system which contributed fill material from various sources depending on climate at the time of sedimentation which has subsequently been altered by fresh water infiltration (irrigation and leaking water lines) in the developed areas of the base.

A useful means of depicting the relative major solute composition of a groundwater is by a Schoeller Plot (Schoeller, 1935). These plots are drawn by plotting logarithmic concentrations of major solutes (in milli-equivalents/litre [meq/L]) in a water, in the order  $\text{Ca}_2^+$ ,  $\text{Mg}_2^+$ ,  $(\text{Na}^+ + \text{K}^+)$ ,  $\text{Cl}^-$ ,  $\text{SO}_4$ , and  $\text{HCO}_3 + \text{CO}_3$  (measured alkalinity). The slope of each line joining the points represents the concentration ratios  $\text{Ca}/\text{Mg}$ ,  $\text{Mg}/(\text{Na} + \text{K})$ ,  $(\text{Na} + \text{K})/\text{Cl}$ ,  $\text{Cl}/\text{SO}_4$ ,  $\text{SO}_4$ ,  $\text{HCO}_3 + \text{CO}_3$  (measured alkalinity) respectively, and the resultant shape that derives from these ratios constitutes a signature for the aquifer in terms of the major solute content of the water. Schoeller plots provide a convenient means for sorting waters into groups, as a first step in identifying the presence of different lithologies. Equilibrated groundwater from a specific rock type produces a known Schoeller Plot signature. Although waters from all aquifers of these types do not conform exactly to these shapes, specific aquifer lithologies are often identifiable from the ratios of major ion concentrations.

The Schoeller plots and resultant signatures provide a convenient means of determining if the groundwater is from different lithologies. Figure 4-7 provides a Schoeller plot signature for the major solute content of the aquifer under HAFB using the 24 wells from the basewide background study. In general, the shapes or signatures from the individual 24 curves indicate that the ratios of major ion concentrations are from the same aquifer lithology. This provides additional graphical evidence utilizing several key constituents to support a single population for groundwater.

Based on the information provided in this conceptual model the following conclusions are offered:

1. The distribution of TDS and relative proportions of individual ions is controlled by drainage regimes that have served to locally concentrate the TDS and ions along ephemeral playas and existing drainages. Freshwater infiltration from developed areas of the base have further modified these regimes to create more apparent variation.
2. The dynamics that have controlled depositional environments in the Tularosa Basin have largely been controlled by climate changes and diverse physiography. This has led to a groundwater environment that exhibits some variations in ionic distribution but ultimately can be statistically considered to be of the same population.
3. Graphical representation of the groundwater data with the Schoeller plots further suggests that the groundwater data set is from a single general lithologic source.



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## **5 TECHNICAL APPROACH**

The following technical approach is to provide HAFB environmental restoration project teams and NMED with details on how the data that was obtained for this background study was graphically and statistical analyzed.

A scientific approach was used to determine the type, quantity, and quality of environmental data needed to support establishing background values at HAFB. This provided the scientific foundation for defensible decision-making by helping to assure that representative field samples were collected at appropriate locations and times, that appropriate graphical and statistical analyses of the resulting data were conducted, and that appropriate interpretations of the data and statistical analyses were made. The following sections include discussions of primarily two different data sets. References to “Raw Data” means that the analytical results were used as reported in the summary tables without modification. The summary tables are Tables 3-1 through 3-6 for soils and Tables 3-7 and 3-8 for groundwater. Reduced Data implies that the data in the summary tables have been analyzed for statistical outliers using the NMED recommended Grubbs test, also known as the maximum normalized residual test or Discordance Test (see Section 5.6.4 of this report). If the test indicates the suspect value(s) are indeed outliers, then the value(s) were removed from the data set. Additionally, six groundwater monitoring wells (MW-24-03, MW-13, MW22-03, MW-1, MW-23-01, and MW-6) contained roots that were observed during sampling or were potential impacted by biological activity. These six wells and the associated data were removed from the reduced data sets (see Section 5.4 of this report). Therefore, the reduced data sets for total groundwater and dissolved metals are based on the remaining 24 groundwater wells.

### **5.1 Sample Location Selection**

Background soil sampling locations were selected using aerial photographs and historical base maps to identify areas with no apparent construction or waste disposal activities and areas which have been undisturbed. These locations were selected to encompass the entire base including the range and industrial areas. Soil sampling locations are shown on Figure 1-4.

The groundwater sample population was derived from the existing monitoring wells located throughout HAFB. Current and historical sampling data, as well as lithologic data, was reviewed in order to select wells that have consistently had organic concentrations less than 5 parts per billion (ppb) and wells constructed within the same hydrostratigraphic unit. Based on communication with NMED, monitoring wells with minor organic contamination could be used as part of this study, provided there is no impact to metals concentrations. From this group, 30 monitoring wells were selected randomly across the base in order to have a representative population of the entire base. Groundwater sampling locations are shown on Figure 1-3 and are listed below.

MW-04-01	MW-29-01	S10-MW4
MW-1	MW30&33-1	S1-MW1

MW-13	MW30&33-2	S1-MW2
MW-19-03	MW37-06	S1-MW5
MW-21-04	MW-38-01	SS61-MW01
MW-22-03	MW3903	SS61-MW11
MW-23-01	MW41-03	TDS-MW01
MW-24-01	MW-58-03	TDS-MW02
MW24-03	MW-6	TDS-MW03
MW24-05	MW-BG-04	TDS-MW04

## 5.2 Determination of Number of Samples

Based on the regional soil descriptions (contained in section 2.3.2 of this report), these soils have the same parent materials, the same history, and very similar pedologic and mineralogic properties. Accordingly, NVB sampled throughout the area, treating the entire installation as a single population for statistical purposes. Based on a study of the soils and lithology involved, discrete samples were collected from the surface from 0 to 6 inches bgs, the subsurface from 6 inches bgs to above the saturated zone, and from the subsurface within the saturated zone. Sample depths varied based on the depth to groundwater. Tables 3-1, 3-2, 3-3, 3-4, 3-5, and 3-6 provide a summary of the soil analytical sampling results for the surface, subsurface, and saturated subsurface soils, respectively. Tables 3-7 and Table 3-8 provide a summary of the groundwater sampling results including total metals and dissolved metals, respectively.

Any sampling plan requires a known or estimated population distribution in order to establish the number of samples needed to achieve a given reliability goal. Information available from previous investigations was used to estimate statistical parameters to 'size' the study. Previous data may or may not be representative of background, but no attempt has been made to qualify earlier data for use in calculation of background. However, the distribution of data from previous investigations provides the best available estimate of the statistical parameters involved.

NVB determined the number of samples required to reliably determine background concentrations by carrying out the following analysis, using the t-statistic, the calculated standard deviation, *s*, of observations of arsenic concentrations from previous investigations and asserting that the desire is to know, at the 95% confidence level ( $\alpha = 0.05$ ), the mean of the concentration in the surface soils to within 0.5 milligrams per kilogram (mg/kg).

$$n = (t^2 * s^2) / d^2$$

where:

- n     number of samples to be collected
- t     the t-statistic for  $\alpha = 0.05$  and the degrees of freedom determined from the previous investigations
- s     the calculated standard deviation from the previous investigations, and

d the desired error bound, 0.5 mg/kg

Data from previous investigations show (for 230 surface samples)  $s = 1.6$ . The corresponding value of “t” is 1.98 (WSMR, 2003b). Substituting, solving for n, and rounding up yields a minimum sample number of 41. NVB collected samples from 42 borings.

To derive the number of samples needed for determination of background groundwater concentrations using the same statistical approach was not plausible given the variability in samples for metals and select radiological constituents. Therefore, the Work Plan proposed to sample 30 monitoring wells. Existing well locations at HAFB were selected as NMED did not require that soil boring and groundwater data be collocated for this background study.

The method described above was also used to determine if the appropriate numbers of samples were collected for this study for each constituent/media. For a given constituent/media, if the number of samples was not adequate, the Work Plan indicated that additional samples would be collected and analyzed as necessary to correct the deficiency in sample size.

As required by comment No. 3 in NMED correspondence dated May 4, 2009 (provided in Attachment 2 of this report), NVB used the same method on the three soils horizons raw data sets to determine whether the appropriate number of samples was actually collected for each constituent, using the corresponding sample standard deviation calculated for each constituent in the background study. Table 5-1 provides a summary of the appropriate number of samples for the surface, subsurface, and saturated subsurface soils, respectively. It should be noted that, if the population from which the data to be analyzed by t-statistic violates one or more of the t-statistic assumptions, the results of the analysis may be incorrect or misleading. For example, if the assumption of normality is violated, then the use of t-statistic is simply not appropriate.

### **5.3 Combining Historical Data Sets**

Combining two or more historical data sets to form a larger data set may improve the ability of statistical tests to detect when a contaminant is a chemical of potential concern (COPC). For example, soil samples may have been collected and measured for the same suite of chemicals at several different times in the land area of concern at HAFB. Pooling the historical data would increase the number of samples available for conducting a statistical test for a COPC and could increase the chances the test result will be accurate. However, an inappropriate combining of historical data sets can have the opposite effect. Ideally, the data sets being considered for pooling should have been obtained using the same sampling design that was applied to the same area of land. On August 24, 2007, NMED indicated in the disapproval letter of the Previous Background Study that both the sample size and sampling locations were either too small or poorly described and do not provide confidence that the samples were collected at locations that are representative of natural conditions.

In order to prevent potential error propagation from the Previous Background Study, NVB recommended an entirely new data set be collected. New sampling data was collected in September 2008 and was used to provide the statistical analysis for this report.

Soil sampling data was collected from three separate horizons (surface, subsurface, and saturated subsurface zones).

#### 5.4 Well Rooting and Reduced Environments

During the groundwater sampling for the basewide background study, NVB field technicians observed roots within the well casings of monitoring wells MW-24-03, MW-13, and MW22-03. The groundwater data set was then evaluated to include well integrity issues. After reviewing the sample collection data sheets, it was determined that six wells may have been compromised due to the presence of roots in the well screens. Three of these wells (MW-24-03, MW-13, and MW22-03) had roots observed during sampling. Three additional wells (MW-1, MW-23-01, and MW-06) were evaluated for potential impact by rooting and suspect biological activity by examining the dissolved oxygen, oxidation reduction potential measurements, chloride, sulfate, nitrate, iron, and TDS.

Dissolved oxygen for MW-1, MW23-01, MW-13, and MW-6 indicated anaerobic conditions or DO concentrations less than 0.5 mg/L. Furthermore the oxidation reduction potential (ORP) values were all negative. The ORP of groundwater is a measure of electron activity and is an indicator of the relative tendency of a solution to accept or transfer electrons. Oxidation-reduction reactions in groundwater containing organic compounds (natural or anthropogenic) are usually biologically mediated, and, therefore, the ORP of a groundwater system depends upon and influences rates of biodegradation. Knowledge of the ORP of groundwater also is important because some biological processes operate only within a prescribed range of ORP conditions.

Chlorine is the most abundant of the halogens. Although chlorine can occur in oxidation states ranging from  $\text{Cl}^-$  to  $\text{Cl}^{+7}$  the chloride form ( $\text{Cl}^-$ ) is the only form of major significance in natural waters. Chloride forms ion pairs or complex ions with some of the cations present in natural waters, but these complexes are not strong enough to be of significance in the chemistry of fresh water. Chloride ions generally do not enter into oxidation-reduction reactions, form no important solute complexes with other ions unless the chloride concentration is extremely high, do not form salts of low solubility, are not significantly adsorbed on mineral surfaces, and play few vital biochemical roles. Thus, physical processes control the migration of chloride ions in the subsurface. Therefore, chloride is not affected by changing ORP environments. Figure 5-138 illustrates the TDS verses chloride concentrations arranged from the northern most well to the southern most (this figure includes all 30 wells sampled during the background study). TDS and chloride concentrations are superimposed on each other and the graph indicates similar responses and deflections across the entire installation. However, Figure 5-139 initially shows the same good agreement between TDS and sulfate except for when the negative ORP environments for MW-24-03, MW-13, MW-22-03, MW-1, MW-23-01, and MW-6 are encountered. Sulfate concentrations for these six wells decreases or demonstrates a significant deflection away from TDS. This negative deflection appears to be in response to the low DO and negative ORP. Figure 5-140 initially shows the same good agreement when comparing aluminum and iron across the installation. However, when the negative ORP environments at MW-24-03, MW-13, MW-22-03, MW-1, MW-23-01, and MW-06 is encountered, the iron concentration increases significantly as compared to aluminum. Aluminum typically doesn't

respond or demonstrate significant changes in its concentration to negative ORP environments whereas Iron (III) is converted to Iron (II) under the correct reducing and biological conditions. Under these conditions, the dissolved iron concentrations increase significantly. Figure 5-140 shows that the iron concentration increases significantly in the six suspect wells. These responses taken together are usually indications of biological activity and potentially on-going biodegradation. Therefore, the three rooted wells and the three suspect wells were removed based on low DO, negative ORP values, and potential biological activity (rooting issues) as well as historical information indicating rooting problems during past sampling events (Basewide Long-term Monitoring program).

### **5.5 Nitrate and Ammonia**

HAFB reviewed the groundwater data relative to the observed concentrations of ammonia and nitrate. It is evident that there are multiple sources of nitrogen which have led to the current distribution of ammonia and consequently, nitrate in the groundwater.

The nitrogen cycle is a biogeochemical cycle which requires both micro-organisms and oxygen. Ammonia, nitrite, and nitrate are historical artifacts resulting from deteriorating infrastructure (sanitary sewer lines and/or septic tanks). The possible source of the ammonia is believed to be from the sanitary sewer system and/or septic tanks and the decomposition of organic matter in those sanitary systems by bacteria which is producing ammonium ions ( $\text{NH}_4^+$ ). In well-oxygenated soil, these are then oxygenated first by bacteria into nitrite ( $\text{NO}_2^-$ ) and then into nitrate. Ammonium ions readily bind to soils, especially to humic substances and clays. Nitrate and nitrite ions, due to their negative charge, bind less readily since there are less positively charged ion-exchange sites (mostly humic substances) in soil than negative. After rain or irrigation, *leaching* (the removal of soluble ions, such as nitrate and nitrite) into groundwater can occur. This is one possible explanation for the elevated nitrate in the groundwater.

Another possible explanation for nitrate in the groundwater is from geogenic sources. Nitrate in groundwater from geogenic sources include those that are desert-derived such as caliche and playa lake evaporate deposits, and desert vadose zone soils. Recent research at the New Mexico Institute of Mining and Technology at the University of Nevada and U.S. Geological Survey has shown that nitrate in desert soils occurred at much greater quantities than previously reported, with subsoil nitrate ranging from 2,000 to 10,000 kilograms per hectare (kg/ha). Farmers typically only apply nitrogen fertilizers in amounts ranging from 25 to 250 kg/ha per year. The researchers concluded that this naturally-occurring vadose zone nitrogen reservoir had the potential to become mobilized thereby leaching large amounts of nitrate to groundwater (Motzer, 2006).

Therefore, nitrate cannot be evaluated and treated in the same manner as other constituents in this study. HAFB is currently moving to investigate releases from the base sewer system (SWMU 183) and has requested funding to perform the septic tanks investigation. Results of these two investigations will provide the information needed to understand the source areas as well as refine the nature and extent of the nitrate/ammonia concentrations in groundwater. Therefore, since the sources of nitrogen observed at the base are unclear at this time, HAFB is

requesting that the nitrate, nitrite and ammonia data be pulled from the background study and resolved when the aforementioned investigation results are available.

## 5.6 Statistics and Data Analysis

### 5.6.1 Descriptive Summary Statistics

Descriptive summary statistics for HAFB and background data were generated as part of a preliminary data review. These descriptions, in conjunction with graphical plots, were generated to develop an understanding of the range, variability, and shape of the underlying probability distribution of the measurements, as well as the number of non-detects and possible outliers that are present. This information was needed to help determine the quality of the data sets and how the data should be statistically analyzed.

Based on USEPA, 2000a, *Guidance for Data Quality Assessment Practical Methods for Data Analysis*, the following statistical evaluation of the background inorganic concentrations data set was conducted in accordance with the Work Plan. A preliminary data review was conducted to include basic statistical quantities (summary statistics). The summary statistics were developed and presented in Tables 5-2 through 5-18 and includes the number of samples; the number of detects; the number of non-detects; the number of outliers excluded from analysis as part of the summary statistics; the mean, median, range, standard deviation, and type of distribution (normal, log normal, or other); 90<sup>th</sup>, 95<sup>th</sup>, and 99<sup>th</sup> percentiles; and the UTL for each constituent in each media. These summary statistics were computed using the USEPA-endorsed program, ProUCL (see Appendix D) that was distributed with the document *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (OSWER 9285.6-10) (USEPA, 2002). Note that calculation of the UTL assumes that data are normally distributed, which may not be the case for some constituents. UTLs were calculated based on a 95% coverage and a 95% confidence limit.

### 5.6.2 Data Sets with No Non-Detects

The number of measurements in a data set is denoted by  $n$ . The  $n$  measurements are denoted by  $x_1, x_2, \dots, x_n$ . The descriptive summary statistics that were computed for the background data sets are: the number of samples; the number of detects; the number of non-detects; the number of outliers excluded from analysis as part of the summary statistics; the mean, median, range, standard deviation, and type of distribution (normal, log normal, or other); 90<sup>th</sup>, 95<sup>th</sup>, and 99<sup>th</sup> percentiles; and the UTL for each constituent in each media.

### 5.6.3 Data Sets That Contain Non-Detects

Non-detects are measurements that the analytical laboratory reports are below some quantitative upper limits such as the detection limit or the limit of quantitation. Data sets that contain non-detects are said to be censored data sets.

The methods used to compute descriptive statistics when non-detects were present were selected based on the number of non-detects and the total number of measurements,  $n$  (detects plus non-detects). If  $n$  is large (say,  $n > 25$ ) and less than 15% of the data set are non-detects, the general

guidance in *Guidance for the Data Quality Assessment, Practical Methods for Data Analysis, EPA QA/G-9, QA97 Update, EPA/600/R-96/084* (USEPA, 1996) is to replace the non-detects with the Detection Limit (DL) or in this case the MDL or MDC (radiological samples only), DL/2, or a very small value. The descriptive summary statistics were then computed using the (now) full data set, although some of the resulting statistics will be biased to some degree. (The median, pth sample percentile, and the interquartile range may not be biased if the number of non-detects is sufficiently small.) The biases may be large, even though less than 15% of the measurements are non-detects, particularly if n is small, say  $n < 25$ .

If 15% to 50% of the data set are non-detects, the guidance offered in the *Guidance for the Data Quality Assessment, Practical Methods for Data Analysis, EPA QA/G-9, QA96 Update, EPA/600/R-96/084* (USEPA, 1996) and *Guidance for the Data Quality Assessment, Practical Methods for Data Analysis, EPA QA/G-9, QA97 Update, EPA/600/R-96/084* (USEPA, 1998) is to forgo replacing non-detects with some value like the DL divided by 2, the DL itself, or a small value. Instead, one should consider computing the mean and standard deviation using the Cohen method.

If 50% to 90% of the measurements in the data set are non-detects, the loss of information is too great for descriptive statistics to provide much insight into the location and shape of the underlying distribution of measurements. The only descriptive statistics that might be possible to compute are pth percentiles for values of p that are greater than the proportion of non-detects present in the sample and when no non-detects are greater than the  $k(n+1)$ th largest datum, where k is the order statistic. In such cases, the recommended UTL developed by the USEPA-endorsed program, ProUCL, that was distributed with the document *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (OSWER 9285.6-10) (USEPA, 2002) was used. A descriptive summary of how the ProUCL 4.0 code generates a UTL is provided on a CD in Appendix D of this report.

If 90% to 99% of the measurements in the data set are non-detects, statistical analysis is not possible and the UTL value was set at 2 x the maximum detected value. This reasoning incorporates the professional judgment of laboratory managers regarding the likelihood of a detection near the detection limit really being a detection and not a false positive. It should be pointed out that this setting of the UTL at 2 x the maximum detect value is only a convention and no statistics were used in calculating the UTL. Therefore, in situations with 3 detections or less, the use of the value in terms of a true "UTL" is somewhat questionable.

If 100% of the measurements in the data set are non-detects, statistical analysis is not possible and the UTL value was set the lowest achievable *quantitation limit (QL)*. In Part 1, comment No. 2 in NMED correspondence dated October 28<sup>th</sup>, 2010 (provided in Attachment 2 of this report) it states "The use of data greater than the MDL, but less than the Practical Quantitation Limit (PQL), is acceptable for use in a background study". This statement is in agreement with the guidance provided in the STATISTICAL ANALYSIS OF GROUNDWATER MONITORING DATA AT RCRA FACILITIES UNIFIED GUIDANCE, March 2009 (EPA 530/R-09-007) as evidenced by the following excerpts from the guidance document:



Page 6-37: “Even if a data set contains only a small proportion of non-detects, care should be taken when choosing between the method detection limit [MDL], the quantification limit [QL], and the RL in characterizing ‘non-detect’ concentrations... As a general rule, non-detect concentrations should not be assumed to be bounded above by the MDL. The MDL is usually estimated on the basis of ideal laboratory conditions with physical analyte samples that may or may not account for matrix or other interferences encountered when analyzing specific field samples”. The RL should typically be taken as a more reasonable upper bound for non-detects when imputing estimated concentration values to these measurements.”

Page 17-19: “If all the sample data are non-detect, an RL (e.g., the lowest achievable quantitation limit [QL]) may serve as an approximate upper tolerance limit.”

Page 18-18: “It is possible to create an approximate non-parametric limit with background data containing all non-detects, by using the RL (often a quantitation limit) as the PQL. A quantified value above the PQL would constitute an exceedance.”

**HAFB concurs with NMED on following statement**, “A PQL is typically five times greater than the MDL. Data at or exceeding the PQL are considered accurate at a high level of confidence. Setting a background level for a data set that consists of all non-detects to twice the MDL, instead of at the MDL, will still result in establishing a background level that is less than the PQL.” Therefore, as provided in the 2009 Unified Guidance, “If all the sample data are non-detect, an RL (e.g., the lowest achievable *quantitation limit* [QL]) may serve as an approximate upper tolerance limit”. HAFB proposes that, for data sets that have all non-detects, to use an RL (e.g., the lowest achievable *quantitation limit* [QL]) as an approximate upper tolerance limit.

Comment No. 6 in NMED correspondence dated May 4, 2009 (provided in Attachment 2 of this report) indicates that aluminum, antimony, arsenic, lead, beryllium, and thallium had several samples with detection limits which were too high for groundwater. NMED stated that the background statistics should be calculated after removing the non-detect data associated with the highest DL in the corresponding data set for each constituent.

Unfiltered groundwater samples produced no detections for: antimony, beryllium, lead, silver, thallium, tin, carbon-14, lead 210, and thorium 232. Groundwater dissolved metals (filtered) produced no detections for: antimony, beryllium, lead, silver, thallium, and tin. These constituents were addressed as indicated above, if 100% of the measurements in the data set are non-detects, then the UTL value was arbitrarily set at the lowest RL in the data set. See note above. The highest DL for the aluminum and arsenic for both unfiltered and filtered groundwater were removed from the datasets prior to UTL determination.

#### 5.6.4 Determining Presence of Data Outliers

The data set was examined to determine the *center* of the data set and the spread or range of the data values. The center is usually characterized by computing the arithmetic mean, denoted by  $x$ , and the *spread* by the standard deviations. In addition, NVB examined to see if any data seemed much larger in value than most of the data. These unusually large data may be due to an error. Not removing true outliers and removing false outliers both lead to a distortion of estimates of

population parameters. Potential outliers may be identified through graphical representations such as the box and whisker plot and normal probability plot which can identify observations that are much larger or smaller than the rest of the data. If some of the data are so large as to cause concern that a mistake has been made, a statistical test for outliers should be conducted. If the test indicates the suspect value(s) are indeed larger than expected, relative to the remaining data, the outliers should be examined to determine if they are mistakes or errors. If they are, they should be removed from the data set.

Prior to conducting the outlier test, a test for normality was performed on the data set. The Grubbs test, also known as the maximum normalized residual test or Discordance Test, was used to detect outliers in a univariate (one-sided variance test) data set. The Grubbs test is based on the assumption of normality. Therefore, a test for normality was performed on the data set before applying the Grubbs test.

The Grubbs test detects one outlier at a time. This test considers two cases: 1) where the extreme value (potential outlier) is the smallest value of the data set, and 2) where the extreme value (potential outlier) is the largest value of the data set. This outlier is expunged from the dataset and the test is iterated until no outliers are detected. However, multiple iterations change the probabilities of detection, and this test should not be used for sample sizes of six or less since it frequently tags most of the points as outliers. Furthermore, if multiple iterations are required to achieve the desired criteria then the normality test is conducted on the data set after the suspected outlier(s) are deleted to ensure that the data set is still normal. The Grubbs test is recommended by the USEPA as a statistical test for outliers (USEPA, 1992). Table A-4 of Appendix A in USEPA 1992, contains critical values for this test for  $n \leq 50$ . The USEPA suggests taking the logarithms of environmental data, which are often log-normally distributed. The data are ranked in ascending order and the mean and standard deviation are calculated.

### **5.6.5 Determining the Probability Distribution of a Data Set**

The Shapiro-Wilk W-test is highly recommended for testing whether the data have a normal distribution; therefore this test was used in the determination of normality for this study. It was also used to test for a lognormal distribution, once the data was first transformed by computing the natural logarithm of each datum. The W-test is recommended in several USEPA guidance documents (USEPA, 1992 and USEPA, 1996) and in many statistical texts (Gilbert 1987; Conover 1980). The W-test has been shown to have more power than other tests to detect when data are not from a normal or lognormal distribution. The W-test should be conducted in conjunction with constructing normal and lognormal probability plots in order to more thoroughly evaluate whether the normal or lognormal distribution is an acceptable fit to the data.

## **5.7 Graphical Data Analysis**

Graphical plots of the background data sets are extremely useful and necessary tools to:

- Conduct exploratory data analyses to develop hypotheses about possible differences in the means, variances, and shapes for the background measurement distributions

- Visually depict and communicate differences in the distribution parameters (means, variances, and shapes) for the background measurement distributions
- Graphically evaluate if the background data have a normal, lognormal, or some other distribution
- Evaluate, illuminate, and communicate the results obtained using formal statistical tests

The following graphical plots were prepared: histogram, box plots, normal probability plots, concentration maps for all constituents/media, and Piper diagrams and stiff diagrams for groundwater constituents.

### **5.7.1 Histogram Plot**

One of the oldest methods for summarizing data distributions is the histogram. The histogram divides the data range into units, counting the number of points within the units, and displaying the data as the height or area within a bar graph. In a histogram, the area within the bar represents the relative density of the data. The histogram provides a means of assessing the symmetry and variability of the data. If the data are symmetric, then the structure of these plots will be symmetric around a central point such as a mean. The histogram will generally indicate if the data are skewed and the direction of the skewness. Histograms were constructed using raw data (outliers included) so that they may be evaluated for the presence of outliers. Histograms are provided in Appendix E of this report.

### **5.7.2 Box and Whisker Plot**

A box and whisker plot or box plot is a schematic diagram useful for visualizing important statistical quantities of the data. Box plots are useful in situations where it is not necessary or feasible to portray all the details of a distribution and can be used to assess the symmetry of the data. If the distribution is symmetrical, then the box is divided in two equal halves by the median, the whiskers will be the same length and the number of extreme data points will be distributed equally on either end of the plot. Box plots were constructed using reduced data (outliers excluded) and are provided in Appendix F of this report.

### **5.7.3 Normal Probability Plot (Quantile-Quantile Plot)**

There are two types of quantile-quantile plots or q-q plots. The first type, an empirical quantile quantile plot, involves plotting the quantiles of two data variables against each other. The second type of a quantile-quantile plot, a theoretical quantile-quantile plot, involves graphing the quantiles of a set of data against the quantiles of a specific distribution. The following discussion will focus on the most common of these plots for environmental data, the normal probability plot (the normal q-q plot); however, the discussion holds for other q-q plots.

The normal probability plot is used to roughly determine how well the data set is modeled by a normal distribution. A normal probability plot is the graph of the quantiles of a data set against the quantiles of the normal distribution using normal probability graph paper. If the graph is linear, the data may be normally distributed. If the graph is not linear, the departures from linearity give important information about how the data distribution deviates from a normal

distribution. If the graph of the normal probability plot is not linear, the graph may be used to determine the degree of symmetry (or asymmetry) displayed by the data. If the data are skewed to the right, the graph is convex. If the data are skewed to the left, the graph is concave. If the data in the upper tail fall above and the data in the lower tail fall below the quartile line, the data are too slender to be well modeled by a normal distribution, i.e., there are fewer values in the tails of the data set than what is expected from a normal distribution. If the data in the upper tail fall below and the data in the lower tail fall above the quartile line, then the tails of the data are too heavy to be well modeled using a normal distribution, i.e., there are more values in the tails of the data than what is expected from a normal distribution. A normal probability plot can be used to visually identify potential outliers. A data value (or a few data values) much larger or much smaller than the rest, will cause the other data values to be compressed into the middle of the graph, ruining the resolution. Normal probability plots for both raw (including outliers) and reduced (excluding outliers) data are provided in Appendix G of this report. The probability plots were also constructed using the combined data sets for soil constituents which represents a single population and are also provided in Appendix G of this report.

#### **5.7.4 Piper and Stiff Diagram**

The relative ionic composition of groundwater samples collected from monitoring wells during the Basewide Background Study area are plotted on a trilinear diagram. A trilinear diagram, also frequently referred to as a Piper diagram, provides a convenient method to classify and compare water types based on the ionic composition of different water samples. Cation and anion concentrations for each groundwater sample are converted to total milli-equivalents per liter (meq/L) and plotted as percentages of their respective totals in two triangles. The cation and anion relative percentages in each triangle are then projected into a quadrilateral polygon that describes the water type or hydrochemical facies. The piper diagram therefore has the potential to represent a large number of analyses and visually describing the differences in major ion chemistry in groundwater flow systems.

The ionic composition of groundwater samples during the study were represented by another type of water-quality diagram - the stiff diagram. Stiff diagrams are used to compare the ionic composition of water samples between different locations, depths, or aquifers. The stiff diagram is a polygon created from three horizontal axes extended on both sides of a vertical axis. Cations are plotted on the left side of the axis and anions are plotted on the right side, both in meq/L. A greater distance from the vertical axis represents a larger ionic concentration. The cation and anion concentrations are connected to form an asymmetric polygon known as a stiff diagram, where the size is a relative indication of the dissolved-solids concentration. Reduced data (outliers removed) were used to construct the Stiff Diagrams for the Basewide Background Study and are provided in Appendix H of this report. Additionally, the Stiff diagrams have been plotted on a map of the base as discussed in Section 4 (Figure 4-6).

Reduced data (outliers removed) were used to construct the Piper Diagram for the Basewide Background Study and is provided in Appendix I of this report. Additionally, Sample Summary reports also included in Appendix I provide a general overview of each groundwater sample including major ions, hydrochemical facies (e.g. sodium-chlorine), calculated hardness, ion

balance, ion ratios, comparison with sea-water, and conversion to milli-equivalents which were used to calculate the cation/anion percentages for plotting on the Piper diagram are also provided in Appendix I. Superimposing the Piper Diagram Legend in Appendix I and the Piper Diagram of the Total Groundwater using Reduced Data Set developed during the Basewide Background Study illustrates that 90% of the dominant cation is sodium and 80% of the dominant anions is chlorides. Of the 24 sampling locations used during the Basewide Background Study, 70% of the locations of the hydrochemical facies are mapped as Na-Mg-Cl-SO<sub>4</sub>. Figure 5-141 illustrates the dominance of the Na-Mg-Cl-SO<sub>4</sub> water type across HAFB. The figure indicates minimal localized dilution or mixing potentially due to deteriorating infrastructure. Finally, Figure 5-141 also supports the single groundwater population set forth in the Conceptual Site Model for Groundwater at HAFB in Section 4 of this report. Therefore, no discrete hydrochemical characteristics were detected during this analysis.

### **5.7.5 Isoconcentration Maps**

Laboratory analyses of soil analytical results and groundwater monitoring wells were plotted to indicate the amount of a particular analyte that is present in the soil or groundwater. Each map includes the approximate boundary of the various amounts of each analyte which is prepared based on the locations of the soil boring or monitoring wells and the concentrations detected in the samples. An isoconcentration map is often used in understanding the distribution of various constituents of a particular analyte. NVB plotted each analyte according to the following horizons: Surface Soil Metals, Radiological Surface Soils, Subsurface Soil Metals, Radiological Subsurface Soil, Saturated Subsurface Soil Metals, Radiological Saturated Subsurface Soil, Groundwater Metals – Unfiltered, Radiological Groundwater, Groundwater Dissolved Metals – Filtered, and Groundwater Natural Attenuation Parameters. Each analyte for the horizons above are illustrated on Figures 5-1 thru 5-137.

Isoconcentration maps were prepared using reduced data. Additionally, concentration data was posted on the maps at the locations where the samples were collected.

During the June 3, 2009, meeting between NMED, United States Air Force (USAF), and NVB, NMED stated that averaging the UTLs to generate a Composite UTL was unacceptable and directed NVB to generate the UTLs by combining the reduced data sets for all three soil horizons and then determining the UTL. Development of a single analyte specific soil map using averaged soil concentrations from the three soil horizons would add confusion to the document since a UTL developed based on averaged soil concentrations from 42 locations will be different than the UTL developed from a combined data set of 126 points. Therefore, no isoconcentration maps were constructed using the averaged soil concentrations where the soil constituents are representative of one population as requested in the NMED issued notice of disapproval in May 2009.

## **5.8 Summary of Methods**

This section summarizes the results of the analytical methods evaluation and the methods and results of the statistical characterization of background.

The approach used for the statistical characterization of background is summarized as follows:

- Review raw data and develop the descriptive summary statistics
- Determine if the data set was normally distributed using Shapiro-Wilk W-test
- Identify potential outliers using both the Grubbs Analysis (Discordance Test) and graphical methods
- Select appropriate statistical methods (parametric or nonparametric) based on distributional information
- Calculate summary statistics and tolerance limits using the appropriate statistical method

Tables 5-2 to 5-17 present a summary of the results for metals and select radiological constituents in surface soil, subsurface soil, and saturated subsurface soil (capillary fringe), dissolved metals in groundwater, and total metals and select radiological constituents in groundwater, respectively. Each table presents the following statistics: number of detects; number of samples; number of non-detects; minimum, maximum, and mean concentration; the standard deviation; median concentration; outlier; and test for normality. All statistics are presented to allow future investigations the flexibility to choose whichever statistic is most appropriate for the comparisons planned for that project. Calculated UTLs are also presented for those instances in which decisions must be made on the basis of a comparison of individual sample results to background.

NVB implemented the following step to determine the UTLs:

1. Raw data were summarized in Tables 3-1 through 3-6 for soils and Tables 3-7 and 3-8 for groundwater.
2. Statistical descriptors were prepared using the raw data (no outliers were identified and excluded at this point). Data sets that contain non-detects were considered censored data sets. The results of these efforts are summarized in Tables 5-2 through 5-6 and 5-12 through 5-17. A normality test was conducted on the raw data. The results of these efforts are summarized in Tables 5-2 through 5-6. If the data was not normally distributed, the decision was made to transform the data which involves taking the natural logarithms of the results, and repeating the Shapiro-Wilk test on the transformed data. The results of these efforts are summarized in Tables 5-7 through 5-18.
3. The data were transformed into their natural logarithms if the raw probability plots indicated that the curve was Not Normal. Outliers were determined and removed from the data sets. The outliers removed are listed in Tables 5-7 through 5-11.
4. Statistical descriptors were prepared using the reduced data (outliers removed) after the data were transformed to their natural logarithms. A second normality test was conducted after the removal of the outliers following the Grubbs Analysis. If the transformed data was found to be normal for a constituent media, and a certain percentage of detects were available in the data set, a UTL was calculated. Otherwise, a UTL was assigned by other means. The results of these efforts are summarized in Tables

5-12 through 5-17. Each table summarizes for each constituent/media the distribution, critical values used to determine conformance with decision criteria, number of outliers removed from the data sets (Tables 5-7 through 5-11), and the method that was used to handle censored data sets.

Combined soil UTLs were generated from the three soil types (surface, subsurface, and saturated subsurface soil) and are reported in Table 5-17.

### **5.8.1 Technical Approach**

As previously stated, the primary objective of this background study was to develop estimates of background concentrations of metals and select radiological constituents in background surface soil, subsurface soil, saturated subsurface soil, and groundwater. These estimates will then be used for comparison with data collected in ongoing and future investigations to help distinguish between naturally occurring concentrations of metals and elevated levels that might be attributable to contamination. Analytical data from surface soil, subsurface soil, saturated subsurface soil, and groundwater samples were collected from background locations around HAFB in support of this effort. This section presents an overview of the study design and describes the data assessment and interpretation process.

