Unit 4 and 5 Buildings Investigation Source Area Characterization Report
Nevada Environmental Response Trust Site
Henderson, Nevada

PREPARED FOR

Nevada Environmental Response Trust
35 E. Wacker Drive, Suite 690
Chicago, IL 60601

PRESENTED BY

Tetra Tech, Inc.
150 S. 4th Street, Unit A
Henderson, NV 89015

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LIST OF ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
3D	three-dimensional
3DVA	three-dimensional visualization analysis
ASTM	ASTM International
AWF	Athens Road well field
BCL	Basic Comparison Level
bgs	below ground surface
BMI	Black Mountain Industrial (Complex)
CH	Fat clay
CL	Lean clay
COPC	chemical of potential concern
CRB	Central Retention Basin
DAF	dilution attenuation factor
DI	deionized water
DOT	United States Department of Transportation
DVSR	data validation summary report
EVS	Earth Volumetric Studio
FSP	Field Sampling Plan
GES	Geotechnical & Environmental Services, Inc.
GWETS	Groundwater Extraction and Treatment System
HRSC	High Resolution Site Characterization
IDW	investigation-derived waste
Investigation Area	The area of the Unit 4 and 5 buildings where field activities and analytical results of the environmental investigation are performed
LBCL	Leaching-based Basic Comparison Level
mg/Kg	milligrams per kilogram
mg/L	milligrams per liter
MH	elastic silt
ML	silt
MS/MSD	matrix spike/matrix spike duplicate
msl	mean sea level
N	Nitrogen
NDCNR	State of Nevada Department of Conservation and Natural Resources
NDEP	Nevada Division of Environmental Protection

Acronyms/Abbreviations	Definition
NERT	Nevada Environmental Response Trust
NRB	Northern Retention Basin
OU	Operable Unit
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PLFA	phospholipid-derived fatty acids
PPE	personal protective equipment
PRG	Preliminary Remediation Goal
PVC	polyvinyl chloride
Qal	Quaternary alluvium
QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
Report	Unit 4 and 5 Buildings Investigation Characterization Report
RI	Remedial Investigation
Site	NERT property
SM	silty sand
SP-SM	poorly graded sand/silty sand
SW-SM	well graded sand/silty sand
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TOC	total organic carbon
TPH	Total Petroleum Hydrocarbons
Tronox	Tronox, LLC
Trust	Nevada Environmental Response Trust
UMCf	Upper Muddy Creek formation
UMCf-fg1	Upper Muddy Creek formation first fine-grained sediment layer
UNLV	University of Nevada, Las Vegas
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
VOCs	Volatile organic compounds
WBZ	Water Bearing Zone
Work Plan	Unit 4 and 5 Buildings Investigation Work Plan
xMCf	transitional Muddy Creek formation

CERTIFICATION

Unit 4 and 5 Buildings Investigation
Source Area Characterization Report

Nevada Environmental Response Trust Site
(Former Tronox LLC Site)
Henderson, Nevada

Nevada Environmental Response Trust (NERT) Representative Certification
I certify that this document and all attachments submitted to the Division were prepared at the request of, or under the direction or supervision of NERT. Based on my own involvement and/or my inquiry of the person or persons who manage the systems(s) or those directly responsible for gathering the information or preparing the document, or the immediate supervisor of such person(s), the information submitted and provided herein is, to the best of my knowledge and belief, true, accurate, and complete in all material respects.

Office of the Nevada Environmental Response Trust

Le Petomane XXVII, not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee

Not Individually, but Solely as President of the Trustee

Signature: Jay A Steinberg ______, not individually, but solely in his representative capacity as President of the Nevada Environmental Response Trust Trustee

Name: Jay A. Steinberg, not individually, but solely in his representative capacity as President of the Nevada Environmental Response Trust Trustee

Title: Solely as President and not individually

Company: Le Petomane XXVII, Inc., not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee

Date: 1/7/2020

CERTIFICATION

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been prepared in a manner consistent with the current standards of the profession, and to the best of my knowledge, comply with all applicable federal, state, and local statutes, regulations, and ordinances. I hereby certify that all laboratory analytical data was generated by a laboratory certified by the NDEP for each constituent and media presented herein.

Description of Services Provided: Prepare Unit 4 and 5 Buildings Investigation Source Area Characterization Report.

Kyle S. Hansen
January 7, 2020

Kyle Hansen, CEM
Field Operations Manager/Geologist
Tetra Tech, Inc.

Date

Nevada CEM Certificate Number: 2167
Nevada CEM Expiration Date: September 18, 2020

EXECUTIVE SUMMARY

On behalf of the Nevada Environmental Response Trust (NERT or Trust), Tetra Tech has prepared this *Unit 4 and 5 Buildings Investigation Source Area Characterization Report* (Report). The purpose of this Report is to summarize the field activities and analytical results of the environmental investigation performed in the area of the Unit 4 and 5 buildings (Investigation Area) in accordance with the approved *Unit 4 and 5 Buildings Investigation Work Plan* (Work Plan) (Tetra Tech, 2015). The Unit 4 and 5 buildings are located on the portion of the NERT property (Site) that was formerly operated by multiple parties, was leased to and operated by Tronox, LLC (Tronox) upon inception of the Trust, and as of August 2018 is leased and operated by EMD doing business as Borman Specialty Materials. The investigation of the Unit Buildings 4 and 5 area is important as historical data indicated that soil and groundwater in this area had very high concentrations of perchlorate and hexavalent chromium. As such, historical data suggests that this area is a significant source of long-term groundwater contamination and a detailed investigation was necessary to evaluate potential remedial action alternatives. To facilitate the Remedial Investigation (RI), the NERT RI Study Area was subdivided into three Operable Units (OUs). OU-1 is the NERT Site and contains historical manufacturing operations. OU-2 is located north of OU-1 and contains commercial/ industrial and residential areas. OU-3 is located north of OU-2 and also contains commercial/industrial areas (i.e., City of Henderson wastewater treatment plant), residential areas, county and federally-owned recreational areas, and the Las Vegas Wash. The Remedial Action Objective for OU-1 is NERT Site Source Control and Containment (Ramboll, 2017a). This source characterization investigation was designed to identify the nature and vertical extent of contamination in the Unit Buildings 4 and 5 area such that source control and containment remedial alternatives can be considered in the forthcoming Feasibility Study. This report will be used with the forthcoming RI Report to define the nature of extent of contamination in the NERT RI Study Area. The Site is located within the Black Mountain Industrial Complex in Henderson, Nevada.

Soil and shallow groundwater investigation data collected in and downgradient of the Investigation Area as part of prior environmental investigations by others and the RI indicate that the Unit 4 and 5 buildings area is a source of perchlorate and hexavalent chromium to the underlying soil and groundwater. To evaluate the magnitude of the source, the objective of this environmental investigation was to determine the nature and extent of contamination in this area and specifically the vertical extent of impacted soil and groundwater underneath the Unit 4 and 5 buildings.

As outlined in the Work Plan, the specific goals of the investigation included the following:

- Collect sufficient soil and groundwater data to provide scale-appropriate data density for characterization of the nature and extent of perchlorate, hexavalent chromium, and other contaminants in the vadose zone and shallow groundwater within the Investigation Area.
- Estimate the mass of perchlorate and hexavalent chromium in the vadose zone and shallow groundwater in the Investigation Area.
- Evaluate potential migration pathways and the velocity of perchlorate and hexavalent chromium migration in shallow groundwater in the Investigation Area.
- Evaluate the potential contribution of perchlorate and hexavalent chromium in the Investigation Area to the previously identified Site-wide shallow groundwater plume.

Early in the investigation it became apparent that the third and fourth goals could only be accomplished with the larger scope of the RI. Therefore, although the third and fourth bullets above were goals of the investigation outlined in the Work Plan, achievement of these goals including data interpretation and conclusions of the Unit 4 and 5 building investigation will be incorporated in the RI Report.

Investigation Phases

Implementation of the Work Plan was divided into three field mobilizations, as described below. The boreholes advanced during the field mobilizations were aligned along five east/west transects that are further described in the main body of this report. Each transect included eight to 15 boreholes, for a total of 51 planned boreholes, the majority of which were advanced during the second mobilization activities. One transect was positioned on the south side of the Investigation Area in the upgradient direction; one transect was located on the north side of the Investigation Area in the downgradient direction; and three transects were located through the central portion of the Investigation Area.

The first mobilization commenced on October 20, 2015 and included advancing four boreholes near the four exterior corners of the Unit 4 cell floor and collecting soil samples and discrete-depth groundwater samples from each borehole. The boreholes were positioned along two of five planned transects. The first mobilization field work concluded on December 7, 2015.

The second field mobilization commenced on June 28, 2016, following Nevada Division of Environmental Protection (NDEP) concurrence with the scope of work and approach proposed in the First Mobilization Technical Memorandum (Tetra Tech, 2016). The second mobilization field work included the advancement of the remaining 47 boreholes along five east/west transects and collecting soil samples and discrete-depth groundwater samples from each borehole. In addition to these boreholes, and as specified in the First Mobilization Technical Memorandum, three additional boreholes were placed around an identified sump located along the southwest side of the Unit 4 basement; eight additional boreholes were field-placed based on the presence of cracks or other potential preferential migration pathways; four step-out borings to 90 feet below ground surface (bgs) were added to further delineate the extent of contamination within the Investigation Area; and seven deeper step-down boreholes ranging in depth from 150 to 250 feet bgs were advanced to further define the vertical extent of contamination at this source area to address data gaps identified during data analysis during the initial stage of the second mobilization. A total of 69 boreholes were advanced and one monitoring well was installed within the Investigation Area during the second field mobilization, which concluded on January 3, 2017.

The third field mobilization commenced on August 8, 2017, following NDEP concurrence with the scope of work and approach proposed in the Second Mobilization Technical Memorandum (Tetra Tech, 2017a). The third mobilization included advancement of four angled boreholes and the installation of 20 monitoring wells within the Investigation Area. The angled boreholes were advanced from outside of the Unit 5 building and angled at a 45-degree angle to collect soil and discrete-depth groundwater samples from underneath the building, an area of active operations, to determine if soil and groundwater below the Unit Building 5 was a long-term source to groundwater contamination. The third mobilization was designed to delineate the vertical extent of contamination in this source area and refine the estimate of contaminant mass in the source area such that appropriate source control and containment remedial alternatives can be considered in the forthcoming Feasibility Study.

Monitoring wells installed during the third mobilization were designed to verify the results obtained from discrete-depth groundwater samples collected from temporary wells installed during the second mobilization and to provide ongoing groundwater monitoring wells in the Investigation Area. At the time the Work Plan was prepared, it was thought that the greatest chemical of potential concern (COPC) concentrations were limited to the Shallow Water Bearing Zone (WBZ) based on previous data collected from the area prior to this source characterization and the monitoring wells were proposed to be advanced and constructed at a maximum depth of 90 feet bgs. However, results from the second and third mobilizations have shown that while the greatest COPC concentrations are observed in the Shallow WBZ in soil, the greatest COPC concentrations in groundwater are observed in the Middle WBZ below and downgradient of the Unit 4 building. For that reason, the depth of the monitoring wells was increased via a modification approved by NDEP on October 13, 2016 from 90 feet bgs to 150 feet bgs with screens at intervals of 60 to 70 feet bgs, 100 to 110 feet bgs, and 140 to 150 feet bgs. The third mobilization field activities were completed on December 21, 2017.

Based on the lithology encountered during the investigation, the first native soil unit underlying the Investigation Area is alluvium (Qal), consisting of fine- to medium-grained sand with some silty sand with gravel. The alluvium is generally overlain by 3 to 6 feet of fill, with up to 10 feet of fill at some locations. The contact between the base of the sandy alluvium and the top of the underlying silty Upper Muddy Creek formation (UMCf) in the Investigation

Area was encountered at approximately 25 to 50 feet bgs. Consistent with other work performed in the Investigation Area, the Transitional Upper Muddy Creek formation, which is encountered at other locations at the NERT Site, was not encountered during the three field mobilizations.

The depth to groundwater as measured in wells installed within the Shallow WBZ within the Investigation Area relative to the surrounding ground surface ranges from approximately 32 to 48 feet bgs. The depth to groundwater as measured in wells screened within the Middle WBZ in the Investigation Area occurs at depths ranging from 31 to 52 feet bgs. Pressures in the Middle WBZ are slightly higher than the Shallow WBZ which cause an upward vertical gradient in the Investigation Area. The direction of groundwater flow in the Investigation Area is generally toward the north-northeast following the slope of the ground surface, with an upward component due to the vertical gradient.