#### **5.8.1.1 Study Design**

The fundamental idea in a background study is to characterize the range of naturally occurring concentrations of a constituent of interest. This study was designed to characterize background in terms of estimates of the UTLs for background metals and select radiological constituent concentrations. These estimates represent upper bounds for concentrations that might be expected in samples collected from uncontaminated areas of HAFB.

For estimates of background concentrations to be useful in helping to distinguish between contaminated and uncontaminated areas on the basis of future sample data, it is important that the background estimates are based on results that are statistically representative of actual background concentrations. This means primarily that the data on which the estimates are based should fairly depict the range of actual background concentrations. For example, they should include samples from different soil series and different groundwater aquifers, if appropriate. Therefore, NVB proposed the advancement of 42 soil borings, collection of three samples per boring at different depths (surface soil, subsurface soil, and saturated subsurface soil) and collection of groundwater samples from 30 existing monitoring wells which have historically exhibited non-detect laboratory analyses.

#### **5.8.1.2 Data Analysis and Interpretation**

As indicated above, the overall goal of the data analysis and interpretation process was to characterize background metals and select radiological constituents concentrations in terms of estimates of the upper bounds for concentrations that might be expected in samples collected from uncontaminated areas of HAFB. This was done by using the measurement results to calculate UTLs for background metals and select radiological constituent concentrations.

Descriptive statistics pertaining to the background sample data were also developed as part of the data analysis process. In general, this process included the following steps:

- Review raw data and develop the descriptive summary statistics
- Identify potential outliers using both the Grubbs Analysis (Discordance Test) and graphical methods
- Determine if the data set was normally distributed using Shapiro-Wilk W-test
- Select appropriate statistical methods (parametric or nonparametric) based on distributional information
- Calculate summary statistics and tolerance limits using the appropriate statistical method

This process is described in more detail in the remainder of this section.

### **5.8.2 Raw Summary Statistics**

Duplicate samples that were collected as part of the field effort were averaged to develop a single representative sample value for the sampling location. A preliminary data review was conducted to include basic statistical quantities (raw summary statistics). The raw summary statistics developed and presented include the number of detections, number of samples, and number of non-detects; the percent non-detects; the reporting limit; the detection limit; the minimum and maximum; the mean, median, and standard deviation; skewness, and coefficient of variance. Tables 5-2, 5-3, 5-4, 5-5, and 5-6 present the raw summary statistics and preliminary Shapiro-Wilk test for metals and select radiological constituents in surface soil, subsurface soil, saturated subsurface soil, dissolved metals in groundwater, and total metals and select radiological constituents in groundwater, respectively.

### **5.8.3 Transformation**

Environmental data commonly exhibit frequency distributions that are non-negative and skewed with heavy or long right tails. Several standard parametric probability models have these properties. The lognormal distribution is a commonly used distribution for modeling environmental contaminant data. The advantage to this distribution is that a simple (logarithmic) transformation will typically transform a lognormal distribution into a normal distribution. Therefore, the methods for testing for normality described in this section can be used to test for lognormality if a logarithmic transformation has been used. By transforming the data, assumptions that are not satisfied in the original data can be satisfied by the transformed data. For example, a right-skewed distribution can be transformed to be approximately normal by using a logarithmic transformation. Then the normal-theory procedures can be applied to the transformed data. When data are lognormally distributed, then procedures to logarithms of the data are applied. If the criteria for normality could not be satisfied, then the data set was transformed into a lognormal distribution in an attempt to obtain a normal distribution in the data set. A statistical test known as the Shapiro-Wilk W-test, was used to test the results for normality.



#### 5.8.4 Outlier Testing and Graphical Data Review

The first steps in the data analysis were to conduct outlier tests to identify anomalous measurement results and to review histograms of the raw measurement data.

Normal or lognormal probability plot (Q-Q plots) and histograms were reviewed throughout the outlier test process to confirm that the measurements used in subsequent analyses were reasonable representations of the background. Appendix G present the raw data, normal or lognormal probability plot (Q-Q plots) and Appendix E presents the histograms used at this stage, respectively.

The Grubbs test, also known as the maximum normalized residual test or Discordance Test, was used to detect outliers in a univariate (one-sided variance test) data set. The Grubbs test is based on the assumption of normality. As indicated above, a test for normality was performed on the data set before applying the Grubbs test. The Grubbs test detects one outlier at a time. This outlier was removed from the dataset and the test was iterated until no outliers were detected. However, multiple iterations change the probabilities of detection, and this test was not used for sample sizes of six or less since it frequently tags most of the points as outliers. Tables 5-7, 5-8, 5-9, 5-10, and 5-11 present the results of the outlier test using a combination of both graphical inspection and the Grubbs test for metals and select radiological constituents in surface soil, subsurface soil, saturated subsurface soil, and total metals and dissolved metals and select radiological constituents in groundwater, respectively.

#### 5.8.5 Normality Testing and Calculation of Transformed Statistics

After determining that no additional outliers exist in the data set, the next step in the statistical analysis was to evaluate whichever was chosen as the most appropriate data set to see if the data appeared to be normally distributed. The assumption of normality is a fundamental tenet of statistical tests involving parametric methods. Therefore, the extent to which the data supported this assumption determined the direction of subsequent analyses. The Shapiro-Wilk W-test was used again to verify that normality was maintained following iterative outlier removal. Tables 5-12, 5-13, 5-14, 5-15, and 5-16 present the results of the Shapiro-Wilk test for metals and select radiological constituents in surface soil, subsurface soil, saturated subsurface soil, dissolved metals in groundwater, and total metals and select radiological constituents in groundwater, respectively. The initial transformed statistics are also included in these tables. These include minimum and maximum measured concentrations, as well as estimates of the mean, median, and standard deviation. Where the Shapiro-Wilk test showed that the assumption of normality was not appropriate, a nonparametric method was used to determine the UTLs.

#### 5.8.6 Calculation of UTLs

The results of the Shapiro-Wilk tests were used to determine whether parametric or nonparametric statistical methods were most appropriate for calculating the UTLs shown in Tables 5-12 through 5-16. Parametric methods are usually used when the population is known or can be assumed to follow a normal distribution. They can also be used when the population of interest can be modeled by some other distribution (such as the log normal) that allows the

measurement data to be transformed to a normal distribution. Parametric methods offer the advantage of achieving greater statistical certainty using smaller numbers of samples than required for corresponding non-parametric methods. For those elements and matrices in which the Shapiro-Wilk tests did not indicate a significant departure from normality, a parametric UTL (USEPA, 1992) for 95% coverage with 95% confidence was calculated. This represents an upper 95% confidence bound for the 95<sup>th</sup> percentile concentration.

As indicated above, for those cases in which the Shapiro-Wilk tests indicated significant departure from normality, the next step was to see if a log transformation could be used to produce a more normally distributed data set. This involved taking the natural logarithms of the results, and repeating the Shapiro-Wilk test on the transformed data. Parametric UTLs were calculated using transformed data in those cases in which the Shapiro-Wilk results indicated that the transformation was effective in achieving normality.

Nonparametric methods were used for subsequent analyses when the Shapiro-Wilk tests indicated that the assumption of normality was not supported by either the raw or transformed data. Nonparametric methods are not based on the assumption of normality, and are sometimes referred to as distribution-free methods. The nonparametric method used to calculate UTLs for this study uses the ranks of the measured values. The UTL is simply the highest observed concentration in the data set. However, unlike parametric tolerance limits which are calculated to include a specified proportion of the parent population, the proportion included in these nonparametric UTLs varies as a function of the number of observations in the sample set. The coverage of the UTL is indicated in the summary tables.

Tables 5-12, 5-13, 5-14, 5-15, 5-16, and 5-17 present the calculated UTLs for metals and select radiological constituents in surface soil, subsurface soil, saturated subsurface soil, total metals and select radiological constituents in groundwater, dissolved metals in groundwater, and combined soil, respectively. Table 5-18 presents a summary of calculated background levels for metals and select radiological constituents in total metals in groundwater, dissolved metals in groundwater, and combined soils. NMED (NOD dated October 2010) required the use of the term "background level" instead of UTLs. Therefore, the "background level" were calculated by determining the 95 % UTL with 95% coverage of the results.

### **5.8.7 Multiple Population Analysis**

The analytical results for soil and groundwater samples have been evaluated for each constituent to determine if the results represent one or more populations. According to the Work Plan, if results indicated multiple populations existed for a constituent, then statistical descriptors for each population would be derived and reported separately for each population. However, the results did not indicate multiple populations, therefore, only one number has been derived from each media for each constituent. The following sections describe how the population analysis was performed on both the soil and groundwater horizons.

### 5.8.7.1 Soil

A qualitative comparison for each analyte between surface/subsurface/saturated subsurface isoconcentration figures, indicates similar isocontours and distribution patterns. This similarity between isocontour patterns and uniform soil types suggests a homogenous matrix in each soil horizon (see Figures 5-1 through 5-87a from the reduced data set). The major geologic unit for the surface soil sampling zone is silty sand. The major unit for the subsurface and saturated subsurface soil sampling zones is also silty sand with interbedded clay lenses. Overall, the primary geologic unit consisted of silty sand with increasing gypsum content with depth. This homogeneity between each soil horizon is further supported by the analytical soil data results which indicate that each constituent is within the same order of magnitude at each depth horizon.

In general, the geochemical trend analysis for the metals concentrations in the three soil horizons stayed within the same order of magnitude. A slight decreasing trend was apparent as the depth of the samples approached the saturated subsurface soil interval. However this is expected given the dynamic nature of the soils and groundwater within the saturated subsurface soil interval. Metals concentrations between surface soil and subsurface soils were nearly identical.

To further test this hypothesis, NVB conducted side by side analysis using box and whiskers plots on the same graphic to illustrate for a given metals constituent for all three soil types that the soil is very similar. The analysis indicated that the distributions of the data for the three soils horizons are similar. In particular, the medians from the three soil horizons occupy similar locations within the boxes, and considerable overlap between the first and third quartiles among the three boxes was noted. Side by side box and whiskers plots were constructed using reduced data (outliers excluded) for only those constituents that had 100% detection in all three soil horizons and are provided in Appendix F of this report.

Following the determination that the three soil horizons were similar, statistical descriptors were prepared using the combined data sets for a single population, and the UTL was determined using ProUCL 4.0. The combined soil UTLs are presented in Table 5-17.

### 5.8.7.2 Groundwater

Comparison of two populations may be a potentially contaminated area with a background area or concentration levels from an upgradient and a downgradient well. The comparison of the two populations may be based on a statistical parameter that characterizes the relative location (e.g., a mean or median), and may be based on a graphical comparison of the two population distributions using box-plots. Populations from differing lithologies will produce significantly different box plots. However, populations from similar lithologies would be expected to have significant overlap.

In general, to determine whether two groundwater populations exist, the 24 wells were divided into two groups based solely on the northern extent on the installation. The overall process included the following steps:

- The descriptive summary statistics were reviewed for non-detects. In general, if n is small, say  $n < 25$ , the non-detect biases may be large, even though less than 15% of the

measurements are non-detects. To minimize this bias and to prevent error propagation into the overall comparison, only those analytes that had non-detects less than 15% were considered for this analysis.

- The data set was evaluated to determine if it was normally distributed using the Shapiro-Wilk W-test.
- Potential outliers were then identified using both the Grubbs Analysis (Discordance Test) and graphical methods.
- Constituent-specific box and whisker plots were then generated for each subset and plotted side by side for selected groundwater constituents.

The comparison of the two box plots focused primarily on comparing the mean and median of one plot to see if those values fell between the 25<sup>th</sup> and 75<sup>th</sup> percentiles of the opposing box-plot. If the values were within the range then it was considered to be comparable. If the values were outside the range then that analyte could potentially be from a secondary population. Comparative box plots are provided in Appendix F of this report. In general, overlapping means and median were observed between the 25<sup>th</sup> and 75<sup>th</sup> percentiles of the opposing box-plot. This indicates that the sample populations are from similar groundwater. This provides additional graphical evidence utilizing several key constituents to support a single population for groundwater.

Finally, as indicated in Section 4.5 of this report, a secondary graphical method was employed to support the single population conclusion. The Schoeller plots and resultant signatures provide a convenient means for identifying if the groundwater is from different lithologies. Figure 4-7 illustrates the overall ratios of the major solute content and resultant signature for the aquifer under HAFB using the 24 wells from the basewide background study. In general, the shapes or signatures from the individual 24 curves indicate that the ratios of major ion concentrations are from the same aquifer lithology. This provides additional graphical evidence utilizing several key constituents to support a single population conclusion for groundwater at HAFB.

### **5.8.8 Comparison of Future Sampling Results to Background UTLs**

Individual site sampling results will be compared to the 95% background upper tolerance limits as a way of determining whether the site results appear to come from a population that is different than the background. The 95% UTL represents an estimate of the upper 95<sup>th</sup> percentile of the true background concentration of the constituent of interest. For the 95% UTL, there is a relatively small chance, in the order of one in twenty, of an uncontaminated site sample (i.e., site data that are no different from background) having a constituent concentration greater than the UTL. When individual sample results are compared to UTLs, they are interpreted to indicate the presence of contamination when they exceed the UTLs. On the other hand, constituent concentrations that do not exceed the UTLs are considered to be background concentrations, not the result of contamination.

## 6 SUMMARY OF RESULTS AND OBSERVATIONS

The objective of the soil and groundwater Basewide Background Study was to collect data of sufficient quantity and quality to enable statistical evaluation of background soil and groundwater characteristics. Data were collected and laboratory and statistical analysis was conducted in accordance with the Work Plan (NVB, August 2008). The objective of this study was achieved and the following conclusions have been made.

### 6.1 Upper Tolerance Limits

The 95% UTL represents an estimate of the upper 95<sup>th</sup> percentile of the true background concentration of the constituent of interest. When individual sample results are compared to UTLs, they are interpreted to indicate the presence of contamination when they exceed the UTLs. On the other hand, constituent concentrations that do not exceed the UTLs are considered to be background concentrations, not the result of contamination. The summary background levels for the entire data set are provided in Table 5-18. NMED (NOD dated October 2010) required the use of the term "background level" instead of UTLs. Therefore, the "background level" were calculated by determining the 95 % UTL with 95% coverage of the results. Details on the UTL calculations for the individual analytes are presented in Tables 5-12 through 5-17.

### 6.2 Limited Number of Detections or Non-Detects

Statistical calculation of soil UTL values were not possible for antimony, selenium, silver, thallium, and carbon-14 since no detections were indicated in the surface soil, subsurface soil, and saturated subsurface soil horizons. Lead 210 and Uranium 235/236 were not determined due to the limited number of detections (less than 10% of the total number of samples in a data set) for the subsurface and saturated subsurface soil horizons.

Similarly, groundwater produced no detections for: antimony, beryllium, lead, silver, thallium, tin, carbon-14, lead 210, and thorium 232. Mercury was detected in only 2 samples for the total groundwater (unfiltered). Groundwater dissolved metals (filtered) produced no detections for: antimony, beryllium, lead, silver, thallium, and tin. Mercury and lead were detected only once in the data set. If a data set contains 3 detections or less, statistical analysis is not possible and the UTL value was set at 2 x the maximum non-outlier, non-detect, or 2 x maximum detected value. This reasoning incorporates the professional judgment of laboratory managers regarding the likelihood of a detection near the detection limit really being a detection and not a false positive. It should be pointed out that this setting of the UTL at 2 x the maximum detect value is only a convention and no statistics were used in calculating the UTL. Therefore, in situation with 3 detections or less the use of the value in terms as a true "UTL" is somewhat questionable.

If 100% of the measurements in the data set are non-detects, statistical analysis is not possible and the UTL value was set the lowest achievable *quantitation limit (QL)*. In Part 1, comment No. 2 in NMED correspondence dated October 28<sup>th</sup>, 2010 (provided in Attachment 2 of this report) states "The use of data greater than the MDL, but less than the Practical Quantitation Limit (PQL), is acceptable for use in a background study". This statement is in agreement with the guidance provided in the STATISTICAL ANALYSIS OF GROUNDWATER

MONITORING DATA AT RCRA FACILITIES UNIFIED GUIDANCE, March 2009 (EPA 530/R-09-007) as evidenced by the following excerpts from the guidance document:

Page 6-37: “Even if a data set contains only a small proportion of non-detects, care should be taken when choosing between the method detection limit [MDL], the quantification limit [QL], and the RL in characterizing ‘non-detect’ concentrations... As a general rule, non-detect concentrations should not be assumed to be bounded above by the MDL. The MDL is usually estimated on the basis of ideal laboratory conditions with physical analyte samples that may or may not account for matrix or other interferences encountered when analyzing specific field samples”. The RL should typically be taken as a more reasonable upper bound for non-detects when imputing estimated concentration values to these measurements.”

Page 17-19: “If all the sample data are non-detect, an RL (e.g., the lowest achievable quantitation limit [QL]) may serve as an approximate upper tolerance limit.”

Page 18-18: “It is possible to create an approximate non-parametric limit with background data containing all non-detects, by using the RL (often a quantitation limit) as the PQL. A quantified value above the PQL would constitute an exceedance.”

HAFB concurs with NMED on following statement, “A PQL is typically five times greater than the MDL. Data at or exceeding the PQL are considered accurate at a high level of confidence. Setting a background level for a data set that consists of all non-detects to twice the MDL, instead of at the MDL, will still result in establishing a background level that is less than the PQL.” Therefore, as provided in the 2009 Unified Guidance, “If all the sample data are non-detect, an RL (e.g., the lowest achievable *quantitation limit* [QL]) may serve as an approximate upper tolerance limit”. HAFB proposes that, for data sets that have all non-detects, to use an RL (e.g., the lowest achievable *quantitation limit* [QL]) as an approximate upper tolerance limit.

### 6.3 Combined Soil UTL

A qualitative comparison for each analyte in between surface/subsurface/saturated subsurface isoconcentration figures, indicates similar isocontours and distribution patterns. These similarities between isocontour patterns and uniform soil types suggests a homogenous matrix in each soil horizon. The major geologic unit for the surface soil sampling zone is silty sand. The major unit for the subsurface and saturated subsurface soil sampling zones is also silty sand with interbedded clay lenses. Overall, the primary geologic unit consisted of silty sand with increasing gypsum content with depth. This homogeneity between each soil horizon is further supported by the analytical soil data results which indicate that each constituent is within the same order of magnitude at each depth horizon. This indicates the presence of a single population of data. Additionally, the similarity of the analytical soil data results presented in the isocontour soil maps (Figures 5-1 through 5-87a) would suggest the presence of uniform soil types.

In general, the geochemical trend analysis for the metals concentrations in the three soil horizons stayed within the same order of magnitude. A slight decreasing trend was apparent as the depth

of the samples approach the saturated subsurface soil interval. However this is expected given the dynamic nature of the soils and groundwater within the saturated subsurface soil interval. Metals concentrations between surface soil and subsurface soils were nearly identical.

Furthermore, NVB conducted side by side analysis using box and whiskers plots on the same graphic to illustrate for a given constituent for all three soil types that the soils are very similar. In particular, the medians from the three soil horizons occupy similar locations within the boxes, and considerable overlap between the first and third quartiles among the three boxes was noted. Side by side box and whiskers plots were constructed using reduced data (outliers excluded) for only those metals constituents that had 100% detection in all three soil horizons and are provided in Appendix F of this report.

Following the determination that the three soil horizons were similar, statistical descriptors were prepared using the combined data sets for a single population, and the UTL was determined using ProUCL 4.0. The combined soil UTLs are presented in Table 5-17.

## **6.4 UTLs Above Regulatory Limits**

### **6.4.1 Surface Soil**

None of the surface soil UTLs exceeded their respective NMED Soil Screening Levels.

### **6.4.2 Subsurface Soil**

The arsenic UTL (4.75 mg/kg) for the subsurface soil exceeded the NMED Soil Screening Level of 3.59 mg/kg. None of the remaining subsurface soil UTLs exceeded their respective NMED Soil Screening Levels.

### **6.4.3 Saturated Subsurface Soil**

None of the saturated subsurface soil UTLs exceeded their respective NMED Soil Screening Levels.

### **6.4.4 Combined Soil**

The arsenic UTL (3.66 mg/kg) for the combined soil slightly exceeded the NMED Soil Screening Level of 3.59 mg/kg. None of the remaining UTLs exceeded their respective NMED Soil Screening Levels.

### **6.4.5 Groundwater**

Eleven UTLs for groundwater (total) exceeded their respective USEPA MCLs (primary or secondary) and eight UTLs exceeded the value in New Mexico Administrative Code (NMAC) 20.6.2. The following is a list of analytes whose UTLs exceeded the Federal MCLs:

- Aluminum
- Arsenic
- Cadmium
- Chloride (secondary)

- Manganese
- Selenium
- Sulfate (secondary)
- Thallium
- Radium (226 and 228 combined)
- Total Uranium
- Total Dissolved Solids

The following is a list of analytes whose UTLs exceeded the NMAC 20.6.2:

- Chloride
- Iron
- Manganese
- Selenium
- Sulfate
- Total Uranium
- Total Dissolved Solids

#### **6.4.6 Groundwater (Dissolved Metals)**

Four UTLs for dissolved metals in groundwater exceeded their respective USEPA primary or secondary MCLs standard. The following is a list of these analytes:

- Aluminum (secondary)
- Arsenic
- Manganese (secondary)
- Thallium

None of the UTLs exceeded their respective NMAC 20.6.2 standards.



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## **FIGURES**

## **TABLES**

**ATTACHMENT 1  
NMED CORRESPONDENCE DATED AUGUST 24, 2007**

**ATTACHMENT 2  
NMED CORRESPONDENCE DATED MAY 4, 2009 AND  
RESPONSE TO COMMENTS**



**APPENDIX A  
HTW DRILLING LOGS**

**APPENDIX B  
MONITORING WELL SAMPLE COLLECTION FORMS**

**APPENDIX C  
DATA VALIDATION AND LABORATORY ANALYTICAL  
RESULTS  
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**APPENDIX D  
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**APPENDIX E  
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**APPENDIX I  
PIPER DIAGRAM**

**Table 5-12**  
**Transformed Statistics and Upper Tolerance Limit**  
**Determination for Surface Soil Samples**  
 Basewide Background Study  
 Holloman Air Force Base, NM  
 NationView|Bhate Project Number: 9081001

Variable	Transformed Statistics													Grubbs Analysis and Test for Outliers						Method Used for Non-Detects	Test for Normality			Calculated UTLs and Percentiles			
	Num Samples	Num Ds	Num NDs	% NDs	MinimumRL	DL or MDC	Minimum	Maximum	Mean	Median	SD	Skewness	CV	Distribution Prior to Discordance Test	Discordance Test	Discordance Critical Value at 5%	Suspected Outlier Value from Data Set?	Statistical Evidence that the point is an Outlier?	# of Outliers Removed		Value of Shapiro-Wilks Normal Test	Shapiro Wilk Critical Value	Conclusion with Alpha (0.05)	95% UTL with 95% Coverage	90% Percentile (z)	95% Percentile (z)	99% Percentile (z)
Aluminum	42	39	0	0.00%	11	1.7	160.000	17,000.000	5,660.976	3,600.000	4,773.692	N/A	0.102	Gamma	1.688	2.857	17000.000	No	3	ProUCL	0.967	0.939	Normal	22,026.37	12,370.23	15,748.46	23,475.72
Antimony	42	0	42	100.00%	1.6	0.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Gamma	N/A	N/A	N/A	N/A	0	N/A	N/A	N/A	1.60	N/A	N/A	N/A	
Arsenic	42	32	7	17.95%	2.2	0.71	0.830	3.400	1.511	1.270	0.747	N/A	0.916	Gamma	2.147	2.773	3.400	No	3	Cohen	0.943	0.930	Normal	3,582	2,535	2,946	3,824
Barium	42	38	0	0.00%	1.1	0.081	2.773	4.868	3.903	3.892	0.512	N/A	0.131	Gamma	1.886	2.846	4.868	No	4	N/A	0.980	0.938	Normal	151.17	103.00	121.89	162.88
Beryllium	42	34	5	12.82%	0.54	0.035	15.000	150.000	57.964	49.000	33.392	N/A	-0.549	Gamma	1.644	2.799	150.000	No	3	DL/2	0.961	0.933	Normal	1.95	0.79	1.25	2.47
Cadmium	42	31	8	20.51%	0.54	0.044	0.420	16.000	5.322	3.450	4.208	N/A	-0.232	Gamma	1.860	2.759	16.000	No	3	Cohen	0.956	0.929	Normal	0.30	0.21	0.25	0.33
Calcium	42	36	0	0.00%	54	15	11.775	12.924	12.268	12.278	0.216	N/A	0.018	Normal	N/A	N/A	N/A	N/A	6	ProUCL	0.943	0.935	Normal	278,818.79	250,050.57	261,862.93	284,020.95
Chromium	42	38	0	0.00%	1.6	0.062	-0.094	2.708	1.409	1.246	0.751	-0.115	0.533	Lognormal	1.730	2.846	2.708	No	4	ProUCL	0.966	0.938	Normal	25.62	12.09	16.80	31.16
Cobalt	42	41	0	0.00%	1.1	0.11	-1.609	1.649	0.249	0.182	0.836	-0.178	3.356	Lognormal	1.674	2.877	1.649	No	1	ProUCL	0.970	0.941	Normal	7.49	3.74	5.07	8.97
Copper	42	41	0	0.00%	2.2	0.23	0.470	2.996	1.544	1.435	0.626	0.301	0.406	Lognormal	2.319	2.877	2.996	No	1	ProUCL	0.965	0.941	Normal	15.80	9.56	11.91	18.01
Iron	42	38	0	0.00%	16	4.1	6.328	9.547	8.141	8.022	0.834	-0.160	0.102	Lognormal	1.686	2.846	9.547	No	4	ProUCL	0.970	0.938	Normal	28,058.74	11,795.11	17,246.54	35,173.37
Lead	42	40	0	0.00%	0.87	0.29	-0.942	2.303	0.802	0.765	0.783	-0.040	0.976	Lognormal	1.918	2.866	2.303	No	2	ProUCL	0.976	0.940	Normal	9.67	5.22	6.79	11.13
Magnesium	42	38	0	0.00%	22	4	130.000	15,000.000	5,885.122	4,900.000	4,023.123	N/A	0.089	Gamma	N/A	N/A	N/A	N/A	4	ProUCL	0.937	0.938	Non-parametric	21,159.18	12,228.12	15,269.78	22,132.81
Manganese	42	38	0	0.00%	1.1	0.11	3.500	360.000	74.000	113.422	99.330	N/A	0.198	Gamma	1.657	2.846	360.000	No	4	ProUCL	0.972	0.938	Normal	451.49	251.10	321.34	482.61
Nickel	42	40	0	0.00%	4.3	0.13	-0.371	2.565	1.132	1.043	0.796	-0.002	0.703	Lognormal	1.801	2.866	2.565	No	2	ProUCL	0.966	0.940	Normal	16.95	8.57	11.56	20.24
Potassium	42	39	0	0.00%	330	44	83.000	2,900.000	880.000	1,146.086	753.023	N/A	0.118	Gamma	1.798	2.857	2900.000	No	3	ProUCL	0.969	0.939	Normal	3,887.99	2,292.53	2,823.60	4,010.03
Selenium	42	0	40	100.00%	1.4	0.92	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2	N/A	N/A	N/A	1.40	N/A	N/A	N/A	
Silver	42	0	41	100.00%	1.1	0.17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	1.10	N/A	N/A	N/A	
Sodium	42	39	0	0.00%	540	63	5.136	8.825	6.562	6.215	1.183	0.500	0.180	Lognormal	N/A	N/A	N/A	N/A	3	ProUCL	0.869	0.939	Non-parametric	679.32	453.61	525.80	693.65
Thallium	42	0	40	100.00%	1.3	0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2	ProUCL	N/A	N/A	N/A	1.30	N/A	N/A	N/A
Tin	42	42	0	0.00%	11	0.98	0.182	0.588	0.384	0.405	0.093	-0.027	0.244	Non-parametric	N/A	N/A	N/A	N/A	0	ProUCL	0.898	0.942	Non-parametric	1.79	1.65	1.71	1.82
Vanadium	42	36	0	0.00%	2.2	0.1	0.788	3.091	2.084	2.128	0.634	N/A	0.304	Gamma	1.588	2.823	3.091	No	6	ProUCL	0.960	0.935	Normal	33.76	20.01	24.93	36.02
Zinc	42	39	0	0.00%	3.3	0.43	0.642	3.784	2.441	2.398	0.796	-0.152	0.326	Lognormal	1.688	2.857	3.784	No	3	ProUCL	0.974	0.939	Normal	68.54	33.86	46.12	82.38
Mercury	42	32	7	17.95%	36	5.9	7.200	15.000	10.274	10.000	2.108	N/A	0.087	Gamma	2.342	2.773	15.000	No	3	Cohen	0.973	0.930	Normal	15.38	13.11	14.05	15.93
Carbon 14	42	0	38	100.00%	0.84	0.84	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4	N/A	N/A	N/A	0.84	N/A	N/A	N/A	
Ra-226 - Total	42	30	10	25.00%	0.11	0.11	0.144	1.650	0.647	0.505	0.416	N/A	-1.291	Gamma	1.615	2.745	1.650	No	2	Cohen	0.965	0.927	Normal	1.82	1.20	1.44	1.97
Ra-228 - Total	42	12	25	67.57%	0.33	0.33	0.400	1.300	0.799	0.816	0.182	N/A	-1.235	Gamma	1.531	2.285	1.300	No	5	ProUCL	0.952	0.859	Normal	1.27	1.06	1.14	1.32
Lead 210	42	4	35	89.74%	0.83	0.83	0.262	0.399	0.321	0.311	0.059	0.833	0.183	Non-parametric	1.327	1.463	0.399	No	3	ProUCL	0.963	0.748	Normal	1.34	1.23	1.27	1.36
Thorium 228	42	32	7	17.95%	0.08	0.08	0.094	1.210	0.419	0.330	0.320	N/A	-0.597	Gamma	2.023	2.773	1.210	No	3	Cohen	0.935	0.930	Normal	1.81	1.04	1.39	2.24
Thorium 230	42	41	0	0.00%	0.03	0.03	0.145	1.560	0.686	0.570	0.406	N/A	-1.313	Gamma	1.935	2.877	1.560	No	1	ProUCL	0.977	0.941	Normal	2.64	1.65	2.19	3.45
Thorium 232	42	37	0	0.00%	0.03	0.03	0.086	0.960	0.349	0.280	0.262	N/A	-0.497	Gamma	1.837	2.857	0.960	No	5	ProUCL	0.970	0.939	Normal	1.46	0.86	1.15	1.83
Uranium 234	42	37	0	0.00%	0.049	0.049	0.087	1.570	0.540	0.405	0.371	N/A	-0.778	Gamma	1.673	2.857	1.570	No	5	ProUCL	0.947	0.939	Normal	2.60	1.44	2.02	3.45
Uranium 235/236	42	4	35	89.74%	0.033	0.033	0.039	0.079	0.044	0.046	0.021	N/A	-0.147	Gamma	1.333	1.463	0.079	No	3	ProUCL	0.969	0.748	Normal	0.12	0.08	0.09	0.12
Uranium 238	42	40	0	0.00%	0.03	0.03	0.063	0.900	0.376	0.310	0.229	N/A	-0.506	Gamma	1.547	2.866	0.900	No	2	ProUCL	0.948	0.940	Normal	1.75	0.99	1.38	2.34
Total Uranium	41	41	0	0.00%	N/A	N/A	-1.977	0.991	-0.056	-0.082	0.694	-0.731	-12.453	Lognormal	1.508	2.877	0.991	No	0	ProUCL	0.941	0.941	Normal	4.09	2.30	2.96	4.75

**Notes:**  
 All metals results are in milligrams per kilogram (mg/kg) with the exception of Mercury which is provided in micrograms per kilogram (µg/kg)  
 Radiological results are in picoCuries per gram (pCi/g) with the exception of Total Uranium which is in micrograms per gram (µg/g)  
 D - Detects  
 ND - Non-detects  
 DL - Detection Limit  
 MDC - Minimum Detectable Concentration (for Radiological constituents)  
 SD - Standard deviation  
 N/A - Not applicable

Value set at the Reporting Limit. No statistics were used, therefore it is not a true UTL.

**Table 5-13**  
**Transformed Statistics and Upper Tolerance Limit**  
**Determination for Subsurface Soil Samples**  
 Basewide Background Study  
 Holloman Air Force Base, NM  
 NationView|Bhate Project Number: 9081001

Variable	Transformed Statistics												Grubbs Analysis and Test for Outliers					Method Used for Non-Detects	Calculated UTLs and Percentiles			
	Num Samples	Num Ds	Num NDs	% NDs	Minimum RL	DL or MDC	Minimum	Maximum	Mean	Median	SD	Skewness	Distribution Prior to Discordance Test	Discordance Test	Discordance Critical Value at 5%	Statistical Evidence that the point is an Outlier?	# of Outliers Removed		95% UTL with 95% Coverage	90% Percentile (z)	95% Percentile (z)	99% Percentile (z)
Aluminum	42	37	0	0.00%	11	1.60	600.00	19,000.00	6,244.00	4,550.00	4,960.00	N/A	Lognormal	1.56	2.835	No	5	N/A	25,679.71	12,917.32	17,276.59	29,809.09
Antimony	42	0	41	100.00%	1.6	0.40	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	1.60	N/A	N/A	N/A
Arsenic	42	28	9	24.32%	2.1	0.70	0.77	5.80	2.36	2.00	1.32	N/A	Gamma	1.41	2.714	No	5	ProUCL	4.75	3.28	3.84	5.05
Barium	42	40	0	0.00%	1.1	0.08	1.97	4.76	3.58	3.68	0.73	-0.302	Lognormal	1.62	2.866	No	2	N/A	175.57	94.39	123.63	205.06
Beryllium	42	35	3	7.89%	0.53	0.04	0.04	1.40	0.43	0.31	0.36	N/A	Lognormal	1.53	2.811	No	4	DL/2	2.39	0.92	1.38	2.97
Cadmium	42	22	14	38.89%	0.53	0.04	-2.94	-1.66	-2.35	-2.35	0.41	0.173	Lognormal	1.67	2.603	No	6	Cohen	0.20	0.14	0.17	0.21
Calcium	42	41	0	0.00%	53	15.00	11.33	12.90	12.05	12.04	0.36	0.364	Lognormal	2.37	2.866	No	1	N/A	361,517.59	269,066.88	306,262.46	390,461.75
Chromium	42	38	0	0.00%	1.6	0.06	0.78	18.00	6.90	5.20	5.30	N/A	Lognormal	1.47	2.846	No	4	N/A	9.69	4.83	6.50	11.35
Cobalt	42	38	0	0.00%	1.1	0.11	0.19	6.80	2.36	1.80	1.85	N/A	Lognormal	1.61	2.846	No	4	N/A	8.38	4.91	6.16	8.99
Copper	42	39	0	0.00%	2.1	0.23	0.64	12.00	4.18	2.80	3.05	N/A	Lognormal	1.57	2.857	No	3	N/A	15.45	8.09	10.69	18.03
Iron	42	38	0	0.00%	16	4.00	470.00	20,000.00	6,442.00	4,650.00	5,205.00	N/A	Lognormal	1.43	2.846	No	4	N/A	28,460.29	12,627.19	17,867.33	34,264.68
Lead	42	40	0	0.00%	0.85	0.29	0.35	9.20	3.30	2.83	2.58	N/A	Lognormal	1.55	2.866	No	2	N/A	14.27	6.76	9.36	17.20
Magnesium	42	37	0	0.00%	21	3.90	460.00	12,000.00	4,312.00	3,725.00	3,049.00	N/A	Lognormal	1.79	2.835	No	5	N/A	14,324.84	8,103.26	10,312.60	16,210.03
Manganese	42	37	0	0.00%	1.1	0.11	11.00	250.00	97.19	76.00	72.35	N/A	Lognormal	1.68	2.835	No	5	N/A	380.77	202.27	265.02	439.95
Nickel	42	37	0	0.00%	4.2	0.13	0.40	16.00	5.46	3.80	4.61	N/A	Lognormal	1.68	2.835	No	5	N/A	22.22	11.13	14.91	25.82
Potassium	42	39	0	0.00%	320	43.00	240.00	4,300.00	1,586.00	1,150.00	1,188.00	N/A	Lognormal	1.63	2.857	No	3	N/A	5,992.12	3,097.71	4,116.60	7,017.78
Selenium	42	0	42	100.00%	1.4	0.91	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	1.40	N/A	N/A	N/A
Silver	42	0	42	100.00%	1.1	0.17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	1.10	N/A	N/A	N/A
Sodium	42	40	0	0.00%	530	63.00	200.00	4,100.00	1,626.00	1,550.00	1,026.00	N/A	Lognormal	1.72	2.866	No	2	N/A	5,253.51	3,050.72	3,863.88	6,018.99
Thallium	42	0	41	100.00%	1.3	0.69	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	1.30	N/A	N/A	N/A
Tin	42	39	0	0.00%	11	0.97	1.20	2.30	1.62	1.60	0.26	N/A	Lognormal	2.31	2.857	No	3	N/A	2.23	1.97	2.08	2.30
Vanadium	42	38	0	0.00%	2.1	0.10	1.40	39.00	13.81	11.50	9.56	N/A	Gamma	1.53	2.811	No	4	N/A	43.34	26.96	32.71	45.42
Zinc	42	39	0	0.00%	3.2	0.42	1.50	47.00	16.99	12.75	13.34	N/A	Lognormal	1.53	2.857	No	3	N/A	71.70	34.84	47.55	85.22
Mercury	42	6	33	84.62%	35	5.90	7.10	13.00	9.06	8.20	2.42	N/A	Non-parametric	1.33	1.822	No	3	ProUCL	9.33	8.54	8.88	9.53
Carbon 14	42	0	42	100.00%	0.85	0.85	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	0.85	N/A	N/A	N/A
Ra-226 - Total	42	35	7	16.67%	0.12	0.12	0.22	1.26	0.52	0.48	0.23	N/A	Gamma	2.37	2.811	No	0	Cohen	1.11	0.79	0.92	1.19
Ra-228 - Total	42	14	27	66.67%	0.35	0.35	0.45	1.33	0.79	0.75	0.26	N/A	Lognormal	2.11	2.371	No	1	ProUCL	1.57	0.96	1.19	1.79
Lead 210	42	2	37	94.87%	0.87	0.87	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3	N/A	3.18	N/A	N/A	N/A
Thorium 228	42	32	7	17.95%	0.06	0.06	0.15	1.12	0.51	0.47	0.24	N/A	Gamma	1.40	2.773	No	3	Cohen	1.07	0.73	0.86	1.14
Thorium 230	42	39	0	0.00%	0.03	0.03	0.15	1.23	0.55	0.49	0.26	N/A	Lognormal	2.08	2.857	No	3	DL/2	1.23	0.87	1.01	1.34
Thorium 232	42	35	3	7.89%	0.03	0.03	0.10	0.94	0.43	0.43	0.22	N/A	Non-parametric	1.52	2.811	No	4	DL/2	1.41	0.76	0.99	1.63
Uranium 234	42	35	0	0.00%	0.04	0.04	-1.65	-0.08	-0.79	-0.76	0.41	-0.533	Normal	1.74	2.811	No	7	DL/2	0.88	0.72	0.79	0.91
Uranium 235/236	42	2	39	95.24%	0.036	0.04	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	0.12	N/A	N/A	N/A
Uranium 238	42	35	0	0.00%	0.029	0.03	0.08	0.84	0.37	0.37	0.18	N/A	Normal	1.91	2.811	No	7	DL/2	0.70	0.57	0.62	0.72
Total Uranium	42	42	0	0.00%	N/A	N/A	0.14	2.53	1.06	1.08	0.56	N/A	Gamma	N/A	2.877	N/A	0	N/A	2.91	1.92	2.29	3.08

**Notes:**  
 All metals results are in milligrams per kilogram (mg/kg) with the exception of Mercury which is provided in micrograms per kilogram (µg/kg)  
 Radiological results are in picoCuries per gram (pCi/g) with the exception of Total Uranium which is in micrograms per gram (µg/g)  
 D - Detects  
 ND - Non-detects  
 DL - Detection Limit  
 MDC - Minimum Detectable Concentration (for Radiological constituents)  
 SD - Standard deviation  
 N/A - Not Applicable

Value set at the Reporting Limit. No statistics were used, therefore it is not a true UTL.  
 Value set at 2 times the Maximum Detected Concentration in the data set

**Table 5-14**  
**Transformed Statistics and Upper Tolerance Limit**  
**Determination for Saturated Subsurface Soil Samples**  
 Basewide Background Study  
 Holloman Air Force Base, NM  
 NationView|Bhate Project Number: 9081001

Variable	Transformed Statistics												Grubbs Analysis and Test for Outliers					Method Used for Non-Detects	Calculated UTLs and Percentiles			
	Num Samples	Num Ds	Num NDs	% NDs	Minimum RL	DL or MDC	Minimum	Maximum	Mean	Median	SD	Skewness	Distribution Prior to Discordance Test	Discordance Test	Discordance Critical Value at 5%	Statistical Evidence that the point is an Outlier?	# of Outliers Removed		95% UTL with 95% Coverage	90% Percentile (z)	95% Percentile (z)	99% Percentile (z)
Aluminum	42	38	0	0.00%	12	1.80	680.00	10,750.00	3,981.25	3,400.00	2,359.83	0.66	Normal	2.34	2.85	No	4	NA	8,977.51	7,005.49	7,862.82	9,471.03
Antimony	42	0	42	100.00%	1.8	0.45	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	1.80	N/A	N/A	N/A
Arsenic	42	27	10	27.03%	2.3	0.77	0.89	2.50	1.41	1.30	0.46	N/A	Gamma	1.95	2.70	No	5	Cohen	2.51	2.00	2.21	2.64
Barium	42	38	0	0.00%	1.2	0.09	2.70	120.00	44.37	37.50	30.74	N/A	Gamma	1.63	2.85	No	4	NA	148.86	89.64	110.81	158.21
Beryllium	42	37	0	0.00%	0.59	0.04	0.06	0.52	0.24	0.18	0.15	N/A	Gamma	1.60	2.84	No	5	DL/2	0.78	0.47	0.58	0.82
Cadmium	42	20	17	45.95%	0.59	0.05	-2.98	-1.43	-2.25	-2.32	0.42	0.20	Non-parametric	1.94	2.56	No	5	Cohen	0.11	0.09	0.10	0.11
Calcium	42	40	0	0.00%	59	17.00	650.00	250,000.00	126,887.80	140,000.00	65,854.17	65,854.17	Normal	2.00	2.87	No	2	NA	265,856.37	211,283.32	235,208.28	280,087.51
Chromium	42	37	0	0.00%	1.8	0.07	0.34	2.59	1.51	1.41	0.60	-0.09	Lognormal	1.80	2.84	No	5	N/A	19.07	10.51	13.65	22.28
Cobalt	42	38	0	0.00%	1.2	0.12	-1.02	1.53	0.19	0.05	0.73	0.19	Lognormal	1.84	2.85	No	4	DL/2	8.21	3.79	5.34	10.12
Copper	42	39	0	0.00%	2.3	0.25	-0.08	2.07	0.90	0.69	0.61	0.26	Non-parametric	1.90	2.86	No	3	N/A	8.90	6.51	7.71	8.90
Iron	42	36	0	0.00%	18	4.50	540.00	14,000.00	4,849.52	3,400.00	3,443.30	N/A	Gamma	1.88	2.82	No	6	N/A	15,675.41	9,656.21	11,873.79	16,822.07
Lead	42	38	0	0.00%	0.94	0.32	-0.24	1.89	0.78	0.69	0.64	0.17	Lognormal	1.75	2.85	No	4	DL/2	10.36	5.45	7.24	12.33
Magnesium	42	39	0	0.00%	23	4.30	6.11	8.95	7.66	7.74	0.63	0.03	Lognormal	2.03	2.86	No	3	N/A	6,249.50	3,880.25	4,738.16	6,891.89
Manganese	42	39	0	0.00%	1.2	0.12	2.17	5.21	3.89	3.83	0.82	-0.15	Lognormal	1.61	2.86	No	3	N/A	322.78	158.26	216.30	388.71
Nickel	42	41	0	0.00%	4.7	0.14	-0.69	2.42	1.00	0.88	0.81	-0.12	Lognormal	1.73	2.88	No	1	DL/2	15.21	7.75	10.42	18.14
Potassium	42	37	0	0.00%	350	48.00	210.00	2,000.00	925.38	810.00	492.09	0.34	Normal	2.46	2.84	No	5	N/A	1,970.82	1,556.02	1,734.80	2,070.16
Selenium	42	0	42	100.00%	1.5	1.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.00	N/A	N/A	0	N/A	1.50	N/A	N/A	N/A
Silver	42	0	42	100.00%	1.2	0.19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	1.20	N/A	N/A	N/A
Sodium	42	38	0	0.00%	590	69.00	5.83	8.13	6.72	6.59	0.62	0.63	Lognormal	2.28	2.85	No	4	N/A	2,216.37	1,396.15	1,697.73	2,450.18
Thallium	42	0	37	100.00%	1.4	0.76	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5	N/A	1.40	N/A	N/A	N/A
Tin	42	38	0	0.00%	12	1.10	1.20	2.10	1.71	1.70	0.21	N/A	Gamma	2.12	2.85	No	4	N/A	2.19	1.99	2.08	2.26
Vanadium	42	38	0	0.00%	2.3	0.11	2.00	29.00	11.26	8.05	7.78	N/A	Gamma	1.72	2.85	No	4	N/A	33.77	21.66	26.31	36.61
Zinc	42	40	0	0.00%	3.5	0.47	0.88	3.64	2.30	2.21	0.70	-0.04	Lognormal	1.91	2.87	No	2	N/A	40.95	22.30	28.98	47.36
Mercury	42	4	35	89.74%	39	6.50	6.80	9.00	7.93	8.12	0.69	N/A	Gamma	1.22	1.46	No	3	ProUCL	9.49	8.86	9.14	9.69
Carbon 14	42	0	42	100.00%	0.84	0.84	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	0.84	N/A	N/A	N/A
Ra-226 - Total	42	35	6	14.63%	0.09	0.09	0.18	0.90	0.42	0.39	0.19	N/A	Gamma	2.17	2.81	No	1	Cohen	1.01	0.71	0.82	1.07
Ra-228 - Total	42	13	23	62.16%	0.26	0.26	0.35	0.74	0.52	0.53	0.07	N/A	Gamma	2.01	2.37	No	6	ProUCL	0.68	0.61	0.64	0.70
Lead 210	42	2	37	94.87%	0.86	0.86	0.20	0.52	0.36	0.36	0.23	N/A	N/A	N/A	N/A	N/A	3	N/A	3.38	N/A	N/A	N/A
Thorium 228	42	39	0	0.00%	0.05	0.05	-1.71	-0.29	-0.91	-0.94	0.40	-0.22	Lognormal	1.57	2.85	No	3	DL/2	1.19	0.75	0.92	1.35
Thorium 230	42	39	0	0.00%	0.03	0.03	-1.43	-0.02	-0.70	-0.69	0.40	-0.14	Lognormal	1.71	2.86	No	3	DL/2	1.50	0.95	1.16	1.70
Thorium 232	42	36	1	2.70%	0.03	0.03	0.09	0.77	0.37	0.33	0.20	N/A	Gamma	1.59	2.82	No	5	DL/2	1.33	0.86	1.13	1.75
Uranium 234	42	40	0	0.00%	0.04	0.04	0.10	0.85	0.35	0.32	0.22	N/A	Gamma	1.66	2.87	No	2	DL/2	1.13	0.70	0.85	1.19
Uranium 235/236	42	1	39	97.50%	0.036	0.04	-2.33	-2.33	-2.33	-2.33	N/A	N/A	N/A	N/A	N/A	N/A	2	N/A	0.19	N/A	N/A	N/A
Uranium 238	42	39	0	0.00%	0.026	0.03	-2.28	-0.21	-1.28	-1.43	0.58	0.25	Lognormal	1.85	2.86	No	3	DL/2	1.06	0.61	0.78	1.23
Total Uranium	42	42	0	0.00%	N/A	-1.44	0.99	-0.25	-0.25	-0.36	0.66	0.17	Non-parametric	N/A	N/A	N/A	0	N/A	2.68	2.03	2.42	2.68

**Notes:**

All metals results are in milligrams per kilogram (mg/kg) with the exception of Mercury which is provided in micrograms per kilogram ( µg/kg)

Radiological results are in picoCuries per gram (pCi/g) with the exception of Total Uranium which is in micrograms per gram ( µg/g)

D - Detects

ND - Non-detects

DL - Detection Limit

SD - Standard deviation

MDC - Minimum Detectable Concentration (for Radiological constituents)

N/A - Not Applicable

Value set at the Reporting Limit. No statistics were used, therefore it is not a true UTL.

Value set at 2 times the Maximum Detected Concentration in the data set



**Table 5-15**  
**Transformed Statistics and Upper Tolerance Limit**  
**Determination for Groundwater - Unfiltered Samples**  
 Basewide Background Study  
 Holloman Air Force Base, NM  
 NationView|Bhate Project Number: 9081001

Variable	Transformed Statistics												Grubbs Analysis and Test for Outliers					Method Used for Non-Detects	Calculated UTLs and Percentiles			
	Num Samples	Num Ds	Num NDs	% NDs	Minimum RL	DL or MDC	Minimum	Maximum	Mean	Median	SD	Skewness	Distribution Prior to Discordance Test	Discordance Test	Discordance Critical Value at 5%	Evidence that the point is an Outlier?	# of Outliers Removed		95% UTL with 95% Coverage	90% Percentile (z)	95% Percentile (z)	99% Percentile (z)
Aluminum <sup>a</sup>	20	13	6	31.58%	100	18	2.89	6.15	4.44	4.20	0.95	0.66	Lognormal	2.04	2.33	No	1	ProUCL	1,042.43	229.53	371.56	917.06
Antimony	24	0	20	100.00%	10	3.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4	N/A	10.00	N/A	N/A	N/A
Arsenic	24	16	4	20.00%	15	4.4	5.30	21.00	10.00	8.90	4.84	N/A	Gamma	1.74	2.44	No	4	Cohen	25.93	16.78	19.50	25.32
Barium	24	24	0	0.00%	10	0.58	1.95	3.53	2.70	2.77	0.41	0.10	Lognormal	2.03	2.64	No	0	N/A	38.00	25.06	29.03	38.27
Beryllium	24	0	24	100.00%	5	0.47	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	5.00	N/A	N/A	N/A
Cadmium	24	24	0	0.00%	5	0.45	-0.63	2.17	0.37	0.47	0.80	1.03	Non-parametric	N/A	N/A	N/A	0	ProUCL	8.80	7.25	8.73	8.80
Calcium	24	24	0	0.00%	200	34	13.06	13.82	13.44	13.38	0.22	0.30	Lognormal	1.72	2.64	No	0	N/A	1,136,663.50	908,786.41	983,605.19	1,140,965.60
Chromium	24	16	7	30.43%	10	0.66	0.85	9.00	2.21	1.64	1.89	N/A	Gamma	2.22	2.44	Yes	1	Cohen	12.00	5.91	8.33	14.27
Cobalt	24	1	23	95.83%	10	1.2	0.18	2.89	0.57	0.18	0.79	1.83	N/A	N/A	N/A	No	0	ProUCL	36	N/A	N/A	N/A
Copper	24	10	14	58.33%	15	1.4	0.34	2.28	0.82	0.47	0.66	1.21	Non-parametric	N/A	N/A	No	0	ProUCL	9.80	6.80	9.05	9.80
Iron	24	17	7	29.17%	100	22	25.50	1,200.00	170.14	80.00	251.60	N/A	Gamma	2.46	2.48	No	0	Cohen	1,306.82	508.84	811.98	1,613.75
Lead	24	0	24	100.00%	9	2.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	9.00	N/A	N/A	N/A
Magnesium	24	24	0	0.00%	200	11	12.97	14.91	13.87	13.86	0.54	0.39	Lognormal	1.93	2.64	No	0	N/A	3,692,781.50	2,116,674.60	2,577,022.30	3,727,645.20
Manganese	24	24	0	0.00%	10	0.25	-2.08	6.46	2.33	2.56	1.85	-0.34	Lognormal	2.23	2.64	No	0	DL/2	745.38	110.86	217.48	769.75
Mercury	24	2	22	91.67%	0.2	0.027	-3.61	-1.51	-3.36	-3.61	0.69	2.42	N/A	N/A	N/A	N/A	0	N/A	0.44	N/A	N/A	N/A
Nickel	24	12	11	47.83%	40	1.3	1.30	14.00	3.83	3.00	3.20	N/A	Gamma	N/A	N/A	No	1	Cohen	21.97	10.39	14.79	25.62
Potassium	24	24	0	0.00%	3000	240	8.68	12.15	10.15	10.31	0.92	0.46	Lognormal	2.19	2.64	No	0	N/A	212,143.56	82,758.79	115,443.61	215,542.28
Selenium	24	12	11	45.83%	15	4.9	5.00	93.00	17.87	12.39	19.72	N/A	Gamma	2.03	2.29	No	1	Cohen	129.52	52.65	81.51	156.42
Silver	24	0	24	100.00%	10	0.93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	10.00	N/A	N/A	N/A
Sodium	24	24	0	0.00%	1000	92	14.00	16.38	15.26	15.37	0.69	-0.09	Lognormal	1.62	2.64	No	0	N/A	20,989,585.00	10,310,931.00	13,257,304.00	21,243,016.00
Thallium	24	0	24	100.00%	15	4.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	15.00	N/A	N/A	N/A
Tin	24	0	24	100.00%	100	5.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	100.00	N/A	N/A	N/A
Vanadium	24	24	0	0.00%	10	1.1	2.22	4.42	3.34	3.26	0.50	0.12	Lognormal	2.15	2.64	No	0	N/A	90.02	53.82	64.55	90.80
Zinc	24	14	10	41.67%	20	4.5	4.60	17.00	7.44	6.45	3.29	N/A	Gamma	N/A	N/A	Yes	0	Cohen	16.95	11.84	13.54	17.14
Carbon 14	24	0	24	100.00%	8.6	8.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	8.60	N/A	N/A	N/A
Ra-226 - Total	24	23	0	0.00%	0.13	0.13	-1.24	0.74	-0.19	-0.12	0.49	-0.28	Lognormal	1.88	2.62	No	1	DL/2	2.62	1.56	1.87	2.61
Ra-228 - Total	24	22	0	0.00%	0.39	0.39	-0.56	1.19	0.34	0.29	0.44	0.19	Lognormal	1.91	2.60	No	2	DL/2	3.99	2.49	2.92	3.95
Lead 210	24	0	24	100.00%	3.1	3.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	3.10	N/A	N/A	N/A
Thorium 228	24	3	21	87.50%	0.15	0.15	-1.90	-0.53	-1.50	-1.51	0.30	1.41	Non-parametric	N/A	N/A	No	0	ProUCL	0.99	0.31	0.82	0.99
Thorium 230	24	9	14	60.87%	0.06	0.06	0.10	0.34	0.21	0.22	0.06	N/A	Gamma	2.09	2.11	No	1	ProUCL	0.37	0.29	0.32	0.37
Thorium 232	24	0	24	100.00%	0.061	0.061	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	0.06	N/A	N/A	N/A
Uranium 234	24	23	0	0.00%	0.1	0.1	1.23	5.21	3.08	3.17	0.90	-0.04	Lognormal	2.37	2.62	No	1	DL/2	175.95	68.85	95.36	175.69
Uranium 235/236	24	19	4	17.39%	0.06	0.06	0.21	3.90	0.76	0.73	0.81	N/A	Gamma	2.23	2.53	No	1	Cohen	4.79	2.09	2.99	5.24
Uranium 238	24	23	0	0.00%	0.08	0.08	0.38	4.60	2.35	2.36	0.96	0.06	Lognormal	2.34	2.62	No	1	DL/2	98.07	35.87	50.86	97.92
Uranium Total	24	23	0	0.00%	N/A	0	1.47	5.69	3.45	3.46	0.96	0.06	Lognormal	2.34	2.62	No	1	DL/2	294.23	107.58	152.56	293.76
Alkalinity (as CaCO <sub>3</sub> )	24	24	0	0.00%	5	1.1	4.05	5.95	5.12	5.30	0.52	-0.54	Normal	1.59	2.64	N/A	0	N/A	386.57	298.44	329.60	388.05
Chloride	24	24	0	0.00%	3	12	7.50	10.09	8.90	8.92	0.68	-0.32	Lognormal	1.75	2.64	No	0	N/A	35,039.73	17,502.94	22,371.89	35,452.81
Sulfate	24	24	0	0.00%	5	0.5	8.01	9.68	8.67	8.75	0.47	0.43	Lognormal	2.13	2.64	No	0	N/A	17,418.99	10,709.40	12,719.36	17,562.64
Sulfide	24	0	15	100.00%	1	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9	N/A	1.00	N/A	N/A	N/A
Total Dissolved Solids	24	24	0	0.00%	10	19	9.01	10.82	9.88	9.95	0.53	0.31	Lognormal	1.78	2.64	No	0	N/A	65,956.58	38,281.91	46,401.92	66,565.21

**Notes:**  
 All metals results are in micrograms per liter (µg/L)  
 Radiological results are in picoCuries per liter (pCi/L) with the exception of Total Uranium which is in micrograms per liter (µg/L)  
 D - Detects  
 ND - Non-detects  
 DL - Detection Limit  
 MDC - Minimum Detectable Concentration (for Radiological constituents)  
 SD - Standard deviation  
 N/A - Not Applicable  
<sup>a</sup> MW-29-01, MW-BG-04, S1-MW2, and TDS-MW02 were removed from the dataset due to elevated Detection Limits  
 Value set at the Reporting Limit. No statistics were used, therefore it is not a true UTL.  
 Value set at 2 times the Maximum Detected Concentration in the Data Set

**Table 5-16**  
**Transformed Statistics and Upper Tolerance Limit**  
**Determination for Groundwater Dissolved Metals - Filtered Samples**  
 Basewide Background Study  
 Holloman Air Force Base, NM  
 NationView|Bhate Project Number: 9081001

Variable	Transformed Statistics												Grubbs Analysis and Test for Outliers					Method Used for Non-Detects	Calculated UTLs and Percentile			
	Num Samples	Num Ds	Num NDs	% NDs	Minimum RL	DL	Minimum	Maximum	Mean	Median	SD	Skewness	Distribution Prior to Discordance Test	Discordance Test	Discordance Critical Value at 5%	Evidence that the point is an Outlier?	# of Outliers Removed		95% UTL with 95% Coverage	90% Percentile (z)	95% Percentile (z)	99% Percentile (z)
Aluminum <sup>a</sup>	21	1	20	95.83%	100	18	3.29	3.29	3.29	3.29	N/A	0.33	N/A	N/A	N/A	No	0	ProUCL	54.00	N/A	N/A	N/A
Antimony	24	0	24	100.00%	10	3.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	10.00	N/A	N/A	N/A
Arsenic <sup>a</sup>	21	16	5	23.81%	15	4.4	4.40	21.00	8.69	6.40	5.41	N/A	Gamma	2.27	2.44	No	0	Cohen	28.53	16.92	20.72	29.17
Barium	24	23	0	0.00%	10	0.58	1.84	3.11	2.59	2.56	0.35	-0.25	Lognormal	1.49	2.62	No	1	NA	30.13	20.88	23.72	30.11
Beryllium	24	0	24	100.00%	1	0.47	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	1.00	N/A	N/A	N/A
Cadmium	24	20	2	9.09%	5	0.45	-0.80	0.83	0.08	0.15	0.53	-0.25	Non-parametric	1.43	2.60	No	2	DL/2	2.41	1.85	2.04	2.40
Calcium	24	24	0	0.00%	200	34	13.06	13.82	13.43	13.38	0.23	0.27	Lognormal	1.69	2.64	No	0	NA	1,151,301.20	910,742.49	989,439.77	1,155,866.50
Chromium	24	11	11	50.00%	10	0.66	0.70	1.90	1.17	1.21	0.42	N/A	Gamma	1.94	2.60	N/A	2	Cohen	2.50	1.79	2.01	2.49
Cobalt	24	2	21	91.30%	10	1.2	0.18	1.82	0.40	0.18	0.56	2.35	N/A	N/A	N/A	No	1	ProUCL	2.60	N/A	N/A	N/A
Copper	24	9	14	60.87%	15	1.4	1.40	18.00	8.86	6.51	7.21	N/A	Gamma	2.16	2.62	No	1	ProUCL	57.46	24.59	35.60	63.02
Iron	24	7	17	70.83%	100	22	22.00	47.50	35.96	36.89	9.98	N/A	Gamma	2.43	2.64	N/A	0	ProUCL	65.56	50.51	55.65	66.18
Lead	24	0	24	100.00%	9	2.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	9.00	N/A	N/A	N/A
Magnesium	24	24	0	0.00%	200	11	12.90	14.95	13.86	13.83	0.54	0.37	Lognormal	2.02	2.64	No	0	NA	3,630,926.70	2,085,525.20	2,537,243.60	3,665,078.60
Manganese	24	20	0	0.00%	10	0.25	0.00	3.87	1.81	1.46	1.24	0.33	Lognormal	1.67	2.56	No	4	NA	118.65	29.83	46.79	108.84
Mercury	24	0	24	100.00%	0.2	0.027	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	0.20	N/A	N/A	N/A
Nickel	24	7	15	68.18%	40	1.3	1.60	8.20	5.16	5.31	2.68	N/A	Gamma	2.23	2.60	N/A	2	ProUCL	15.89	9.42	11.25	15.25
Potassium	24	22	0	0.00%	3000	240	8.92	11.10	9.98	9.94	0.73	0.04	Lognormal	1.53	2.60	No	2	NA	120,479.98	55,130.46	71,936.13	118,497.71
Selenium	24	12	10	45.45%	15	4.9	6.30	23.00	11.87	11.52	4.40	N/A	Gamma	1.51	2.60	No	2	Cohen	25.26	18.07	20.39	25.23
Silver	24	0	24	100.00%	10	0.93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	10.00	N/A	N/A	N/A
Sodium	24	24	0	0.00%	1000	92	14.00	16.30	15.24	15.26	0.68	-0.17	Lognormal	1.56	2.64	No	0	NA	19,972,499.00	9,923,033.30	12,707,578.00	20,209,785.00
Thallium	24	0	24	100.00%	15	4.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	15.00	N/A	N/A	N/A
Tin	24	0	24	100.00%	100	5.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	100.00	N/A	N/A	N/A
Vanadium	24	23	0	0.00%	10	1.1	2.27	4.08	3.26	3.22	0.45	-0.09	Lognormal	1.83	2.62	No	1	NA	73.73	46.22	54.35	73.68
Zinc	24	18	6	25.00%	20	4.5	4.60	26.00	10.83	7.47	7.10	N/A	Gamma	1.63	2.64	No	0	Cohen	56.28	28.98	40.84	69.87

**Notes:**  
 All metals results are in micrograms per liter ( µg/L)  
 D - Detects  
 ND - Non-detects  
 DL - Detection limit  
 SD - Standard deviation  
 N/A - Not Applicable  
<sup>a</sup> MW-BG-04, S1-MW2, and TDS-MW02 were removed from the dataset due to elevated Detection Limits  
 Value set at the Reporting Limit. No statistics were used, therefore it is not a true UTL.  
 Value set at 2 times the Maximum Detected Concentration in the Data Set

**Table 5-17**  
**Transformed Statistics and Upper Tolerance Limit**  
**Determination for Combined Soil Samples**  
 Basewide Background Study  
 Holloman Air Force Base, NM  
 NationView|Bhate Project Number: 9081001

Variable	Transformed Statistics											Solution	Calculated UTLs and Percentiles			
	Num Samples	Num Ds	Num NDs	% NDs	Minimum RL	DL or MDC	Minimum	Maximum	Mean	Median	SD		95% UTL with 95% Coverage	90% Percentile (z)	95% Percentile (z)	99% Percentile (z)
Aluminum	126	125	0	0.00%	11	1.70	5.08	9.85	8.24	8.19	0.87	Non-parametric	13,722.27	11,051.42	12,643.17	15,629.02
Antimony	126	0	123	100.00%	1.6	0.42	-0.92	-0.54	-0.74	-0.73	0.01	N/A	1.60	N/A	N/A	N/A
Arsenic	126	91	32	26.02%	2.1	0.73	-0.26	1.55	0.39	0.26	0.28	Non-parametric	3.66	3.02	3.40	4.11
Barium	126	126	0	0.00%	1.1	0.08	0.99	5.08	3.68	3.78	0.59	Lognormal	169.25	105.94	140.13	236.80
Beryllium	126	107	17	13.71%	0.53	0.04	-3.24	0.10	-1.59	-1.64	0.90	Lognormal	1.53	0.77	1.16	2.48
Cadmium	126	74	48	39.34%	0.53	0.05	-3.02	-1.31	-2.48	-2.68	0.26	Non-parametric	0.28	0.17	0.23	0.40
Calcium	126	126	0	0.00%	53	15.67	6.48	12.92	11.85	12.04	0.73	Normal	317,331.59	269,324.04	297,985.62	351,749.97
Chromium	126	126	0	0.00%	1.6	0.06	-2.63	3.04	1.43	1.50	0.89	Lognormal	24.95	14.06	19.80	37.65
Cobalt	126	125	1	0.79%	1.1	0.11	-1.90	1.97	0.31	0.34	0.82	Lognormal	7.70	4.40	6.14	11.50
Copper	126	125	0	0.00%	2.1	0.24	-0.62	2.56	1.16	1.16	0.55	Lognormal	12.96	8.24	10.80	17.91
Iron	126	126	0	0.00%	16	4.20	5.19	9.90	8.21	8.27	0.94	Lognormal	23,049.48	12,768.09	18,167.00	35,203.09
Lead	126	125	1	0.79%	0.85	0.30	-1.05	2.40	0.81	0.77	0.68	Lognormal	10.87	6.53	8.85	15.66
Magnesium	126	124	0	0.00%	21	4.07	4.87	9.62	8.06	8.10	0.79	Lognormal	16,990.65	9,878.17	13,639.47	24,982.80
Manganese	126	125	0	0.00%	1.1	0.11	1.25	5.89	4.18	4.22	0.90	Lognormal	393.47	220.35	311.30	595.21
Nickel	126	126	0	0.00%	4.2	0.13	-0.93	2.83	1.15	1.18	0.81	Lognormal	17.34	10.02	13.90	25.69
Potassium	126	124	0	0.00%	320	45.00	4.42	8.56	6.92	6.91	0.72	Lognormal	5,077.12	3,019.17	4,113.17	7,346.50
Selenium	126	0	125	100.00%	1.4	0.94	-0.09	0.34	0.09	0.10	0.01	N/A	1.40	N/A	N/A	N/A
Silver	126	0	124	100.00%	1.1	0.18	-1.77	-1.43	-1.60	-1.61	0.01	N/A	1.10	N/A	N/A	N/A
Sodium	126	125	0	0.00%	530	65.00	4.87	8.52	6.78	6.73	0.89	Lognormal	5,195.97	2,927.36	4,120.84	7,826.49
Thallium	126	0	124	100.00%	1.3	0.72	-0.37	0.00	-0.20	-0.20	0.01	N/A	1.30	N/A	N/A	N/A
Tin	126	126	0	0.00%	11	1.02	0.18	0.83	0.46	0.47	0.02	Non-parametric	2.10	1.90	2.08	2.27
Vanadium	126	126	0	0.00%	2.1	0.10	-0.82	3.66	2.15	2.21	0.72	Lognormal	42.53	25.38	34.55	61.58
Zinc	126	125	0	0.00%	3.2	0.44	0.18	3.85	2.40	2.40	0.72	Lognormal	54.53	32.53	44.26	78.86
Mercury	126	38	82	68.33%	35	6.10	1.77	2.56	2.05	1.97	0.03	Non-parametric	10.76	9.77	10.35	11.45
Carbon 14	126	0	126	100.00%	0.84	0.84	-0.17	0.18	0.05	0.10	0.01	N/A	0.84	N/A	N/A	N/A
Ra-226 - Total	126	99	24	19.51%	0.09	0.11	-1.94	0.29	-0.82	-0.81	0.26	Lognormal	1.35	0.90	1.14	1.79
Ra-228 - Total	126	39	74	65.49%	0.26	0.31	-1.35	0.29	-0.48	-0.53	0.12	Non-parametric	0.95	0.81	0.89	1.05
Lead 210	126	7	111	94.07%	0.83	0.85	-0.19	0.59	0.13	0.18	0.03	Lognormal	1.04	0.87	0.97	1.18
Thorium 228	126	111	15	11.90%	0.05	0.06	-2.36	0.19	-1.01	-0.99	0.36	Lognormal	1.35	0.86	1.13	1.86
Thorium 230	126	121	3	2.42%	0.03	0.03	-2.12	0.44	-0.68	-0.69	0.32	Lognormal	1.55	1.08	1.34	2.01
Thorium 232	126	113	13	10.32%	0.03	0.03	-3.06	-0.04	-1.20	-1.17	0.47	Lognormal	1.33	0.81	1.09	1.91
Uranium 234	126	120	5	4.00%	0.04	0.04	-2.45	0.24	-0.99	-0.92	0.45	Lognormal	1.43	0.92	1.20	1.97
Uranium 235/236	126	8	118	93.65%	0.033	0.04	-5.43	-1.90	-2.71	-2.73	0.17	Non-parametric	0.08	0.06	0.07	0.10
Uranium 238	126	120	6	4.76%	0.026	0.03	-2.76	-0.11	-1.23	-1.19	0.41	Non-parametric	0.75	0.62	0.69	0.84
Total Uranium	126	125	0	0.00%	N/A	N/A	-1.99	0.99	-0.14	-0.10	0.46	Non-parametric	2.43	2.01	2.36	2.69

**Notes:**

All metals results are in milligrams per kilogram (mg/kg) with the exception of Mercury which is provided in micrograms per kilogram (µg/kg)

Radiological results are in picoCuries per gram (pCi/g) with the exception of Total Uranium which is in micrograms per gram (µg/g)

D - Detects

ND - Non-detects

DL - Detection Limit

MDC - Minimum Detectable Concentration (for Radiological constituents)

SD - Standard deviation

N/A - Not Applicable

Value set at the Reporting Limit. No statistics were used, therefore it is not a true UTL.