Technical Approach

Each of the three mobilizations implemented in the Investigation Area were performed in accordance with the Work Plan, NDEP approved modifications to the Work Plan, and applicable regulatory and project guidance documents. As such, each of the three mobilizations included the following activities:

- Borehole permitting and surveying,
- Geophysical utility clearance, coring, and hydro-vacuum utility clearance,
- Drilling, soil sampling, and temporary well installation,
- Permanent well installation, development, and sampling (Second and Third Mobilization),
- Slug testing and specific capacity testing (Third Mobilization), and
- Investigative-Derived Waste management.

In addition to the analyses for the main COPCs, data were also collected through the investigation to support future treatability testing, remedial action analysis, and design.

Lithology Encountered

The lithology encountered during the investigation consists of interlayered clay, silt, sand, and gravel of varying thicknesses, which is consistent with the Qal deposits and UMCf deposits identified in previous investigations. The Qal deposits consist primarily of sand and silty sand which transition into interbedded sandy silt and silt at the top of the UMCf at approximately 35 feet bgs. The UMCf underlies the Qal within the Investigation Area and consists of interbedded coarse-grained and fine-grained sediments.

Contaminant Distribution in Soil

Perchlorate was observed throughout the Investigation Area in both the Qal and the UMCf at concentrations that exceeded the Leaching-based Basic Comparison Level (LBCL) of 0.0155 milligrams per kilogram (mg/Kg). The LBCL is a soil screening level developed to prevent an exceedance of the risk-based groundwater screening level via the soil-to-groundwater leaching pathway. The perchlorate LBCL was calculated following the methodology of the 2017 NDEP LBCL calculation table, but was based on a groundwater screening level of 0.015 mg/L, which is the federal Interim Drinking Water Health Advisory, federal Preliminary Remediation Goal (PRG), and groundwater screening level used in NERT's ongoing Remedial Investigation. The groundwater screening level of 0.015 mg/L was selected as the most applicable and relevant criteria to be considered in developing remediation alternatives for the NERT Site (Environ 2014a). Perchlorate was also observed above the Industrial/Commercial BCL for soil at two points in the upper 10 feet of the Investigation Area, in borehole U4U5-59 at 10 feet bgs and in borehole U4U5-60 at 5 feet bgs; however, perchlorate was below the Industrial/Commercial BCL within the upper 10 feet throughout the remainder of the Investigation Area. Within the Qal, the greatest perchlorate concentrations (up to 25,000 mg/kg) were observed on the east and the west sides of Unit 4 at a depth of approximately 35 feet bgs. Perchlorate concentrations decreased below the Qal, ranging from approximately 0.12 to 210 mg/kg at 60 feet bgs within the upper, coarse-grained interval of the UMCf. Below this lower concentration interval, perchlorate concentrations increased with depth within the UMCf, with the highest perchlorate concentrations in soil (29,000 mg/kg) present directly below the west side of Unit 4 at a depth of approximately 95 feet bgs. Elevated concentrations were also observed approximately 200 feet north of the Unit 4 Chlorinator building within the UMCf. Perchlorate concentrations decreased in soil below a depth of 125 feet bgs in the UMCf.

The distribution of hexavalent chromium in soil was similar to the distribution of perchlorate with the greatest hexavalent chromium concentrations observed in the Qal and the UMCf with concentrations exceeding the LBCL of 2 mg/Kg throughout the Investigation Area. Hexavalent chromium was present above the Industrial/Commercial BCL in the upper 10 feet of soil within 12 boreholes throughout the Investigation Area. Soil samples from boreholes with Industrial/Commercial BCL exceedances were located primarily in and adjacent to the Unit 4 basement, with the exception of borehole U4U5-15, located north of the Unit 5 building. The greatest hexavalent chromium concentrations in the Qal were observed on the east and west sides of Unit 4, from approximately 10 to 35 feet bgs, at concentrations as high as 380 mg/kg (U4U5-21 at 17.5 feet bgs). Below the Qal, within the upper coarse-grained interval of the UMCf, concentrations of hexavalent chromium were lower, ranging from approximately 0.21 to 2.8 mg/kg at a depth of 60 feet bgs. Below this interval, concentrations increase with depth within the UMCf, reaching the greatest hexavalent chromium concentrations in the UMCf (up to 62 mg/Kg) at a depth of approximately 95 feet bgs along the west side of Unit 4. Elevated hexavalent chromium concentrations were also observed approximately 200 feet north of the Unit 4 chlorinator building within the UMCf. Hexavalent chromium concentrations in soil decrease below a depth of 125 feet bgs in the UMCf.

Additional COPCs analyzed during the investigation included total chromium, chloroform, chlorate, and nitrate. These COPCs exhibited a similar spatial distribution pattern to perchlorate and hexavalent chromium and are discussed in more detail in the body of the report.

Contaminant Distribution in Groundwater

In groundwater, perchlorate exceeded the NERT's RI groundwater screening level of 0.015 milligrams per liter (mg/L) throughout most of the Investigation Area. This risk-based perchlorate groundwater screening level is the federal Interim Drinking Water Health Advisory, federal PRG, and groundwater screening level used in NERT's ongoing Remedial Investigation. Perchlorate was detected in groundwater within the Qal (0-35 feet bgs) at concentrations as great as 2,900 mg/L and in the upper saturated interval of the UMCf (35-75 feet bgs) as great as 3,500 mg/L. The greatest concentrations of perchlorate, up to 6,700 mg/L, were detected in the UMCf between 75 to 125 feet bgs. Perchlorate concentrations decreased below 125 feet bgs within the UMCf, where perchlorate was detected at concentrations no greater than 570 mg/L. The perchlorate concentration detected in the sample collected from 240 feet bgs was non-detect and below the groundwater screening level. The greatest perchlorate concentrations in groundwater were observed directly below and downgradient of the Unit 4 Building in the UMCf. Groundwater samples collected below the Unit 5 building indicated a similar distribution pattern, but at concentrations of perchlorate approximately an order of magnitude lower.

The distribution of hexavalent chromium in groundwater was similar to the distribution of perchlorate in groundwater with concentrations exceeding the groundwater BCL of 0.000134 mg/L at most locations throughout the Investigation Area. As was observed with perchlorate, the greatest concentrations were observed below and downgradient of the Unit 4 Building within the UMCf at approximately 100 and 110 feet bgs. Similar to the observed groundwater perchlorate distribution with depth, hexavalent chromium concentrations generally decrease with depth below approximately 130 ft bgs. A slight increase in hexavalent chromium concentrations was noted in groundwater samples collected from a depth of 150 feet bgs from the angled borings beneath Unit 5, with concentrations peaking at 0.5 mg/L.

Mass Estimates

As specified in the Work Plan, mass estimates for perchlorate, chlorate, chromium, hexavalent chromium, chloroform, nitrate, and total dissolved solids (TDS) were developed for the Qal and UMCf. Consistent with the RI Study Area Mass Estimate and Extended Performance Metrics Technical Approach (Ramboll, 2017b), the mass of each parameter was calculated using kriging to produce an estimate over a regular grid based on available soil data. The mass estimates of each constituent are presented in the following table, which presents a range of estimates.

Constituent of Concern Mass Estimates[1]

Analyte	Qal Mass Estimates		UMCf Mass Estimates		Total Mass Estimates
	Nominal	Statistical Range[1]	Nominal	Statistical Range[1]	Nominal
Perchlorate	103,000	53,000-208,000	581,000	221,000-1,621,000	684,000
Chlorate	577,000	202,000-1,744,000	3,300,000	1,020,000-11,100,000	3,877,000
Chromium	52,100	45,400-60,000	358,000	300,000-428,000	410,100
Hexavalent Chromium	1,600	840-3,000	15,600	6,200-41,100	17,200
Chloroform	13	8-24	880	350-2,300	893
Nitrate	2,160	876-5,416	8,070	3,248-20,344	10,230
TDS*	-	-	12,450,000	10,010,000-15,500,000	12,450,000

Note:
[1] Statistical Range is based on the upper and lower bounding mass estimates using an 80% confidence level (80% min and 80% max as further discussed in the footnote below).
Mass estimates are reported in units of pounds.
Groundwater mass calculations assume a porosity of 55%, uniformly.
*Groundwater mass estimates are based on groundwater calculations; all other estimates based on soil calculations.

Based on the three-dimensional (3D) distribution of perchlorate in soil, the centroid (i.e., the mass-weighted geometric center) of the perchlorate mass in the Qal is located near the southeastern corner of Unit 4 at an approximate depth of 24 feet bgs. The centroid of perchlorate mass in soil within the UMCf is located near the northeast corner of Unit 4 at an approximate depth of 88 feet bgs.

Based on the 3D distribution of hexavalent chromium in soil, the centroid of the hexavalent chromium mass in the Qal is located near the center of the western edge of Unit 4 at an approximate depth of 21 feet bgs. The centroid of the hexavalent chromium mass in soil in the UMCf is located north of the northern side of Unit 4 at an approximate depth of 94 feet bgs.

Three-Dimensional Distribution of Investigation Area Contaminants

Three-dimensional visualizations of the distribution of perchlorate, hexavalent chromium, chloroform, chlorate, nitrate, and TDS were prepared and are presented in Appendix H. For reference, the lithologic contacts between the Qal and the UMCf are included in the visualizations to show the relationship between lithology and the distribution of perchlorate, hexavalent chromium, chloroform, chlorate, nitrate, and TDS. The contact planes portrayed are an approximation based on the lithology encountered during the investigation.

Aquifer Testing Results

A total of 10 slug tests were conducted to determine hydraulic parameters laterally and vertically within the UMCf in the Investigation Area. The hydraulic conductivity values ranged from 5.71 x 10^{-3} feet per day at monitoring well

[1] In addition to the nominal mass estimate calculated by the Earth Volumetric Studio (EVS) software listed in the table above, the geostatistics associated with the kriging process produce estimates for the maximum and minimum concentrations associated with the dataset at an 80% confidence level. This method produces high and low estimates of the mass while accounting for the uncertainty associated with the interpolation method, resulting in upper and lower bounds for the mass estimates in the model block, which are presented in the summary table as the statistical range.

M-253-100 to 5.71 x 10^{-1} feet per day at monitoring well M-253-60. Hydraulic conductivity values for the intervals of the UMCf where the monitoring wells are screened are within the typical range for clay, silt, and silty sand.

In addition to the 10 slug tests performed, a total of three low flow specific capacity tests were conducted to corroborate the hydraulic parameters determined by slug tests and calculate specific capacity. The tests were conducted at monitoring wells M-251-60, M-251-100, and M-252 located in the Unit 4 footprint where greater perchlorate and hexavalent chromium concentrations were observed. The hydraulic conductivity values ranged from 9.0 x 10^{-3} feet per day at monitoring well M-252 to 8.1 x 10^{-2} feet per day at monitoring well M-251-100.

The hydraulic conductivity values obtained from the specific capacity testing at M-251-60, M-251-100, and M-252 were consistent with the slug test results. These values are within typical ranges of clay, silt, and silty sand (Johnson Screens, 2007).

Summary

The environmental investigation performed in the area of the Unit 4 and 5 buildings yielded significant new information regarding the nature and extent of the COPCs in soil and groundwater within the Investigation Area which will be incorporated into the forthcoming RI Report for OU-1 and OU-2. Two key goals of this investigation: 1) collecting suitable and sufficient soil and groundwater data to characterize the nature and extent of perchlorate, hexavalent chromium, and other contaminants in the vadose zone and shallow groundwater within the Investigation Area, and 2) estimating the mass of perchlorate and hexavalent chromium in the vadose zone and shallow groundwater in the Investigation Area were both achieved. As noted above, the goals of evaluating potential migration pathways and velocities of perchlorate and hexavalent chromium migration and evaluating the potential contribution of perchlorate and hexavalent chromium in the Investigation Area to the previously identified Site-wide shallow groundwater plume will be addressed separately in the RI Report for OU-1 and OU-2.

As described in this report, soil and groundwater beneath the Unit 4 building appear to be a source of perchlorate, hexavalent chromium, chlorate, chloroform, TDS, and nitrate to groundwater. Soil and groundwater beneath the Unit 5 building also appear to be a source of COPCs to groundwater but, the magnitude of contributions to groundwater is much lower than the Unit 4 building. The dataset obtained through this investigation is sufficient to characterize the nature and extent of these COPCs within the Investigation Area and there are no additional data gaps to be addressed. The dataset is suitable to support future source area treatability testing and development of source control and containment remedial alternatives to be considered in the forthcoming Feasibility Study for OU-1 and OU-2.

1.0 INTRODUCTION

On behalf of the Nevada Environmental Response Trust (NERT or Trust), Tetra Tech has prepared this *Unit 4 and 5 Buildings Investigation Source Area Characterization Report* (Report). The purpose of this Report is to summarize the field activities and analytical results of the environmental investigation performed in the area of the Unit 4 and 5 buildings (Investigation Area) and to present three-dimensional visualization analysis (3DVA) of the collected data. The Unit 4 and 5 Buildings Investigation is a component of the NERT Remedial Investigation (RI).

The Unit 4 and 5 buildings are located on the portion of the NERT property (Site) that was formerly operated by multiple parties, was leased to and operated by Tronox upon inception of the Trust, and as of August 2018 is leased and operated by EMD doing business as Borman Specialty Materials. Tronox and EMD are jointly referred to as “the Tenant” in this report. The Site is located within the Black Mountain Industrial (BMI) Complex in Henderson, Nevada. The location of the Site is shown on Figure 1 and the Investigation Area within the leased portion of the Site is shown on Figure 2. These buildings were targeted for investigation because sodium chlorate and sodium perchlorate were produced by electrolytic processes at this location from 1945 to 1989. These processes involved the use of sodium dichromate (hexavalent chromium). Historical data indicates that perchlorate and hexavalent chromium concentrations are elevated in soil and groundwater adjacent to these buildings.

The *Unit 4 and 5 Buildings Investigation Work Plan* (Work Plan) was submitted to the Nevada Division of Environmental Protection (NDEP) on March 30, 2015 (Tetra Tech, 2015). The Work Plan detailed the advancement of 54 boreholes and the construction of up to 7 monitoring wells. Of the proposed boreholes, 51 boreholes were located along five east/west transects and 3 boreholes were placed around a sump located along the southwest site of the Unit 4 basement. Each transect included eight to 15 boreholes. One transect was positioned on the south side of the Investigation Area (in the upgradient direction), one transect was located on the north side of the Investigation Area (in the downgradient direction), and three transects were located through the central portion of the Investigation Area (Figure 3). Implementation of the Work Plan was divided into three field mobilizations to provide a data review period between mobilizations that would be utilized to adjust the sampling plan based on the recent data and obtain regulatory concurrence before moving forward. A brief description of the scope of work and objectives for each of the three field events is provided below, including details about modifications to the planned mobilizations that resulted in the advancement of an additional 23 boreholes.

1.1 FIRST FIELD MOBILIZATION

The objective of the first mobilization was to obtain preliminary baseline data that would be used to direct and refine the scope of work for the second field mobilization. Both lithologic and analytical data from the first mobilization were used to guide the depth of the borings and analytical methodology to be followed during the second mobilization. The first mobilization commenced on October 20, 2015 and included advancing four boreholes and collecting discrete-depth groundwater samples from the four exterior corners of the Unit 4 cell building. The four boreholes were positioned along two of the five east/west transects. The first mobilization field work concluded on December 7, 2015. Although this report presents the comprehensive results from all three mobilizations, detailed results of only the first field mobilization are summarized in the May 6, 2016, Technical Memorandum, *Unit 4 and 5 Buildings First Mobilization* (Tetra Tech, 2016), which was approved by NDEP on June 28, 2016 following submittal of response to comments on June 24, 2016.

1.2 SECOND FIELD MOBILIZATION

The second field mobilization commenced on June 28, 2016, following NDEP concurrence with the scope of work and approach proposed in the First Mobilization Technical Memorandum (Tetra Tech, 2016). The second mobilization consisted of advancing 69 boreholes throughout the Investigation Area and installation of 140 temporary wells and one permanent monitoring well. Initially, the planned field work included the advancement of 50 boreholes. Forty-seven boreholes were positioned along five east/west transects and three boreholes were placed around the identified sump located along the southwest side of the Unit 4 basement. Eight additional boreholes were field-placed based on the presence of cracks or other preferential migration pathways. During the implementation of the second mobilization, the scope of work was modified via NDEP approved RI modifications to include four additional step-out borings to 90 feet bgs and seven deeper step-down boreholes ranging in depth from 150 to 250 feet below ground surface (bgs). The purpose of the step-out borings was to address lateral data gaps identified during data analysis, while the step-down borings were designed to address vertical data gaps. These step-out and step-down borings were located based on statistical analyses performed as part of the 3DVA implemented during the initial stage of the second mobilization. One of the boreholes was converted to a monitoring well during the second mobilization. The field work of the second field mobilization concluded on January 3, 2017.

This Report presents the comprehensive results from all three mobilizations in Section 4. Details of the results from only the second field mobilization are summarized in the May 4, 2017, Technical Memorandum: *Unit 4 and 5 Buildings Investigation Second Mobilization* (Tetra Tech, 2017a). Within this Technical Memorandum, Tetra Tech proposed advancement of four angled borings underneath the Unit 5 building to address a soil and groundwater data gap, installation and sampling of seven monitoring well clusters within the Investigation Area, and aquifer testing of up to 10 newly installed monitoring wells to quantify the hydraulic conductivity of the Upper Muddy Creek formation (UMCf).

1.3 THIRD FIELD MOBILIZATION

The third field mobilization commenced on August 8, 2017, following NDEP concurrence with the scope of work and approach proposed in the Second Mobilization Technical Memorandum (Tetra Tech, 2017a). The third mobilization consisted of advancing four angled boreholes, installing 24 temporary wells within the angled boreholes and installing 20 permanent monitoring wells inside 13 boreholes at seven locations within the Investigation Area. Due to active operations within the Unit 5 building, boreholes were advanced from the outside of the Unit 5 building and angled to collect samples from underneath the building to determine if Unit 5 was a potential uncharacterized source to groundwater. The angled boreholes beneath Unit 5 were designed to supplement data collected during the second mobilization.

Monitoring wells installed during the third mobilization were designed to confirm the results obtained from discrete-depth groundwater samples collected from temporary wells during the second mobilization and provide ongoing groundwater monitoring locations in the Investigation Area. At the time the Work Plan was originally prepared, it was thought that the greatest COPC concentrations were limited to the Shallow Water Bearing Zone (WBZ) based on previous data collected from the area. Therefore, monitoring wells were proposed to be advanced and constructed at a maximum depth of 90 feet bgs, the bottom of the Shallow WBZ. However, results from the second and third mobilizations revealed that while the greatest COPC concentrations are observed in the vadose zone and Shallow WBZ in soil, the greatest COPC concentrations in groundwater are observed in the Middle WBZ, which extends from 90 feet to 300 feet bgs, and downgradient of the Unit 4 building. For this reason, the depth of the monitoring wells installed during the third mobilization was increased from the planned depth of 90 feet bgs as described in the Work Plan, to 150 feet bgs with screen intervals of 60 to 70 feet bgs, 100 to 110 feet bgs, and 140 to 150 feet bgs. The third mobilization field activities were completed on December 21, 2017.

1.4 REPORT STRUCTURE

This Report presents the results of the Unit 4 and 5 Buildings Investigation from the first, second, and third mobilization field events. The Report is organized as follows:

- Section 2.0 presents the project background, including the following:
  - NERT Site Background/Location and Description;
  - Unit 4 and 5 Buildings Investigation Project Objectives;
  - Geology/Lithology in Unit 4 and 5 Buildings Investigation Area; and
  - Hydrogeology and Hydrogeologic Conditions in Unit 4 and 5 Buildings Investigation Area.
- Section 3.0 presents a description of the technical approach, including the following:
  - Implementation strategy for each field mobilization;
  - Borehole siting, notification, permitting, and surveying;
  - Drilling, sampling, and temporary well installation;
  - Investigation-derived waste (IDW) management; and
  - Field variances from the Work Plan.
- Section 4.0 presents a summary of the results of the investigation, including the following:
  - Description of the lithology encountered;
  - Analytical laboratory results for both soil and groundwater;
  - Geotechnical soil testing results;
  - Aquifer testing results; and
  - A brief discussion of data validation methodology and results.
- Section 5.0 describes how the investigation achieved the objectives and goals identified in the Work Plan.
- Section 6.0 provides a listing of references.

2.0 BACKGROUND

This section of the Report provides background information including project objectives and goals, a Site description, and a summary of previous investigations in and around the Investigation Area.

2.1 PROJECT OBJECTIVES AND GOALS

At the time that the Work Plan was published, soil and shallow groundwater investigation data collected in and downgradient of the Investigation Area indicated that the Unit 4 and 5 buildings area was a potential perchlorate and hexavalent chromium source to the underlying soil and groundwater (ENVIRON, 2014a). To evaluate if, and to what extent, the Unit 4 and 5 buildings area was a source, the objective of this investigation was to characterize the vertical and horizontal extent of impacted soil and shallow groundwater underneath the Unit 4 cell building and within the Investigation Area as a part of the NERT RI. As outlined in the Work Plan, the specific goals of the investigation included the following:

- Collect sufficient soil and groundwater data to provide scale-appropriate data density for characterization of the nature and extent of perchlorate, hexavalent chromium, and other contaminants in the vadose zone and shallow groundwater within the Investigation Area;
- Estimate the mass of perchlorate and hexavalent chromium in the vadose zone and shallow groundwater in the Investigation Area;
- Evaluate potential migration pathways and the velocity of perchlorate and hexavalent chromium migration in shallow groundwater in the Investigation Area; and
- Evaluate the potential contribution of perchlorate and hexavalent chromium in the Investigation Area to the previously identified Site-wide shallow groundwater plume.

Early in the investigation, it became apparent that the third and fourth goals could only be accomplished with the larger scope of the RI. Therefore, although the third and fourth bullet above were goals of the investigation outlined in the Work Plan, achievement of these goals including data interpretation and conclusions of the Unit 4 and 5 building area will be incorporated in the RI Reports.

In addition to the project objectives defined in the Work Plan, the NDEP and the United States Environmental Protection Agency (USEPA) requested that the following Work Plan modifications be integrated into the investigation:

- In an email dated April 9, 2015, NDEP provided three primary comments on the Work Plan: 1) Clarification regarding the decision criteria and distance for step-out borings; 2) Request for additional/supplemental laboratory analyses; and 3) Modification of the soil sampling frequency. During a follow-up conference call on April 10, 2015, NERT and Tetra Tech adequately responded to and addressed NDEP's comments 1 and 3, resulting in no changes to the proposed scope of work pertaining to these comments. In response to comment 2, NERT agreed to analyze shallow soil samples for additional analyses during the first mobilization and evaluate the need to analyze this additional analytical suite during subsequent mobilizations. Based on the first mobilization analytical results, the additional suite of analyses was not required and not performed for the second and third mobilization soil samples. NDEP subsequently approved the Work Plan with the additional supplemental analyses. Additional discussion of the soil sampling is provided in Section 3.3.1.
- Six of the planned borehole locations (U4U5-13, U4U5-15, U4U5-26, U4U5-33, U4U5-34, and U4U5-46) encountered subsurface utilities or obstructions within the upper 12 feet during the hydro-vacuum clearance. As a result, these boreholes were relocated to avoid the obstructions. Relocated borehole locations were subsequently reviewed and approved by the Tenant. Pursuant to the lease, environmental activities conducted within the leasehold must comply with the Tenant's established facilities security and

workplace safety procedures and policies, therefore, all borehole locations were reviewed and approved by Tenant through its established groundbreaking permit process. At the request of NDEP, Tetra Tech recorded all locations where utilities were encountered and, when possible, documented the following information: type of utility encountered, depth of utility, orientation of utility, and location of new borehole.

- In a letter dated June 8, 2017, NDEP included the following comments to the third mobilization scope of work: 1) A 30-minute low-flow test would be insufficient to stress the aquifer and obtain representative hydraulic properties; 2) Additional data gaps include porosity, effective porosity, and total organic carbon (TOC); and 3) that monitoring well M-241 be resampled during the third mobilization. NERT agreed to conduct tests at sufficient rates and durations to obtain representative hydraulic properties; to collect porosity, effective porosity, and TOC samples from boreholes throughout the Investigation Area; and to include monitoring well M-241 in the third mobilization groundwater monitoring activities.

In addition to the above modifications, any variances from the work plan that were necessitated due to conditions encountered in the field are summarized in Section 3.3.