**Table 5-18**  
**Summary of Soil and Groundwater Background Levels**  
**Basewide Background Study**  
**Holloman Air Force Base, NM**  
**NationView|Bhate Project Number: 9081001**

Variable	NMED Soil Screening Levels <sup>a</sup>	Groundwater USEPA MCL <sup>b</sup>	Groundwater New Mexico Administrative Code (NMAC)	Total Groundwater Background Level <sup>e</sup>	Dissolved Metals in Groundwater Background Level <sup>e</sup>	Combined Soil Background Level <sup>e</sup>	Total Groundwater Background Level <sup>e</sup> Above USEPA MCL?	Total Groundwater Background Level <sup>e</sup> Above NMAC?	Dissolved Metals in Groundwater Background Level <sup>e</sup> Above USEPA MCL?	Dissolved Metals in Groundwater Background Level <sup>e</sup> Above NMAC?	Combined Soil Background Level <sup>e</sup> Above NMED Soil Screening Levels?
<b>Metals - Units are in mg/kg for soil and µg/L for groundwater (except for Mercury which is in µg/kg for soil and µg/L for groundwater)</b>											
Aluminum	78,100	50 <sup>d</sup>	NE	1,042.43	54.00	13,722.27	Yes	N/A	Yes	N/A	No
Antimony	31.3	6	NE	10.00	10.00	1.60	Yes	N/A	Yes	N/A	No
Arsenic	3.9	10	100	25.93	28.53	3.66	Yes	No	Yes	No	No
Barium	15,600	2,000	1,000	38.00	30.13	169.25	No	No	No	No	No
Beryllium	156	4	NE	5.00	1.00	1.53	Yes	N/A	No	N/A	No
Cadmium	77.9	5	10	8.80	2.41	0.28	Yes	No	No	No	No
Calcium	NE	NE	NE	1,136,663.50	1,151,301.20	317,331.59	N/A	N/A	N/A	N/A	N/A
Chromium	18,000	100	50	12.00	2.50	24.95	No	No	No	No	No
Cobalt	23 <sup>c</sup>	NE	50	36.00	2.60	7.70	N/A	No	N/A	No	No
Copper	3,130	1,300	1,000	9.80	57.46	12.96	No	No	No	No	No
Iron	54,800	NE	1,000	1,306.82	65.56	23,049.48	N/A	Yes	N/A	No	No
Lead	400	15	50	9.00	9.00	10.87	No	No	No	No	No
Magnesium	NE	NE	NE	3,692,781.50	3,630,926.70	16,990.65	N/A	N/A	N/A	N/A	N/A
Manganese	10,700	50 <sup>d</sup>	200	745.38	118.65	393.47	Yes	Yes	Yes	No	No
Mercury	7,710	2	2	0.44	0.200	10.76	No	No	No	No	No
Nickel	1,560	NE	200	21.97	15.89	17.34	N/A	No	N/A	No	No
Potassium	NE	NE	NE	212,143.56	120,479.98	5,077.12	N/A	N/A	N/A	N/A	N/A
Selenium	391	50	50	129.52	25.26	1.40	Yes	Yes	No	No	No
Silver	391	100 <sup>d</sup>	50	10.00	10.00	1.10	No	No	No	No	No
Sodium	NE	NE	NE	20,989,585.00	19,972,499.00	5,195.97	N/A	N/A	N/A	N/A	N/A
Thallium	5.16	2	NE	15.00	15.00	1.30	Yes	N/A	Yes	N/A	No
Tin	47,000 <sup>c</sup>	NE	NE	100.00	100.00	2.10	N/A	N/A	N/A	N/A	No
Vanadium	391	NE	NE	90.02	73.73	42.53	N/A	N/A	N/A	N/A	No
Zinc	23,500	NE	10,000	16.95	56.28	54.53	N/A	No	N/A	No	No
<b>Radiological Constituents - Units are in pCi/g for soil and pCi/L for groundwater (except for Total Uranium which is in µg/g for soil and µg/L for groundwater)</b>											
Carbon 14	NE	NE	NE	8.60	N/A	0.84	N/A	N/A	N/A	N/A	N/A
Ra-226 - Total	NE	5	30	2.62	N/A	1.35	Yes	No	N/A	N/A	N/A
Ra-228 - Total	NE	5	30	3.99	N/A	0.95	Yes	No	N/A	N/A	N/A
Lead 210	NE	NE	NE	3.10	N/A	1.04	N/A	N/A	N/A	N/A	N/A
Thorium 228	NE	NE	NE	0.99	N/A	1.35	N/A	N/A	N/A	N/A	N/A
Thorium 230	NE	NE	NE	0.37	N/A	1.55	N/A	N/A	N/A	N/A	N/A
Thorium 232	NE	NE	NE	0.061	N/A	1.33	N/A	N/A	N/A	N/A	N/A
Uranium 234	NE	NE	NE	175.95	N/A	1.43	N/A	N/A	N/A	N/A	N/A
Uranium 235/236	NE	NE	NE	4.79	N/A	0.08	N/A	N/A	N/A	N/A	N/A
Uranium 238	NE	NE	NE	98.07	N/A	0.75	N/A	N/A	N/A	N/A	N/A
Total Uranium	NE	30	30	294.23	N/A	2.43	Yes	Yes	N/A	N/A	N/A
<b>Natural Attenuation Parameters - Units are in mg/L</b>											
Alkalinity (as CaCO <sub>3</sub> )	N/A	NE	NE	386.57	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chloride	N/A	250 <sup>d</sup>	250	35,039.73	N/A	N/A	Yes	Yes	N/A	N/A	N/A
Sulfate	N/A	250 <sup>d</sup>	600	17,418.99	N/A	N/A	Yes	Yes	N/A	N/A	N/A
Sulfide	N/A	NE	NE	1.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Dissolved Solids	N/A	500 <sup>d</sup>	1,000	65,956.58	N/A	N/A	Yes	Yes	N/A	N/A	N/A

**Notes:**

NE - Not established  
N/A - Not applicable  
mg/kg - Milligrams per kilogram  
µg/L - Micrograms per liter  
mg/L - Milligrams per liter  
µg/kg - Micrograms per kilogram  
pCi/g - PicoCuries per gram  
pCi/L - PicoCuries per liter  
µg/g - Micrograms per gram

<sup>a</sup> New Mexico Environment Department (NMED) Soil Screening Levels, December 2009

<sup>b</sup> U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Levels (MCLs), May 2009

<sup>c</sup> USEPA Regional Screening Level, April 2009

<sup>d</sup> USEPA Secondary Drinking Water Standard (May 2009)

<sup>e</sup> NMED (NOD dated October 2010) required the use of the term "background level" instead of UTLs. Therefore, the "background level" were calculated by determining the 95 % UTL with 95% Coverage of the results

Value set at the Reporting Limit. No statistics were used, therefore it is not a true UTL.  
Value set at 2 times the Maximum Detected Concentration in the Data Set  
Total Chromium value set at the EPA Region 6 RSL, Protection of Ground Water SSLs



**FINAL  
BASEWIDE BACKGROUND STUDY REPORT  
HOLLOMAN AIR FORCE BASE,  
NEW MEXICO**

Prepared for:  
**49 CES/CEA  
Holloman Air Force Base  
New Mexico**

Under Contract To:  
**U.S. Army Corps of Engineers  
Omaha District  
Omaha, Nebraska**

**Contract No. W9128F-07-D-0022  
Task Order No. 0003**

~~October 2009~~July 2011  
~~Revision 01~~Revision 03

Prepared by:  
**NationViewIBhate JV III, LLC  
1608 13<sup>th</sup> Avenue South, Suite 300  
Birmingham, Alabama 35205**

**NationViewIBhate Project No. 9081001**

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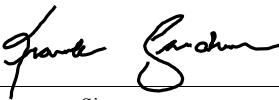
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NEW MEXICO**

**REVIEW SHEET**

This Report has been reviewed and approved by:

Katherine Thompson Geologist/Field Manager	Signature	Date
J. Mark Stapleton, Ph.D., P.E., AEE Technical Director	Signature	Date
Frank Gardner, P.G. Program Manager	 Signature	Date

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**FINAL  
BASEWIDE BACKGROUND STUDY REPORT  
HOLLOMAN AIR FORCE BASE,  
NEW MEXICO**

**CERTIFICATION**

I certify that I am a qualified groundwater scientist who has received a baccalaureate or postgraduate degree in the natural sciences or engineering, and have sufficient training and experience in groundwater hydrology and related fields, as demonstrated by state registration and completion of accredited university courses, that enables me to make sound professional judgments regarding groundwater monitoring and contaminant fate and transport. I further certify that I am a Professional Engineer for Bhatte Environmental Associates, Inc., and this report was prepared by myself or by a subordinate working under my direction and that the information contained in this report is correct and accurate to the best of my knowledge.

---

J. Mark Stapleton, Ph.D., P.E., AEE  
Technical Director  
New Mexico Registered Professional Engineer  
No. 17492  
Expiration Date: December 31, 201~~20~~

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

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**FINAL**  
**BASEWIDE BACKGROUND STUDY REPORT**  
**HOLLOMAN AIR FORCE BASE,**  
**NEW MEXICO**

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**Appendices**

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- Appendix B Monitoring Well Sample Collection Forms
- Appendix C Data Validation (Provided in Hard Copy) and Laboratory Analytical Results (Provided on CD)
- Appendix D ProUCL 4.00.04 Technical Guide - [Input and Output File](#) -(Provided on CD)
- Appendix E Histograms
- Appendix F Box Plots
- Appendix G Normal Probability Plots (Q-Q Plots)
- Appendix H Stiff Diagrams
- Appendix I Piper Diagram

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## **ACRONYMS AND ABBREVIATIONS**

AAF	Army Air Field
AEE	Associate to the American Academy of Environmental Engineering
AF FM	Air Force Form
amsl	Above mean sea level
ASTM	American Society for Testing and Materials
bgs	Below ground surface
Bhate	Bhate Environmental Associates, Inc.
BWBG	Basewide background
CES/CEA	Civil Engineering Squadron/Asset Management Flight
COC	Chain-of-custody
COPC	Chemical of Potential Concern
DL	Detection Limit
DO	Dissolved oxygen
DOE	Department of Energy
DQO	Data Quality Objective
EDD	Electronic data deliverable
ERP	Environmental Restoration Program
ERPIMS	Environmental Restoration Program Information Management System
°F	Degrees Fahrenheit
ft	Feet
GPS	Global positioning system
HAFB	Holloman Air Force Base
HSA	Hollow Stem Auger
IDLs	Instrument detection limits
IDW	Investigation-Derived Waste
LCS	Laboratory control samples
LCSD	Laboratory control sample duplicates
MCL	Maximum Contaminant Level
MDC	Minimum Detectable Concentration
MDL	Method Detection Limit
meq/L	Milli-equivalents per liter
mg/kg	Milligrams per kilogram
mg/L	Milligrams per liter
µg/L	Micrograms per liter
MS	Matrix spike
MSD	Matrix spike duplicate
NAD	North American Datum
NAPs	Natural Attenuation Parameters
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMWQCC	New Mexico Water Quality Control Commission

## ACRONYMS AND ABBREVIATIONS (CONTINUED)

NTUs	Nephelometric turbidity units
NVB	NationView/Bhate JV III, LLC
ORP	Oxidation reduction potential
OSWER	Office of Solid Waste and Emergency Response
pCi/L	PicoCuries per liter
P.E.	Professional Engineer
P.G.	Professional Geologist
PhD	Doctor of Philosophy
PPE	Personal protective equipment
ppb	Parts per billion
PQL	Practical quantitation limit
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
%R	Percent Recovery
RL	Reporting Limit
RPD	Relative Percent Difference
SOP	Standard Operating Procedure
SWMU	Solid Waste Management Unit
TAL	Target Analyte List
TDS	Total dissolved solids
USACE	United States Army Corps of Engineers
USAF	United States Air Force
USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
UTL	Upper Tolerance Limit
WRCC	Western Regional Climate Center
WSMR	White Sands Missile Range

## **EXECUTIVE SUMMARY**

NationView/Bhate JV III, LLC (NVB) was retained by the United States Army Corps of Engineers (USACE), to conduct a Basewide Background Study at Holloman Air Force Base (HAFB), New Mexico. The objective of the soil and groundwater Basewide Background Study was to collect data of sufficient quantity and quality to enable statistical evaluation of background soil and groundwater characteristics. Data collection, laboratory analysis, and statistical treatment were performed in accordance with the Work Plan (NVB, August 2008) that was approved by the New Mexico Environment Department (NMED) on July 30, 2008. The objective of this study was achieved.

This report presents a summary of the work conducted at the base and background values based upon the calculated statistical analysis. The following steps were conducted in order to determine the background values:

- An evaluation of the Previous Background Study dataset and existing Environmental Restoration Program Information Management System (ERPIMS) database was conducted to consider combining the historical datasets with the new investigation to generate a more robust background dataset. A combined background dataset would increase the overall accuracy of the statistical evaluation and level of confidence in the resulting Upper Tolerance Limits (UTLs). However, on August 24, 2007, NMED indicated in the disapproval letter of the Previous Background Study that both the sample size and sampling locations were either too small or poorly described and did not provide confidence that the samples were collected at locations that are representative of natural conditions. In order to prevent potential error propagation from the Previous Background Study or incorporation of the ERPIMS datasets which contains limited information regarding natural conditions, HAFB will only use the data set that was collected for the background study.
- Collection and analysis of surface, subsurface, and saturated subsurface soil samples from 42 borings
- Collection and analysis of groundwater samples from 30 existing monitoring wells
- Performance of statistical evaluation of sampling data to establish background values

Based on the statistical analysis, the following conclusions/observations were made:

- Background levels are based on the 95% Upper Tolerance Limit (UTL) which represents an estimate of the upper 95<sup>th</sup> percentile of the true background concentration of the constituent of interest.
- The 95% UTL values were not calculated for antimony, selenium, silver, thallium, and carbon-14 in surface soil, subsurface soil, and saturated subsurface soil; and, 95% UTL values were not calculated for antimony, beryllium, lead, silver, thallium, tin, carbon-14, lead 210, and thorium 232 in groundwater due to the limited number of detections or the fact that all samples were non-detects. It should be noted that, if 1 to 3 of the measurements in the data set were non-detects, the UTL was set at 2 times the maximum detected value. If 100%

of the measurements in the data set were non-detect, the UTL was set to the lowest detection limit in the data set as required by the NMED.

- One UTL was developed for all three soil horizons (surface, subsurface, and saturated subsurface) although samples were collected from various depths
- One UTL for the combined soil (arsenic) exceeded the NMED Soil Screening Level.
- Twelve UTLs for groundwater (total) exceeded their respective federal Maximum Contaminant Levels (MCLs) and eight UTLs exceed the New Mexico Water Quality Control Commission (NMWQCC) Regulations (New Mexico Administrative Code [NMAC] 20.6.2).
- Four UTLs for groundwater (dissolved metals) exceeded their respective federal MCLs and no UTL exceeded the NMWQCC regulations in NMAC 20.6.2.

## 1 INTRODUCTION

NationView/Bhate JV III, LLC (NVB) has been retained by the United States Army Corps of Engineers (USACE), under contract W9128F-07-D-0022, Task Order No. 0003, to conduct a Basewide Background Study at Holloman Air Force Base (HAFB), New Mexico (Figures 1-1 and 1-2). On August 24, 2007, the New Mexico Environment Department (NMED) notified the 49th Civil Engineering Squadron/Asset Management Flight (CES/CEA) at HAFB that it had completed its review of the document entitled *Base-wide Background Study, Sewage Lagoons and Lakes Investigation*, submitted in December 1993 by Radian Corporation (hereinafter referred to as the "Previous Background Study") and disapproved the Previous Background Study for several technical reasons. NMED indicated that the Previous Background Study was inadequate from a technical and statistical perspective and indicated that it must be completely redone. A copy of the NMED Disapproval letter is provided as Attachment 1 of this report. Following is a chronology of events following receipt of the disapproval letter:

- In November 2007 HAFB met with NMED to formulate the conceptual design for the new background study.
- In February 2008, HAFB submitted a Work Plan to conduct the necessary investigation to support a background study which included: identification of clean background soil boring locations (42); identification of existing wells appropriate for background study (30); development of statistical methodology; collection and analysis of surface soil, subsurface soil, and saturated subsurface soil samples from 42 soil borings located across HAFB for metals and radionuclides; collection of groundwater samples from 30 existing monitoring wells for metals, radionuclides, and natural attenuation parameters; and finally perform the statistical evaluation of sampling data to establish background values.
- On July 2, 2008, HAFB received comments from NMED on the Work Plan.
- On July 14, 2008, HAFB responded to NMED comments and began revising the Work Plan following verbal concurrence.
- In August 2008, the Final Work Plan was submitted and field activities commenced.
- In January 2009, the Basewide Background Study Report was submitted to NMED.
- On May 4, 2009, NMED provided comments (Notice of Disapproval) regarding the Basewide Background Study Report (provided in Attachment 2 of this report).
- On June 1, 2009, HAFB submitted responses to comments regarding the Basewide Background Study Report and requested a meeting for clarification.
- On June 3, 2009, HAFB and NMED personnel met in Albuquerque, New Mexico to discuss the response to comments regarding the Basewide Background Study Report.
- On August 11, 2009, HAFB and NMED met in Albuquerque, New Mexico to discuss the response to comments and additional verbal comments received during the June 3 meeting. NMED solicited graphic representation of the revised groundwater data using 24 wells instead of 30.

- On August 28, 2009, HAFB provided NMED a conceptual write up of groundwater geochemistry and revised groundwater concentration maps for the 24 wells as requested by NMED so that guidance on the revised data set could be provided to HAFB.
- On September 4, 2009, NMED replied via e-mail that additional guidance could not be provided until the entire document was re-submitted as a complete re-analysis of the data could not be performed.
- On November 3, 2009, HAFB submitted the Basewide Background Study to Air Force Center for Engineering and the Environment (AFCEE).
- On November 18, 2009, AFCEE provided comments regarding the Basewide Background Study Report and indicated that they concur with the technical approach used to develop the document.
- On December 7, 2009, the Revised Basewide Background Study Report was submitted to NMED.
- On October 28, 2010, NMED provided a second set of comments (Notice of Disapproval) regarding the Basewide Background Study Report (provided in Attachment 2 of this report).
- On December 17, 2010, HAFB submitted responses to comments regarding the Basewide Background Study Report and requested a meeting for clarification.
- On January 3, 2011, HAFB and NMED met in Albuquerque, New Mexico to discuss the response to comments received on October 28<sup>th</sup>, 2010.
- On July 13, 2011, NMED indicated via email that they were prepared to provide partial approval with respect to metals.

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This document is the ~~third~~<sup>first</sup> revision of the Basewide Background Study Report which was submitted to the NMED in January 2009, and incorporates the comments made in the NOD letter. This document includes a Response to Comments table (included in Attachment 2 of this report following the NOD letters) which provides a response to how each line item was addressed within this document.

## 1.1 Objectives

The primary objective of this report is to fulfill the requirements identified by the NMED in order to establish background values for the occurrence of certain naturally occurring inorganic constituents in both groundwater and soil. This report presents a summary of the work conducted at the base and background values developed based upon the calculated statistical analysis.

### 1.1.1 Purpose of the Basewide Background Study

The purpose of this study is to establish background values for the occurrence of certain naturally occurring inorganic constituents in soil (surface, subsurface, and saturated subsurface) and groundwater.



### 1.1.2 Scope of Work

The scope of work and evaluation methods presented in this report were developed based on the previous background study report in concurrence with NMED. Additionally, the work plan which met scope requirements, was approved by NMED. The following list is a summary of the work performed in order to complete this Basewide Background Study.

- Held a scoping meeting at NMED in November 15, 2007, to frame the scope of work to be performed and discuss technical and statistical approaches
- Prepared and submitted a work plan
- Implemented the work plan which included the following:
  - identification of clean background soil boring locations (42)
  - identification of existing wells appropriate for background study (30) (see Figure 1-3)
  - development of statistical methodology
  - collection and analysis of surface soil, subsurface soil, and saturated subsurface soil samples from 42 soil borings located across HAFB (see Figure 1-4)
  - collection of groundwater samples from 30 existing monitoring wells
  - performance of statistical evaluation of sampling data to establish background values
- Prepared and submitted sampling data in the appropriate format for inclusion in the Environmental Restoration Program Information Management System (ERPIMS)
- Prepared and submitted this Basewide Background Study Report

### 1.2 Site Description

HAFB is situated in south central New Mexico, in the northwest central part of Otero County, approximately 75 miles north-northeast of El Paso, Texas (Figure 1-1). HAFB has a population of 6,000 and occupies 59,600 acres in the northeast quarter of Section 1, Township 17 South, Range 8 East. The White Sands Missile Range (WSMR) testing facilities occupy additional land extending northward from the Base. Private and public owned lands border the remainder of HAFB. The major highway servicing HAFB is Highway 70, which runs southwest from the town of Alamogordo and separates HAFB from publicly owned lands to the south. Alamogordo which has a population of approximately 35,000 is located approximately 7 miles east of the base.

HAFB was first established in 1942 as Alamogordo Army Air Field (AAF). From 1942 through 1945, Alamogordo AAF served as the training grounds for over 20 different flight groups, flying primarily B-17s, B-24s, and B-29s. After World War II, most operations had ceased at the base. In 1947, Air Material Command announced the air field would be its primary site for the testing and development of un-manned aircraft, guided missiles, and other research programs. On January 13, 1948, the Alamogordo installation was renamed Holloman Air Force Base, in honor of the late Col. George V. Holloman; a pioneer in guided missile research. In 1968, the 49th Tactical Fighter Wing arrived at HAFB and has remained since. Today, HAFB also serves as the training center for the German Air Force's Tactical Training Center.

### 1.3 Document Organization

The report is organized into the following chapters and appendices:

- **Chapter 1 – Introduction.** This chapter discusses the objectives of the Basewide Background Study and provides a site description.
- **Chapter 2 – Environmental Setting.** This chapter provides a description of the physiography and topography, surface water and hydrology, regional geology and soils, regional hydrogeology, climate, and current and future land and water use at the site.
- **Chapter 3 – Investigation Activities.** This chapter provides a description of all field activities conducted for the Basewide Background Study and a summary of the data quality objectives, standard operating procedures, sample identification, and project documentation.
- **Chapter 4 – Conceptual Site Model.** This chapter provides a description of the hydrogeologic framework and depositional environments that affect soil and groundwater chemistry.
- **Chapter 5 – Technical Approach.** This chapter provides a description of how the data collected for the Basewide Background Study was graphically and statistically analyzed.
- **Chapter 6 – Summary of Results and Observations.** This chapter provides a summary of the results and observations associated with the statistical analysis of the Basewide Background Study.
- **Chapter 7 – References.** This chapter provides references used in this Basewide Background Study Report.

The *Tables* and *Figures* referenced throughout this Basewide Background Study Report are included following the text (after Chapter 7). In addition, the following Attachments and Appendices are included:

- **Attachment 1** – NMED Disapproval Letter dated August 24, 2007
- **Attachment 2** - – NMED Disapproval Letter dated May 4, 2009, regarding the Basewide Background Study and Response to Comments
- **Appendix A** – HTW Drilling Logs
- **Appendix B** – Monitoring Well Sample Collection Forms
- **Appendix C** – Data Validation (provided in Hard Copy) and Laboratory Analytical Results (Provided on CD)
- **Appendix D** – ProUCL 4.00.04 Technical Guide (Provided on CD)
- **Appendix E** – Histograms
- **Appendix F** – Box Plots
- **Appendix G** – Normal Probability Plots (Q-Q Plots)
- **Appendix H** – Stiff Diagrams
- **Appendix I** – Piper Diagram



## 2 ENVIRONMENTAL SETTING

### 2.1 Physiography and Topography

HAFB is located within the Sacramento Mountains Physiographic Province on the western edge of the Sacramento Mountains (Figure 1-1). HAFB is approximately 59,600 acres in area, and is located at a mean elevation of 4,093 feet above mean sea level (amsl) (Figure 1-2). The region is characterized by high tablelands with rolling summit plains; cuesta-formed mountains dipping eastward and of west-facing escarpments with the wide bracketed basin forming the basin and range complex. The Base is located in the Tularosa Sub-basin which is part of the Central Closed Basins. The bordering mountains rise abruptly to altitudes of 7,000 to 12,000 feet amsl. The San Andres Mountains bound the basin to the west (about 30 miles) with the Sacramento Mountains approximately 10 miles to the east. At its widest, the basin is about 60 miles east to west and stretches approximately 150 miles north to south.

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### 2.2 Surface Water and Hydrology

The Tularosa Basin contains all of the surface flow in its boundaries. The nearest inflow of surface waters to the Base comes from the Lost River, located in the north-central region of the Base. The upper reaches of the Three Rivers and the Sacramento River are perennial in the basin. HAFB is dissected by several southwest trending arroyos that control the surface drainage. Hay Draw arroyo is located in the far north. Malone and Rita's Draw, which drain into the Lost River, and Dillard Draw arroyos are located along the eastern perimeter of the Base. Approximately 10,000 years ago, indications are of a much wetter climate. The present day Lake Otero encompassed a much larger area, possibly upwards of several hundred square miles. Its remains are the Alkali Flat and Lake Lucero. Lake Lucero is a temporary feature of merely a few inches in depth during the rainy season.

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Ancient lakes and streams deposited water bearing deposits over the older bedrock basement material. Fractures, cracks, and fissures in the Permian and Pennsylvanian bedrock yield small quantities of relatively good quality water in the deeper peripheral. Potable water is only found from a handful of wells near the edges of the basin with more saline water towards the center. Two of the principal sources of potable water are a long narrow north-south trending area east of Tularosa and Alamogordo and in the far southwestern part of the basin. Alamogordo's water, as well as the Base's, is supplied from Lake Bonito (which is in the Pecos River Basin).

### 2.3 Regional Geology and Soils

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#### 2.3.1 Geology

The sedimentary rocks which make up the adjacent mountain ranges are between 500 and 250 million years old (WSMR, 2003a). During the period when the area was submerged under the shallow intra-continental sea, the layers of limestone, shale, gypsum, and sandstone were deposited. In time, these layers were pushed upward through various tectonic forces forming a large bulge on the surface. Approximately 10 million years ago the center began to subside resulting in a vertical drop of thousands of feet leaving the edges still standing (the present day

Sacramento and San Andres mountain ranges). In the millions of years following, rainfall, snowmelt, and wind eroded the mountain sediments depositing them in the valley (i.e. Tularosa Basin). Water carrying eroded limestone, dolomite, gravel, and other matter continue to flow into the basin.

As the Tularosa Basin is a bolson, which is a basin with no surface drainage outlet, sediments carried by surface water into a closed basin are bolson deposits. The overlying alluvium generally consists of unconsolidated gravels, sands, and clays. Soils in the basin are derived from the adjacent ranges as erosional deposits of limestone, dolomite, and gypsum. A fining sequence from the ranges towards the basin's center characterizes the area with the near surface soils as alluvial, eolian, and lacustrine deposits. The alluvial fan deposits are laterally discontinuous units of interbedded sand, silt, and clay while the eolian deposits consist primarily of gypsum sands. The eolian and alluvial deposits are usually indistinguishable due to the reworking of the alluvial sediment by eolian processes. The playa, or lacustrine deposits, consist of clay containing gypsum and are contiguous with the alluvial fan and eolian deposits throughout HAFB. There has been the identification of stiff caliche layers, varying in thickness, at different areas of the Base.

### 2.3.2 Soils

The United States Department of Agriculture (USDA) Soil Conservation Service has identified two soil associations in the vicinity of HAFB; the Holloman-Gypsum Land-Yesum complex, and the Mead silty clay loam. The permeability of these horizons ranges from  $4 \times 10^{-4}$  to  $1 \times 10^{-3}$  centimeters per second.

The Holloman-Gypsum land-Yesum complex, 0 to 5 percent slopes soil consists of large areas of shallow and deep, well drained soils and areas of exposed gypsum. The Holloman soil makes up about 35 percent of the complex. Typically, the surface layer is light brown very fine sandy loam about 3 inches thick. The upper 13 inches of the substratum is pink very fine sandy loam that is very high in gypsum. Below that, the substratum is white gypsum to a depth of more than 60 inches. This soil is calcareous and mildly alkaline to moderately alkaline throughout. Permeability is moderate, and available water capacity is very low.

Gypsum land makes up about 30 percent of the Holloman-Gypsum land-Yesum complex, 0 to 5 percent slopes. Typically, less than 1 inch of very fine sandy loam overlies soft to hard, white gypsum. The deep Yesum very fine sandy loam makes up about 20 percent of the complex. Typically, the surface layer is light brown very fine sandy loam about 3 inches thick. The upper 9 inches of the substratum is light brown fine sandy loam that is very high in gypsum. Below that, the substratum is pink very fine sandy loam to a depth of more than 60 inches. The soil is calcareous throughout and is mildly alkaline. Permeability is moderate, and available water capacity is moderate. Many fine gypsum crystals are found throughout the profile.

The soil type located across the main drainage area for the installation is Mead silty clay loam, 0 to 1 percent slopes. This deep, poorly drained, nearly level soil is on outer fringes of alluvial fans. This soil formed in fine textured alluvium over lacustrine lake sediment. It is very high in salt content because of periodic flooding and poor drainage. Slopes are smooth and concave.

Typically, the surface layer is reddish brown silty clay loam and clay loam about 5 inches thick. The substratum, to a depth of 48 inches, is light reddish brown clay that has a high content of salts. Below that, the substratum is lacustrine material of variable texture and color to a depth of more than 60 inches. Included with this soil are areas of Holloman soils and Gypsum land along the margins of the unit of steep, short gully sides and knolls. These inclusions make up about 15 percent of the map unit for this soil type. Individual areas are generally smaller than 10 acres. This soil is moderately calcareous throughout and is moderately to strongly alkaline. It has a layer of salt that is more soluble than gypsum. Permeability is very slow, and available water capacity is low.

### **2.3.3 Site Specific Geology**

Drilling activities were conducted from September 3 through September 20, 2008, using Hollow Stem Auger (HSA) technology and soil boring locations are shown on Figure 1-4. During drilling activities, soils were logged continuously down to the deepest sample collected (64 feet below ground surface [bgs] from sample BWBG-SB23). HTW Drilling Logs are provided in Appendix A of this report.

The overall geology of these soil borings consisted primarily of silts and sands (mostly silty sand) with higher gypsum content with increasing depth. Some borings consisted of clay lenses or mixtures of clayey sand and clayey silt. Samples were collected from the surface, subsurface, and the saturated subsurface zones and are discussed in further detail below. A cross-section is provided as Figure 2-1.

#### **2.3.3.1 Surface Soil**

Surficial soil samples were collected from the ground surface to 0.5 feet (ft) bgs. Surface soils consisted primarily of well sorted, very fine-grained silty sands.

#### **2.3.3.2 Subsurface Soil**

Subsurface soil samples were collected mid-way between the surface and the saturated zone. These samples were collected from depths ranging from 7 ft bgs to 30 ft bgs. These samples consisted primarily of silty sand. Some samples were collected in zones with higher sand content or higher silt content and only a few samples were collected in zones with clay contents. The subsurface geology generally consisted of silty sands near the surface and increased in both sand and clay content with depth, however, mixtures of silt and sand were predominate throughout the base.

#### **2.3.3.3 Saturated Subsurface Soil**

Saturated subsurface soil samples were collected immediately upon encountering groundwater within the saturated zone. These samples were collected from depths ranging from 15 ft bgs to 64 ft bgs. These samples consisted primarily of silty sand and sands. Very few samples were collected in zones containing some clay content.

## 2.4 Hydrogeology

### 2.4.1 Regional Hydrogeology

Groundwater occurs as an unconfined aquifer in the unconsolidated deposits of the central basin, with the primary source of recharge as rainfall percolation and minor amounts of stream run-off along the western edge of the Sacramento Mountains. Surface water/rainfall migrates downward into the alluvial sediments at the edge of the shallow aquifer near the ranges, and flows downgradient through progressively finer-grained sediments towards the central basin. Because the Tularosa Basin is a closed system, water that enters the area only leaves either through evaporation or percolation. This elevated amount of percolation results in a fairly high water table. Beneath HAFB, groundwater ranges from 5 to 50 feet bgs. Flow for the Base is generally towards the southwest with localized influences from the variations in the topography of the Base. In the northern and western portions of the Base, groundwater flows more to the west toward the Ritas Draw, Malone Draw, and Lost River drainages. Groundwater flow is affected by local topography in areas immediately adjacent to arroyos, where groundwater flows directly toward the drainages regardless of the regional flow pattern. A groundwater potentiometric surface map from measurements collected in September 2008 is provided as Figure 2-2.

Groundwater quality in the Tularosa Basin is of potable quality at the recharge areas in close proximity to the Sacramento Mountains and becomes increasingly mineralized toward the central portion of the basin and discharge areas. The majority (over 70%) of the Environmental Restoration Program (ERP) Sites/Solid Waste Management Units (SWMUs) located across HAFB have groundwater monitoring wells containing water with an average total dissolved solids (TDS) concentration greater than 10,000 milligrams per liter (mg/L). This TDS data supports the hypothesis that TDS concentrations below 10,000 mg/L at HAFB are caused by dilution of natural groundwater from leaking water lines and surface irrigation from the domestic water supply. TDS concentrations greater than 10,000 mg/L exceed the New Mexico Water Quality Control Commission (NMWQCC) limit as potable water and thus, the groundwater beneath HAFB has been designated as unfit for human consumption. Likewise, the United States Environmental Protection Agency (USEPA) guidelines have identified the groundwater as a Class IIIB water source, characterized by TDS concentrations exceeding 10,000 mg/L. Class IIIB groundwater is also characterized by a low degree of interconnection with adjacent surface waters or groundwater of a higher class. Groundwater does not discharge or connect to any adjacent aquifers because the Tularosa Basin is a closed basin. Adjacent surface waters include Lost River and Lake Holloman, which also have high concentrations of TDS, and are not considered potential drinking water sources.

### 2.4.2 Site-Specific Hydrogeology

During field activities associated with this Basewide Background Study, 30 existing monitoring wells were measured and sampled (Figure 1-3). Depth to groundwater was measured prior to sampling and groundwater elevations were calculated based on the top-of-casing elevation. Groundwater elevations ranged from 4,031.21 ft amsl to 4,112.59 ft amsl. Based on the measurements collected in September 2008, groundwater generally appears to be flowing

towards the southwest. A groundwater potentiometric surface map is provided as Figure 2-2. Monitoring Well Sample Collection Forms are provided in Appendix B of this report.

## 2.5 Climate

As a whole, New Mexico has a mild, arid to semi-arid continental climate characterized by light precipitation totals, abundant sunshine, relatively low humidity, and relatively large annual and diurnal temperature range (Western Regional Climate Center [WRCC], 2003). The climate of the Central Closed Basins varies with elevation. The Base is found in the low areas and is characterized by warm temperatures and dry air. Daytime temperatures often exceed 100 degrees Fahrenheit (°F) in the summer months and are in the middle 50s in the winter. A preponderance of clear skies and relatively low humidity permits rapid night time cooling resulting in average diurnal temperature ranges of 25 to 35°F. Potential evapotranspiration, at 67 inches per year, significantly exceeds annual precipitation, usually less than 10 inches. The very low rainfall amounts resulting in the arid conditions, which with the topographically induced wind patterns combining with the sparse vegetation, tend to cause localized “dust devils”. The annual rainfall for Alamogordo is 12 inches per year<sup>1</sup>. Much of the precipitation falls during the mid-summer monsoonal period (July and August) as brief, yet frequent, intense thunderstorms culminating to 30 – 40% of the annual total rainfall.

## 2.6 Current and Future Land Use

The land surrounding HAFB consists of residential areas to the east and northeast (City of Alamogordo), rangeland to the south, the White Sands National Monument to the west, and areas where military activities are conducted to the north. The desert terrain of the area immediately surrounding HAFB has limited development, and there are no agricultural operations, residential communities, or large industrial operations located adjacent to the Base. HAFB is an active military installation and is expected to remain active for the foreseeable future. No transfer of military property to the public is anticipated, and public access to the Base is restricted (Foster Wheeler, 2002).

Residential development on the Base is limited by environmental and operational constraints imposed by the 100-year floodplain, historic sites, and areas identified under the Installation Restoration Program. Safety and noise zones also limit residential development on HAFB. Future plans for residential development on the Base include renovation of existing structures, replacement of inefficient buildings, and expansion into open areas in the southeast corner of the Base (HAFB, 2000). Future land use is not expected to differ significantly from current land use practices (Foster Wheeler, 2002).

## 2.7 Current and Future Water Use

At present, the primary fresh water resource for the City of Alamogordo and HAFB is Lake Bonita, 60 miles northeast of the Tularosa Basin. Currently, there are no potable supplies of

<sup>1</sup> <http://countrystudies.us/united-states/weather/new-mexico/>

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groundwater or surface water located on the Base. HAFB obtains its water supply from the City of Alamogordo and the HAFB wells in the Boles, San Andres, and Douglas well fields at the base of the Sacramento Mountains. No water supply wells are located on or near the Base because of poor groundwater quality (TDS greater than 10,000 mg/L). The nearest production well downgradient from HAFB is a livestock well located 13 miles southwest of DP-63. There are no potable or irrigation wells near to or immediately downgradient of the Base (Foster Wheeler, 2002).

### **3 SAMPLING ACTIVITIES**

The purpose of this section is to describe the sampling activities associated with surface soil, subsurface soil, saturated subsurface soil (capillary fringe), and groundwater data collection used in order to establish background values for the occurrence of certain naturally occurring inorganic constituents. To meet the sampling objectives the following field activities were performed:

- Advancement of 42 soil borings,
- Collection of three soil samples per boring,
- Collection of groundwater samples from 30 existing monitoring wells with historically non-detect laboratory analyses, and
- Laboratory analysis of soil and groundwater samples.

Prior to sampling activities, an Air Force Form (AF FM) 332 and dig permit were submitted to the proper offices. All sampling activities were completed following the *Basewide Background Study Work Plan, Holloman Air Force Base, New Mexico* (NVB, August 2008) and standard industry practices.

#### **3.1 Field Activities**

##### **3.1.1 Sampling Requirements**

Field activities were performed in accordance with the *Site-Specific Addendum to the Basewide Health and Safety Plan* (Appendix A of the Work Plan), the *Quality Assurance Project Plan [QAPP] Addendum* (Appendix B of the Work Plan), as well as other USACE mandated procedures for laboratories. The field work for sampling activities was conducted in accordance with HAFB Standard Operating Procedures (SOPs) provided in the *Basewide Quality Assurance Project Plan* (Bhate, 2003a) and the *Bhate Standard Operating Procedures* (Bhate, 2002). These SOPs outline methodologies for soil boring advancement, soil sampling, soil sample description, groundwater sampling, sample management, equipment decontamination, and chain-of-custody procedures. Sample nomenclature followed the ERPIMS format. The specific HAFB SOPs used for the associated sampling are listed below:

- HAFB SOP-1, Documentation, Sample Handling, Chain-of-Custody, and Shipping
- HAFB SOP-2, Sampling Equipment Documentation
- HAFB SOP-3, Staking, Utility Clearance, and Permitting
- HAFB SOP-5, Soil Sampling for Chemical Analysis
- HAFB SOP-6, Procedure for Field Screening of Volatile Organics
- HAFB SOP-7, Lithologic Description and Geotechnical Sampling
- HAFB SOP-8, Groundwater Sampling for Chemical Analysis
- HAFB SOP-10, Borehole Abandonment and Site Restoration

The following sections describe the procedures for soil sampling, groundwater sampling, and the analyses performed.

### 3.1.2 Soil Sampling

Soil samples were collected from 42 borings located across the base which are shown on Figure 1-4. A total of three samples (surface, subsurface, and saturated) were collected from each boring using hollow stem auger technology. The samples were collected continuously with a 5-foot interval stainless steel sampler.

#### 3.1.2.1 Laboratory Analyses for Soil Sampling

The analysis of soil samples collected for the Basewide Background Study followed the USEPA SW-846 protocol. The soil samples were analyzed for the following:

- Target Analyte List (TAL) Metals by USEPA Methods 6010B and 7471A
- Radionuclides by Methods C-01-1/E903.0/E904.0/STL-RC-0211/A-01-R

Samples submitted for laboratory analysis were labeled, handled, and prepared for shipment in accordance with HAFB SOP-1. The samples were placed on ice and shipped under strict chain-of-custody to TestAmerica Laboratories, Inc., in Arvada, Colorado and St. Louis, Missouri.

Tables 3-1, 3-2, 3-3, 3-4, 3-5, and 3-6 provide a summary of the soil and radiological analytical sampling results for the surface, subsurface, and saturated subsurface soils, respectively. Data Validation Reports and Laboratory Analytical Results for soil are provided in Appendix C of this report.

#### 3.1.2.2 Quality Control Samples

Field duplicate samples were collected at a frequency of 10 percent and matrix spike and matrix spike duplicate (MS/MSD) samples were collected at a frequency of 5 percent. Homogenous quality control samples were collected from the same interval as the discrete sample. This method was used in order to achieve consistency between the discrete samples and their associated quality control samples.

The detection reporting limits for all analytical parameters and the quality assurance sampling requirements (duplicate and MS/MSD) are summarized in the QAPP Addendum previously provided in Appendix B of the Work Plan.

#### 3.1.2.3 Sampling Depths

At each boring location, three discrete soil samples were collected from the surface (0-6 inches bgs), the subsurface (mid-point between the surface sample and the saturated zone), and the saturated zone. Samples depths for subsurface soil samples ranged from 7 to 30 feet bgs, and sample depths for saturated subsurface soil samples ranged from 15 to 64 feet bgs. The depths of the saturated subsurface sample locations were dependent upon the localized water table.

### **3.1.2.4 Soil Description and Classification**

Each boring was visually classified and lithology described in the field according to HAFB SOP - 7 and the Unified Soil Classification System (USCS) (American Society for Testing and Materials [ASTM] D 2487-06 and ASTM D 2488-06) by a qualified geologist. HTW Drilling logs were completed in the field and are presented in Appendix A of this report to validate that the sampling locations demonstrated mineralogical uniformity across the base.

### **3.1.2.5 Sampling Procedures**

All sampling equipment was decontaminated prior to sample collection using appropriate decontamination procedures. Before and during sampling, all decontaminated sampling equipment and bottles were placed on clean plastic sheeting to avoid contamination. Soil from the sampler was placed into the sampling jars provided by the laboratory. Excess soil around the top of the sample jars was wiped away with a clean cloth or paper towel to ensure the cap fit tightly. When all required sample jars were filled, excess soil was returned to the sampling site. New, disposable gloves were worn to collect each soil sample. Residual soil from the soil sampling was discarded in accordance with the waste management procedures established in Section 4.3 of the Work Plan, Investigation-Derived Waste (IDW) Management (NVB, August 2008).

### **3.1.2.6 Identification System**

Each sample collected was identified on the sample label and chain-of-custody (COC) records, regardless of type. Sample documentation, handling, and shipping was conducted in accordance with HAFB SOP-1. Sample collection information inclusive of the container type and quantity for the soil samples collected during this background study was performed in accordance with the QAPP Addendum of the previously submitted Work Plan. An example of the sample identification nomenclature used for soil samples collected from the boreholes was as follows:

BWBG-SB01-5-a

Investigation identifier: BWBG = Basewide Background

Sample type identifier: SB = soil boring

Sequential soil boring number: 01, 02, etc.

Ending depth of sample interval: 5

Reserved for quality assurance (QA) sample identifiers: a = field duplicate, TB = trip blank, MS = matrix spike, MSD = matrix spike duplicate

### **3.1.2.7 Survey**

Prior to leaving the sample location, a qualified surveyor located the boreholes using a global positioning system (GPS). All horizontal coordinates are referenced to the State Plane Coordinate System, New Mexico Central and surveyed to an accuracy of +/- 1.0 foot.

### 3.1.3 Groundwater Sampling

Groundwater samples were collected from 30 existing monitoring wells located across the base which are shown on Figure 1-3.

#### 3.1.3.1 Laboratory Analyses for Groundwater Sampling

The analysis of groundwater samples collected for the Basewide Background Study followed the USEPA SW-846 protocol. The groundwater samples were analyzed for the following:

- TAL Metals by USEPA Method 6010B and 7470A (filtered and unfiltered)
- Radionuclides by Methods C-01-1/E903.0/E904.0/STL-RC-0211/A-01-R
- Natural Attenuation Parameters (NAPs) by Methods SM18 2320B (alkalinity), SW846 4500-CL-C (chloride), 353.2 (nitrate), SM20-4500-NO2-B (nitrite), SM20-4500S-F (sulfide), SW846 9056 (sulfate), and E350.1 (ammonia)
- TDS by Method SM18 2540C

Samples submitted for laboratory analysis were labeled, handled, and prepared for shipment in accordance with HAFB SOP-1. The samples were placed on ice and shipped under strict chain-of-custody to TestAmerica Laboratories, Inc., in Arvada, Colorado and St. Louis, Missouri.

Table 3-7 and Table 3-8 provide a summary of the groundwater total metals (unfiltered) and dissolved metals (filtered) analytical results, respectively. Data Validation Reports and Laboratory Analytical Results for groundwater are provided in Appendix C of this report.

#### 3.1.3.2 Quality Control Samples

Field duplicate samples were collected at a frequency of 10 percent and MS/MSD samples were collected at a frequency of 5 percent.

The detection reporting limits for all analytical parameters and the quality assurance sampling requirements (duplicate and MS/MSD) are summarized in the QAPP Addendum previously provided in Appendix B of the Work Plan.

#### 3.1.3.3 Sampling Procedures

Prior to the collection of groundwater samples, depth-to-water and total well depth measurements were collected from each well using an electronic water level indicator. Field measurements of pH, temperature, dissolved oxygen (DO), oxidation reduction potential (ORP), conductivity, turbidity, and groundwater level were also recorded. Groundwater sampling activities were conducted in accordance with HAFB SOP-8. Monitoring Well Sample Collection Forms for the 30 wells sampled are provided in Appendix B of this report.

Monitoring wells were purged by pumping each well until the water level, pH, temperature, DO, ORP, conductivity, and turbidity stabilized by +/- 10 percent for at least three consecutive readings. It should be noted that turbidity readings ranged from 0.27 nephelometric turbidity units (NTUs) to 22.6 NTUs. High turbidity readings can indicate high metals concentrations,

however, based on the range of turbidity readings collected during sampling, turbidity is not expected to impact the laboratory analytical data for groundwater.

Groundwater samples were labeled, handled, and prepared for shipment in accordance with HAFB SOP-1. The samples were analyzed for TAL Metals, Radionuclides, NAPs (including alkalinity, ammonia, chloride, nitrate, nitrite, sulfate, and sulfide), and TDS. Samples collected for metals analysis were collected both filtered (using a 0.45 micron filter in the field) and unfiltered.

#### **3.1.3.4 Identification System**

Each sample collected was identified on the sample label and COC records, regardless of type. Sample documentation, handling, and shipping were in accordance with HAFB SOP-1. Sample collection information inclusive of the container type and quantity for the groundwater samples collected during this background study was performed in accordance with the QAPP Addendum in the previously submitted Work Plan.

The sample identification nomenclature for groundwater samples collected from the existing monitoring wells was based on the existing well identification number (i.e. SS61-MW11). QA sample identifiers were denoted after the well identification, as necessary (i.e. SS-61-MW11-a).

#### **3.1.3.5 Groundwater Elevations**

During the sampling of monitoring wells, groundwater elevations were determined. Elevations were measured for the 30 existing wells selected for the Basewide Background Study by using the top of casing elevation and the depth-to-water measurement. All horizontal coordinates are referenced to the State Plane Coordinate System, New Mexico Central and surveyed to an accuracy of +/- 1.0 foot. Vertical elevations are referenced to North American Datum (NAD) 1983 coordinates. A groundwater potentiometric map is provided as Figure 2-2 for the data collected in September 2008.

### **3.2 Data Quality Objectives Process**

To support the overall investigation objectives, Data Quality Objectives (DQOs) were established. The DQOs were qualitative and quantitative statements that specified the quality of data required to meet the goals of the basewide background study. The DQOs were expressed in terms of precision, accuracy, representativeness, comparability, completeness, and sensitivity. Data developed during this basewide background study will be used to support site-specific studies of existing and/or potential solid waste management units in the area.

DQOs were used to:

- Ensure data comparability through the use of standard methods and controlled systems to collect and analyze samples;
- Provide analytical results of known and acceptable precision and accuracy; and to provide a minimum of 95 percent data completeness for analytical results representing each matrix-method combination.

The level of analytical support utilized to meet these goals was both screening (pH, temperature, dissolved oxygen, oxidation reduction potential, and turbidity) and definitive data. As part of the analytical reporting requirements for the definitive data, both reporting laboratories provided the following data, in addition to the data deliverables, as described in the QAPP Addendum found in Appendix B of the previously submitted Work Plan:

- Sample identification numbers cross-referenced with laboratory identification numbers and quality control (QC) sample numbers,
- Problems with arriving samples noted on chain-of-custody,
- Analytes reported as an actual value or less than a specified detection limit, and
- Dilution factors, preparation dates, and analysis dates.

QC sample results for laboratory blanks, MS, laboratory control samples (LCS), and field duplicates were used to evaluate the reliability of the data. The data quality objectives expressed in terms of precision, accuracy, representativeness, completeness, comparability, and sensitivity, are discussed below.

### 3.2.1 Precision

Precision is a measure of the degree of reproducibility of an analytical value and was used as a check on the quality of the sampling and analytical procedures. Laboratory replicates, field duplicates, and duplicate analysis (such as MS/MSD and LCS/LCS duplicates [LCSD]) were used to quantify precision. Laboratory replicates measured the analytical method precision, whereas field duplicate analysis provided a precision measurement that included the sampling procedures and the potential variability of the sample matrix.

Precision of the analytical method, at each stage was expressed in terms of a relative percent difference (RPD) between duplicate determinations. A detailed calculation of the RPD is presented in the *Basewide QAPP*. Soil sample measurements were usually less precise than water sample measurements because it was more difficult to achieve a homogeneous, representative sample. Based on this, the precision targets for soil field duplicates were an RPD of 50 or less, while the target water matrix RPD was 35 or less. The laboratory RPDs are presented in the QAPP Addendum in Appendix B of the previously submitted Work Plan.

Field duplicates were collected at the frequency of one in 10 field samples collected. MS/MSD samples were collected at a frequency of one set per 20 samples. Precision calculations are presented in the Data Validation Reports provided in Appendix C of this report.

### 3.2.2 Accuracy

Accuracy is the degree to which a measurement agrees with the actual value, i.e., the amount of measurement bias. Accuracy was expressed as a percent recovery (%R) of a known concentration of reference material. For this background study at HAFB, MS/MSDs were used to determine the accuracy for a given method and sample matrix. An aliquot of a normal sample was designated as the MS/MSD. The laboratory spiked the MS/MSD sample set as described below.

The spiked compounds included representative compounds that were quantified during the method, and spiked during sample preparation, on a specially prepared aliquot of the sample matrix. Results of those spiked aliquots were then compared to the original concentrations of the analytes spiked, and a %R was calculated. The %R of the spiked compound was used as an assessment of analytical accuracy on the sample matrix analyzed, which was essential in identifying sample matrix interferences. The %Rs were between 48 and 203 percent with some exceptions. See the individual Data Validation Reports provided in Appendix C of this report for these exceptions.

### **3.2.3 Completeness**

Data completeness represented the percentage of valid data collected from a sampling/analytical program or measurement system compared to the amount expected to be obtained under optimal conditions. The completeness goal for the definitive water matrix samples was 95% while the definitive soil matrix goal was 90%. The completeness results were calculated following data validation and review. The 95% goal was met as the data was 100% complete.

### **3.2.4 Representativeness**

Representativeness is a qualitative parameter that expresses the degree to which sample data actually represent the matrix conditions. Requirements and procedures for sample collection and handling were designed to maximize sample representativeness. Representativeness was also monitored by reviewing field documentation. The determination of the representativeness of the data was performed by:

- Comparing actual sampling procedures and chain of custody forms to those described in the work plan,
- Identifying and eliminating non-representative data in basewide background study, and
- Evaluating holding times and condition of samples on arrival at the laboratory.

The objective of this element was to eliminate all non-representative data. As collected, the field samples represented the geographical areas that were required to accurately define the Holloman basewide background concentrations.

### **3.2.5 Comparability**

Comparability is a qualitative measure of the confidence with which one data set can be compared to another. These data sets include data generated by different laboratories, data generated by laboratories in previous investigative phases, data generated by the same laboratory over a period of several years, or data obtained using differing sampling techniques or analytical protocols. The measurement comparability objective for this Background Study was to generate consistent data using standard test methods, standard field data sheets, and uniform concentration units. These data are intended to be accepted and used by other investigators who are considering specific sites within the HAFB.

The data set was generated and will be used as a baseline for the background level concentrations. Future investigations will use this data for background baseline concentrations.



### 3.2.6 Sensitivity

Sensitivity is a general term referring to the calibration sensitivity and the analytical sensitivity of a piece of equipment, used to establish detection/quantitation/reporting limits. Several limits have been established to describe sensitivity requirements (i.e. instrument detection limits [IDLs], method detection limits [MDLs], minimum detectable concentrations [MDCs], and reporting limits [RLs]). Since IDLs and MDLs are normally based on a reagent water matrix or a purified soil matrix, published IDLs and MDLs are presumed not to be consistently achievable for environmental samples. It is because of this inconsistency and the goal to promote the generation of comparable data that the following definitions were used to meet the project DQOs:

- Instrument Detection Limit – The IDL references the absolute limit of detection for a compound or analyte in a media that is free from matrix interferences at a level greater than two times the noise level of the instrument. Certain programs require the laboratory to publish IDLs on an annual basis; however, achievement of these detection levels generally cannot be met during routine analyses.
- Method Detection Limit – The MDL is the minimum concentration of an analyte that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero, and is determined from the analysis of sample in a given matrix containing the analyte. The laboratory is required to perform an MDL study during the initial setup of the analytical procedure and annually thereafter. An MDL study is also performed whenever the basic chemistry of the procedure is changed. When MDLs are reported with analytical data, they should be adjusted for sample weight, moisture content, and volumetric dilution on a per-sample basis. The project specific MDLs were presented in Tables 4-2 and 4-4 of the QAPP Addendum found in Appendix B of the previously submitted Work Plan.
- Minimum Detectable Concentration – The minimum radionuclide concentration that must be present in a sample to give a specified probability of detecting the radionuclide and is expressed in concentration units relative to the sample weight or volume.
- Reporting Limit - The RL is the threshold value below which the laboratory reports a result as non-detected and is established at a level between the laboratory's Practical Quantitation Limit (PQL) and the level needed to meet project requirements. The RL is usually based upon project-specific requirements including risk-based concentrations of concern, or regulatory action levels. RLs should be adjusted based on the sample matrix and any necessary sample dilutions. The RLs for this project were presented in Tables 4-2 and 4-4 of the QAPP Addendum found in Appendix B of the previously submitted Work Plan.

### 3.2.7 Data Validation

Data validation includes the elements of verification, in which a complete accuracy check of the laboratory hardcopies are checked against the electronic data deliverable (EDD), in order to assure agreement; however, the assessment process was designed to result in data that are of "known" accuracy and precision. Individual data that cannot be validated under established criteria for acceptance are flagged to indicate that the results are either estimated, or unusable.

Validation is an alternative to adversarial review and was performed by a qualified chemist who exercised the use of professional judgment during the validation process.

Data validation was performed on 100% of the definitive analytical data and was conducted by the NVB Project Chemist, in order to verify compliance with the QAPP and the specified methodology. Data validation procedures were based on the *USEPA National Functional Guidelines for Inorganic Data Review* (USEPA, 2004) and the *Evaluation of Radiochemical Data Usability* (Department of Energy [DOE], 1997). Upon completion of the data validation process, the usability of the data was determined.

It was determined that 100% of the definitive data was usable based on the data validation reports. Although some data points were qualified as estimated, J, those data points were not rejected and were therefore considered usable.

It should be noted that, in one instance, the EDD did not agree with the hardcopy data report. Sample BWBG-SB-18-18 indicated the incorrect concentration on the EDD for Radium 228. The concentration provided on the EDD was from the same boring but the wrong depth. In such cases, the hard copy always takes precedence over the EDD. This disagreement does not impact the data because the data from the hard copy was used in our summary tables and statistical analysis.

### 3.3 Investigation-Derived Waste Management

The soil sampling locations and the groundwater monitoring wells were chosen based on previous investigations, therefore, these locations were not considered to be contaminated. All material generated while drilling was used to backfill the borehole and/or spread on the ground at the boring. Purge water was also spread on the ground at the monitoring well location. Personal protective equipment (PPE) and other site non-hazardous debris/waste was disposed of in standard trash receptacles.

### 3.4 Site Restoration

Upon completion of the sampling activities, the sampling locations were restored to their original condition. Soil sampling locations were backfilled with soil cuttings and bentonite.

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## 4 CONCEPTUAL SITE MODEL FOR GROUNDWATER

### 4.1 Background Information

Historical and recent literature document that HAFB is located within a very saline portion of the Tularosa basin where groundwater with TDS greater than 10,000 mg/L is typical (see Figure 4-1 adapted from the New Mexico Water Resources Institute [NMWRRI], June 2002). McLean (1970) also observed the same conditions as presented on Figure 4-2. The literature is further supported by recent groundwater sampling performed for the background study and numerous previous sampling events associated with corrective action investigations at the base where TDS concentrations in excess of 70,000 mg/L have been observed and reported. Observation of TDS concentrations less than 10,000 mg/L have also been observed but only in wells located in developed areas of the base, a condition attributed to the anthropogenic effects of leaking fresh water lines and irrigation activities.

The following documents were used as reference materials for the development of the conceptual model for groundwater at HAFB:

1. Fryberger, S.G. 2009. Geological Overview of White Sands National Monument <http://www.nature.nps.gov/geology/parks/whsa/geows/index.htm>
2. Geo-Marine. 1996. Delineations of Jurisdictional Waters of the United States and Wetlands on Holloman Air Force Base, New Mexico. U.S. Army Corps of Engineers, Fort Worth District, Fort Worth, Texas.
3. Herrick, C.L. 1904. Lake Otero, and ancient salt lake in southeastern New Mexico: *American Geologist*, v. 34, p. 174–189.
4. McLean, J.S. July 1970. “Saline Ground-Water Resources of the Tularosa Basin, New Mexico,” U.S. Department of Interior, Office of Saline Water No. 561.
5. Meinzer, O.E., and Hare, R.F. 1915. Geology and water resources of Tularosa Basin, New Mexico. U.S. Geological Survey Water Supply Paper 343, 317 p.
6. NMWRRI. June 2002. Tularosa, Sacramento River and Great Salt Basin Regional Water Plan.
7. Wilkins, D.W. 1986. Geohydrology of the Southwest Alluvial Basins Regional Aquifer-Systems Analysis, Parts of Colorado, New Mexico, and Texas U.S. Geological Survey Water-Resources Investigations Report 84-4224.

HAFB is located on the northwest corner of a large alkali flat or playa feature measuring approximately 120 miles square that emanates from alluvial fan drainage features along the western flank of the Sacramento Mountains (see Figure 4-3). The sediments underlying the base are comprised of older basin fill (Miocene) which is overlain by lacustrine (gypsiferous lake floor) and fluvial sands and silts (distal piedmont sediments) of Pleistocene to Recent age that are several thousand feet thick (Fryberger, 2009). Fryberger (2009) also noted the younger valley fill has a basin-centered pattern, with rather porous and permeable fluvial sands and gravels from alluvial fans around the edge of the basin, and much less porous and permeable

silty or evaporitic facies in the lower central portions of the basin. The 42 soil borings advanced during the background study encountered gypsiferous lacustrine and fluvial sediments as documented in the lithologic logs presented in Appendix A of this report. The evaluation and analysis of the analytical data concluded that the soils are statistically from the same parent material and cannot be further subdivided.

#### 4.2 Groundwater Recharge

Groundwater recharge in the Tularosa Basin occurs largely from rainfall and snowmelt in the Sacramento and San Andres mountains, where intermittent stream flow infiltrates into the coarse, loosely consolidated alluvial fan material. Although stream flow is greatest during the summer monsoons, most recharge occurs in the winter months (Wilkins, 1986). Recharge for the Tularosa Basin was estimated to be greater than 100,000 acre-feet per year, with the greatest portion accumulating at the base of the Sacramento Mountains (Meinzer and Hare, 1915).

HAFB lies within the ground flow gradient from the Sacramento foothills to the lowest point within the basin, Lake Lucero, to the southwest of the main base. Groundwater at the margins of the basin within the bajada of the Sacramento Mountains grade from fresh water (containing less than 1,000 mg/L TDS) to highly alkaline sources near the center of the basin with more than 100,000 mg/L TDS (Geo-Marine, 1996). The evidence of recharge (and dissolution of evaporates that are in turn carried toward the White Sands) is quite dramatic in the basin, due to the shallow evaporates of either Pliocene or Permian origin that have been dissolved by fresh water. Herrick (1904, p. 187) noted that the sand dunes on the eastern side of White Sands serve as a dam for storm water runoff from the Sacramento mountains (Lost River and Dillard Draw). Infiltration from the ponded water accelerates the solution of the underlying Quaternary lacustrine deposits, forming many sinkholes and caverns and increasing the TDS concentrations in groundwater associated with the drainage networks.

The primary hydrologic processes in this desert ecosystem are summer monsoons and large storm events falling on the rocky slopes of the Sacramento Mountains. Most of the thunderstorm precipitation is absorbed quickly into the gravels and sandy surfaces at the base of the alluvial fans. At the terminus of the alluvial fan channels, ephemeral playa-like depressions can hold water for several weeks, creating hydric soil conditions (Geo-Marine, 1996). A hydric soil is a soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part. Ephemeral flats occur most notably within the low lying area between Lake Holloman and Lagoon G but also are dispersed sporadically throughout the various drainages. These flats are generally not densely vegetated but may have an algal layer on the surface (Geo-Marine, 1996).

#### 4.3 Surface Drainage

There are at least nine prominent east-west drainages on the base that receive intermittent flows during seasonal thunderstorms, including several which are 100-year floodplain zones. These areas are associated with the presence of alluvial floodplain soils and are present within Dillard Draw; Lagoon G; Malone, Ritas, and Allen Draws; and Lost River drainages. The flood-prone areas associated with Allen, Malone, and Ritas Draws and the Lost River are within the more

remote, less densely developed sections of the base. These drainages are broad and deeply entrenched where extensive downcutting has occurred by as much as 50 feet below the basin floor. The largest of these drainages is the Lost River drainage system, including Malone Draw and Ritas Draw.

Ephemeral drainage features bound the southern and southeastern areas of the base. Much of the southern area of the base appears to have been built over the playa feature discussed above and illustrated on Figure 4-4. The most pronounced drainage feature begins along the southeastern boundary of the base where Dillard Draw forms as the result of multiple drainages (six counted on Figure 4-3), emanating from the alluvial fan feature west of the Sacramento Mountains, combine. Prior to extensive management of the surface topography and construction of U.S. Highways 70/54, Dillard Draw emptied into the main base, creating a network of alkali flats and ephemeral playas including what are now Lake Holloman, Stinky Playa, and Lagoon G. Much of the main base was built over this network. Ephemeral flats and vegetated wetlands have developed north of the golf course as a result of the diversion of drainages associated with construction of U.S. Highway 70/54. The remnant ephemeral playas south of U.S. Highway 70/54 are classified as “active sands” associated with the White Sands Geomorphic Map (Fryberger, 2009, Figure 2-17A) which is provided as Figure 4-5. The historic desert wetland ecosystem that existed between Lagoon G and Lake Holloman has been enhanced to form a “constructed” wetland to provide valuable habitat for wildlife. These wetlands contain a network of earthen berms and channels to direct storm water runoff from the cantonment area and treated wastewater effluents into these alkali flats. Flows into the completed constructed wetlands began in November 1997. A synergistic effect of capturing runoff from the cantonment area in addition to the natural drainage area serviced by Dillard Draw has been the concentration in natural abundance of dissolved solids in groundwater in this area of the base.

Dillard Draw continues south across Highway 70 and appears to braid out to the southwest into a prominent playa feature characterized with noticeable alkali deposits paralleling the southern boundary of the base along Highway 70. Several wells sampled during the background study are located within this drainage complex including S1-MW2, S1-MW5, S10-MW4, and MW19-03. The latter well is located within this playa feature and exhibits some of the highest concentrations for TDS, uranium, manganese, potassium, chloride, sodium, and sulfate observed during the background study. Two more drainages truncate the base from east to west to the north of the airfield. The southern most of these drainages ultimately is known as the Lost River but has a southern fork named Ritas Draw where well MW-BG-04 is located. As with other wells located in or adjacent to the historic drainage features, well MW-BG-04 also exhibits some of the highest TDS concentrations observed during the background study. In contrast, well MW-04-01 located approximately 1,000 feet southwest of MW-BG-04, has significantly lower TDS concentrations. The reason for these different concentration profiles is attributed to the fact that MW-BG-04 is located within the drainage area and is representative of shallow saline groundwater affected by ponding, while MW-04-01 is located outside of the drainage network.

#### **4.4 Distribution of Total Dissolved Solids**

The distribution of the highest TDS and ion concentrations in groundwater correlate well with the drainage and playa network previously described. The occurrence of the higher

concentrations in association with the regional drainage features is attributed to episodic runoff events that have concentrated the dissolved solids and ions in the groundwater underlying the playa and drainage networks over time. Fryberger (2009) noted that several factors in the climate and hydrology of the Tularosa basin cause strong seasonal phenomena to occur in the depositional system at White Sands. Primarily these factors are: (1) the presence of widespread shallow groundwater, (2) seasonally high evaporation and evapotranspiration rates due to extreme heat and strong winds, and (3) sudden influxes of fresh water into the saline groundwater system by flash floods and rainstorms. These factors can cause sudden and extreme changes to water table levels and groundwater salinity, sometimes quite locally.

The distribution of the higher concentrations of TDS and ions is typically associated with four monitoring wells (TDS-MW02, MWBG-04, S1-MW2, and MW19-03) shown on Figure 4-6. The TDS concentrations measured during the background study range up to 50,000 mg/L with a mean concentration of approximately 22,000 mg/L. This is in good agreement with the literature for the region suggesting HAFB overlies a saline groundwater unit that is more than 1,000 feet thick with TDS concentrations ranging from 10,000 to 35,000 mg/L. The alignment of high TDS and ionic concentrations associated with wells located near drainage features and ephemeral playas would indicate the distribution of these constituents is consistent with the regional literature.

#### 4.5 Geochemical Evaluation

The geochemical evaluation of the groundwater data using stiff diagrams superimposed on the TDS concentration map (Figure 4-6) provides a useful comparison tool. The wells exhibiting the highest TDS concentrations correspond with the highest sodium/chloride dominated water. In fact, there is a linear relationship between TDS and sodium/chloride dominated groundwater across the map that would suggest the variability in ion concentrations is proportional to TDS concentration. It should be noted, however, this variability is to be expected given the diverse physiography of the Tularosa Basin that led to a complex drainage system which contributed fill material from various sources depending on climate at the time of sedimentation which has subsequently been altered by fresh water infiltration (irrigation and leaking water lines) in the developed areas of the base.

A useful means of depicting the relative major solute composition of a groundwater is by a Schoeller Plot (Schoeller, 1935). These plots are drawn by plotting logarithmic concentrations of major solutes (in milli-equivalents/litre [meq/L]) in a water, in the order  $Ca_2^+$ ,  $Mg_2^+$ ,  $(Na^+K^+)$ ,  $Cl^-$ ,  $SO_4$ , and  $HCO_3^- + CO_3$  (measured alkalinity). The slope of each line joining the points represents the concentration ratios  $Ca/Mg$ ,  $Mg/(Na+K)$ ,  $(Na+K)/Cl$ ,  $Cl/SO_4$ ,  $SO_4$ ,  $HCO_3^- + CO_3$  (measured alkalinity) respectively, and the resultant shape that derives from these ratios constitutes a signature for the aquifer in terms of the major solute content of the water. Schoeller plots provide a convenient means for sorting waters into groups, as a first step in identifying the presence of different lithologies. Equilibrated groundwater from a specific rock type produces a known Schoeller Plot signature. Although waters from all aquifers of these types do not conform exactly to these shapes, specific aquifer lithologies are often identifiable from the ratios of major ion concentrations.

The Schoeller plots and resultant signatures provide a convenient means of determining if the groundwater is from different lithologies. Figure 4-7 provides a Schoeller plot signature for the major solute content of the aquifer under HAFB using the 24 wells from the basewide background study. In general, the shapes or signatures from the individual 24 curves indicate that the ratios of major ion concentrations are from the same aquifer lithology. This provides additional graphical evidence utilizing several key constituents to support a single population for groundwater.

Based on the information provided in this conceptual model the following conclusions are offered:

1. The distribution of TDS and relative proportions of individual ions is controlled by drainage regimes that have served to locally concentrate the TDS and ions along ephemeral playas and existing drainages. Freshwater infiltration from developed areas of the base have further modified these regimes to create more apparent variation.
2. The dynamics that have controlled depositional environments in the Tularosa Basin have largely been controlled by climate changes and diverse physiography. This has led to a groundwater environment that exhibits some variations in ionic distribution but ultimately can be statistically considered to be of the same population.
3. Graphical representation of the groundwater data with the Schoeller plots further suggests that the groundwater data set is from a single general lithologic source.

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## **5 TECHNICAL APPROACH**

The following technical approach is to provide HAFB environmental restoration project teams and NMED with details on how the data that was obtained for this background study was graphically and statistical analyzed.

A scientific approach was used to determine the type, quantity, and quality of environmental data needed to support establishing background values at HAFB. This provided the scientific foundation for defensible decision-making by helping to assure that representative field samples were collected at appropriate locations and times, that appropriate graphical and statistical analyses of the resulting data were conducted, and that appropriate interpretations of the data and statistical analyses were made. The following sections include discussions of primarily two different data sets. References to “Raw Data” means that the analytical results were used as reported in the summary tables without modification. The summary tables are Tables 3-1 through 3-6 for soils and Tables 3-7 and 3-8 for groundwater. Reduced Data implies that the data in the summary tables have been analyzed for statistical outliers using the NMED recommended Grubbs test, also known as the maximum normalized residual test or Discordance Test (see Section 5.6.4 of this report). If the test indicates the suspect value(s) are indeed outliers, then the value(s) were removed from the data set. Additionally, six groundwater monitoring wells (MW-24-03, MW-13, MW22-03, MW-1, MW-23-01, and MW-6) contained roots that were observed during sampling or were potential impacted by biological activity. These six wells and the associated data were removed from the reduced data sets (see Section 5.4 of this report). Therefore, the reduced data sets for total groundwater and dissolved metals are based on the remaining 24 groundwater wells.

### **5.1 Sample Location Selection**

Background soil sampling locations were selected using aerial photographs and historical base maps to identify areas with no apparent construction or waste disposal activities and areas which have been undisturbed. These locations were selected to encompass the entire base including the range and industrial areas. Soil sampling locations are shown on Figure 1-4.

The groundwater sample population was derived from the existing monitoring wells located throughout HAFB. Current and historical sampling data, as well as lithologic data, was reviewed in order to select wells that have consistently had organic concentrations less than 5 parts per billion (ppb) and wells constructed within the same hydrostratigraphic unit. Based on communication with NMED, monitoring wells with minor organic contamination could be used as part of this study, provided there is no impact to metals concentrations. From this group, 30 monitoring wells were selected randomly across the base in order to have a representative population of the entire base. Groundwater sampling locations are shown on Figure 1-3 and are listed below.

MW-04-01	MW-29-01	S10-MW4
MW-1	MW30&33-1	S1-MW1

MW-13	MW30&33-2	S1-MW2
MW-19-03	MW37-06	S1-MW5
MW-21-04	MW-38-01	SS61-MW01
MW-22-03	MW3903	SS61-MW11
MW-23-01	MW41-03	TDS-MW01
MW-24-01	MW-58-03	TDS-MW02
MW24-03	MW-6	TDS-MW03
MW24-05	MW-BG-04	TDS-MW04

## 5.2 Determination of Number of Samples

Based on the regional soil descriptions (contained in section 2.3.2 of this report), these soils have the same parent materials, the same history, and very similar pedologic and mineralogic properties. Accordingly, NVB sampled throughout the area, treating the entire installation as a single population for statistical purposes. Based on a study of the soils and lithology involved, discrete samples were collected from the surface from 0 to 6 inches bgs, the subsurface from 6 inches bgs to above the saturated zone, and from the subsurface within the saturated zone. Sample depths varied based on the depth to groundwater. Tables 3-1, 3-2, 3-3, 3-4, 3-5, and 3-6 provide a summary of the soil analytical sampling results for the surface, subsurface, and saturated subsurface soils, respectively. Tables 3-7 and Table 3-8 provide a summary of the groundwater sampling results including total metals and dissolved metals, respectively.

Any sampling plan requires a known or estimated population distribution in order to establish the number of samples needed to achieve a given reliability goal. Information available from previous investigations was used to estimate statistical parameters to 'size' the study. Previous data may or may not be representative of background, but no attempt has been made to qualify earlier data for use in calculation of background. However, the distribution of data from previous investigations provides the best available estimate of the statistical parameters involved.

NVB determined the number of samples required to reliably determine background concentrations by carrying out the following analysis, using the t-statistic, the calculated standard deviation, s, of observations of arsenic concentrations from previous investigations and asserting that the desire is to know, at the 95% confidence level ( $\alpha = 0.05$ ), the mean of the concentration in the surface soils to within 0.5 milligrams per kilogram (mg/kg).

$$n = (t^2 * s^2) / d^2$$

where:

- n number of samples to be collected
- t the t-statistic for  $\alpha = 0.05$  and the degrees of freedom determined from the previous investigations
- s the calculated standard deviation from the previous investigations, and

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d the desired error bound, 0.5 mg/kg

Data from previous investigations show (for 230 surface samples)  $s = 1.6$ . The corresponding value of “t” is 1.98 (WSMR, 2003b). Substituting, solving for n, and rounding up yields a minimum sample number of 41. NVB collected samples from 42 borings.

To derive the number of samples needed for determination of background groundwater concentrations using the same statistical approach was not plausible given the variability in samples for metals and select radiological constituents. Therefore, the Work Plan proposed to sample 30 monitoring wells. Existing well locations at HAFB were selected as NMED did not require that soil boring and groundwater data be collocated for this background study.

The method described above was also used to determine if the appropriate numbers of samples were collected for this study for each constituent/media. For a given constituent/media, if the number of samples was not adequate, the Work Plan indicated that additional samples would be collected and analyzed as necessary to correct the deficiency in sample size.

As required by comment No. 3 in NMED correspondence dated May 4, 2009 (provided in Attachment 2 of this report), NVB used the same method on the three soils horizons raw data sets to determine whether the appropriate number of samples was actually collected for each constituent, using the corresponding sample standard deviation calculated for each constituent in the background study. Table 5-1 provides a summary of the appropriate number of samples for the surface, subsurface, and saturated subsurface soils, respectively. It should be noted that, if the population from which the data to be analyzed by t-statistic violates one or more of the t-statistic assumptions, the results of the analysis may be incorrect or misleading. For example, if the assumption of normality is violated, then the use of t-statistic is simply not appropriate.