2.2 SITE LOCATION AND DESCRIPTION

This section provides a brief description of Site location and operation history. Additional details will be provided in the forthcoming OU-1 and OU-2 RI Report. The Site comprises approximately 346 acres of the BMI Complex in an unincorporated portion of Clark County surrounded by the City of Henderson, Nevada. The Site has been used for industrial operations since 1942, when the U.S. government developed it as a magnesium plant in support of World War II operations. Following the war, various industrial activities, including the production of perchlorates, boron, and manganese compounds, continued at the BMI Complex. Former industrial and waste management practices at the Site and adjacent properties have resulted in impacts to soil, groundwater, and surface water.

Tronox formerly owned and operated the Site, including the Investigation Area. In conjunction with the settlement of Tronox's bankruptcy proceeding, ownership of the Site was transferred to NERT on February 14, 2011, and a lease between NERT and Tronox was entered into on that same day establishing a 114-acre leasehold under which Tronox was allowed to operate its business which consisted of production of manganese dioxide, batteries, and boron products. In August 2018, EMD assumed the Tronox lease and continues to operate the same business.

There were ten Unit buildings (numbered 1 through 10) aligned in a row from west to east, six of which are located along the southern portion of the NERT property, that were constructed during World War II. To support historical operations, each Unit building consisted of three structures: a chlorinator building on the north side, a cell building in the center, and substation building on the south side. Four of the Unit buildings (Units 3, 4, 5, and 6) are included in the property leased from NERT by Tenant (Figure 2). The roof, above grade walls and floors of the Units 1 and 2 cell buildings were demolished between 1996 and 1997, with the basement walls and slabs remaining intact. In addition, the eastern half of the Unit 3 cell building has been demolished.

The Unit 4 cell building is no longer used. Its above-ground structures were demolished in the mid-2000s and the exposed floor of the Unit 4 cell Building was demolished by the Trust in 2016 to provide access for the implementation of the Work Plan. In 2012, the Unit 4 substation building was retrofitted to house an advanced battery manufacturing process and manufacturing continues to present day. The Unit 4 chlorinator building is currently used primarily for storage. EMD currently uses the Unit 5 and 6 buildings for the production of manganese dioxide. A portion of the Unit 5 building is also used for storage.

North of the Unit 4 building, EMD currently produces boron products at a boron plant. To the north of the Unit 5 and 6 buildings, the Tenant produces manganese sulfate for use in the manganese dioxide production process within a leach plant.

The Unit 4 cell building historically contained chlorinators (furnaces) that created molten magnesium chloride by reacting magnesium oxide/carbon pellets with chlorine gas at high temperatures. Magnesium metal was then produced in banks of electrolytic cells in the cell building by electrochemical reduction of the molten magnesium chloride. Sodium chlorate and sodium perchlorate were also historically produced within the Unit 4 cell building by electrolytic processes, which involved the use of sodium dichromate (hexavalent chromium) on the first floor of the Unit 4 and 5 cell buildings. The concrete basements reportedly served as sumps to collect process liquor, spillage, and wash water, and process chemicals may have leaked to soil through cracks in the basements of the Unit 4 and 5 cell buildings, thus forming the basis for the conceptual site model for the Investigation Area.

Asphalt, concrete roads, active and inactive utility lines, and railroad spurs cross the Investigation Area. An extensive network of active and inactive underground utility lines are present under the roads and open areas at the Investigation Area.

2.3 GEOLOGY

The Site is located near the southeast end of the Las Vegas Valley, a northwest-southeast trending structural basin that extends approximately 55 miles and includes the metropolitan areas of North Las Vegas, Las Vegas, and Henderson. Locally, the ground surface slopes to the north towards the Las Vegas Wash which lays approximately 3.25 miles north of the Investigation Area. Las Vegas Valley is bounded on the west by the Spring Mountains, on the north by the southern ends of the Sheep and Las Vegas Ranges, on the east by Frenchman and Sunrise Mountains, and on the south by the River Mountains and McCullough Range (Plume, 1989). The structural basin that underlies Las Vegas Valley is comprised of Precambrian crystalline rocks; Precambrian and Paleozoic carbonate rocks; Permian, Triassic, and Jurassic clastic rocks; and Miocene igneous rocks. Gravity data indicate that the deeper portions of the basin are filled with 3,000 to 5,000 feet of clastic sedimentary deposits that range in age from Miocene through Holocene (Plume, 1989).

The clastic sedimentary valley-fill deposits of Las Vegas Valley are more than 4,000 feet thick beneath Henderson (Plume, 1989), and consist of Quaternary alluvial (Qal) deposits, transitional Muddy Creek formation (xMCf), and Pleistocene UMCf. The alluvium at the Site is generally described as reddish-brown discontinuous layers of sand and silty-sand and gravel with minor amounts of clay and caliche. The thickness of these alluvial deposits ranges from less than one foot to more than 50 feet beneath the NERT Site, which includes the Investigation Area. (Ramboll Environ, 2016a).

Localized thicker deposits of alluvium that are structurally narrow and linear have been interpreted as stream-deposited sands and gravels that were deposited within paleochannels during historical flooding events. The paleochannel sand and gravel deposits exhibit significantly greater permeability than the adjacent surrounding formation material, thus acting as contaminant transport pathways. There are two main paleochannels that originate on the NERT Site and these will be described in greater detail in the forthcoming RI Report for OU-1 and OU-2. At the base of the alluvium, the xMCf is encountered at some locations, and consists of reworked sediments derived from the UMCf. The UMCf underlies the xUMCf or alluvium and consists of interbedded coarse-grained and fine-grained sediments that become progressively finer-grained to the north towards the central portion of the valley.

Within the southern 1,000 feet of the Site, the uppermost first fine-grained sediment layer of Upper Muddy Creek formation (UMCf-fg1) pinches out along a roughly west-northwesterly trend line. South of this transitional trend line, the first coarse-grained sediment layer of the UMCf directly underlies the alluvium. The contact between the alluvium and the UMCf is reportedly marked by the appearance of a well-compacted brown silt, sandy silt, stiff clay, or sandy clay (Ramboll Environ, 2016a).

Based on the lithology encountered during the Unit 4 and 5 buildings investigation, the first native soil unit underlying the Investigation Area is alluvium, consisting of fine- to medium-grained sand with some silty sand with gravel. The alluvium is generally overlain by 3 to 6 feet of fill, with up to 10 feet of fill at some locations. The contact between the base of the sandy alluvium and the top of the underlying silty UMCf-fg1 in the Investigation Area was encountered at a depth of approximately 25 to 50 feet bgs. The xUMCf was not encountered underneath the Investigation Area during drilling activities. A detailed description of the geology underlying the Unit 4 and 5 buildings is provided in Section 4.1.

2.4 HYDROLOGY AND HYDROGEOLOGICAL CONDITIONS

Surface water at the Site generally flows with topography from south to north toward the Las Vegas Wash. During the 2011 Soil Removal Action (ENVIRON International Corporation (ENVIRON), 2012), many portions of the Site were graded such that storm water would be retained on the Site. Existing roads, utility berms, and other site features were created to prevent storm water from flowing off the Site. Two main storm water retention basins, the Central Retention Basin (CRB) and Northern Retention Basin (NRB), were constructed to control storm water flow and maintain storm water on the Site. The CRB collects surface runoff from the leased area. The NRB collects surface runoff water from north of the former Beta Ditch (located near the center of the Site) and accepts overflow from the CRB.

The depth to groundwater in the Site vicinity ranges from approximately 27 to 80 feet bgs, and is generally deepest in the southern portion of the Site and becomes shallower to the north as it approaches the Las Vegas Wash. The average groundwater gradient ranges from 0.015 to 0.020 feet/foot south of the Athens Road Well Field (AWF) located approximately 2 miles north of the Investigation Area, decreasing to approximately 0.007 to 0.010 feet/foot to the north of the AWF (Ramboll Environ, 2016a). The direction of groundwater flow on the Site is generally north to north-northeast; to the north of the Site, the direction of groundwater flow is toward the northeast.

The NDEP has defined the following three WBZs that occur within the BMI Complex:

- Shallow WBZ – The first occurrence of groundwater in the area occurs within either the alluvium or the UMCf. Groundwater in the Shallow WBZ occurs under unconfined to partially confined conditions and is considered a "water table aquifer." At the Site, the Shallow WBZ is comprised of the saturated portions of the alluvium and the uppermost portion of the UMCf to depths of approximately 90 feet bgs (Ramboll Environ, 2016b).
- Middle WBZ – Groundwater in the Middle WBZ generally occurs between 90 and 300 feet bgs. Water-bearing units in Middle WBZ are confined (Ramboll Environ, 2016a). Groundwater in the Middle WBZ exhibits an upward vertical gradient (Ramboll Environ, 2016b).
- Deep WBZ – Groundwater in the Deep WBZ generally occurs between 300 and 400 feet bgs. Water-bearing units in Deep WBZ are confined. Groundwater in the Deep WBZ exhibits an upward vertical gradient (Ramboll Environ, 2016b).

Historical environmental investigation performed at the Site has primarily focused on the Shallow WBZ; therefore, limited data was available on the Middle WBZ at the Site. However, investigations conducted by Northgate Environmental Management in 2009 included the installation of several monitoring wells in the Middle WBZ to characterize the vertical distribution of chemical constituents (Ramboll Environ, 2016a). In addition, the investigation summarized in this report, and other components of the NERT RI, have included the advancement of boreholes and the construction of monitoring wells within the Middle WBZ all of which will be detailed in the forthcoming OU-1 and OU-2 RI Report.

The depth to groundwater as measured in wells installed within the Shallow WBZ within the Investigation Area relative to the surrounding ground surface ranges from approximately 32 to 48 feet bgs. The depth to groundwater as measured in wells screened within the Middle WBZ in the Investigation Area occurs at depths ranging from 31 to 52 feet bgs. Pressures in the Middle WBZ are slightly higher than the Shallow WBZ which cause an upward vertical gradient in the Investigation Area. This will be described in greater detail in the forthcoming RI Report for OU-1 and OU-2. The direction of groundwater flow in the Investigation Area is generally toward the north-northeast following the slope of the ground surface, with an upward component due to the vertical gradient. A detailed description of the hydrogeology underlying the Unit 4 and 5 buildings is provided in Section 4.1.

3.0 TECHNICAL APPROACH

This section provides a description of the Unit 4 and 5 Buildings Investigation implementation strategy and details of the work that was performed during the three field mobilizations. The results from the work are presented following these details in Section 4 of this report.

To effectively characterize the Investigation Area, Tetra Tech developed the Work Plan to perform the investigation using High Resolution Site Characterization (HRSC) strategies as defined by USEPA. The HRSC strategies, associated technologies, and best practices were used to ensure efficient collection of reliable data at an appropriate scale and density to effectively characterize heterogeneous environmental media during the site investigation.

The HRSC-based characterization for the Investigation Area consisted of the collection of soil and groundwater samples from boreholes positioned: 1) along five transects aligned perpendicular to the direction of groundwater flow, 2) at potential contaminant source areas (hot spots); and 3) at step-out borehole locations. Preliminary borehole locations sited in the Work Plan are shown on Figure 3. The transect boreholes were designed to provide scale-appropriate spatial data for 3DVA presentations. As such, the location and number of boreholes were adjusted based on field results to ensure data gaps were filled.

In addition to the boreholes positioned along the five transects, boreholes were advanced at potential contaminant source areas, including two sumps and drainage trenches in the Unit 4 cell building basement and railcar loading and unloading areas. Additionally, in consultation with NDEP and USEPA, step-out and step-down boreholes were advanced at scale-appropriate locations adjacent to areas of elevated concentrations. The strategy for advancing step-out boreholes was based on statistical criteria that was developed from data collected during the investigation, providing a means of comparing relative contaminant levels. A detailed description of the investigation and data collection process is provided in Section 3.2. Final borehole locations from all three field mobilizations are shown on Figure 4.

3.1 IMPLEMENTATION STRATEGY

As detailed in the Work Plan, three field mobilizations were planned and implemented. Details of the activities conducted during each mobilization is provided below. The results of the investigation are discussed in Section 4.