### 5.3 Combining Historical Data Sets

Combining two or more historical data sets to form a larger data set may improve the ability of statistical tests to detect when a contaminant is a chemical of potential concern (COPC). For example, soil samples may have been collected and measured for the same suite of chemicals at several different times in the land area of concern at HAFB. Pooling the historical data would increase the number of samples available for conducting a statistical test for a COPC and could increase the chances the test result will be accurate. However, an inappropriate combining of historical data sets can have the opposite effect. Ideally, the data sets being considered for pooling should have been obtained using the same sampling design that was applied to the same area of land. On August 24, 2007, NMED indicated in the disapproval letter of the Previous Background Study that both the sample size and sampling locations were either too small or poorly described and do not provide confidence that the samples were collected at locations that are representative of natural conditions.

In order to prevent potential error propagation from the Previous Background Study, NVB recommended an entirely new data set be collected. New sampling data was collected in September 2008 and was used to provide the statistical analysis for this report.

Soil sampling data was collected from three separate horizons (surface, subsurface, and saturated subsurface zones).

#### 5.4 Well Rooting and Reduced Environments

During the groundwater sampling for the basewide background study, NVB field technicians observed roots within the well casings of monitoring wells MW-24-03, MW-13, and MW22-03. The groundwater data set was then evaluated to include well integrity issues. After reviewing the sample collection data sheets, it was determined that six wells may have been compromised due to the presence of roots in the well screens. Three of these wells (MW-24-03, MW-13, and MW22-03) had roots observed during sampling. Three additional wells (MW-1, MW-23-01, and MW-06) were evaluated for potential impact by rooting and suspect biological activity by examining the dissolved oxygen, oxidation reduction potential measurements, chloride, sulfate, nitrate, iron, and TDS.

Dissolved oxygen for MW-1, MW23-01, MW-13, and MW-6 indicated anaerobic conditions or DO concentrations less than 0.5 mg/L. Furthermore the oxidation reduction potential (ORP) values were all negative. The ORP of groundwater is a measure of electron activity and is an indicator of the relative tendency of a solution to accept or transfer electrons. Oxidation-reduction reactions in groundwater containing organic compounds (natural or anthropogenic) are usually biologically mediated, and, therefore, the ORP of a groundwater system depends upon and influences rates of biodegradation. Knowledge of the ORP of groundwater also is important because some biological processes operate only within a prescribed range of ORP conditions.

Chlorine is the most abundant of the halogens. Although chlorine can occur in oxidation states ranging from  $\text{Cl}^-$  to  $\text{Cl}^{+7}$  the chloride form ( $\text{Cl}^-$ ) is the only form of major significance in natural waters. Chloride forms ion pairs or complex ions with some of the cations present in natural waters, but these complexes are not strong enough to be of significance in the chemistry of fresh water. Chloride ions generally do not enter into oxidation-reduction reactions, form no important solute complexes with other ions unless the chloride concentration is extremely high, do not form salts of low solubility, are not significantly adsorbed on mineral surfaces, and play few vital biochemical roles. Thus, physical processes control the migration of chloride ions in the subsurface. Therefore, chloride is not affected by changing ORP environments. Figure 5-138 illustrates the TDS versus chloride concentrations arranged from the northern most well to the southern most (this figure includes all 30 wells sampled during the background study). TDS and chloride concentrations are superimposed on each other and the graph indicates similar responses and deflections across the entire installation. However, Figure 5-139 initially shows the same good agreement between TDS and sulfate except for when the negative ORP environments for MW-24-03, MW-13, MW-22-03, MW-1, MW-23-01, and MW-6 are encountered. Sulfate concentrations for these six wells decreases or demonstrates a significant deflection away from TDS. This negative deflection appears to be in response to the low DO and negative ORP. Figure 5-140 initially shows the same good agreement when comparing aluminum and iron across the installation. However, when the negative ORP environments at MW-24-03, MW-13, MW-22-03, MW-1, MW-23-01, and MW-06 is encountered, the iron concentration increases significantly as compared to aluminum. Aluminum typically doesn't

respond or demonstrate significant changes in its concentration to negative ORP environments whereas Iron (III) is converted to Iron (II) under the correct reducing and biological conditions. Under these conditions, the dissolved iron concentrations increase significantly. Figure 5-140 shows that the iron concentration increases significantly in the six suspect wells. These responses taken together are usually indications of biological activity and potentially on-going biodegradation. Therefore, the three rooted wells and the three suspect wells were removed based on low DO, negative ORP values, and potential biological activity (rooting issues) as well as historical information indicating rooting problems during past sampling events (Basewide Long-term Monitoring program).

### 5.5 Nitrate and Ammonia

HAFB reviewed the groundwater data relative to the observed concentrations of ammonia and nitrate. It is evident that there are multiple sources of nitrogen which have led to the current distribution of ammonia and consequently, nitrate in the groundwater. ~~Figure 5-116a illustrates the distribution of the ammonia and nitrate and would suggest the nitrate (white) is developing downgradient of the ammonia concentrations in green.~~

The nitrogen cycle is a biogeochemical cycle which requires both micro-organisms and oxygen. Ammonia, nitrite, and nitrate are historical artifacts resulting from deteriorating infrastructure (sanitary sewer lines and/or septic tanks). The possible source of the ammonia is believed to be from the sanitary sewer system and/or septic tanks and the decomposition of organic matter in those sanitary systems by bacteria which is producing ammonium ions ( $\text{NH}_4^+$ ). In well-oxygenated soil, these are then oxygenated first by bacteria into nitrite ( $\text{NO}_2^-$ ) and then into nitrate. Ammonium ions readily bind to soils, especially to humic substances and clays. Nitrate and nitrite ions, due to their negative charge, bind less readily since there are less positively charged ion-exchange sites (mostly humic substances) in soil than negative. After rain or irrigation, *leaching* (the removal of soluble ions, such as nitrate and nitrite) into groundwater can occur. This is one possible explanation for the elevated nitrate in the groundwater. ~~Figure 5-116a illustrates that the elevated ammonia detections are immediately upgradient of the elevated nitrate detections which may indicate a possible connection to the conversion of ammonia to nitrate via the nitrogen cycle in well-oxygenated soil systems.~~

~~The source of ammonia is most likely anthropogenic, particularly since its distribution at present appears to correspond to areas of both nearly 70 years of ongoing human habitation and livestock operations such as SWMU 136 which, according to the historical information, was originally a stock tank pond. While nitrate and nitrogen are a part of the natural ecosystem at HAFB, the present quantities, distributions, and historical conditions at HAFB are not natural.~~

Another possible explanation for nitrate in the groundwater is from geogenic sources. Nitrate in groundwater from geogenic sources include those that are desert-derived such as caliche and playa lake evaporate deposits, and desert vadose zone soils. Recent research at the New Mexico Institute of Mining and Technology at the University of Nevada and U.S. Geological Survey has shown that nitrate in desert soils occurred at much greater quantities than previously reported, with subsoil nitrate ranging from 2,000 to 10,000 kilograms per hectare (kg/ha). Farmers

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typically only apply nitrogen fertilizers in amounts ranging from 25 to 250 kg/ha per year. The researchers concluded that this naturally-occurring vadose zone nitrogen reservoir had the potential to become mobilized thereby leaching large amounts of nitrate to groundwater (Motzer, 2006).

Therefore, nitrate cannot be evaluated and treated in the same manner as other constituents in this study. HAFB is currently moving to investigate releases from the base sewer system (SWMU 183) and has requested funding to perform the septic tanks investigation. Results of these two investigations will provide the information needed to understand the source areas as well as refine the nature and extent of the nitrate/ammonia concentrations in groundwater. Therefore, since the sources of nitrogen observed at the base are unclear at this time most likely not naturally occurring, HAFB is requesting that the nitrate, nitrite and ammonia data be pulled from the background study and resolved when the aforementioned investigation results are available.

## 5.6 Statistics and Data Analysis

### 5.6.1 Descriptive Summary Statistics

Descriptive summary statistics for HAFB and background data were generated as part of a preliminary data review. These descriptions, in conjunction with graphical plots, were generated to develop an understanding of the range, variability, and shape of the underlying probability distribution of the measurements, as well as the number of non-detects and possible outliers that are present. This information was needed to help determine the quality of the data sets and how the data should be statistically analyzed.

Based on USEPA, 2000a, *Guidance for Data Quality Assessment Practical Methods for Data Analysis*, the following statistical evaluation of the background inorganic concentrations data set was conducted in accordance with the Work Plan. A preliminary data review was conducted to include basic statistical quantities (summary statistics). The summary statistics were developed and presented in Tables 5-2 through 5-18 and includes the number of samples; the number of detects; the number of non-detects; the number of outliers excluded from analysis as part of the summary statistics; the mean, median, range, standard deviation, and type of distribution (normal, log normal, or other); 90<sup>th</sup>, 95<sup>th</sup>, and 99<sup>th</sup> percentiles; and the UTL for each constituent in each media. These summary statistics were computed using the USEPA-endorsed program, ProUCL (see Appendix D) that was distributed with the document *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (OSWER 9285.6-10) (USEPA, 2002). Note that calculation of the UTL assumes that data are normally distributed, which may not be the case for some constituents. UTLs were calculated based on a 95% coverage and a 95% confidence limit.

### 5.6.2 Data Sets with No Non-Detects

The number of measurements in a data set is denoted by n. The n measurements are denoted by x<sub>1</sub>, x<sub>2</sub>, ..., x<sub>n</sub>. The descriptive summary statistics that were computed for the background data sets are: the number of samples; the number of detects; the number of non-detects; the number

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of outliers excluded from analysis as part of the summary statistics; the mean, median, range, standard deviation, and type of distribution (normal, log normal, or other); 90<sup>th</sup>, 95<sup>th</sup>, and 99<sup>th</sup> percentiles; and the UTL for each constituent in each media.

### 5.6.3 Data Sets That Contain Non-Detects

Non-detects are measurements that the analytical laboratory reports are below some quantitative upper limits such as the detection limit or the limit of quantitation. Data sets that contain non-detects are said to be censored data sets.

The methods used to compute descriptive statistics when non-detects were present were selected based on the number of non-detects and the total number of measurements,  $n$  (detects plus non-detects). If  $n$  is large (say,  $n > 25$ ) and less than 15% of the data set are non-detects, the general guidance in *Guidance for the Data Quality Assessment, Practical Methods for Data Analysis, EPA QA/G-9, QA97 Update, EPA/600/R-96/084* (USEPA, 1996) is to replace the non-detects with the Detection Limit (DL) or in this case the MDL or MDC (radiological samples only),  $DL/2$ , or a very small value. The descriptive summary statistics were then computed using the (now) full data set, although some of the resulting statistics will be biased to some degree. (The median,  $p$ th sample percentile, and the interquartile range may not be biased if the number of non-detects is sufficiently small.) The biases may be large, even though less than 15% of the measurements are non-detects, particularly if  $n$  is small, say  $n < 25$ .

If 15% to 50% of the data set are non-detects, the guidance offered in the *Guidance for the Data Quality Assessment, Practical Methods for Data Analysis, EPA QA/G-9, QA96 Update, EPA/600/R-96/084* (USEPA, 1996) and *Guidance for the Data Quality Assessment, Practical Methods for Data Analysis, EPA QA/G-9, QA97 Update, EPA/600/R-96/084* (USEPA, 1998) is to forgo replacing non-detects with some value like the DL divided by 2, the DL itself, or a small value. Instead, one should consider computing the mean and standard deviation using the Cohen method.

If 50% to 90% of the measurements in the data set are non-detects, the loss of information is too great for descriptive statistics to provide much insight into the location and shape of the underlying distribution of measurements. The only descriptive statistics that might be possible to compute are  $p$ th percentiles for values of  $p$  that are greater than the proportion of non-detects present in the sample and when no non-detects are greater than the  $k(n+1)$ th largest datum, where  $k$  is the order statistic. In such cases, the recommended UTL developed by the USEPA-endorsed program, ProUCL, that was distributed with the document *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (OSWER 9285.6-10) (USEPA, 2002) was used. A descriptive summary of how the ProUCL 4.0 code generates a UTL is provided on a CD in Appendix D of this report.

If 90% to 99% of the measurements in the data set are non-detects, statistical analysis is not possible and the UTL value was set at 2 x the maximum detected value. This reasoning incorporates the professional judgment of laboratory managers regarding the likelihood of a detection near the detection limit really being a detection and not a false positive. It should be pointed out that this setting of the UTL at 2 x the maximum detect value is only a convention and

no statistics were used in calculating the UTL. Therefore, in situations with 3 detections or less, the use of the value in terms of a true “UTL” is somewhat questionable.

~~If 100% of the measurements in the data set are non-detects, statistical analysis is not possible and the UTL value was set the lowest achievable *quantitation limit (QL)*. In Part 1, comment No. 2 in NMED correspondence dated October 28<sup>th</sup>, 2010 (provided in Attachment 2 of this report), it states “The use of data greater than the MDL, but less than the Practical Quantitation Limit (PQL), is acceptable for use in a background study”. This statement is in agreement with the guidance provided in the STATISTICAL ANALYSIS OF GROUNDWATER MONITORING DATA AT RCRA FACILITIES UNIFIED GUIDANCE, March 2009 (EPA 530/R-09-007) as evidenced by the following excerpts from the guidance document:~~

~~Page 6-37: “Even if a data set contains only a small proportion of non-detects, care should be taken when choosing between the method detection limit [MDL], the quantification limit [QL], and the RL in characterizing ‘non-detect’ concentrations... As a general rule, non-detect concentrations should not be assumed to be bounded above by the MDL. The MDL is usually estimated on the basis of ideal laboratory conditions with physical analyte samples that may or may not account for matrix or other interferences encountered when analyzing specific field samples”. The RL should typically be taken as a more reasonable upper bound for non-detects when imputing estimated concentration values to these measurements.”~~

~~Page 17-19: “If all the sample data are non-detect, an RL (e.g., the lowest achievable quantitation limit [QL]) may serve as an approximate upper tolerance limit.”~~

~~Page 18-18: “It is possible to create an approximate non-parametric limit with background data containing all non-detects, by using the RL (often a quantitation limit) as the PQL. A quantified value above the PQL would constitute an exceedance.”~~

~~HAFB concurs with NMED on following statement. “A PQL is typically five times greater than the MDL. Data at or exceeding the PQL are considered accurate at a high level of confidence. Setting a background level for a data set that consists of all non-detects to twice the MDL, instead of at the MDL, will still result in establishing a background level that is less than the PQL.” Therefore, as provided in the 2009 Unified Guidance, “If all the sample data are non-detect, an RL (e.g., the lowest achievable *quantitation limit (QL)*) may serve as an approximate upper tolerance limit”. HAFB proposes that, for data sets that have all non-detects, to use an RL (e.g., the lowest achievable *quantitation limit (QL)*) as an approximate upper tolerance limit.~~

~~As required by comment No. 5 in NMED correspondence dated May 4, 2009 (provided in Attachment 2 of this report), if 100% of the measurements in the data set are non-detects, then the UTL value was arbitrarily set at the lowest DL in the data set. This practice is not in agreement with current USEPA guidance but was determined to be non-negotiable after significant discussion with NMED. See note below.~~

~~Note: The UTL represents a value that 95% of the population will fall below with 95% confidence. The UTL is typically higher than the highest value in the background data set that was used to calculate the UTL. With the UTL set higher than the largest value in the data set it~~

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~~will compensate for site variations across the installation. Typically, once the UTL is established, a single data point from the site that exceeds the background UTL has a high probability that indicates contamination is present. Therefore, the use of the term "UTL" is inappropriate to describe a value that was arbitrarily set at the DL. Furthermore, setting the UTL at the DL, the overall facility wide false positive rate during future sampling events may be unacceptably high. Furthermore, the USEPA 1992 *Statistical Analysis of Ground Water Monitoring Data at RCRA Facilities—Addendum to Interim Final Guidance*, states that, "the MDL is estimated on the basis of ideal laboratory conditions with ideal analyte samples and does not account for matrix or other interferences encountered when analyzing specific, actual field samples. For this reason, the PQL should be taken as the most reasonable upper bound for non-detect concentrations". The above statement is consistent with a methodology used in a document developed for USEPA Region 10, titled, *Statistical Approach for Discrimination of Background and Impacted Areas for Midnite Mine RI/FS*. In summary, the arbitrary setting of a UTL to the lowest DL in the data set for 100% non-detect data sets is being performed to comply with NMED comments provided in Attachment 2 of this report.~~

Comment No. 6 in NMED correspondence dated May 4, 2009 (provided in Attachment 2 of this report) indicates that aluminum, antimony, arsenic, lead, beryllium, and thallium had several samples with detection limits which were too high for groundwater. NMED stated that the background statistics should be calculated after removing the non-detect data associated with the highest DL in the corresponding data set for each constituent.

Unfiltered groundwater samples produced no detections for: antimony, beryllium, lead, silver, thallium, tin, carbon-14, lead 210, and thorium 232. Groundwater dissolved metals (filtered) produced no detections for: antimony, beryllium, lead, silver, thallium, and tin. These constituents were addressed as indicated above, if 100% of the measurements in the data set are non-detects, then the UTL value was arbitrarily set at the lowest ~~DL~~RL in the data set. See note above. The highest DL for the aluminum and arsenic for both unfiltered and filtered groundwater were removed from the datasets prior to UTL determination.

#### 5.6.4 Determining Presence of Data Outliers

The data set was examined to determine the *center* of the data set and the spread or range of the data values. The center is usually characterized by computing the arithmetic mean, denoted by  $x$ , and the *spread* by the standard deviations. In addition, NVB examined to see if any data seemed much larger in value than most of the data. These unusually large data may be due to an error. Not removing true outliers and removing false outliers both lead to a distortion of estimates of population parameters. Potential outliers may be identified through graphical representations such as the box and whisker plot and normal probability plot which can identify observations that are much larger or smaller than the rest of the data. If some of the data are so large as to cause concern that a mistake has been made, a statistical test for outliers should be conducted. If the test indicates the suspect value(s) are indeed larger than expected, relative to the remaining data, the outliers should be examined to determine if they are mistakes or errors. If they are, they should be removed from the data set.

Prior to conducting the outlier test, a test for normality was performed on the data set. The Grubbs test, also known as the maximum normalized residual test or Discordance Test, was used to detect outliers in a univariate (one-sided variance test) data set. The Grubbs test is based on the assumption of normality. Therefore, a test for normality was performed on the data set before applying the Grubbs test.

The Grubbs test detects one outlier at a time. This test considers two cases: 1) where the extreme value (potential outlier) is the smallest value of the data set, and 2) where the extreme value (potential outlier) is the largest value of the data set. This outlier is expunged from the dataset and the test is iterated until no outliers are detected. However, multiple iterations change the probabilities of detection, and this test should not be used for sample sizes of six or less since it frequently tags most of the points as outliers. Furthermore, if multiple iterations are required to achieve the desired criteria then the normality test is conducted on the data set after the suspected outlier(s) are deleted to ensure that the data set is still normal. The Grubbs test is recommended by the USEPA as a statistical test for outliers (USEPA, 1992). Table A-4 of Appendix A in USEPA 1992, contains critical values for this test for  $n \leq 50$ . The USEPA suggests taking the logarithms of environmental data, which are often log-normally distributed. The data are ranked in ascending order and the mean and standard deviation are calculated.

#### 5.6.5 Determining the Probability Distribution of a Data Set

The Shapiro-Wilk W-test is highly recommended for testing whether the data have a normal distribution; therefore this test was used in the determination of normality for this study. It was also used to test for a lognormal distribution, once the data was first transformed by computing the natural logarithm of each datum. The W-test is recommended in several USEPA guidance documents (USEPA, 1992 and USEPA, 1996) and in many statistical texts (Gilbert 1987; Conover 1980). The W-test has been shown to have more power than other tests to detect when data are not from a normal or lognormal distribution. The W-test should be conducted in conjunction with constructing normal and lognormal probability plots in order to more thoroughly evaluate whether the normal or lognormal distribution is an acceptable fit to the data.

#### 5.7 Graphical Data Analysis

Graphical plots of the background data sets are extremely useful and necessary tools to:

- Conduct exploratory data analyses to develop hypotheses about possible differences in the means, variances, and shapes for the background measurement distributions
- Visually depict and communicate differences in the distribution parameters (means, variances, and shapes) for the background measurement distributions
- Graphically evaluate if the background data have a normal, lognormal, or some other distribution
- Evaluate, illuminate, and communicate the results obtained using formal statistical tests

The following graphical plots were prepared: histogram, box plots, normal probability plots, concentration maps for all constituents/media, and Piper diagrams and stiff diagrams for groundwater constituents.

### 5.7.1 Histogram Plot

One of the oldest methods for summarizing data distributions is the histogram. The histogram divides the data range into units, counting the number of points within the units, and displaying the data as the height or area within a bar graph. In a histogram, the area within the bar represents the relative density of the data. The histogram provides a means of assessing the symmetry and variability of the data. If the data are symmetric, then the structure of these plots will be symmetric around a central point such as a mean. The histogram will generally indicate if the data are skewed and the direction of the skewness. Histograms were constructed using raw data (outliers included) so that they may be evaluated for the presence of outliers. Histograms are provided in Appendix E of this report.

### 5.7.2 Box and Whisker Plot

A box and whisker plot or box plot is a schematic diagram useful for visualizing important statistical quantities of the data. Box plots are useful in situations where it is not necessary or feasible to portray all the details of a distribution and can be used to assess the symmetry of the data. If the distribution is symmetrical, then the box is divided in two equal halves by the median, the whiskers will be the same length and the number of extreme data points will be distributed equally on either end of the plot. Box plots were constructed using reduced data (outliers excluded) and are provided in Appendix F of this report.

### 5.7.3 Normal Probability Plot (Quantile-Quantile Plot)

There are two types of quantile-quantile plots or q-q plots. The first type, an empirical quantile quantile plot, involves plotting the quantiles of two data variables against each other. The second type of a quantile-quantile plot, a theoretical quantile-quantile plot, involves graphing the quantiles of a set of data against the quantiles of a specific distribution. The following discussion will focus on the most common of these plots for environmental data, the normal probability plot (the normal q-q plot); however, the discussion holds for other q-q plots.

The normal probability plot is used to roughly determine how well the data set is modeled by a normal distribution. A normal probability plot is the graph of the quantiles of a data set against the quantiles of the normal distribution using normal probability graph paper. If the graph is linear, the data may be normally distributed. If the graph is not linear, the departures from linearity give important information about how the data distribution deviates from a normal distribution. If the graph of the normal probability plot is not linear, the graph may be used to determine the degree of symmetry (or asymmetry) displayed by the data. If the data are skewed to the right, the graph is convex. If the data are skewed to the left, the graph is concave. If the data in the upper tail fall above and the data in the lower tail fall below the quartile line, the data are too slender to be well modeled by a normal distribution, i.e., there are fewer values in the tails of the data set than what is expected from a normal distribution. If the data in the upper tail fall below and the data in the lower tail fall above the quartile line, then the tails of the data are too heavy to be well modeled using a normal distribution, i.e., there are more values in the tails of the data than what is expected from a normal distribution. A normal probability plot can be

used to visually identify potential outliers. A data value (or a few data values) much larger or much smaller than the rest, will cause the other data values to be compressed into the middle of the graph, ruining the resolution. Normal probability plots for both raw (including outliers) and reduced (excluding outliers) data are provided in Appendix G of this report. The probability plots were also constructed using the combined data sets for soil constituents which represents a single population and are also provided in Appendix G of this report.

#### 5.7.4 Piper and Stiff Diagram

The relative ionic composition of groundwater samples collected from monitoring wells during the Basewide Background Study area are plotted on a trilinear diagram. A trilinear diagram, also frequently referred to as a Piper diagram, provides a convenient method to classify and compare water types based on the ionic composition of different water samples. Cation and anion concentrations for each groundwater sample are converted to total milli-equivalents per liter (meq/L) and plotted as percentages of their respective totals in two triangles. The cation and anion relative percentages in each triangle are then projected into a quadrilateral polygon that describes the water type or hydrochemical facies. The piper diagram therefore has the potential to represent a large number of analyses and visually describing the differences in major ion chemistry in groundwater flow systems.

The ionic composition of groundwater samples during the study were represented by another type of water-quality diagram - the stiff diagram. Stiff diagrams are used to compare the ionic composition of water samples between different locations, depths, or aquifers. The stiff diagram is a polygon created from three horizontal axes extended on both sides of a vertical axis. Cations are plotted on the left side of the axis and anions are plotted on the right side, both in meq/L. A greater distance from the vertical axis represents a larger ionic concentration. The cation and anion concentrations are connected to form an asymmetric polygon known as a stiff diagram, where the size is a relative indication of the dissolved-solids concentration. Reduced data (outliers removed) were used to construct the Stiff Diagrams for the Basewide Background Study and are provided in Appendix H of this report. Additionally, the Stiff diagrams have been plotted on a map of the base as discussed in Section 4 (Figure 4-6).

Reduced data (outliers removed) were used to construct the Piper Diagram for the Basewide Background Study and is provided in Appendix I of this report. Additionally, Sample Summary reports also included in Appendix I provide a general overview of each groundwater sample including major ions, hydrochemical facies (e.g. sodium-chlorine), calculated hardness, ion balance, ion ratios, comparison with sea-water, and conversion to milli-equivalents which were used to calculate the cation/anion percentages for plotting on the Piper diagram are also provided in Appendix I. Superimposing the Piper Diagram Legend in Appendix I and the Piper Diagram of the Total Groundwater using Reduced Data Set developed during the Basewide Background Study illustrates that 90% of the dominant cation is sodium and 80% of the dominant anions is chlorides. Of the 24 sampling locations used during the Basewide Background Study, 70% of the locations of the hydrochemical facies are mapped as Na-Mg-Cl-SO<sub>4</sub>. Figure 5-141 illustrates the dominance of the Na-Mg-Cl-SO<sub>4</sub> water type across HAFB. The figure indicates minimal localized dilution or mixing potentially due to deteriorating infrastructure. Finally, Figure 5-141

also supports the single groundwater population set forth in the Conceptual Site Model for Groundwater at HAFB in Section 4 of this report. Therefore, no discrete hydrochemical characteristics were detected during this analysis.

### 5.7.5 Isoconcentration Maps

Laboratory analyses of soil analytical results and groundwater monitoring wells were plotted to indicate the amount of a particular analyte that is present in the soil or groundwater. Each map includes the approximate boundary of the various amounts of each analyte which is prepared based on the locations of the soil boring or monitoring wells and the concentrations detected in the samples. An isoconcentration map is often used in understanding the distribution of various constituents of a particular analyte. NVB plotted each analyte according to the following horizons: Surface Soil Metals, Radiological Surface Soils, Subsurface Soil Metals, Radiological Subsurface Soil, Saturated Subsurface Soil Metals, Radiological Saturated Subsurface Soil, Groundwater Metals – Unfiltered, Radiological Groundwater, Groundwater Dissolved Metals – Filtered, and Groundwater Natural Attenuation Parameters. Each analyte for the horizons above are illustrated on Figures 5-1 thru 5-137.

Isoconcentration maps were prepared using reduced data. Additionally, concentration data was posted on the maps at the locations where the samples were collected.

During the June 3, 2009, meeting between NMED, United States Air Force (USAF), and NVB, NMED stated that averaging the UTLs to generate a Composite UTL was unacceptable and directed NVB to generate the UTLs by combining the reduced data sets for all three soil horizons and then determining the UTL. Development of a single analyte specific soil map using averaged soil concentrations from the three soil horizons would add confusion to the document since a UTL developed based on averaged soil concentrations from 42 locations will be different than the UTL developed from a combined data set of 126 points. Therefore, no isoconcentration maps were constructed using the averaged soil concentrations where the soil constituents are representative of one population as requested in the NMED issued notice of disapproval in May 2009.

## 5.8 Summary of Methods

This section summarizes the results of the analytical methods evaluation and the methods and results of the statistical characterization of background.

The approach used for the statistical characterization of background is summarized as follows:

- Review raw data and develop the descriptive summary statistics
- Determine if the data set was normally distributed using Shapiro-Wilk W-test
- Identify potential outliers using both the Grubbs Analysis (Discordance Test) and graphical methods
- Select appropriate statistical methods (parametric or nonparametric) based on distributional information

- Calculate summary statistics and tolerance limits using the appropriate statistical method

Tables 5-2 to 5-17 present a summary of the results for metals and select radiological constituents in surface soil, subsurface soil, and saturated subsurface soil (capillary fringe), dissolved metals in groundwater, and total metals and select radiological constituents in groundwater, respectively. Each table presents the following statistics: number of detects; number of samples; number of non-detects; minimum, maximum, and mean concentration; the standard deviation; median concentration; outlier; and test for normality. All statistics are presented to allow future investigations the flexibility to choose whichever statistic is most appropriate for the comparisons planned for that project. Calculated UTLs are also presented for those instances in which decisions must be made on the basis of a comparison of individual sample results to background.

NVB implemented the following step to determine the UTLs:

1. Raw data were summarized in Tables 3-1 through 3-6 for soils and Tables 3-7 and 3-8 for groundwater.
2. Statistical descriptors were prepared using the raw data (no outliers were identified and excluded at this point). Data sets that contain non-detects were considered censored data sets. The results of these efforts are summarized in Tables 5-2 through 5-6 and 5-12 through 5-17. A normality test was conducted on the raw data. The results of these efforts are summarized in Tables 5-2 through 5-6. If the data was not normally distributed, the decision was made to transform the data which involves taking the natural logarithms of the results, and repeating the Shapiro-Wilk test on the transformed data. The results of these efforts are summarized in Tables 5-7 through 5-18.
3. The data were transformed into their natural logarithms if the raw probability plots indicated that the curve was Not Normal. Outliers were determined and removed from the data sets. The outliers removed are listed in Tables 5-7 through 5-11.
4. Statistical descriptors were prepared using the reduced data (outliers removed) after the data were transformed to their natural logarithms. A second normality test was conducted after the removal of the outliers following the Grubbs Analysis. If the transformed data was found to be normal for a constituent media, and a certain percentage of detects were available in the data set, a UTL was calculated. Otherwise, a UTL was assigned by other means. The results of these efforts are summarized in Tables 5-12 through 5-17. Each table summarizes for each constituent/media the distribution, critical values used to determine conformance with decision criteria, number of outliers removed from the data sets (Tables 5-7 through 5-11), and the method that was used to handle censored data sets.

Combined soil UTLs were generated ~~from~~ the three soil types (surface, subsurface, and saturated subsurface soil) and are reported in Table 5-17.

### 5.8.1 Technical Approach

As previously stated, the primary objective of this background study was to develop estimates of background concentrations of metals and select radiological constituents in background surface soil, subsurface soil, saturated subsurface soil, and groundwater. These estimates will then be used for comparison with data collected in ongoing and future investigations to help distinguish between naturally occurring concentrations of metals and elevated levels that might be attributable to contamination. Analytical data from surface soil, subsurface soil, saturated subsurface soil, and groundwater samples were collected from background locations around HAFB in support of this effort. This section presents an overview of the study design and describes the data assessment and interpretation process.

#### 5.8.1.1 Study Design

The fundamental idea in a background study is to characterize the range of naturally occurring concentrations of a constituent of interest. This study was designed to characterize background in terms of estimates of the UTLs for background metals and select radiological constituent concentrations. These estimates represent upper bounds for concentrations that might be expected in samples collected from uncontaminated areas of HAFB.

For estimates of background concentrations to be useful in helping to distinguish between contaminated and uncontaminated areas on the basis of future sample data, it is important that the background estimates are based on results that are statistically representative of actual background concentrations. This means primarily that the data on which the estimates are based should fairly depict the range of actual background concentrations. For example, they should include samples from different soil series and different groundwater aquifers, if appropriate. Therefore, NVB proposed the advancement of 42 soil borings, collection of three samples per boring at different depths (surface soil, subsurface soil, and saturated subsurface soil) and collection of groundwater samples from 30 existing monitoring wells which have historically exhibited non-detect laboratory analyses.

#### 5.8.1.2 Data Analysis and Interpretation

As indicated above, the overall goal of the data analysis and interpretation process was to characterize background metals and select radiological constituents concentrations in terms of estimates of the upper bounds for concentrations that might be expected in samples collected from uncontaminated areas of HAFB. This was done by using the measurement results to calculate UTLs for background metals and select radiological constituent concentrations. Descriptive statistics pertaining to the background sample data were also developed as part of the data analysis process. In general, this process included the following steps:

- Review raw data and develop the descriptive summary statistics
- Identify potential outliers using both the Grubbs Analysis (Discordance Test) and graphical methods
- Determine if the data set was normally distributed using Shapiro-Wilk W-test

- Select appropriate statistical methods (parametric or nonparametric) based on distributional information
- Calculate summary statistics and tolerance limits using the appropriate statistical method

This process is described in more detail in the remainder of this section.

### 5.8.2 Raw Summary Statistics

Duplicate samples that were collected as part of the field effort were averaged to develop a single representative sample value for the sampling location. A preliminary data review was conducted to include basic statistical quantities (raw summary statistics). The raw summary statistics developed and presented include the number of detections, number of samples, and number of non-detects; the percent non-detects; [the reporting limit](#); the detection limit; the minimum and maximum; the mean, median, and standard deviation; skewness, and coefficient of variance. Tables 5-2, 5-3, 5-4, 5-5, and 5-6 present the raw summary statistics and preliminary Shapiro-Wilk test for metals and select radiological constituents in surface soil, subsurface soil, saturated subsurface soil, dissolved metals in groundwater, and total metals and select radiological constituents in groundwater, respectively.

### 5.8.3 Transformation

Environmental data commonly exhibit frequency distributions that are non-negative and skewed with heavy or long right tails. Several standard parametric probability models have these properties. The lognormal distribution is a commonly used distribution for modeling environmental contaminant data. The advantage to this distribution is that a simple (logarithmic) transformation will typically transform a lognormal distribution into a normal distribution. Therefore, the methods for testing for normality described in this section can be used to test for lognormality if a logarithmic transformation has been used. By transforming the data, assumptions that are not satisfied in the original data can be satisfied by the transformed data. For example, a right-skewed distribution can be transformed to be approximately normal by using a logarithmic transformation. Then the normal-theory procedures can be applied to the transformed data. When data are lognormally distributed, then procedures to logarithms of the data are applied. If the criteria for normality could not be satisfied, then the data set was transformed into a lognormal distribution in an attempt to obtain a normal distribution in the data set. A statistical test known as the Shapiro-Wilk W-test, was used to test the results for normality.

### 5.8.4 Outlier Testing and Graphical Data Review

The first steps in the data analysis were to conduct outlier tests to identify anomalous measurement results and to review histograms of the raw measurement data.

Normal or lognormal probability plot (Q-Q plots) and histograms were reviewed throughout the outlier test process to confirm that the measurements used in subsequent analyses were reasonable representations of the background. Appendix G present the raw data, normal or



lognormal probability plot (Q-Q plots) and Appendix E presents the histograms used at this stage, respectively.

The Grubbs test, also known as the maximum normalized residual test or Discordance Test, was used to detect outliers in a univariate (one-sided variance test) data set. The Grubbs test is based on the assumption of normality. As indicated above, a test for normality was performed on the data set before applying the Grubbs test. The Grubbs test detects one outlier at a time. This outlier was removed from the dataset and the test was iterated until no outliers were detected. However, multiple iterations change the probabilities of detection, and this test was not used for sample sizes of six or less since it frequently tags most of the points as outliers. Tables 5-7, 5-8, 5-9, 5-10, and 5-11 present the results of the outlier test using a combination of both graphical inspection and the Grubbs test for metals and select radiological constituents in surface soil, subsurface soil, saturated subsurface soil, and total metals and dissolved metals and select radiological constituents in groundwater, respectively.

### **5.8.5 Normality Testing and Calculation of Transformed Statistics**

After determining that no additional outliers exist in the data set, the next step in the statistical analysis was to evaluate whichever was chosen as the most appropriate data set to see if the data appeared to be normally distributed. The assumption of normality is a fundamental tenet of statistical tests involving parametric methods. Therefore, the extent to which the data supported this assumption determined the direction of subsequent analyses. The Shapiro-Wilk W-test was used again to verify that normality was maintained following iterative outlier removal. Tables 5-12, 5-13, 5-14, 5-15, and 5-16 present the results of the Shapiro-Wilk test for metals and select radiological constituents in surface soil, subsurface soil, saturated subsurface soil, dissolved metals in groundwater, and total metals and select radiological constituents in groundwater, respectively. The initial transformed statistics are also included in these tables. These include minimum and maximum measured concentrations, as well as estimates of the mean, median, and standard deviation. Where the Shapiro-Wilk test showed that the assumption of normality was not appropriate, a nonparametric method was used to determine the UTLs.

### **5.8.6 Calculation of UTLs**

The results of the Shapiro-Wilk tests were used to determine whether parametric or nonparametric statistical methods were most appropriate for calculating the UTLs shown in Tables 5-12 through 5-16. Parametric methods are usually used when the population is known or can be assumed to follow a normal distribution. They can also be used when the population of interest can be modeled by some other distribution (such as the log normal) that allows the measurement data to be transformed to a normal distribution. Parametric methods offer the advantage of achieving greater statistical certainty using smaller numbers of samples than required for corresponding non-parametric methods. For those elements and matrices in which the Shapiro-Wilk tests did not indicate a significant departure from normality, a parametric UTL (USEPA, 1992) for 95% coverage with 95% confidence was calculated. This represents an upper 95% confidence bound for the 95<sup>th</sup> percentile concentration.

As indicated above, for those cases in which the Shapiro-Wilk tests indicated significant departure from normality, the next step was to see if a log transformation could be used to produce a more normally distributed data set. This involved taking the natural logarithms of the results, and repeating the Shapiro-Wilk test on the transformed data. Parametric UTLs were calculated using transformed data in those cases in which the Shapiro-Wilk results indicated that the transformation was effective in achieving normality.

Nonparametric methods were used for subsequent analyses when the Shapiro-Wilk tests indicated that the assumption of normality was not supported by either the raw or transformed data. Nonparametric methods are not based on the assumption of normality, and are sometimes referred to as distribution-free methods. The nonparametric method used to calculate UTLs for this study uses the ranks of the measured values. The UTL is simply the highest observed concentration in the data set. However, unlike parametric tolerance limits which are calculated to include a specified proportion of the parent population, the proportion included in these nonparametric UTLs varies as a function of the number of observations in the sample set. The coverage of the UTL is indicated in the summary tables.

Tables 5-12, 5-13, 5-14, 5-15, 5-16, and 5-17 present the calculated UTLs for metals and select radiological constituents in surface soil, subsurface soil, saturated subsurface soil, total metals and select radiological constituents in groundwater, dissolved metals in groundwater, and combined soil, respectively. Table 5-18 presents a summary of calculated UTLs-background levels for metals and select radiological constituents in surface soil, subsurface soil, saturated subsurface soil, total metals in groundwater, dissolved metals in groundwater, and combined soils. NMED (NOD dated October 2010) required the use of the term "background level" instead of UTLs. Therefore, the "background level" were calculated by determining the 95 % UTL with 95% coverage of the results.

### 5.8.7 Multiple Population Analysis

The analytical results for soil and groundwater samples have been evaluated for each constituent to determine if the results represent one or more populations. According to the Work Plan, if results indicated multiple populations existed for a constituent, then statistical descriptors for each population would be derived and reported separately for each population. However, the results did not indicate multiple populations, therefore, only one number has been derived from each media for each constituent. The following sections describe how the population analysis was performed on both the soil and groundwater horizons.

#### 5.8.7.1 Soil

A qualitative comparison for each analyte between surface/subsurface/saturated subsurface isoconcentration figures, indicates similar isocontours and distribution patterns. This similarity between isocontour patterns and uniform soil types suggests a homogenous matrix in each soil horizon (see Figures 5-1 through 5-87a from the reduced data set). The major geologic unit for the surface soil sampling zone is silty sand. The major unit for the subsurface and saturated subsurface soil sampling zones is also silty sand with interbedded clay lenses. Overall, the primary geologic unit consisted of silty sand with increasing gypsum content with depth. This

homogeneity between each soil horizon is further supported by the analytical soil data results which indicate that each constituent is within the same order of magnitude at each depth horizon.

In general, the geochemical trend analysis for the metals concentrations in the three soil horizons stayed within the same order of magnitude. A slight decreasing trend was apparent as the depth of the samples approached the saturated subsurface soil interval. However this is expected given the dynamic nature of the soils and groundwater within the saturated subsurface soil interval. Metals concentrations between surface soil and subsurface soils were nearly identical.

To further test this hypothesis, NVB conducted side by side analysis using box and whiskers plots on the same graphic to illustrate for a given metals constituent for all three soil types that the soil is very similar. The analysis indicated that the distributions of the data for the three soil horizons are similar. In particular, the medians from the three soil horizons occupy similar locations within the boxes, and considerable overlap between the first and third quartiles among the three boxes was noted. Side by side box and whiskers plots were constructed using reduced data (outliers excluded) for only those constituents that had 100% detection in all three soil horizons and are provided in Appendix F of this report.

Following the determination that the three soil horizons were similar, statistical descriptors were prepared using the combined data sets for a single population, and the UTL was determined using ProUCL 4.0. The combined soil UTLs are presented in Table 5-17.

#### **5.8.7.2 Groundwater**

Comparison of two populations may be a potentially contaminated area with a background area or concentration levels from an upgradient and a downgradient well. The comparison of the two populations may be based on a statistical parameter that characterizes the relative location (e.g., a mean or median), and may be based on a graphical comparison of the two population distributions using box-plots. Populations from differing lithologies will produce significantly different box plots. However, populations from similar lithologies would be expected to have significant overlap.

In general, to determine whether two groundwater populations exist, the 24 wells were divided into two groups based solely on the northern extent on the installation. The overall process included the following steps:

- The descriptive summary statistics were reviewed for non-detects. In general, if n is small, say  $n < 25$ , the non-detect biases may be large, even though less than 15% of the measurements are non-detects. To minimize this bias and to prevent error propagation into the overall comparison, only those analytes that had non-detects less than 15% were considered for this analysis.
- The data set was evaluated to determine if it was normally distributed using the Shapiro-Wilk W-test.
- Potential outliers were then identified using both the Grubbs Analysis (Discordance Test) and graphical methods.

- Constituent-specific box and whisker plots were then generated for each subset and plotted side by side for selected groundwater constituents.

The comparison of the two box plots focused primarily on comparing the mean and median of one plot to see if those values fell between the 25<sup>th</sup> and 75<sup>th</sup> percentiles of the opposing box-plot. If the values were within the range then it was considered to be comparable. If the values were outside the range then that analyte could potentially be from a secondary population. Comparative box plots are provided in Appendix F of this report. In general, overlapping means and median were observed between the 25<sup>th</sup> and 75<sup>th</sup> percentiles of the opposing box-plot. This indicates that the sample populations are from similar groundwater. This provides additional graphical evidence utilizing several key constituents to support a single population for groundwater.

Finally, as indicated in Section 4.5 of this report, a secondary graphical method was employed to support the single population conclusion. The Schoeller plots and resultant signatures provide a convenient means for identifying if the groundwater is from different lithologies. Figure 4-7 illustrates the overall ratios of the major solute content and resultant signature for the aquifer under HAFB using the 24 wells from the basewide background study. In general, the shapes or signatures from the individual 24 curves indicate that the ratios of major ion concentrations are from the same aquifer lithology. This provides additional graphical evidence utilizing several key constituents to support a single population conclusion for groundwater at HAFB.

#### 5.8.8 Comparison of Future Sampling Results to Background UTLs

Individual site sampling results will be compared to the 95% background upper tolerance limits as a way of determining whether the site results appear to come from a population that is different than the background. The 95% UTL represents an estimate of the upper 95<sup>th</sup> percentile of the true background concentration of the constituent of interest. For the 95% UTL, there is a relatively small chance, in the order of one in twenty, of an uncontaminated site sample (i.e., site data that are no different from background) having a constituent concentration greater than the UTL. When individual sample results are compared to UTLs, they are interpreted to indicate the presence of contamination when they exceed the UTLs. On the other hand, constituent concentrations that do not exceed the UTLs are considered to be background concentrations, not the result of contamination.

## 6 SUMMARY OF RESULTS AND OBSERVATIONS

The objective of the soil and groundwater Basewide Background Study was to collect data of sufficient quantity and quality to enable statistical evaluation of background soil and groundwater characteristics. Data were collected and laboratory and statistical analysis was conducted in accordance with the Work Plan (NVB, August 2008). The objective of this study was achieved and the following conclusions have been made.

### 6.1 Upper Tolerance Limits

The 95% UTL represents an estimate of the upper 95<sup>th</sup> percentile of the true background concentration of the constituent of interest. When individual sample results are compared to UTLs, they are interpreted to indicate the presence of contamination when they exceed the UTLs. On the other hand, constituent concentrations that do not exceed the UTLs are considered to be background concentrations, not the result of contamination. The summary background levels UTLs for the entire data set are provided in Table 5-18. NMED (NOD dated October 2010) required the use of the term "background level" instead of UTLs. Therefore, the "background level" were calculated by determining the 95 % UTL with 95% coverage of the results. Details on the UTL calculations for the individual analytes are presented in Tables 5-12 through 5-17.

### 6.2 Limited Number of Detections or Non-Detects

Statistical calculation of soil UTL values were not possible for antimony, selenium, silver, thallium, and carbon-14 since no detections were indicated in the surface soil, subsurface soil, and saturated subsurface soil horizons. Lead 210 and Uranium 235/236 were not determined due to the limited number of detections (less than 10% of the total number of samples in a data set) for the subsurface and saturated subsurface soil horizons.

Similarly, groundwater produced no detections for: antimony, beryllium, lead, silver, thallium, tin, carbon-14, lead 210, and thorium 232. Mercury was detected in only 2 samples for the total groundwater (unfiltered). Groundwater dissolved metals (filtered) produced no detections for: antimony, beryllium, lead, silver, thallium, and tin. Mercury and lead were detected only once in the data set. If a data set contains 3 detections or less, statistical analysis is not possible and the UTL value was set at 2 x the maximum non-outlier, non-detect, or 2 x maximum detected value. This reasoning incorporates the professional judgment of laboratory managers regarding the likelihood of a detection near the detection limit really being a detection and not a false positive. It should be pointed out that this setting of the UTL at 2 x the maximum detect value is only a convention and no statistics were used in calculating the UTL. Therefore, in situation with 3 detections or less the use of the value in terms as a true "UTL" is somewhat questionable.

If 100% of the measurements in the data set are non-detects, statistical analysis is not possible and the UTL value was set the lowest achievable quantitation limit (QL). In Part 1, comment No. 2 in NMED correspondence dated October 28<sup>th</sup>, 2010 (provided in Attachment 2 of this report) states "The use of data greater than the MDL, but less than the Practical Quantitation Limit (PQL), is acceptable for use in a background study". This statement is in agreement with

the guidance provided in the STATISTICAL ANALYSIS OF GROUNDWATER MONITORING DATA AT RCRA FACILITIES UNIFIED GUIDANCE, March 2009 (EPA 530/R-09-007) as evidenced by the following excerpts from the guidance document:

Page 6-37: “Even if a data set contains only a small proportion of non-detects, care should be taken when choosing between the method detection limit [MDL], the quantification limit [QL], and the RL in characterizing ‘non-detect’ concentrations... As a general rule, non-detect concentrations should not be assumed to be bounded above by the MDL. The MDL is usually estimated on the basis of ideal laboratory conditions with physical analyte samples that may or may not account for matrix or other interferences encountered when analyzing specific field samples”. The RL should typically be taken as a more reasonable upper bound for non-detects when imputing estimated concentration values to these measurements.”

Page 17-19: “If all the sample data are non-detect, an RL (e.g., the lowest achievable quantitation limit [QL]) may serve as an approximate upper tolerance limit.”

Page 18-18: “It is possible to create an approximate non-parametric limit with background data containing all non-detects, by using the RL (often a quantitation limit) as the PQL. A quantified value above the PQL would constitute an exceedance.”

HAFB concurs with NMED on following statement, “A PQL is typically five times greater than the MDL. Data at or exceeding the PQL are considered accurate at a high level of confidence. Setting a background level for a data set that consists of all non-detects to twice the MDL, instead of at the MDL, will still result in establishing a background level that is less than the PQL.” Therefore, as provided in the 2009 Unified Guidance, “If all the sample data are non-detect, an RL (e.g., the lowest achievable quantitation limit [QL]) may serve as an approximate upper tolerance limit”. HAFB proposes that, for data sets that have all non-detects, to use an RL (e.g., the lowest achievable quantitation limit [QL]) as an approximate upper tolerance limit.

As required by comment No. 5 in NMED correspondence dated May 4, 2009 (provided in Attachment 2 of this report), if 100% of the measurements in the data set are non-detects, then the UTL value was arbitrarily set at the lowest DL in the data set. This practice is not in agreement with current USEPA guidance but was determined to be non-negotiable after significant discussion with NMED. See note below.

Note: The UTL represents a value that 95% of the population will fall below with 95% confidence. The UTL is typically higher than the highest value in the background data set that was used to calculate the UTL. With the UTL set higher than the largest value in the data set it will compensate for site variations across the installation. Typically, once the UTL is established, a single data point from the site that exceeds the background UTL has a high probability that indicates contamination is present. Therefore, the use of the term “UTL” is inappropriate to describe a value that was arbitrarily set at the DL. Furthermore, setting the UTL at the DL, the overall facility wide false positive rate during future sampling events may be unacceptably high. Furthermore, the USEPA 1992 *Statistical Analysis of Ground Water Monitoring Data at RCRA Facilities Addendum To Interim Final Guidance* states that, “the MDL is estimated on the basis of ideal laboratory conditions with ideal analyte samples and does

~~not account for matrix or other interferences encountered when analyzing specific, actual field samples. For this reason, the PQL should be taken as the most reasonable upper bound for nondetect concentrations". The above statement is consistent with a methodology used in a document developed for USEPA Region 10, titled, *Statistical Approach for Discrimination of Background and Impacted Areas for Midnite Mine RI/FS*. In summary, the arbitrary setting of a UTL to the lowest DL in the data set for 100% non-detect data sets is being performed to comply with NMED comments provided in Attachment 2.~~

### 6.3 Combined Soil UTL

A qualitative comparison for each analyte in between surface/subsurface/saturated subsurface isoconcentration figures, indicates similar isocontours and distribution patterns. These similarities between isocontour patterns and uniform soil types suggests a homogenous matrix in each soil horizon. The major geologic unit for the surface soil sampling zone is silty sand. The major unit for the subsurface and saturated subsurface soil sampling zones is also silty sand with interbedded clay lenses. Overall, the primary geologic unit consisted of silty sand with increasing gypsum content with depth. This homogeneity between each soil horizon is further supported by the analytical soil data results which indicate that each constituent is within the same order of magnitude at each depth horizon. This indicates the presence of a single population of data. Additionally, the similarity of the analytical soil data results presented in the isocontour soil maps (Figures 5-1 through 5-87a) would suggest the presence of uniform soil types.

In general, the geochemical trend analysis for the metals concentrations in the three soil horizons stayed within the same order of magnitude. A slight decreasing trend was apparent as the depth of the samples approach the saturated subsurface soil interval. However this is expected given the dynamic nature of the soils and groundwater within the saturated subsurface soil interval. Metals concentrations between surface soil and subsurface soils were nearly identical.

Furthermore, NVB conducted side by side analysis using box and whiskers plots on the same graphic to illustrate for a given constituent for all three soil types that the soils are very similar. In particular, the medians from the three soil horizons occupy similar locations within the boxes, and considerable overlap between the first and third quartiles among the three boxes was noted. Side by side box and whiskers plots were constructed using reduced data (outliers excluded) for only those metals constituents that had 100% detection in all three soil horizons and are provided in Appendix F of this report.

Following the determination that the three soil horizons were similar, statistical descriptors were prepared using the combined data sets for a single population, and the UTL was determined using ProUCL 4.0. The combined soil UTLs are presented in Table 5-17.

### 6.4 UTLs Above Regulatory Limits

#### 6.4.1 Surface Soil

None of the surface soil UTLs exceeded their respective NMED Soil Screening Levels.

#### 6.4.2 Subsurface Soil

The arsenic UTL (4.75 mg/kg) for the subsurface soil exceeded the NMED Soil Screening Level of 3.59 mg/kg. None of the remaining subsurface soil UTLs exceeded their respective NMED Soil Screening Levels.

#### 6.4.3 Saturated Subsurface Soil

None of the saturated subsurface soil UTLs exceeded their respective NMED Soil Screening Levels.

#### 6.4.4 Combined Soil

The arsenic UTL (3.66 mg/kg) for the combined soil slightly exceeded the NMED Soil Screening Level of 3.59 mg/kg. None of the remaining UTLs exceeded their respective NMED Soil Screening Levels.

#### 6.4.5 Groundwater

~~Twelve~~ Eleven UTLs for groundwater (total) exceeded their respective USEPA MCLs (primary or secondary) and eight UTLs exceeded the value in New Mexico Administrative Code (NMAC) 20.6.2. The following is a list of analytes whose UTLs exceeded the Federal MCLs:

- Aluminum
- Arsenic
- Cadmium
- Chloride (secondary)
- Manganese
- ~~Nitrate~~
- Selenium
- Sulfate (secondary)
- Thallium
- Radium (226 and 228 combined)
- Total Uranium
- Total Dissolved Solids

The following is a list of analytes whose UTLs exceeded the NMAC 20.6.2:

- Chloride
- Iron
- Manganese
- ~~Nitrate~~
- Selenium
- Sulfate
- Total Uranium
- Total Dissolved Solids



#### 6.4.6 Groundwater (Dissolved Metals)

Four UTLs for dissolved metals in groundwater exceeded their respective USEPA primary or secondary MCLs standard. The following is a list of these analytes:

- Aluminum (secondary)
- Arsenic
- Manganese (secondary)
- Thallium

None of the UTLs exceeded their respective NMAC 20.6.2 standards.

## **7 REFERENCES**

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## **FIGURES**

## **TABLES**

**ATTACHMENT 1  
NMED CORRESPONDENCE DATED AUGUST 24, 2007**



**ATTACHMENT 2**  
**NMED CORRESPONDENCE DATED MAY 4, 2009 AND**  
**RESPONSE TO COMMENTS**

**APPENDIX A  
HTW DRILLING LOGS**

**APPENDIX B  
MONITORING WELL SAMPLE COLLECTION FORMS**

**APPENDIX C  
DATA VALIDATION AND LABORATORY ANALYTICAL  
RESULTS  
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**APPENDIX D  
PROUCL 4.00.04 TECHNICAL GUIDE  
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**APPENDIX H  
STIFF DIAGRAMS**

**APPENDIX I  
PIPER DIAGRAM**

**Table 5-12**  
**Transformed Statistics and Upper Tolerance Limit**  
**Determination for Surface Soil Samples**  
 Basewide Background Study  
 Holloman Air Force Base, NM  
 NationView|Bhate Project Number: 9081001

Variable	Transformed Statistics													Grubbs Analysis and Test for Outliers						Method Used for Non-Detects	Test for Normality			Calculated UTLs and Percentiles			
	Num Samples	Num Ds	Num NDs	% NDs	MinimumRL	DL or MDC	Minimum	Maximum	Mean	Median	SD	Skewness	CV	Distribution Prior to Discordance Test	Discordance Test	Discordance Critical Value at 5%	Suspected Outlier Value from Data Set?	Statistical Evidence that the point is an Outlier?	# of Outliers Removed		Value of Shapiro-Wilks Normal Test	Shapiro Wilk Critical Value	Conclusion with Alpha (0.05)	95% UTL with 95% Coverage	90% Percentile (z)	95% Percentile (z)	99% Percentile (z)
Aluminum	42	39	0	0.00%	11	1.7	160.000	17,000.000	5,660.976	3,600.000	4,773.692	N/A	0.102	Gamma	1.688	2.857	17000.000	No	3	ProUCL	0.967	0.939	Normal	22,026.37	12,370.23	15,748.46	23,475.72
Antimony	42	0	42	100.00%	1.6	0.41	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Gamma	N/A	N/A	N/A	N/A	0	N/A	N/A	N/A	1.60	N/A	N/A	N/A	
Arsenic	42	32	7	17.95%	2.2	0.71	0.830	3.400	1.511	1.270	0.747	N/A	0.916	Gamma	2.147	2.773	3.400	No	3	Cohen	0.943	0.930	Normal	3,582	2,535	2,946	3,824
Barium	42	38	0	0.00%	1.1	0.081	2.773	4.868	3.903	3.892	0.512	N/A	0.131	Gamma	1.886	2.846	4.868	No	4	N/A	0.980	0.938	Normal	151.17	103.00	121.89	162.88
Beryllium	42	34	5	12.82%	0.54	0.035	15.000	150.000	57.964	49.000	33.392	N/A	-0.549	Gamma	1.644	2.799	150.000	No	3	DL/2	0.961	0.933	Normal	1.95	0.79	1.25	2.47
Cadmium	42	31	8	20.51%	0.54	0.044	0.420	16.000	5.322	3.450	4.208	N/A	-0.232	Gamma	1.860	2.759	16.000	No	3	Cohen	0.956	0.929	Normal	0.30	0.21	0.25	0.33
Calcium	42	36	0	0.00%	54	15	11.775	12.924	12.268	12.278	0.216	N/A	0.018	Normal	N/A	N/A	N/A	N/A	6	ProUCL	0.943	0.935	Normal	278,818.79	250,050.57	261,862.93	284,020.95
Chromium	42	38	0	0.00%	1.6	0.062	-0.094	2.708	1.409	1.246	0.751	-0.115	0.533	Lognormal	1.730	2.846	2.708	No	4	ProUCL	0.966	0.938	Normal	25.62	12.09	16.80	31.16
Cobalt	42	41	0	0.00%	1.1	0.11	-1.609	1.649	0.249	0.182	0.836	-0.178	3.356	Lognormal	1.674	2.877	1.649	No	1	ProUCL	0.970	0.941	Normal	7.49	3.74	5.07	8.97
Copper	42	41	0	0.00%	2.2	0.23	0.470	2.996	1.544	1.435	0.626	0.301	0.406	Lognormal	2.319	2.877	2.996	No	1	ProUCL	0.965	0.941	Normal	15.80	9.56	11.91	18.01
Iron	42	38	0	0.00%	16	4.1	6.328	9.547	8.141	8.022	0.834	-0.160	0.102	Lognormal	1.686	2.846	9.547	No	4	ProUCL	0.970	0.938	Normal	28,058.74	11,795.11	17,246.54	35,173.37
Lead	42	40	0	0.00%	0.87	0.29	-0.942	2.303	0.802	0.765	0.783	-0.040	0.976	Lognormal	1.918	2.866	2.303	No	2	ProUCL	0.976	0.940	Normal	9.67	5.22	6.79	11.13
Magnesium	42	38	0	0.00%	22	4	130.000	15,000.000	5,885.122	4,900.000	4,023.123	N/A	0.089	Gamma	N/A	N/A	N/A	N/A	4	ProUCL	0.937	0.938	Non-parametric	21,159.18	12,228.12	15,269.78	22,132.81
Manganese	42	38	0	0.00%	1.1	0.11	3.500	360.000	74.000	113.422	99.330	N/A	0.198	Gamma	1.657	2.846	360.000	No	4	ProUCL	0.972	0.938	Normal	451.49	251.10	321.34	482.61
Nickel	42	40	0	0.00%	4.3	0.13	-0.371	2.565	1.132	1.043	0.796	-0.002	0.703	Lognormal	1.801	2.866	2.565	No	2	ProUCL	0.966	0.940	Normal	16.95	8.57	11.56	20.24
Potassium	42	39	0	0.00%	330	44	83.000	2,900.000	880.000	1,146.086	753.023	N/A	0.118	Gamma	1.798	2.857	2900.000	No	3	ProUCL	0.969	0.939	Normal	3,887.99	2,292.53	2,823.60	4,010.03
Selenium	42	0	40	100.00%	1.4	0.92	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2	N/A	N/A	N/A	1.40	N/A	N/A	N/A	
Silver	42	0	41	100.00%	1.1	0.17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	N/A	N/A	1.10	N/A	N/A	N/A	
Sodium	42	39	0	0.00%	540	63	5.136	8.825	6.562	6.215	1.183	0.500	0.180	Lognormal	N/A	N/A	N/A	N/A	3	ProUCL	0.869	0.939	Non-parametric	679.32	453.61	525.80	693.65
Thallium	42	0	40	100.00%	1.3	0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2	ProUCL	N/A	N/A	N/A	1.30	N/A	N/A	N/A
Tin	42	42	0	0.00%	11	0.98	0.182	0.588	0.384	0.405	0.093	-0.027	0.244	Non-parametric	N/A	N/A	N/A	N/A	0	ProUCL	0.898	0.942	Non-parametric	1.79	1.65	1.71	1.82
Vanadium	42	36	0	0.00%	2.2	0.1	0.788	3.091	2.084	2.128	0.634	N/A	0.304	Gamma	1.588	2.823	3.091	No	6	ProUCL	0.960	0.935	Normal	33.76	20.01	24.93	36.02
Zinc	42	39	0	0.00%	3.3	0.43	0.642	3.784	2.441	2.398	0.796	-0.152	0.326	Lognormal	1.688	2.857	3.784	No	3	ProUCL	0.974	0.939	Normal	68.54	33.86	46.12	82.38
Mercury	42	32	7	17.95%	36	5.9	7.200	15.000	10.274	10.000	2.108	N/A	0.087	Gamma	2.342	2.773	15.000	No	3	Cohen	0.973	0.930	Normal	15.38	13.11	14.05	15.93
Carbon 14	42	0	38	100.00%	0.84	0.84	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4	N/A	N/A	N/A	0.84	N/A	N/A	N/A	
Ra-226 - Total	42	30	10	25.00%	0.11	0.11	0.144	1.650	0.647	0.505	0.416	N/A	-1.291	Gamma	1.615	2.745	1.650	No	2	Cohen	0.965	0.927	Normal	1.82	1.20	1.44	1.97
Ra-228 - Total	42	12	25	67.57%	0.33	0.33	0.400	1.300	0.799	0.816	0.182	N/A	-1.235	Gamma	1.531	2.285	1.300	No	5	ProUCL	0.952	0.859	Normal	1.27	1.06	1.14	1.32
Lead 210	42	4	35	89.74%	0.83	0.83	0.262	0.399	0.321	0.311	0.059	0.833	0.183	Non-parametric	1.327	1.463	0.399	No	3	ProUCL	0.963	0.748	Normal	1.34	1.23	1.27	1.36
Thorium 228	42	32	7	17.95%	0.08	0.08	0.094	1.210	0.419	0.330	0.320	N/A	-0.597	Gamma	2.023	2.773	1.210	No	3	Cohen	0.935	0.930	Normal	1.81	1.04	1.39	2.24
Thorium 230	42	41	0	0.00%	0.03	0.03	0.145	1.560	0.686	0.570	0.406	N/A	-1.313	Gamma	1.935	2.877	1.560	No	1	ProUCL	0.977	0.941	Normal	2.64	1.65	2.19	3.45
Thorium 232	42	37	0	0.00%	0.03	0.03	0.086	0.960	0.349	0.280	0.262	N/A	-0.497	Gamma	1.837	2.857	0.960	No	5	ProUCL	0.970	0.939	Normal	1.46	0.86	1.15	1.83
Uranium 234	42	37	0	0.00%	0.049	0.049	0.087	1.570	0.540	0.405	0.371	N/A	-0.778	Gamma	1.673	2.857	1.570	No	5	ProUCL	0.947	0.939	Normal	2.60	1.44	2.02	3.45
Uranium 235/236	42	4	35	89.74%	0.033	0.033	0.039	0.079	0.044	0.046	0.021	N/A	-0.147	Gamma	1.333	1.463	0.079	No	3	ProUCL	0.969	0.748	Normal	0.12	0.08	0.09	0.12
Uranium 238	42	40	0	0.00%	0.03	0.03	0.063	0.900	0.376	0.310	0.229	N/A	-0.506	Gamma	1.547	2.866	0.900	No	2	ProUCL	0.948	0.940	Normal	1.75	0.99	1.38	2.34
Total Uranium	41	41	0	0.00%	N/A	N/A	-1.977	0.991	-0.056	-0.082	0.694	-0.731	-12.453	Lognormal	1.508	2.877	0.991	No	0	ProUCL	0.941	0.941	Normal	4.09	2.30	2.96	4.75

**Notes:**  
 All metals results are in milligrams per kilogram (mg/kg) with the exception of Mercury which is provided in micrograms per kilogram (µg/kg)  
 Radiological results are in picoCuries per gram (pCi/g) with the exception of Total Uranium which is in micrograms per gram (µg/g)  
 D - Detects  
 ND - Non-detects  
 DL - Detection Limit  
 MDC - Minimum Detectable Concentration (for Radiological constituents)  
 SD - Standard deviation  
 N/A - Not applicable

Value set at the Reporting Limit. No statistics were used, therefore it is not a true UTL.

**Table 5-13**  
**Transformed Statistics and Upper Tolerance Limit**  
**Determination for Subsurface Soil Samples**  
 Basewide Background Study  
 Holloman Air Force Base, NM  
 NationView|Bhate Project Number: 9081001

Variable	Transformed Statistics												Grubbs Analysis and Test for Outliers					Method Used for Non-Detects	Calculated UTLs and Percentiles			
	Num Samples	Num Ds	Num NDs	% NDs	Minimum RL	DL or MDC	Minimum	Maximum	Mean	Median	SD	Skewness	Distribution Prior to Discordance Test	Discordance Test	Discordance Critical Value at 5%	Statistical Evidence that the point is an Outlier?	# of Outliers Removed		95% UTL with 95% Coverage	90% Percentile (z)	95% Percentile (z)	99% Percentile (z)
Aluminum	42	37	0	0.00%	11	1.60	600.00	19,000.00	6,244.00	4,550.00	4,960.00	N/A	Lognormal	1.56	2.835	No	5	N/A	25,679.71	12,917.32	17,276.59	29,809.09
Antimony	42	0	41	100.00%	1.6	0.40	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	1.60	N/A	N/A	N/A
Arsenic	42	28	9	24.32%	2.1	0.70	0.77	5.80	2.36	2.00	1.32	N/A	Gamma	1.41	2.714	No	5	ProUCL	4.75	3.28	3.84	5.05
Barium	42	40	0	0.00%	1.1	0.08	1.97	4.76	3.58	3.68	0.73	-0.302	Lognormal	1.62	2.866	No	2	N/A	175.57	94.39	123.63	205.06
Beryllium	42	35	3	7.89%	0.53	0.04	0.04	1.40	0.43	0.31	0.36	N/A	Lognormal	1.53	2.811	No	4	DL/2	2.39	0.92	1.38	2.97
Cadmium	42	22	14	38.89%	0.53	0.04	-2.94	-1.66	-2.35	-2.35	0.41	0.173	Lognormal	1.67	2.603	No	6	Cohen	0.20	0.14	0.17	0.21
Calcium	42	41	0	0.00%	53	15.00	11.33	12.90	12.05	12.04	0.36	0.364	Lognormal	2.37	2.866	No	1	N/A	361,517.59	269,066.88	306,262.46	390,461.75
Chromium	42	38	0	0.00%	1.6	0.06	0.78	18.00	6.90	5.20	5.30	N/A	Lognormal	1.47	2.846	No	4	N/A	9.69	4.83	6.50	11.35
Cobalt	42	38	0	0.00%	1.1	0.11	0.19	6.80	2.36	1.80	1.85	N/A	Lognormal	1.61	2.846	No	4	N/A	8.38	4.91	6.16	8.99
Copper	42	39	0	0.00%	2.1	0.23	0.64	12.00	4.18	2.80	3.05	N/A	Lognormal	1.57	2.857	No	3	N/A	15.45	8.09	10.69	18.03
Iron	42	38	0	0.00%	16	4.00	470.00	20,000.00	6,442.00	4,650.00	5,205.00	N/A	Lognormal	1.43	2.846	No	4	N/A	28,460.29	12,627.19	17,867.33	34,264.68
Lead	42	40	0	0.00%	0.85	0.29	0.35	9.20	3.30	2.83	2.58	N/A	Lognormal	1.55	2.866	No	2	N/A	14.27	6.76	9.36	17.20
Magnesium	42	37	0	0.00%	21	3.90	460.00	12,000.00	4,312.00	3,725.00	3,049.00	N/A	Lognormal	1.79	2.835	No	5	N/A	14,324.84	8,103.26	10,312.60	16,210.03
Manganese	42	37	0	0.00%	1.1	0.11	11.00	250.00	97.19	76.00	72.35	N/A	Lognormal	1.68	2.835	No	5	N/A	380.77	202.27	265.02	439.95
Nickel	42	37	0	0.00%	4.2	0.13	0.40	16.00	5.46	3.80	4.61	N/A	Lognormal	1.68	2.835	No	5	N/A	22.22	11.13	14.91	25.82
Potassium	42	39	0	0.00%	320	43.00	240.00	4,300.00	1,586.00	1,150.00	1,188.00	N/A	Lognormal	1.63	2.857	No	3	N/A	5,992.12	3,097.71	4,116.60	7,017.78
Selenium	42	0	42	100.00%	1.4	0.91	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	1.40	N/A	N/A	N/A
Silver	42	0	42	100.00%	1.1	0.17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	1.10	N/A	N/A	N/A
Sodium	42	40	0	0.00%	530	63.00	200.00	4,100.00	1,626.00	1,550.00	1,026.00	N/A	Lognormal	1.72	2.866	No	2	N/A	5,253.51	3,050.72	3,863.88	6,018.99
Thallium	42	0	41	100.00%	1.3	0.69	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	1.30	N/A	N/A	N/A
Tin	42	39	0	0.00%	11	0.97	1.20	2.30	1.62	1.60	0.26	N/A	Lognormal	2.31	2.857	No	3	N/A	2.23	1.97	2.08	2.30
Vanadium	42	38	0	0.00%	2.1	0.10	1.40	39.00	13.81	11.50	9.56	N/A	Gamma	1.53	2.811	No	4	N/A	43.34	26.96	32.71	45.42
Zinc	42	39	0	0.00%	3.2	0.42	1.50	47.00	16.99	12.75	13.34	N/A	Lognormal	1.53	2.857	No	3	N/A	71.70	34.84	47.55	85.22
Mercury	42	6	33	84.62%	35	5.90	7.10	13.00	9.06	8.20	2.42	N/A	Non-parametric	1.33	1.822	No	3	ProUCL	9.33	8.54	8.88	9.53
Carbon 14	42	0	42	100.00%	0.85	0.85	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	0.85	N/A	N/A	N/A
Ra-226 - Total	42	35	7	16.67%	0.12	0.12	0.22	1.26	0.52	0.48	0.23	N/A	Gamma	2.37	2.811	No	0	Cohen	1.11	0.79	0.92	1.19
Ra-228 - Total	42	14	27	66.67%	0.35	0.35	0.45	1.33	0.79	0.75	0.26	N/A	Lognormal	2.11	2.371	No	1	ProUCL	1.57	0.96	1.19	1.79
Lead 210	42	2	37	94.87%	0.87	0.87	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3	N/A	3.18	N/A	N/A	N/A
Thorium 228	42	32	7	17.95%	0.06	0.06	0.15	1.12	0.51	0.47	0.24	N/A	Gamma	1.40	2.773	No	3	Cohen	1.07	0.73	0.86	1.14
Thorium 230	42	39	0	0.00%	0.03	0.03	0.15	1.23	0.55	0.49	0.26	N/A	Lognormal	2.08	2.857	No	3	DL/2	1.23	0.87	1.01	1.34
Thorium 232	42	35	3	7.89%	0.03	0.03	0.10	0.94	0.43	0.43	0.22	N/A	Non-parametric	1.52	2.811	No	4	DL/2	1.41	0.76	0.99	1.63
Uranium 234	42	35	0	0.00%	0.04	0.04	-1.65	-0.08	-0.79	-0.76	0.41	-0.533	Normal	1.74	2.811	No	7	DL/2	0.88	0.72	0.79	0.91
Uranium 235/236	42	2	39	95.24%	0.036	0.04	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	0.12	N/A	N/A	N/A
Uranium 238	42	35	0	0.00%	0.029	0.03	0.08	0.84	0.37	0.37	0.18	N/A	Normal	1.91	2.811	No	7	DL/2	0.70	0.57	0.62	0.72
Total Uranium	42	42	0	0.00%	N/A	N/A	0.14	2.53	1.06	1.08	0.56	N/A	Gamma	N/A	2.877	N/A	0	N/A	2.91	1.92	2.29	3.08

**Notes:**  
 All metals results are in milligrams per kilogram (mg/kg) with the exception of Mercury which is provided in micrograms per kilogram (µg/kg)  
 Radiological results are in picoCuries per gram (pCi/g) with the exception of Total Uranium which is in micrograms per gram (µg/g)  
 D - Detects  
 ND - Non-detects  
 DL - Detection Limit  
 MDC - Minimum Detectable Concentration (for Radiological constituents)  
 SD - Standard deviation  
 N/A - Not Applicable

Value set at the Reporting Limit. No statistics were used, therefore it is not a true UTL.  
 Value set at 2 times the Maximum Detected Concentration in the data set

**Table 5-14**  
**Transformed Statistics and Upper Tolerance Limit**  
**Determination for Saturated Subsurface Soil Samples**  
 Basewide Background Study  
 Holloman Air Force Base, NM  
 NationView|Bhate Project Number: 9081001