- First Field Mobilization – The first field mobilization included the advancement of four soil boreholes to 90 feet bgs and collection of soil and groundwater samples for laboratory analysis. Data generated during the first field mobilization was used to direct and refine the scope of work and implementation strategy of the subsequent field mobilizations. Activities performed during the first mobilization are summarized in Section 3.2 and in the Technical Memorandum: *Unit 4 and 5 Buildings Investigation First Mobilization* (Tetra Tech, 2016).
- Second Field Mobilization – The second mobilization included the advancement of 69 soil boreholes to depths ranging from 90 to 250 feet bgs and collection of soil and groundwater samples for laboratory analysis. Tetra Tech also installed one permanent groundwater monitoring well during the second mobilization to confirm the results obtained from discrete-depth samples collected from temporary wells.

  Data and results obtained during the initial stages of the second field mobilization were used to direct the placement of both step-out and step-down boreholes to depths of up to 250 feet bgs. In addition to advancing boreholes along the transects as prescribed in the Work Plan, Tetra Tech also advanced boreholes to investigate the sumps and trenches located in the Unit 4 basement that may have served as potential conduits to the subsurface. Activities performed during the second mobilization are described in Section 3.2 and in the Technical Memorandum: *Unit 4 and 5 Buildings Investigation Second Mobilization* (Tetra Tech, 2017a).

- Third Field Mobilization – The third mobilization was implemented following review of the soil and groundwater results obtained during the second mobilization and concurrence from NDEP on the placement and design of seven monitoring well clusters in the Investigation Area. The monitoring wells were installed to collect groundwater data that would be used to confirm the results of the discrete-depth groundwater sampling and provide ongoing monitoring locations. The wells locations and screened intervals were designed to provide lateral definition throughout the Investigation Area and vertical definition within the UMCf, with screen intervals at 50-60 feet bgs, 100-110 feet bgs, and 140-150 feet bgs.

  In addition to the installation of permanent monitoring wells, four soil boreholes were advanced at a 45-degree angle underneath the Unit 5 building. The purpose of these four soil boreholes was to fill a data gap identified from the previous two mobilizations. Both soil and groundwater samples from temporary wells were collected from the angled soil boreholes. Activities performed during the third mobilization are described in Section 3.2.

3.2 OVERVIEW OF SCOPE OF WORK

This section presents a description of field activities performed during the three field mobilizations associated with the Unit 4 and 5 Buildings Investigation. The work was conducted in accordance with the *Unit 4 and 5 Buildings Investigation Work Plan* (Tetra Tech, 2015), the Unit 4 and 5 Investigation First Mobilization Technical Memorandum (Tetra Tech, 2016), and the Unit 4 and 5 Buildings Investigation Second Mobilization (Tetra Tech, 2017a), and under the direction of a Nevada Certified Environmental Manager. The following activities were performed during the three mobilizations, between October 2015 and December 2017:

- Borehole permitting and surveying;
- Geophysical utility clearance, coring, and hydro-vacuum utility clearance;
- Drilling, soil sampling, and temporary well installation;
- Permanent well installation, development, and sampling;
- Slug testing and specific capacity testing; and
- IDW management.

A description of each of these tasks is presented in the following sections.

3.2.1 Permitting and Surveying

Prior to performing invasive subsurface activities, Tetra Tech field-marked the proposed borehole locations and for all locations within the leasehold, submitted groundbreaking permit application packages to the Tenant, as required under its lease with the Trust, for review and approval. At the request of the Tenant, the groundbreaking permit applications were submitted as groups of boreholes or monitoring wells, generally in close proximity. A total of four groundbreaking permit packages were submitted for the first mobilization, 14 groundbreaking permit packages were submitted for the second mobilization, and seven groundbreaking permit packages were submitted for the third mobilization. No boreholes were advanced until their respective groundbreaking permit package had been reviewed and approved by the Tenant.

Borehole U4U5-9 was converted into a permanent monitoring well (M-241) during the second mobilization. An additional 20 permanent monitoring well casings within 13 boreholes were constructed during the third mobilization. As required by the State of Nevada Division of Water Resources, Tetra Tech's drilling contractors (National EWP, Inc., Cascade Drilling, Inc., and Walker-Hill Environmental, Inc.) were approved for a "Request For a Waiver For Observation or Monitor Well(s)" before the monitoring wells were installed.

Each borehole location was surveyed by Atkins North America, Inc., a Nevada-licensed land surveyor, for coordinates and elevation per the North American Datum of 1983 State Coordinate System and North American Vertical Datum of 1988. All borehole coordinates and elevations are provided in Appendix A.

3.2.2 Geophysical Utility Clearance

Each proposed borehole/monitoring well location, which was marked in the field by a Tetra Tech representative, was screened for subsurface utilities and other potential subsurface obstructions by a third-party geophysical utility clearance contractor prior to initiating subsurface work. Potential obstructions were indicated on the surface with marking paint.

3.2.3 Coring

All boreholes that were located on an asphalt or concrete surface required coring/saw-cutting prior to hydro-vacuum services and drilling operations. The coring was performed by the drilling subcontractors, National EWP, Inc., Cascade Drilling, Inc., or Walker-Hill Environmental, Inc. In some cases, the coring was performed by Penhall Company, Inc., a subcontractor to Cascade Drilling, or the hydro-vac subcontractor Clean Harbors, Inc.

3.2.4 Hydro-Vacuum Utility Clearance

Tetra Tech contracted a hydro-vacuum contractor to advance the upper 12 to 21 feet of each borehole prior to drilling. Hydro-vacuum is a minimally invasive method to advance the upper portion of a borehole without damaging subsurface utilities, if encountered. The hydro-vacuum injects water to dislodge soil within the borehole, vacuums the soil and water from the borehole, and transfers the soil and water to a holding tank located at the surface.

At a minimum, each borehole was advanced by hydro-vacuum to a depth of 12 feet bgs. In the case of the angled boreholes hydro-vacuum services were performed through the upper 21 linear feet prior to drilling. At some locations, hydro-vacuum boreholes were advanced to depths of 20 feet as a condition of the approved groundbreaking permit.

3.2.4.1 Vertical Boreholes

As stated above, utility clearance at vertical borehole locations consisted of hydro-vacuum procedures to a minimum of 12 feet bgs. If subsurface utilities or obstructions were encountered during the hydro-vacuum clearance, the boreholes were relocated to avoid the obstructions (described in Section 3.2.4.3). While advancing each borehole with the hydro-vacuum, soil samples were collected at 1-foot and 2.5-foot depth intervals for lithologic logging and analytical purposes. Soil samples were collected in stainless steel sleeves using a slide hammer sampling tool from undisturbed soil ahead of the hydro-vacuum. The soil samples were logged pursuant to the lithologic logging procedures presented in Section 3.2.5.1. Upon advancement to the total depth, the borehole was filled with sand to the ground surface.

3.2.4.2 Angled Boreholes

As stated in Section 3.2.4, utility clearance at angled borehole locations consisted of hydro-vacuum procedures to 21 linear feet (15 vertical feet). The hydro-vacuum was conducted at 45-degree angle to match the angle of the borehole. After the hydro-vacuum borehole was completed to the total depth, and after review and approval by the Tenant as specified in the groundbreaking permit, a 20-foot long by 12-inch diameter polyvinyl chloride (PVC) pipe was installed in the open hydro-vacuum borehole. The upper 3 feet of the PVC pipe was cut off to match the ground surface. The void between the PVC pipe and open borehole was backfilled with sand to grade. The PVC pipe was hammered during the placement of the sand backfill to ensure the sand filled the void and to prevent sand bridging. During pauses in drilling activities, a temporary steel traffic plate was installed over the PVC pipe opening to keep the hole open and to protect nearby workers from a potential fall hazard.

3.2.4.3 Borehole Relocation

Six of the second mobilization planned borehole locations (U4U5-13, U4U5-15, U4U5-26, U4U5-33, U4U5-34, and U4U5-46) and three of the third mobilization planned monitoring well cluster locations (M-249/M-250, M-256/M-257, and M-258/M-259) encountered subsurface utilities or obstructions during the hydro-vacuum clearance. These boreholes were relocated to avoid the obstructions. Relocated borehole locations were subsequently reviewed and approved by the Tenant. At the request of NDEP following the completion of the first mobilization, Tetra Tech recorded all locations where utilities were encountered and, when possible, documented the following information: type of utility encountered, depth of utility, orientation of utility, and location of the new borehole. The field forms used to record this information are provided in Appendix B.

3.2.5 Drilling

Drilling was accomplished through conventional sonic drilling methods which advances tooling by pushing and rotating the drill string while simultaneously vibrating the drill head. The drill string consists of an inner 4- or 6-inch diameter core barrel used to collect and recover soil samples and an outer conductor casing to maintain borehole stability while soil collected within the inner core barrel is retrieved to the surface. The inner core barrel is advanced in 5- to 10-foot increments ahead of the outer casing and then the outer casing is advanced. Once the outer casing is advanced to the same depth as the inner core barrel, the inner core barrel is retrieved to the surface for lithologic logging and sampling. Following recovery of the sample core, the inner core barrel is returned to the head of the drill string and the borehole is advanced to the next target depth. Drilling of boreholes U4U5-74, U4U5-75, U4U5-76, and U4U5-77 were performed at a 45-degree angle to collect samples from underneath the Unit 5 building.

The soil cores in all boreholes were logged in accordance with the Unified Soil Classification System (USCS) and utilized the modified ASTM International (ASTM) Method D-2488 as follows: textural classification of soil, color classification of soil, grain type, grading, roundness, matrix, plasticity, cementation, strength, and lithologic contact. Field equipment used during logging included the following items: Munsell™ color chart, USCS classification chart, grain size chart, and sample collection bags. Borehole logs from each of the three mobilizations are provided in Appendix C.

Additionally, discrete-depth groundwater samples were collected from each borehole, as described in the following sections.

3.2.5.1 Vertical Sonic Boreholes

As discussed in Section 3.2.4, the hydro-vacuum was utilized to advance each borehole from ground surface to a depth of 12 to 20 feet bgs in each vertical borehole. Following completion of the hydro-vacuum utility clearance, continuous soil samples were collected using a roto-sonic drill rig from the bottom of the hydrovac hole to the total investigation depth of 90, 150, or 250 feet bgs. Boreholes that were advanced below 90 vertical feet bgs were completed using a modified drilling procedure. In order to minimize the potential for cross contaminating deeper sampling intervals, Tetra Tech proposed, and NDEP approved, the following modified drilling method for 150-foot deep vertical boreholes that utilized the sonic casing as a temporary conductor casing:

- Boreholes were advanced to 90 feet bgs using a 10-inch diameter sonic casing.
- The 90-foot deep borehole was cleaned out and the casing was raised three to five feet above the bottom of the borehole.
- A three-foot plug composed of time-release bentonite pellets was installed at the bottom of the borehole (below the casing) and allowed to hydrate for 90 minutes.
- Following hydration, the casing was advanced two-feet into the hydrated bentonite plug, leaving the bottom one foot undisturbed.

- Water inside the casing was bailed out, the depth to water in the casing was measured, and the casing was left in position overnight.
- The following morning, the depth to water in the casing was measured.
    - If the water level remained at the same depth, the seal was determined to be competent.
    - If the seal did not hold overnight, the borehole was cleaned out and the seal was re-installed.
    - If a seal constructed of bentonite failed twice at the same interval, a seal of neat cement was installed.
- With the 10-inch diameter sonic casing remaining in place, a 9-inch diameter sonic casing was advanced through the bentonite plug to the next sampling interval at 110 feet bgs.
- The seal installation procedure was repeated at 110 feet and 130 feet bgs using 8-inch and 6-inch diameter sonic casings, respectively, until the total depth of 150 feet bgs was reached with the 6-inch diameter sonic casing.

The procedure was modified slightly for the 250-foot deep step-down borehole following approval from NDEP. In lieu of the seal installation at 90, 110, and 130 feet bgs, seals for these deep boreholes were installed at 90, 150, and 200 feet bgs.

3.2.5.1.1 Soil Sampling

A Tetra Tech field geologist logged the entire soil profile of each borehole from ground surface to total depth. Soil samples were collected for laboratory analysis at regular intervals from ground surface to the top of groundwater and from the top of the water table to the bottom of the borehole. ***Table 1*** details the sample collection intervals for vertical boreholes advanced during the investigation.