Variable	Transformed Statistics												Grubbs Analysis and Test for Outliers					Method Used for Non-Detects	Calculated UTLs and Percentiles			
	Num Samples	Num Ds	Num NDs	% NDs	Minimum RL	DL or MDC	Minimum	Maximum	Mean	Median	SD	Skewness	Distribution Prior to Discordance Test	Discordance Test	Discordance Critical Value at 5%	Statistical Evidence that the point is an Outlier?	# of Outliers Removed		95% UTL with 95% Coverage	90% Percentile (z)	95% Percentile (z)	99% Percentile (z)
Aluminum	42	38	0	0.00%	12	1.80	680.00	10,750.00	3,981.25	3,400.00	2,359.83	0.66	Normal	2.34	2.85	No	4	NA	8,977.51	7,005.49	7,862.82	9,471.03
Antimony	42	0	42	100.00%	1.8	0.45	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	1.80	N/A	N/A	N/A
Arsenic	42	27	10	27.03%	2.3	0.77	0.89	2.50	1.41	1.30	0.46	N/A	Gamma	1.95	2.70	No	5	Cohen	2.51	2.00	2.21	2.64
Barium	42	38	0	0.00%	1.2	0.09	2.70	120.00	44.37	37.50	30.74	N/A	Gamma	1.63	2.85	No	4	NA	148.86	89.64	110.81	158.21
Beryllium	42	37	0	0.00%	0.59	0.04	0.06	0.52	0.24	0.18	0.15	N/A	Gamma	1.60	2.84	No	5	DL/2	0.78	0.47	0.58	0.82
Cadmium	42	20	17	45.95%	0.59	0.05	-2.98	-1.43	-2.25	-2.32	0.42	0.20	Non-parametric	1.94	2.56	No	5	Cohen	0.11	0.09	0.10	0.11
Calcium	42	40	0	0.00%	59	17.00	650.00	250,000.00	126,887.80	140,000.00	65,854.17	65,854.17	Normal	2.00	2.87	No	2	NA	265,856.37	211,283.32	235,208.28	280,087.51
Chromium	42	37	0	0.00%	1.8	0.07	0.34	2.59	1.51	1.41	0.60	-0.09	Lognormal	1.80	2.84	No	5	N/A	19.07	10.51	13.65	22.28
Cobalt	42	38	0	0.00%	1.2	0.12	-1.02	1.53	0.19	0.05	0.73	0.19	Lognormal	1.84	2.85	No	4	DL/2	8.21	3.79	5.34	10.12
Copper	42	39	0	0.00%	2.3	0.25	-0.08	2.07	0.90	0.69	0.61	0.26	Non-parametric	1.90	2.86	No	3	N/A	8.90	6.51	7.71	8.90
Iron	42	36	0	0.00%	18	4.50	540.00	14,000.00	4,849.52	3,400.00	3,443.30	N/A	Gamma	1.88	2.82	No	6	N/A	15,675.41	9,656.21	11,873.79	16,822.07
Lead	42	38	0	0.00%	0.94	0.32	-0.24	1.89	0.78	0.69	0.64	0.17	Lognormal	1.75	2.85	No	4	DL/2	10.36	5.45	7.24	12.33
Magnesium	42	39	0	0.00%	23	4.30	6.11	8.95	7.66	7.74	0.63	0.03	Lognormal	2.03	2.86	No	3	N/A	6,249.50	3,880.25	4,738.16	6,891.89
Manganese	42	39	0	0.00%	1.2	0.12	2.17	5.21	3.89	3.83	0.82	-0.15	Lognormal	1.61	2.86	No	3	N/A	322.78	158.26	216.30	388.71
Nickel	42	41	0	0.00%	4.7	0.14	-0.69	2.42	1.00	0.88	0.81	-0.12	Lognormal	1.73	2.88	No	1	DL/2	15.21	7.75	10.42	18.14
Potassium	42	37	0	0.00%	350	48.00	210.00	2,000.00	925.38	810.00	492.09	0.34	Normal	2.46	2.84	No	5	N/A	1,970.82	1,556.02	1,734.80	2,070.16
Selenium	42	0	42	100.00%	1.5	1.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.00	N/A	N/A	0	N/A	1.50	N/A	N/A	N/A
Silver	42	0	42	100.00%	1.2	0.19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	1.20	N/A	N/A	N/A
Sodium	42	38	0	0.00%	590	69.00	5.83	8.13	6.72	6.59	0.62	0.63	Lognormal	2.28	2.85	No	4	N/A	2,216.37	1,396.15	1,697.73	2,450.18
Thallium	42	0	37	100.00%	1.4	0.76	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5	N/A	1.40	N/A	N/A	N/A
Tin	42	38	0	0.00%	12	1.10	1.20	2.10	1.71	1.70	0.21	N/A	Gamma	2.12	2.85	No	4	N/A	2.19	1.99	2.08	2.26
Vanadium	42	38	0	0.00%	2.3	0.11	2.00	29.00	11.26	8.05	7.78	N/A	Gamma	1.72	2.85	No	4	N/A	33.77	21.66	26.31	36.61
Zinc	42	40	0	0.00%	3.5	0.47	0.88	3.64	2.30	2.21	0.70	-0.04	Lognormal	1.91	2.87	No	2	N/A	40.95	22.30	28.98	47.36
Mercury	42	4	35	89.74%	39	6.50	6.80	9.00	7.93	8.12	0.69	N/A	Gamma	1.22	1.46	No	3	ProUCL	9.49	8.86	9.14	9.69
Carbon 14	42	0	42	100.00%	0.84	0.84	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	0.84	N/A	N/A	N/A
Ra-226 - Total	42	35	6	14.63%	0.09	0.09	0.18	0.90	0.42	0.39	0.19	N/A	Gamma	2.17	2.81	No	1	Cohen	1.01	0.71	0.82	1.07
Ra-228 - Total	42	13	23	62.16%	0.26	0.26	0.35	0.74	0.52	0.53	0.07	N/A	Gamma	2.01	2.37	No	6	ProUCL	0.68	0.61	0.64	0.70
Lead 210	42	2	37	94.87%	0.86	0.86	0.20	0.52	0.36	0.36	0.23	N/A	N/A	N/A	N/A	N/A	3	N/A	3.38	N/A	N/A	N/A
Thorium 228	42	39	0	0.00%	0.05	0.05	-1.71	-0.29	-0.91	-0.94	0.40	-0.22	Lognormal	1.57	2.85	No	3	DL/2	1.19	0.75	0.92	1.35
Thorium 230	42	39	0	0.00%	0.03	0.03	-1.43	-0.02	-0.70	-0.69	0.40	-0.14	Lognormal	1.71	2.86	No	3	DL/2	1.50	0.95	1.16	1.70
Thorium 232	42	36	1	2.70%	0.03	0.03	0.09	0.77	0.37	0.33	0.20	N/A	Gamma	1.59	2.82	No	5	DL/2	1.33	0.86	1.13	1.75
Uranium 234	42	40	0	0.00%	0.04	0.04	0.10	0.85	0.35	0.32	0.22	N/A	Gamma	1.66	2.87	No	2	DL/2	1.13	0.70	0.85	1.19
Uranium 235/236	42	1	39	97.50%	0.036	0.04	-2.33	-2.33	-2.33	-2.33	N/A	N/A	N/A	N/A	N/A	N/A	2	N/A	0.19	N/A	N/A	N/A
Uranium 238	42	39	0	0.00%	0.026	0.03	-2.28	-0.21	-1.28	-1.43	0.58	0.25	Lognormal	1.85	2.86	No	3	DL/2	1.06	0.61	0.78	1.23
Total Uranium	42	42	0	0.00%	N/A	-1.44	0.99	-0.25	-0.25	-0.36	0.66	0.17	Non-parametric	N/A	N/A	N/A	0	N/A	2.68	2.03	2.42	2.68

**Notes:**

All metals results are in milligrams per kilogram (mg/kg) with the exception of Mercury which is provided in micrograms per kilogram ( µg/kg)

Radiological results are in picoCuries per gram (pCi/g) with the exception of Total Uranium which is in micrograms per gram ( µg/g)

D - Detects

ND - Non-detects

DL - Detection Limit

SD - Standard deviation

MDC - Minimum Detectable Concentration (for Radiological constituents)



N/A - Not Applicable

Value set at the Reporting Limit. No statistics were used, therefore it is not a true UTL.

Value set at 2 times the Maximum Detected Concentration in the data set



**Table 5-15**  
**Transformed Statistics and Upper Tolerance Limit**  
**Determination for Groundwater - Unfiltered Samples**  
 Basewide Background Study  
 Holloman Air Force Base, NM  
 NationView|Bhate Project Number: 9081001

Variable	Transformed Statistics												Grubbs Analysis and Test for Outliers					Method Used for Non-Detects	Calculated UTLs and Percentiles			
	Num Samples	Num Ds	Num NDs	% NDs	Minimum RL	DL or MDC	Minimum	Maximum	Mean	Median	SD	Skewness	Distribution Prior to Discordance Test	Discordance Test	Discordance Critical Value at 5%	Evidence that the point is an Outlier?	# of Outliers Removed		95% UTL with 95% Coverage	90% Percentile (z)	95% Percentile (z)	99% Percentile (z)
Aluminum <sup>a</sup>	20	13	6	31.58%	100	18	2.89	6.15	4.44	4.20	0.95	0.66	Lognormal	2.04	2.33	No	1	ProUCL	1,042.43	229.53	371.56	917.06
Antimony	24	0	20	100.00%	10	3.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4	N/A	10.00	N/A	N/A	N/A
Arsenic	24	16	4	20.00%	15	4.4	5.30	21.00	10.00	8.90	4.84	N/A	Gamma	1.74	2.44	No	4	Cohen	25.93	16.78	19.50	25.32
Barium	24	24	0	0.00%	10	0.58	1.95	3.53	2.70	2.77	0.41	0.10	Lognormal	2.03	2.64	No	0	N/A	38.00	25.06	29.03	38.27
Beryllium	24	0	24	100.00%	5	0.47	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	5.00	N/A	N/A	N/A
Cadmium	24	24	0	0.00%	5	0.45	-0.63	2.17	0.37	0.47	0.80	1.03	Non-parametric	N/A	N/A	N/A	0	ProUCL	8.80	7.25	8.73	8.80
Calcium	24	24	0	0.00%	200	34	13.06	13.82	13.44	13.38	0.22	0.30	Lognormal	1.72	2.64	No	0	N/A	1,136,663.50	908,786.41	983,605.19	1,140,965.60
Chromium	24	16	7	30.43%	10	0.66	0.85	9.00	2.21	1.64	1.89	N/A	Gamma	2.22	2.44	Yes	1	Cohen	12.00	5.91	8.33	14.27
Cobalt	24	1	23	95.83%	10	1.2	0.18	2.89	0.57	0.18	0.79	1.83	N/A	N/A	N/A	No	0	ProUCL	36	N/A	N/A	N/A
Copper	24	10	14	58.33%	15	1.4	0.34	2.28	0.82	0.47	0.66	1.21	Non-parametric	N/A	N/A	No	0	ProUCL	9.80	6.80	9.05	9.80
Iron	24	17	7	29.17%	100	22	25.50	1,200.00	170.14	80.00	251.60	N/A	Gamma	2.46	2.48	No	0	Cohen	1,306.82	508.84	811.98	1,613.75
Lead	24	0	24	100.00%	9	2.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	9.00	N/A	N/A	N/A
Magnesium	24	24	0	0.00%	200	11	12.97	14.91	13.87	13.86	0.54	0.39	Lognormal	1.93	2.64	No	0	N/A	3,692,781.50	2,116,674.60	2,577,022.30	3,727,645.20
Manganese	24	24	0	0.00%	10	0.25	-2.08	6.46	2.33	2.56	1.85	-0.34	Lognormal	2.23	2.64	No	0	DL/2	745.38	110.86	217.48	769.75
Mercury	24	2	22	91.67%	0.2	0.027	-3.61	-1.51	-3.36	-3.61	0.69	2.42	N/A	N/A	N/A	N/A	0	N/A	0.44	N/A	N/A	N/A
Nickel	24	12	11	47.83%	40	1.3	1.30	14.00	3.83	3.00	3.20	N/A	Gamma	N/A	N/A	No	1	Cohen	21.97	10.39	14.79	25.62
Potassium	24	24	0	0.00%	3000	240	8.68	12.15	10.15	10.31	0.92	0.46	Lognormal	2.19	2.64	No	0	N/A	212,143.56	82,758.79	115,443.61	215,542.28
Selenium	24	12	11	45.83%	15	4.9	5.00	93.00	17.87	12.39	19.72	N/A	Gamma	2.03	2.29	No	1	Cohen	129.52	52.65	81.51	156.42
Silver	24	0	24	100.00%	10	0.93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	10.00	N/A	N/A	N/A
Sodium	24	24	0	0.00%	1000	92	14.00	16.38	15.26	15.37	0.69	-0.09	Lognormal	1.62	2.64	No	0	N/A	20,989,585.00	10,310,931.00	13,257,304.00	21,243,016.00
Thallium	24	0	24	100.00%	15	4.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	15.00	N/A	N/A	N/A
Tin	24	0	24	100.00%	100	5.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	100.00	N/A	N/A	N/A
Vanadium	24	24	0	0.00%	10	1.1	2.22	4.42	3.34	3.26	0.50	0.12	Lognormal	2.15	2.64	No	0	N/A	90.02	53.82	64.55	90.80
Zinc	24	14	10	41.67%	20	4.5	4.60	17.00	7.44	6.45	3.29	N/A	Gamma	N/A	N/A	Yes	0	Cohen	16.95	11.84	13.54	17.14
Carbon 14	24	0	24	100.00%	8.6	8.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	8.60	N/A	N/A	N/A
Ra-226 - Total	24	23	0	0.00%	0.13	0.13	-1.24	0.74	-0.19	-0.12	0.49	-0.28	Lognormal	1.88	2.62	No	1	DL/2	2.62	1.56	1.87	2.61
Ra-228 - Total	24	22	0	0.00%	0.39	0.39	-0.56	1.19	0.34	0.29	0.44	0.19	Lognormal	1.91	2.60	No	2	DL/2	3.99	2.49	2.92	3.95
Lead 210	24	0	24	100.00%	3.1	3.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	3.10	N/A	N/A	N/A
Thorium 228	24	3	21	87.50%	0.15	0.15	-1.90	-0.53	-1.50	-1.51	0.30	1.41	Non-parametric	N/A	N/A	No	0	ProUCL	0.99	0.31	0.82	0.99
Thorium 230	24	9	14	60.87%	0.06	0.06	0.10	0.34	0.21	0.22	0.06	N/A	Gamma	2.09	2.11	No	1	ProUCL	0.37	0.29	0.32	0.37
Thorium 232	24	0	24	100.00%	0.061	0.061	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	0.06	N/A	N/A	N/A
Uranium 234	24	23	0	0.00%	0.1	0.1	1.23	5.21	3.08	3.17	0.90	-0.04	Lognormal	2.37	2.62	No	1	DL/2	175.95	68.85	95.36	175.69
Uranium 235/236	24	19	4	17.39%	0.06	0.06	0.21	3.90	0.76	0.73	0.81	N/A	Gamma	2.23	2.53	No	1	Cohen	4.79	2.09	2.99	5.24
Uranium 238	24	23	0	0.00%	0.08	0.08	0.38	4.60	2.35	2.36	0.96	0.06	Lognormal	2.34	2.62	No	1	DL/2	98.07	35.87	50.86	97.92
Uranium Total	24	23	0	0.00%	N/A	0	1.47	5.69	3.45	3.46	0.96	0.06	Lognormal	2.34	2.62	No	1	DL/2	294.23	107.58	152.56	293.76
Alkalinity (as CaCO <sub>3</sub> )	24	24	0	0.00%	5	1.1	4.05	5.95	5.12	5.30	0.52	-0.54	Normal	1.59	2.64	N/A	0	N/A	386.57	298.44	329.60	388.05
Chloride	24	24	0	0.00%	3	12	7.50	10.09	8.90	8.92	0.68	-0.32	Lognormal	1.75	2.64	No	0	N/A	35,039.73	17,502.94	22,371.89	35,452.81
Sulfate	24	24	0	0.00%	5	0.5	8.01	9.68	8.67	8.75	0.47	0.43	Lognormal	2.13	2.64	No	0	N/A	17,418.99	10,709.40	12,719.36	17,562.64
Sulfide	24	0	15	100.00%	1	23	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9	N/A	1.00	N/A	N/A	N/A
Total Dissolved Solids	24	24	0	0.00%	10	19	9.01	10.82	9.88	9.95	0.53	0.31	Lognormal	1.78	2.64	No	0	N/A	65,956.58	38,281.91	46,401.92	66,565.21

**Notes:**  
 All metals results are in micrograms per liter (µg/L)  
 Radiological results are in picoCuries per liter (pCi/L) with the exception of Total Uranium which is in micrograms per liter (µg/L)  
 D - Detects  
 ND - Non-detects  
 DL - Detection Limit  
 MDC - Minimum Detectable Concentration (for Radiological constituents)  
 SD - Standard deviation  
 N/A - Not Applicable  
<sup>a</sup> MW-29-01, MW-BG-04, S1-MW2, and TDS-MW02 were removed from the dataset due to elevated Detection Limits  
 Value set at the Reporting Limit. No statistics were used, therefore it is not a true UTL.  
 Value set at 2 times the Maximum Detected Concentration in the Data Set

**Table 5-16**  
**Transformed Statistics and Upper Tolerance Limit**  
**Determination for Groundwater Dissolved Metals - Filtered Samples**  
 Basewide Background Study  
 Holloman Air Force Base, NM  
 NationView|Bhate Project Number: 9081001

Variable	Transformed Statistics												Grubbs Analysis and Test for Outliers					Method Used for Non-Detects	Calculated UTLs and Percentile			
	Num Samples	Num Ds	Num NDs	% NDs	Minimum RL	DL	Minimum	Maximum	Mean	Median	SD	Skewness	Distribution Prior to Discordance Test	Discordance Test	Discordance Critical Value at 5%	Evidence that the point is an Outlier?	# of Outliers Removed		95% UTL with 95% Coverage	90% Percentile (z)	95% Percentile (z)	99% Percentile (z)
Aluminum <sup>a</sup>	21	1	20	95.83%	100	18	3.29	3.29	3.29	3.29	N/A	0.33	N/A	N/A	N/A	No	0	ProUCL	54.00	N/A	N/A	N/A
Antimony	24	0	24	100.00%	10	3.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	10.00	N/A	N/A	N/A
Arsenic <sup>a</sup>	21	16	5	23.81%	15	4.4	4.40	21.00	8.69	6.40	5.41	N/A	Gamma	2.27	2.44	No	0	Cohen	28.53	16.92	20.72	29.17
Barium	24	23	0	0.00%	10	0.58	1.84	3.11	2.59	2.56	0.35	-0.25	Lognormal	1.49	2.62	No	1	NA	30.13	20.88	23.72	30.11
Beryllium	24	0	24	100.00%	1	0.47	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	1.00	N/A	N/A	N/A
Cadmium	24	20	2	9.09%	5	0.45	-0.80	0.83	0.08	0.15	0.53	-0.25	Non-parametric	1.43	2.60	No	2	DL/2	2.41	1.85	2.04	2.40
Calcium	24	24	0	0.00%	200	34	13.06	13.82	13.43	13.38	0.23	0.27	Lognormal	1.69	2.64	No	0	NA	1,151,301.20	910,742.49	989,439.77	1,155,866.50
Chromium	24	11	11	50.00%	10	0.66	0.70	1.90	1.17	1.21	0.42	N/A	Gamma	1.94	2.60	N/A	2	Cohen	2.50	1.79	2.01	2.49
Cobalt	24	2	21	91.30%	10	1.2	0.18	1.82	0.40	0.18	0.56	2.35	N/A	N/A	N/A	No	1	ProUCL	2.60	N/A	N/A	N/A
Copper	24	9	14	60.87%	15	1.4	1.40	18.00	8.86	6.51	7.21	N/A	Gamma	2.16	2.62	No	1	ProUCL	57.46	24.59	35.60	63.02
Iron	24	7	17	70.83%	100	22	22.00	47.50	35.96	36.89	9.98	N/A	Gamma	2.43	2.64	N/A	0	ProUCL	65.56	50.51	55.65	66.18
Lead	24	0	24	100.00%	9	2.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	9.00	N/A	N/A	N/A
Magnesium	24	24	0	0.00%	200	11	12.90	14.95	13.86	13.83	0.54	0.37	Lognormal	2.02	2.64	No	0	NA	3,630,926.70	2,085,525.20	2,537,243.60	3,665,078.60
Manganese	24	20	0	0.00%	10	0.25	0.00	3.87	1.81	1.46	1.24	0.33	Lognormal	1.67	2.56	No	4	NA	118.65	29.83	46.79	108.84
Mercury	24	0	24	100.00%	0.2	0.027	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	0.20	N/A	N/A	N/A
Nickel	24	7	15	68.18%	40	1.3	1.60	8.20	5.16	5.31	2.68	N/A	Gamma	2.23	2.60	N/A	2	ProUCL	15.89	9.42	11.25	15.25
Potassium	24	22	0	0.00%	3000	240	8.92	11.10	9.98	9.94	0.73	0.04	Lognormal	1.53	2.60	No	2	NA	120,479.98	55,130.46	71,936.13	118,497.71
Selenium	24	12	10	45.45%	15	4.9	6.30	23.00	11.87	11.52	4.40	N/A	Gamma	1.51	2.60	No	2	Cohen	25.26	18.07	20.39	25.23
Silver	24	0	24	100.00%	10	0.93	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	10.00	N/A	N/A	N/A
Sodium	24	24	0	0.00%	1000	92	14.00	16.30	15.24	15.26	0.68	-0.17	Lognormal	1.56	2.64	No	0	NA	19,972,499.00	9,923,033.30	12,707,578.00	20,209,785.00
Thallium	24	0	24	100.00%	15	4.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	15.00	N/A	N/A	N/A
Tin	24	0	24	100.00%	100	5.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	N/A	100.00	N/A	N/A	N/A
Vanadium	24	23	0	0.00%	10	1.1	2.27	4.08	3.26	3.22	0.45	-0.09	Lognormal	1.83	2.62	No	1	NA	73.73	46.22	54.35	73.68
Zinc	24	18	6	25.00%	20	4.5	4.60	26.00	10.83	7.47	7.10	N/A	Gamma	1.63	2.64	No	0	Cohen	56.28	28.98	40.84	69.87

**Notes:**  
 All metals results are in micrograms per liter ( µg/L)  
 D - Detects  
 ND - Non-detects  
 DL - Detection limit  
 SD - Standard deviation  
 N/A - Not Applicable  
<sup>a</sup> MW-BG-04, S1-MW2, and TDS-MW02 were removed from the dataset due to elevated Detection Limits  
 Value set at the Reporting Limit. No statistics were used, therefore it is not a true UTL.  
 Value set at 2 times the Maximum Detected Concentration in the Data Set

**Table 5-17**  
**Transformed Statistics and Upper Tolerance Limit**  
**Determination for Combined Soil Samples**  
 Basewide Background Study  
 Holloman Air Force Base, NM  
 NationView|Bhate Project Number: 9081001

Variable	Transformed Statistics											Solution	Calculated UTLs and Percentiles			
	Num Samples	Num Ds	Num NDs	% NDs	Minimum RL	DL or MDC	Minimum	Maximum	Mean	Median	SD		95% UTL with 95% Coverage	90% Percentile (z)	95% Percentile (z)	99% Percentile (z)
Aluminum	126	125	0	0.00%	11	1.70	5.08	9.85	8.24	8.19	0.87	Non-parametric	13,722.27	11,051.42	12,643.17	15,629.02
Antimony	126	0	123	100.00%	1.6	0.42	-0.92	-0.54	-0.74	-0.73	0.01	N/A	1.60	N/A	N/A	N/A
Arsenic	126	91	32	26.02%	2.1	0.73	-0.26	1.55	0.39	0.26	0.28	Non-parametric	3.66	3.02	3.40	4.11
Barium	126	126	0	0.00%	1.1	0.08	0.99	5.08	3.68	3.78	0.59	Lognormal	169.25	105.94	140.13	236.80
Beryllium	126	107	17	13.71%	0.53	0.04	-3.24	0.10	-1.59	-1.64	0.90	Lognormal	1.53	0.77	1.16	2.48
Cadmium	126	74	48	39.34%	0.53	0.05	-3.02	-1.31	-2.48	-2.68	0.26	Non-parametric	0.28	0.17	0.23	0.40
Calcium	126	126	0	0.00%	53	15.67	6.48	12.92	11.85	12.04	0.73	Normal	317,331.59	269,324.04	297,985.62	351,749.97
Chromium	126	126	0	0.00%	1.6	0.06	-2.63	3.04	1.43	1.50	0.89	Lognormal	24.95	14.06	19.80	37.65
Cobalt	126	125	1	0.79%	1.1	0.11	-1.90	1.97	0.31	0.34	0.82	Lognormal	7.70	4.40	6.14	11.50
Copper	126	125	0	0.00%	2.1	0.24	-0.62	2.56	1.16	1.16	0.55	Lognormal	12.96	8.24	10.80	17.91
Iron	126	126	0	0.00%	16	4.20	5.19	9.90	8.21	8.27	0.94	Lognormal	23,049.48	12,768.09	18,167.00	35,203.09
Lead	126	125	1	0.79%	0.85	0.30	-1.05	2.40	0.81	0.77	0.68	Lognormal	10.87	6.53	8.85	15.66
Magnesium	126	124	0	0.00%	21	4.07	4.87	9.62	8.06	8.10	0.79	Lognormal	16,990.65	9,878.17	13,639.47	24,982.80
Manganese	126	125	0	0.00%	1.1	0.11	1.25	5.89	4.18	4.22	0.90	Lognormal	393.47	220.35	311.30	595.21
Nickel	126	126	0	0.00%	4.2	0.13	-0.93	2.83	1.15	1.18	0.81	Lognormal	17.34	10.02	13.90	25.69
Potassium	126	124	0	0.00%	320	45.00	4.42	8.56	6.92	6.91	0.72	Lognormal	5,077.12	3,019.17	4,113.17	7,346.50
Selenium	126	0	125	100.00%	1.4	0.94	-0.09	0.34	0.09	0.10	0.01	N/A	1.40	N/A	N/A	N/A
Silver	126	0	124	100.00%	1.1	0.18	-1.77	-1.43	-1.60	-1.61	0.01	N/A	1.10	N/A	N/A	N/A
Sodium	126	125	0	0.00%	530	65.00	4.87	8.52	6.78	6.73	0.89	Lognormal	5,195.97	2,927.36	4,120.84	7,826.49
Thallium	126	0	124	100.00%	1.3	0.72	-0.37	0.00	-0.20	-0.20	0.01	N/A	1.30	N/A	N/A	N/A
Tin	126	126	0	0.00%	11	1.02	0.18	0.83	0.46	0.47	0.02	Non-parametric	2.10	1.90	2.08	2.27
Vanadium	126	126	0	0.00%	2.1	0.10	-0.82	3.66	2.15	2.21	0.72	Lognormal	42.53	25.38	34.55	61.58
Zinc	126	125	0	0.00%	3.2	0.44	0.18	3.85	2.40	2.40	0.72	Lognormal	54.53	32.53	44.26	78.86
Mercury	126	38	82	68.33%	35	6.10	1.77	2.56	2.05	1.97	0.03	Non-parametric	10.76	9.77	10.35	11.45
Carbon 14	126	0	126	100.00%	0.84	0.84	-0.17	0.18	0.05	0.10	0.01	N/A	0.84	N/A	N/A	N/A
Ra-226 - Total	126	99	24	19.51%	0.09	0.11	-1.94	0.29	-0.82	-0.81	0.26	Lognormal	1.35	0.90	1.14	1.79
Ra-228 - Total	126	39	74	65.49%	0.26	0.31	-1.35	0.29	-0.48	-0.53	0.12	Non-parametric	0.95	0.81	0.89	1.05
Lead 210	126	7	111	94.07%	0.83	0.85	-0.19	0.59	0.13	0.18	0.03	Lognormal	1.04	0.87	0.97	1.18
Thorium 228	126	111	15	11.90%	0.05	0.06	-2.36	0.19	-1.01	-0.99	0.36	Lognormal	1.35	0.86	1.13	1.86
Thorium 230	126	121	3	2.42%	0.03	0.03	-2.12	0.44	-0.68	-0.69	0.32	Lognormal	1.55	1.08	1.34	2.01
Thorium 232	126	113	13	10.32%	0.03	0.03	-3.06	-0.04	-1.20	-1.17	0.47	Lognormal	1.33	0.81	1.09	1.91
Uranium 234	126	120	5	4.00%	0.04	0.04	-2.45	0.24	-0.99	-0.92	0.45	Lognormal	1.43	0.92	1.20	1.97
Uranium 235/236	126	8	118	93.65%	0.033	0.04	-5.43	-1.90	-2.71	-2.73	0.17	Non-parametric	0.08	0.06	0.07	0.10
Uranium 238	126	120	6	4.76%	0.026	0.03	-2.76	-0.11	-1.23	-1.19	0.41	Non-parametric	0.75	0.62	0.69	0.84
Total Uranium	126	125	0	0.00%	N/A	N/A	-1.99	0.99	-0.14	-0.10	0.46	Non-parametric	2.43	2.01	2.36	2.69

**Notes:**

All metals results are in milligrams per kilogram (mg/kg) with the exception of Mercury which is provided in micrograms per kilogram (µg/kg)

Radiological results are in picoCuries per gram (pCi/g) with the exception of Total Uranium which is in micrograms per gram (µg/g)

D - Detects

ND - Non-detects

DL - Detection Limit

MDC - Minimum Detectable Concentration (for Radiological constituents)

SD - Standard deviation

N/A - Not Applicable

Value set at the Reporting Limit. No statistics were used, therefore it is not a true UTL.



**Table 5-18**  
**Summary of Soil and Groundwater Background Levels**  
**Basewide Background Study**  
**Holloman Air Force Base, NM**  
**NationView|Bhate Project Number: 9081001**

Variable	NMED Soil Screening Levels <sup>a</sup>	Groundwater USEPA MCL <sup>b</sup>	Groundwater New Mexico Administrative Code (NMAC)	Total Groundwater Background Level <sup>e</sup>	Dissolved Metals in Groundwater Background Level <sup>e</sup>	Combined Soil Background Level <sup>e</sup>	Total Groundwater Background Level <sup>e</sup> Above USEPA MCL?	Total Groundwater Background Level <sup>e</sup> Above NMAC?	Dissolved Metals in Groundwater Background Level <sup>e</sup> Above USEPA MCL?	Dissolved Metals in Groundwater Background Level <sup>e</sup> Above NMAC?	Combined Soil Background Level <sup>e</sup> Above NMED Soil Screening Levels?
<b>Metals - Units are in mg/kg for soil and µg/L for groundwater (except for Mercury which is in µg/kg for soil and µg/L for groundwater)</b>											
Aluminum	78,100	50 <sup>d</sup>	NE	1,042.43	54.00	13,722.27	Yes	N/A	Yes	N/A	No
Antimony	31.3	6	NE	10.00	10.00	1.60	Yes	N/A	Yes	N/A	No
Arsenic	3.9	10	100	25.93	28.53	3.66	Yes	No	Yes	No	No
Barium	15,600	2,000	1,000	38.00	30.13	169.25	No	No	No	No	No
Beryllium	156	4	NE	5.00	1.00	1.53	Yes	N/A	No	N/A	No
Cadmium	77.9	5	10	8.80	2.41	0.28	Yes	No	No	No	No
Calcium	NE	NE	NE	1,136,663.50	1,151,301.20	317,331.59	N/A	N/A	N/A	N/A	N/A
Chromium	18,000	100	50	12.00	2.50	24.95	No	No	No	No	No
Cobalt	23 <sup>c</sup>	NE	50	36.00	2.60	7.70	N/A	No	N/A	No	No
Copper	3,130	1,300	1,000	9.80	57.46	12.96	No	No	No	No	No
Iron	54,800	NE	1,000	1,306.82	65.56	23,049.48	N/A	Yes	N/A	No	No
Lead	400	15	50	9.00	9.00	10.87	No	No	No	No	No
Magnesium	NE	NE	NE	3,692,781.50	3,630,926.70	16,990.65	N/A	N/A	N/A	N/A	N/A
Manganese	10,700	50 <sup>d</sup>	200	745.38	118.65	393.47	Yes	Yes	Yes	No	No
Mercury	7,710	2	2	0.44	0.200	10.76	No	No	No	No	No
Nickel	1,560	NE	200	21.97	15.89	17.34	N/A	No	N/A	No	No
Potassium	NE	NE	NE	212,143.56	120,479.98	5,077.12	N/A	N/A	N/A	N/A	N/A
Selenium	391	50	50	129.52	25.26	1.40	Yes	Yes	No	No	No
Silver	391	100 <sup>d</sup>	50	10.00	10.00	1.10	No	No	No	No	No
Sodium	NE	NE	NE	20,989,585.00	19,972,499.00	5,195.97	N/A	N/A	N/A	N/A	N/A
Thallium	5.16	2	NE	15.00	15.00	1.30	Yes	N/A	Yes	N/A	No
Tin	47,000 <sup>c</sup>	NE	NE	100.00	100.00	2.10	N/A	N/A	N/A	N/A	No
Vanadium	391	NE	NE	90.02	73.73	42.53	N/A	N/A	N/A	N/A	No
Zinc	23,500	NE	10,000	16.95	56.28	54.53	N/A	No	N/A	No	No
<b>Radiological Constituents - Units are in pCi/g for soil and pCi/L for groundwater (except for Total Uranium which is in µg/g for soil and µg/L for groundwater)</b>											
Carbon 14	NE	NE	NE	8.60	N/A	0.84	N/A	N/A	N/A	N/A	N/A
Ra-226 - Total	NE	5	30	2.62	N/A	1.35	Yes	No	N/A	N/A	N/A
Ra-228 - Total	NE			3.99	N/A	0.95			N/A	N/A	N/A
Lead 210	NE	NE	NE	3.10	N/A	1.04	N/A	N/A	N/A	N/A	N/A
Thorium 228	NE	NE	NE	0.99	N/A	1.35	N/A	N/A	N/A	N/A	N/A
Thorium 230	NE	NE	NE	0.37	N/A	1.55	N/A	N/A	N/A	N/A	N/A
Thorium 232	NE	NE	NE	0.061	N/A	1.33	N/A	N/A	N/A	N/A	N/A
Uranium 234	NE	NE	NE	175.95	N/A	1.43	N/A	N/A	N/A	N/A	N/A
Uranium 235/236	NE	NE	NE	4.79	N/A	0.08	N/A	N/A	N/A	N/A	N/A
Uranium 238	NE	NE	NE	98.07	N/A	0.75	N/A	N/A	N/A	N/A	N/A
Total Uranium	NE	30	30	294.23	N/A	2.43	Yes	Yes	N/A	N/A	N/A
<b>Natural Attenuation Parameters - Units are in mg/L</b>											
Alkalinity (as CaCO <sub>3</sub> )	N/A	NE	NE	386.57	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Chloride	N/A	250 <sup>d</sup>	250	35,039.73	N/A	N/A	Yes	Yes	N/A	N/A	N/A
Sulfate	N/A	250 <sup>d</sup>	600	17,418.99	N/A	N/A	Yes	Yes	N/A	N/A	N/A
Sulfide	N/A	NE	NE	1.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Dissolved Solids	N/A	500 <sup>d</sup>	1,000	65,956.58	N/A	N/A	Yes	Yes	N/A	N/A	N/A

**Notes:**

NE - Not established  
N/A - Not applicable  
mg/kg - Milligrams per kilogram  
µg/L - Micrograms per liter  
mg/L - Milligrams per liter  
µg/kg - Micrograms per kilogram  
pCi/g - PicoCuries per gram  
pCi/L - PicoCuries per liter  
µg/g - Micrograms per gram

<sup>a</sup> New Mexico Environment Department (NMED) Soil Screening Levels, December 2009

<sup>b</sup> U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Levels (MCLs), May 2009

<sup>c</sup> USEPA Regional Screening Level, April 2009

<sup>d</sup> USEPA Secondary Drinking Water Standard (May 2009)

<sup>e</sup> NMED (NOD dated October 2010) required the use of the term "background level" instead of UTLs. Therefore, the "background level" were calculated by determining the 95 % UTL with 95% Coverage of the results

Value set at the Reporting Limit. No statistics were used, therefore it is not a true UTL.  
Value set at 2 times the Maximum Detected Concentration in the Data Set  
Total Chromium value set at the EPA Region 6 RSL, Protection of Ground Water SSLs