Table 1 Soil Sample Collection Intervals

Sample Intervals	Boreholes		Step-Out Boreholes		Step-Down Boreholes	
	90-Foot Boreholes	150-Foot Boreholes*	90-Foot Boreholes	150-Foot Boreholes	90-Foot Boreholes	150-Foot Boreholes
2.5-Foot Interval in the Vadose Zone	X	X	X	X		
10-Foot Interval Below the Water Table		X	X	X	X	X

Note:
*Planned 150-Foot boreholes were originally designed to be 90 feet, but were extended to 150 following approval by NERT and NDEP

Step-out and step-down boreholes were added to the second mobilization field investigation following a meeting with NDEP and USEPA on October 12, 2016. The purpose of step-out boreholes was to address lateral data gaps identified during data analysis and the step-down boreholes were designed to address vertical data gaps (further discussed in Section 3.3).

If visible staining or discoloration were observed, additional soil samples for laboratory analysis would have been performed. There was no visible staining or discoloration observed throughout the soil column therefore, no additional soil samples were collected. In addition to the collection of soil samples at planned intervals, beginning on November 1, 2016, and continuing through the end of the second mobilization, additional soil samples were collected where sand lenses were encountered to provide additional analytical characterization data in zones where greater flow rates would be expected.

Soil samples for laboratory analysis were collected in laboratory-supplied containers, labeled, placed in sealed plastic bags, and stored on ice in a cooler for transport to the project analytical laboratory (TestAmerica, Inc., a Nevada-certified analytical laboratory) under chain-of-custody. Soil samples were analyzed for the following constituents during the three mobilizations of the investigation:

- Perchlorate by USEPA Method 314.0
- Hexavalent chromium by USEPA Method 7199
- Total chromium by USEPA Method 6010B
- Volatile organic compounds (VOCs) by USEPA Method 8260B

3.2.5.1.2 Supplementary Sampling

In addition to the samples collected throughout the investigation, additional (supplementary) samples were collected during the first mobilization as requested by NDEP. The supplemental analyses are described below.

Ammonia Sampling

During the first mobilization, soil samples were analyzed for ammonia as nitrogen (N) by SM4500NH3_D. Soil samples were analyzed for ammonia for health and safety purposes to determine if perchlorate in the Investigation Area was ammonium perchlorate or sodium perchlorate. Ammonium perchlorate is more reactive, and the presence of ammonium perchlorate would have required more restrictive health and safety practices and personal protective equipment (PPE). Due to the low levels of ammonia detected during the first mobilization, ammonia analysis was not performed during the second or third mobilizations and the health and safety protocols were adjusted accordingly for the subsequent mobilizations.

First Mobilization Shallow Soil Sampling

Additional/supplemental soil samples were collected in the upper 7.5 feet of boreholes U4U5-1, U4U5-2, U4U5-3, and U4U5-4 during the first mobilization. The additional/supplemental soil samples from these four soil boreholes were analyzed for the following:

- Asbestos by USEPA Method 600/R-93-116 and 600/M4-82-020
- Dioxins/furans by USEPA Method 8290
- Polychlorinated biphenyls (PCBs) by USEPA Method 8082
- Radionuclides by USEPA Method 9315, 9320, and US Department of Energy Method A-01-R

Soil samples were collected at 1, 2.5, and 5 feet bgs with the exception of borehole U4U5-2, where a sample was collected at 7.5 feet bgs, and borehole U4U5-3, where a 1-foot bgs sample could not be collected. These intervals are discussed in the field variance below in Section 3.3.

Remedial Action Alternative Analysis Sampling

Beginning on November 7, 2016 and continuing through the end of the second and third mobilizations, soil samples collected below the water table were also analyzed for the following constituents to support future remedial action alternative analysis:

- Nitrate by USEPA Method 300.0
- Sulfate by USEPA Method 300.0
- Chlorate by USEPA Method 300.1

3.2.5.1.3 Discrete-Depth Groundwater Sampling and Temporary Well Construction

Temporary wells were used for the collection of three to eight discrete-depth groundwater samples from each borehole, for a total of 320 samples across all of the mobilizations. In 90-foot boreholes, discrete-depth groundwater samples were collected at the top, middle, and bottom of the Shallow WBZ. The collection depth of the top shallow groundwater samples was dependent on the depth that groundwater was first encountered in each borehole. The collection depth of the deepest groundwater samples was based on the bottom of the Shallow WBZ (e.g., 90 feet bgs, as defined by NDEP). The intermediate depth groundwater sample was collected at a depth interval between the shallow and deep discrete-depth groundwater samples. In boreholes U4U5-28 and U4U5-33, additional groundwater samples were collected at 52.5 and 77.5 feet bgs to provide intermediate data points that would be used for development of the 3DVA. In 150-foot boreholes, groundwater samples were generally collected from the first three intervals described above and at 110, 130, and 150 feet bgs. In the 250-foot borehole, groundwater samples were collected from the first six intervals described above and at 200 and 250 feet bgs. In boreholes advanced within the Unit 4 basement, as shown on Figure 4, sample depths were adjusted by 8 feet to account for the difference in elevation between the surrounding ground surface and the basement floor.

Discrete-depth groundwater samples collected during the investigation were collected through the installation of temporary wells. Each temporary well consisted of a manufacturer-supplied 2-inch PVC well casing with five feet of 0.010-inch slot screen at the bottom of the well. A #2/12 sand filter pack was installed around the well screen and placed to a level of at least two feet above the top of the screen interval. Three to five feet of hydrated bentonite was installed above the top of the filter pack.

Each temporary well was purged prior to the collection of the discrete-depth groundwater sample. A minimum of three casing volumes of water was purged prior to sampling using a submersible pump. Throughout well purging, field parameters (consisting of temperature, pH, turbidity, and electrical conductivity) were collected and recorded on field sampling forms. Following the completion of purging, a small diameter bailer was lowered into the well to retrieve the groundwater sample. The collected groundwater sample was immediately transferred into a clean laboratory-supplied container. Groundwater samples to be analyzed for perchlorate were also field filtered using a syringe and a 0.2-micron filter, in accordance with NDEP guidance and the *Quality Assurance Project Plan (QAPP), Revision 1* (ENVIRON, 2014b). If the water appeared turbid before filtering, a 45-micron filter was used before the 0.2-micron filter. On October 26, 2017, Revision 2 to the Ramboll Environ QAPP was published (Ramboll Environ, 2017). The QAPP Revision 2 removed the requirement for field filtering of perchlorate. This revision occurred during the implementation of the third mobilization. For consistency, the remaining perchlorate samples collected during the third mobilization were field filtered. Discrete-depth groundwater samples were submitted to TestAmerica, Inc. for the following analyses:

- Perchlorate by USEPA Method 314.0
- Hexavalent chromium by USEPA Method 7199/218.6
- Total chromium by USEPA Method 200.7
- Total dissolved solids (TDS) analysis by Method SM2540C
- VOCs by USEPA Method 8260B

Beginning on November 7, 2016, and continuing through the end of the second and third mobilizations, groundwater samples were also analyzed to support future remedial action alternative analysis using the following methods:

- Nitrate by USEPA Method 300.0
- Sulfate by USEPA Method 300.0
- Chlorate by USEPA Method 300.1

Following the collection of a discrete-depth groundwater sample, the temporary well casing was removed from the borehole and disposed, and the borehole was advanced to the next discrete-depth sampling interval. For boreholes advanced below 90 feet bgs, the telescoping drilling method described in Section 3.2.5.1 was implemented. Upon collection of the final discrete-depth groundwater sample from each borehole, the well casing was removed from the borehole and the filter pack and bentonite were drilled out of the borehole. Following drilling out the borehole, the borehole was plugged in accordance with the State of Nevada Department of

Conservation and Natural Resources (NDCNR) Division of Water Resources regulations. Each borehole was plugged with bentonite grout from the bottom of the borehole to the surface, using a tremie pipe as required in the "Regulations for Water Well and Related Drilling" provided by NDCNR. The top of the seal material for each borehole was finished to approximately 6 inches below the surrounding grade. After the seal material cured, a concrete patch was installed to match grade and dyed black to match the surrounding asphalt.

All sampling equipment was decontaminated before and after collecting each groundwater sample. The sampling pump was decontaminated between each sample collection using the procedures outlined in the *Field Sampling Plan, Revision 1* (FSP) (ENVIRON, 2014c).

Following collection of each groundwater sample, the PVC casing used to construct the temporary well was removed from the borehole, decontaminated using a pressure washer, and disposed as solid waste in a licensed municipal landfill. Casing that was not decontaminated was containerized and disposed of with soil waste at Apex Landfill, Las Vegas, Nevada.

3.2.5.2 Angled Boreholes

To evaluate if past operations at the Unit 5 building were a potential source to groundwater, four boreholes were advanced at a 45-degree angle from outside of the building to sample soil and groundwater from underneath the Unit 5 building. Each of the four 45-degree angle boreholes were advanced to a linear depth of 212 feet, which is an equivalent vertical depth of 150 feet bgs to be consistent with the other boreholes advanced within the Investigation Area. The drilling procedures described in Section 3.2.5.1 were modified to accommodate advancement of the borehole and collection of samples at a 45-degree angle. The modified drilling method for the four angled boreholes utilized the sonic casing as a temporary conductor casing as described below:

- Boreholes were advanced to 21 linear feet at a 45-degree angle using hydro-vacuum for utility clearance, rather than 15 vertical feet as described in Section 3.2.4. Soil samples were collected at approximately 3.5 linear feet intervals for analysis. The 3.5 linear-foot interval corresponds to a 2.5-foot vertical sampling interval. A 12-inch PVC pipe was subsequently installed in the borehole as a surface casing to provide upper borehole stability.
- Boreholes were advanced to 127 linear feet bgs (90 vertical feet) using a 10-inch diameter sonic casing.
- The 127-foot deep borehole was cleaned out and the casing raised five to eight feet above the bottom of the borehole.
    - A three- to eight-foot plug composed of time-release bentonite pellets was installed at the bottom of the borehole (below the casing) and allowed to hydrate for a minimum of 90 minutes.
    - Following hydration, the casing was advanced three feet into the hydrated bentonite plug, leaving the bottom hydrated bentonite undisturbed.
    - Water inside the casing was bailed out, the depth to water in the casing was measured, and the casing was left in position overnight.
    - The following morning, the depth to water in the casing was measured.
        - If the water level remained at the same depth, the seal was deemed competent.
        - If the seal did not hold overnight, the borehole was cleaned out and the seal was re-installed.
        - If a seal constructed of bentonite failed twice at the same interval, a seal of neat cement was installed.
- With the 10-inch diameter sonic casing remaining in place, a 9-inch diameter sonic casing was advanced through the bentonite plug to the next sampling interval at 156 linear feet bgs (110 vertical feet).
- The seal installation procedure used at 127 linear feet (90 vertical feet) was repeated at 156 linear feet (110 vertical feet) and 184 linear feet (130 vertical feet) bgs using 8-inch and 6-inch diameter sonic

casings until the total depth of 212 linear feet bgs (150 vertical feet) was reached with the 6-inch diameter sonic casing. A 4-inch drill core was used to advance and collect the soil within the 6-inch casing.

3.2.5.2.1 Soil Sampling

Soil samples from the angle boreholes were collected at 3.5-foot intervals (equivalent to 2.5 vertical feet) from ground surface to the top of groundwater at approximately 50 feet bgs and at 14 linear-foot intervals (equivalent to 10 vertical feet) from 60 feet bgs to total depth of 212 linear feet (approximately 150 feet bgs). The sample collection intervals were designed to be equivalent to the vertical depth intervals used in the prior vertical boreholes (e.g., 2.5-foot intervals above 50 feet bgs and 10-foot intervals below 50 feet bgs). The soil samples were submitted to TestAmerica for the following analyses:

- Perchlorate by USEPA Method 314.0
- Hexavalent chromium by USEPA Method 7199/218.6
- Total chromium by USEPA Method 200.7
- VOCs by USEPA Method 8260B
- Nitrate by USEPA Method 300.0
- Sulfate by USEPA Method 300.0
- Chlorate by USEPA Method 300.1

3.2.5.2.2 Discrete-Depth Groundwater Sampling and Temporary Well Construction

Groundwater samples were collected through the installation of temporary wells, using similar techniques and sampling intervals followed during the second mobilization described in Section 3.2.5.1.3. Discrete-depth groundwater samples were collected at 71, 99, 127, 156, 184, and 212 feet bgs, which are equivalent to the vertical depths of the prior discrete-depth groundwater samples (e.g., 50, 70, 90, 110, 130, and 150 feet bgs) collected during the second mobilization. Groundwater samples were analyzed for the following analytes:

- Perchlorate by USEPA Method 314.0
- Hexavalent chromium by USEPA Method 7199
- Total chromium by USEPA Method 200.7
- TDS analysis by Method SM2540C
- VOCs by USEPA Method 8260B
- Nitrate by USEPA Method 300.0
- Sulfate by USEPA Method 300.0
- Chlorate by USEPA Method 300.1

Temporary wells constructed at each discrete groundwater sampling depth consisted of either a commercially available pre-packed well casing or installation of a temporary well. The pre-packed casing and temporary well consisted of a new manufacturer-supplied 2-inch PVC well casing with five feet of 0.010-inch slot screen at the bottom of the well. A #2/12-sized filter pack was installed around the well screen and placed to a level of at least two feet above the top of the screen interval. Three to five feet of hydrated bentonite was installed above the top of the filter pack.

Prior to collecting a discrete-depth sample, a minimum of three casing volumes of water were purged from the well using a pre-cleaned submersible pump. Throughout well purging, field parameters (consisting of temperature, pH, turbidity, and electrical conductivity) were collected and recorded on field sampling forms. Following the completion of purging, the well was sampled from the discharge hose of the submersible pump. If insufficient water was produced by the formation for the equivalent of three casing volumes, the temporary well was pumped or bailed dry, allowed to recharge, and then sampled using a bailer or the submersible pump output tubing. The collected groundwater sample was immediately transferred into clean laboratory-supplied containers.

Groundwater samples analyzed for perchlorate were field filtered using a syringe and a 0.2 micron filter, in accordance with NDEP guidance and the Ramboll Environ QAPP, Revision 1 (ENVIRON, 2014b). If the water appeared turbid before filtering, a 45-micron filter was used before the 0.2 micron filter. On October 26, 2017, Revision 2 to the Ramboll Environ QAPP was published (Ramboll Environ, 2017) and subsequently approved by NDEP on November 8, 2017. The QAPP Revision 2 removed the requirement for field filtering of perchlorate. This revision occurred during the implementation of the third mobilization. For consistency, the remaining perchlorate samples collected during the third mobilization were field filtered. Discrete-depth groundwater samples were submitted to TestAmerica for the following analyses:

- Perchlorate by USEPA Method 314.0
- Hexavalent chromium by USEPA Method 7199
- Total chromium by USEPA Method 200.7
- TDS analysis by Method SM2540C
- VOCs by USEPA Method 8260B
- Nitrate by USEPA Method 300.0
- Sulfate by USEPA Method 300.0
- Chlorate by USEPA Method 300.1

Following the collection of a discrete-depth groundwater sample, the temporary well casing, bentonite seal, and filter pack were removed from the borehole and the borehole was advanced to the next discrete-depth sampling interval. Upon collection of the final discrete-depth groundwater sample from each borehole, the well casing was removed from the borehole and the filter pack and bentonite were drilled out of the borehole. Following drilling out the borehole, the borehole was plugged in accordance with the NDCNR regulations. Each borehole was plugged with bentonite grout from the bottom of the borehole to the surface. The top of the seal material for each borehole was finished to approximately 6 inches below the surrounding grade. After the seal material was set, a concrete patch was installed to match grade and dyed black to match the surrounding asphalt.

All sampling equipment was decontaminated before and after collecting each groundwater sample. The submersible pump was decontaminated between each sample collection using the procedures outlined in the *Field Sampling Plan, Revision 1* (ENVIRON, 2014c). New, unused tubing was used for each temporary well.

3.2.5.3 Monitoring Well Installation

Permanent groundwater monitoring wells were constructed to confirm the results of discrete-depth groundwater samples collected from temporary wells. A total of seven nested and clustered groundwater monitoring wells were constructed during the second and third mobilizations. Each well cluster consisted of two adjacent boreholes constructed with a total of three casings at each cluster. The monitoring well locations are shown on Figure 5. The nested and clustered wells were designed to be screened across the following intervals:

Borehole 1 – Two Casings

- 60 – 70 feet bgs (Shallow WBZ)
- 100 – 110 feet bgs (Middle WBZ)

Borehole 2 – One Casing

- 140 – 150 feet bgs (Middle WBZ)

The typical nested and clustered well design is shown on Figure 6. As-built well construction schematics for each well including filter pack, transition sand, bentonite seal, and bentonite grout are included in Appendix D. One monitoring well (M-241) installed during the second mobilization was constructed of 4-inch diameter Schedule 80 PVC with a 0.010-inch slot screen between 145 and 150 feet bgs. The monitoring wells installed during the third mobilization were constructed of 2-inch diameter Schedule 80 PVC with 10-feet of 0.010-inch slot screen. All of the wells were completed with flush-mounted, tamper-resistant, traffic-rated well boxes installed at an elevation approximately one-half inch above grade, with the exception of the wells installed in the basement of the Unit 4 building. Monitoring wells M-251 and M-252 installed in the Unit 4 basement were each constructed within a 3-foot tall, high visibility riser.

Each monitoring well was surveyed by Atkins North America, Inc., a Nevada-licensed land surveyor, for coordinates and elevation according to the North American Datum of 1983 State Coordinate System and North American Vertical Datum of 1988. The monitoring well coordinates and elevations are provided in Appendix A.

Table 2 provides a summary of well locations relative to the Investigation Area and screened intervals for each well.

Table 2 Permanent Groundwater Monitoring Wells

Well Location	Well ID	Number of Casings in Borehole	Screen Zone (feet bgs)		
			60 - 70	100 - 110	140 - 150
South (upgradient) of the Unit 4 Building	M-247	2	X	X	
	M-248	1			X
West of Unit 4 Building	M-249	2	X	X	
	M-250	1			X
East of Unit 4 Building	M-253	2	X	X	
	M-254	1			X
Basement of Unit 4 Building	M-251	2	X	X	
	M-252	1			X
North (downgradient) of Unit 4	M-255	2	X	X	
	M-241[1]	1			X[1]
North (downgradient) of Unit 4	M-256	2	X	X	
	M-257	1			X
North (downgradient) of Unit 5	M-259	2	X	X	
	M-258	1			X

Note:
[1]Well M-241 was completed during the second mobilization and is screened from 145 to 150 feet bgs.

3.2.5.3.1 Soil Sampling – Monitoring Well Boreholes

As stated in the NDEP approved Second Mobilization Technical Memorandum (Tetra Tech, 2017a), a sufficient quantity of soil samples had been collected and analyzed from the vadose zone during the first and second mobilization. Therefore, it was determined that additional vadose zone soil samples would not be collected during the Phase 3 drilling activities. Soil samples below the water table were collected from the monitoring well boreholes to supplement the existing dataset. Soil samples were collected at 10-foot intervals from the top of the water table to total depth. All soil samples collected from the monitoring well boreholes were analyzed for the same suite of analytes as previous soil samples collected from the saturated zone, including the following:

- Perchlorate by USEPA Method 314.0
- Hexavalent chromium by USEPA Method 7199
- Total chromium by USEPA Method 6010B
- VOCs by USEPA Method 8260B
- Nitrate by USEPA Method 300.0
- Sulfate by USEPA Method 300.0
- Chlorate by USEPA Method 300.1

An expanded list of analyses was performed for soil samples collected from the monitoring well boreholes advanced within the Unit 4 basement to support future remedial action analysis. This expanded list included the following:

- TOC by USEPA Method 9060
- Soil pH by USEPA Method SW9045
- Soluble cations by USEPA Method SW6010B (sodium, potassium, calcium, and magnesium)
- Soluble anions by USEPA Method E300/SW9056 (chloride, sulfate, nitrate, carbonate, and bicarbonate)
- TDS by USEPA Method SM2540C (analysis to be prepared on water extracted prepared per method SW9056)
- Metals by SW6020 USEPA Method (including arsenic, iron, and manganese)

Soil samples were collected for analysis from the deeper of the two boreholes at each borehole cluster.

3.2.5.3.2 Geotechnical Analysis

In addition to the collection of soil samples for chemical analyses, soil samples were also collected during the third mobilization for geotechnical analyses to support future remedial action analysis and design. The planned geotechnical tests conducted during the third mobilization were expanded to obtain data to support the Unit 4 Source Area In-Situ Bioremediation Treatability Study Bench-Scale work, as discussed in Section 3.3.3.1. The samples were collected using a thin-walled Shelby Tube Sampler, as described in the "Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes" (ASTM D 1587). This sampler consists of a two-foot long thin-walled tube with a cutting edge at the toe. A sampler head attaches the Shelby tube to the center drill rod and contains a check valve and pressure vents. Soil samples collected in this manner are considered undisturbed and representative of in-situ conditions. The sampling procedure for the collection of Shelby tube samples was performed in accordance with the ASTM D 1587 standard.

Table 3 summarizes the Shelby tube samples that were collected from the following monitoring well locations and depths:

Table 3 Shelby Tube Sampling

Well ID	Sample Intervals (feet bgs)
M-248	48, 58, 68, 78, 88, 98, 108, 118, 128, 138, 148
M-249	108

Well ID	Sample Intervals (feet bgs)
M-250	48, 58, 68, 78, 88, 98, 109, 118, 128, 138, 148
M-251	88
M-252	48, 58, 68, 78, 98, 108, 130, 140
M-254	48, 58, 68, 78, 88, 98, 110, 130, 138, 148
M-256	78, 98
M-257	48, 58, 68, 88, 108, 119, 128, 138, 148
M-258	48, 58, 68, 78, 88, 98, 118, 128, 138, 148

The Shelby tube samples from monitoring well locations M-248, M-249, M-250, M-251, M-252, M-254, M-256, M-257 and M-258 were submitted to Geotechnical & Environmental Services, Inc. (GES), a geotechnical laboratory, for analysis of total porosity, TOC (Method SM 5310B), and effective porosity. Shelby tubes from monitoring well locations M-251, and M-252 were also analyzed for moisture content (ASTM Method D2216), dry bulk density (ASTM Method D2937), specific gravity (ASTM Method D854), intrinsic permeability (API Method RP40), pH (USEPA Method 9045), TOC (Walkley-Black Method), fraction organic carbon (Walkley-Black Method), and grain size distribution (ASTM Method D422).

Pending transport to GES, Shelby tubes were stored in a climate-controlled office trailer in a storage rack designed to keep the tubes stable and upright. The Shelby tubes were transported to GES in a storage rack mounted to the bed of a pick-up truck and were kept upright.

3.2.5.3.3 Well Development

Following well construction, the monitoring wells were developed to remove sediment produced during well construction. A description of well development procedures is provided below.

Second Mobilization Monitoring Well

Monitoring well MW-241 was installed and developed during the second field mobilization. Primary development was performed by the drilling contractor no sooner than 24 hours after well construction was completed and consisted of using a surge block and bailer to swab and surge the filter pack and remove sediment from the well. The full length of each screen was swabbed by adjusting the depth of the foot valve and surge block. A bailer was periodically used to recover sediments generated by development. Following completion of primary development by the drilling contractor, Tetra Tech completed the secondary development by pumping the well with a submersible pump to remove fine-grained sediment from the well.

Third Mobilization Monitoring Wells

Due to the low yield, well development of groundwater monitoring wells installed during the third mobilization was performed by Tetra Tech. Well development commenced no sooner than 24 hours after well construction was completed and consisted of using a surge block and pump to swab and surge the filter pack and remove sediment from the well. The surge block was operated by a Waterra pump, which developed the wells through simultaneous pumping and surging. Development began with the installation of dedicated tubing with foot valves in each of the monitoring wells. Primary development consisted of swabbing the vertical length of the screened zone with a surge block attached to the dedicated tubing. The full length of each screen was swabbed by adjusting the depth of the foot valve and surge block. Secondary development consisted of continuing to pump each well with the Waterra pump to remove fine-grained sediment from the well. The surge block was removed from the dedicated tubing during secondary well development.

Well development for wells installed during both mobilizations was considered complete at each well when a minimum of ten casing volumes of water were removed from the well and the index parameters (consisting of pH, specific conductivity, turbidity, and temperature) were within 10 percent of each reading over three consecutive measurements. All index parameter readings were recorded by Tetra Tech on well development logs, which are provided in Appendix E. All solids were transported to an onsite roll-off bin for characterization and off-site disposal. Development water was containerized, transported, and transferred to the GW-11 pond in coordination with the groundwater extraction and treatment system (GWETS) operator, Envirogen Technologies.

3.2.5.3.4 Monitoring Well Sampling

A total of 28 samples were collected from the permanent monitoring wells following well development. In accordance with Field Guidance Document No. 004 of the FSP, the monitoring wells were not sampled until the water level in each well recovered to at least 90 percent of the static water level. Groundwater sampling was conducted using low-flow purging and sampling techniques at flow rates between approximately 300 to 500 milliliters per minute to minimize drawdown and induce inflow of fresh groundwater. The discharge water passed through a flow-through cell field water analyzer for continuous monitoring of water quality parameters (temperature, pH, turbidity, specific conductivity, dissolved oxygen, and oxidation reduction potential) with the parameters recorded on the field sampling forms during purging. The field sampling forms are included in Appendix E. Purging was considered complete and the well was sampled when the field parameter readings and water level stabilized.

In accordance with the Work Plan (Tetra Tech, 2015), Monitoring well M-241, completed during the second mobilization, was first sampled on January 3, 2017, and samples were analyzed for the following:

- Perchlorate by USEPA Method 314.0
- Hexavalent chromium by USEPA Method 7199
- Total chromium by USEPA Method 200.7
- TDS analysis by Method SM2540C
- Nitrate by USEPA Method 300.0
- Sulfate by USEPA Method 300.0
- Chlorate by USEPA Method 300.1

In accordance with the Work Plan (Tetra Tech, 2015), all of the monitoring wells installed during the second and third mobilizations were sampled in November 2017. Collected groundwater samples were analyzed for the following:

- Perchlorate by USEPA Method 314.0
- Hexavalent chromium by USEPA Method 7199
- Total chromium by USEPA Method 200.7
- TDS analysis by Method SM2540C
- Nitrate by USEPA Method 300.0
- Sulfate by USEPA Method 300.0
- Chlorate by USEPA Method 300.1
- Niobium, palladium, antimony, arsenic, selenium, thallium by USEPA Method 6020A
- Dissolved metals by USEPA Method 6010B and mercury by USEPA Method 7470A

- Thorium by USEPA Methods 903, 904, A-01-R and uranium by USEPA Method A-01-R and ASTM Method D5174
- Sulfur by USEPA Method 6020
- Ammonia by USEPA Method SM 4500 NH3 G and total phosphorous by USEPA Method 365.3
- Bromide, chloride, sulfate, nitrate, nitrite, and ortho-phosphate by USEPA 300
- Carbonate by USEPA Method SM 2320B
- VOCs by USEPA Method 8260B_LL
- 1,4-Dioxane and 1,2,3-trichloropropane by USEPA Method 8260B SIM
- Total petroleum hydrocarbons (TPH) gasoline, diesel, and oil by USEPA Method 8015B
- Dioxins by USEPA Method 8290
- PCBs by USEPA Method 1668A and USEPA Method 8082
- Dimethoate/Stirophos by USEPA Method 8141
- Formaldehyde by USEPA 8315A
- Polycyclic aromatic hydrocarbons (PAHs) by USEPA Method 8270C and, USEPA 8270C SIM
- Organo-pesticides by USEPA Method 8081A
- Phthalic acid USEPA 8270C

An expanded list of analyses for samples from monitoring wells installed within the Unit 4 basement (M-251-60, M-251-100, and M-252) was included to support the bench scale activities described in the Unit 4 Source Area In-Situ Bioremediation Treatability Study Bench-Scale Work Plan (Tetra Tech, 2017b) and for the development of the Unit 4 Source Area In-Situ Bioremediation Treatability Study Work Plan (Tetra Tech, 2018). This expanded list of analyses included the following:

- Chlorite by USEPA Method 300.1
- Dissolved methane by USEPA Method RSK175
- Volatile fatty acid by USEPA Method VFA-IC
- TOC by USEPA Method SM 5310B
- Sulfide by USEPA Method SM 4500-S2-D
- Total phosphorus by USEPA Method 365.3
- Total nitrogen by USEPA Method 351.2
- Hardness by Calcium/Magnesium Calculation Method by USEPA Method SM 2340B
- Total chromium, manganese by USEPA Method 6010B
- Alkalinity by USEPA Method SM 2320B
- Ferrous and ferric iron by USEPA Method SM 3500-Fe+3-D
- Chloride by USEPA Method 9056
- Dissolved metals by USEPA Method 6010

Additionally, samples collected at wells M-251-60, M-251-100, and M-252, were analyzed for phospholipid-derived fatty acids (PLFA) and Census-DNA analyses at Microbial Insights, Inc. Bulk soil and groundwater samples were collected from wells M-251-100 and M-253-100 for treatability studies to be conducted at the University of Nevada, Las Vegas (UNLV) in support of the Unit 4 Source Area In-Situ Bioremediation Treatability Study.

3.2.5.4 Sample Packaging and Transport

Following the collection of soil and groundwater samples, Tetra Tech geologists immediately packaged samples for transport to TestAmerica. Samples were collected in new laboratory-supplied containers. Containers were labeled, contained in airtight plastic bags, and immediately placed in an ice-filled cooler to maintain a sample temperature of 4° centigrade or less. Glass containers were also packaged in bubble wrap to provide additional protection during transport. Sample labels contained the following information:

- Site name and project number
- Sample identification number. The sample identification number for soil samples incorporated the borehole identification number and depth from which the sample was collected (e.g., U4U5-6-35' represents a sample collected from borehole U4U5-6 at a depth of 35 feet bgs).
- Date and time of sample collection. The time was recorded in 24-hour clock format to avoid ambiguity.
- Preservative, if any
- Name or initials of sampler
- Analyses requested

Chain-of-custody forms were handed to the TestAmerica courier during sample pickup or were stored in an airtight plastic bag in the cooler if shipped directly to the laboratory by Tetra Tech. Shipped coolers adhered to the requirements outlined in the FSP and Department of Transportation (DOT) requirements.

Due to the short hold times associated with hexavalent chromium water samples, Tetra Tech scheduled up to two laboratory courier pickups per day. The first pickup was scheduled at 12:00 pm and included transport of hexavalent chromium water samples collected that morning for same day air freight to the laboratory for analysis. The second pickup was scheduled for approximately 4:00 pm and included all remaining samples collected that day. Drilling activities were allowed to continue beyond the second pickup, up to the point of groundwater sample collection. Given the short hold time associated with hexavalent chromium samples, groundwater samples were not collected after the second pickup of the day.

Shelby tube geotechnical samples were stored upright in a wooden frame in an air-conditioned trailer pending transport to the laboratory. The tubes were transported and delivered directly to the GES laboratory located in Las Vegas.

3.2.6 Quality Assurance/Quality Control Sample Collection

Tetra Tech collected field quality assurance/quality control samples in accordance with the FSP as follows:

- Equipment Blanks
  - Obtained by filling decontaminated sampling equipment with reagent-grade deionized (DI) water and sampling the rinsate water.
  - Collected at a frequency of one in every 20 samples.
  - 91 equipment blanks were collected.
- Field Blanks
  - Obtained by filling a clean sampling container with reagent-grade DI water, in the field at a sample location.
  - Collected at a frequency of one in every 20 samples.
  - 91 field blanks were collected.
- Trip Blanks
  - Prepared by the analytical laboratory by filling volatile organic analysis vial with reagent-grade DI water and adding to the cooler as soon as the first sample is collected.

  - Collected at a frequency of one for every cooler containing VOC samples.
  - 195 trip blanks were collected.
- Field Duplicates
  - Collected sample was labeled and packaged in the same manner as the primary samples, but with "FD" appended to the sample identification, which is consistent with the FSP approved by NDEP.
  - Collected at a frequency of one in every 10 samples.
  - 178 duplicate samples were collected.
- Matrix Spike/Matrix Spike Duplicates (MS/MSD)
  - A double sample volume of field samples was collected for samples to be used for MS/MSD.
  - Collected at a frequency of one in every 20 samples.
  - 92 MS/MSD samples were collected.

3.2.7 Aquifer Testing

Following the completion of well development, Tetra Tech performed a series of aquifer tests to quantify the hydraulic parameters laterally and vertically in the UMCf within the Investigation Area. This section of the Report provides a description of the aquifer test implementation and analysis methodology.

3.2.7.1 Slug Test Methods

Slug tests were conducted by Tetra Tech at the following ten monitoring wells M-251-60, M-251-100, M-252, M-253-60, M-253-100, M-254, M-255-60, M-255-100, M-256-60, and M-256-100 between November 21, 2017, and November 29, 2017. Slug tests were conducted in accordance with Field Guidance Document No. 011 – Aquifer Hydraulic Testing (ENVIRON, 2014c) dated January 24, 2014.

Each test consisted of a falling-head (e.g., slug in) portion and rising-head (e.g., slug-out) portion of the test using a solid cylinder mass (i.e., slug) to displace water within the well. Prior to testing, the depth to water in each well was manually measured to establish a static groundwater level, followed by the placement of a pressure transducer in the well below the anticipated submerged depth of the slug, to measure hydraulic displacement at a high measurement frequency during the slug tests.

The slug tests were conducted by dropping the slug into the water column, causing the water to displace upward creating a rise in hydraulic head followed by the water level dropping to static conditions. The slug was then rapidly removed after equilibrium of the water level, causing the hydraulic head to fall and then equilibrate back to static conditions. Water level displacement and elapsed time were recorded by Tetra Tech staff until water level equilibrium had been reached. Manual depth-to-water measurements were recorded to confirm pressure transducer data during testing activities. A barometric transducer was also utilized to measure barometric pressure required to correct for atmospheric pressure.

Field data were recorded on field logs for each slug test. At the end of each test, groundwater level data were downloaded from the pressure transducer to a field laptop computer, reviewed for data quality completeness, and saved for data analysis.

Transmissivity and hydraulic conductivities of each test were calculated by mathematical solution developed by Bouwer and Rice for determining hydraulic conductivity of an unconfined aquifer from an overdamped slug test (Bouwer and Rice, 1976). Analysis involves matching a straight line to water-level displacement data collected overtime. This solution was applied using AQTESOLV (HydroSolve, 2007), a commercially available industry standard software commonly used for aquifer test analysis. The results of the analysis are provided in Section 4.6.1.

3.2.7.2 Specific Capacity Methods

Specific capacity tests were conducted by Tetra Tech on wells M-251-60, M-251-100, and M-252 between December 6, 2017 and December 13, 2017. The specific capacity testing consists of low-flow pumping of the wells to determine the flow rate and drawdown. Specific Capacity Tests were conducted in accordance with Field Guidance Document No. 011 – Aquifer Hydraulic Testing (ENVIRON, 2014d) dated January 24, 2014. Specific capacity tests were implemented to corroborate hydraulic parameters determined by the slug tests. Specific capacity is then calculated by dividing the pumping flow rate by the total drawdown.

Prior to testing, depth to water measurements were manually collected at each well to establish a baseline (static) groundwater level. Following the collection of depth to water measurements, a downhole pneumatic pump and pressure transducer were installed in the test well such that the intake of the pump would be below the anticipated drawdown and the transducer is positioned above the pump. After allowing groundwater to equilibrate back to static water level, each well was pumped and adjusted to a sustainable flow rate that would not dewater the well (e.g., <1 liter per minute). At the completion of the pumping period, the pump was shut off and recovery data recorded by manual depth to water measurement to confirm pressured transducer data. A barometric transducer was also utilized to measure barometric pressure required to correct for atmospheric pressure. Wastewater generated during the tests was containerized and transported to the GW-11 pond.

Start and stop times, pump rates, and pump rate adjustment times were recorded on field logs for each test. At the end of each test, groundwater level data were downloaded from the pressure transducer to a field laptop computer, reviewed for data quality completeness, and saved for hydraulic conductivity analysis.

Transmissivity and hydraulic conductivities of each test were calculated by using a mathematical solution initially developed by Charles V. Theis (Theis, 1935) and further refined by Mahdi S. Hantush (Hantush, 1961) which determines the hydraulic properties of non-leaky confined aquifers. Analysis with this method is performed by matching the Theis type curve to drawdown data plotted as a function of time on double logarithmic axes. The Theis-Hantush solution was applied to the specific capacity data collected using AQTESOLV (HydroSolve, 2007). The results of these analyses are provided in Section 4.6.2.

3.2.8 Investigation-Derived Waste Management

IDW included soil cuttings, asphalt and concrete cores, temporary well casings and well screens, PPE, equipment decontamination water, plastic sheeting, and disposable bailers. Additionally, IDW consisted of groundwater generated during discrete-depth groundwater sampling, monitoring well development, well purging and sampling, and specific capacity aquifer testing. All IDW was contained, labeled, and stored in United States DOT-approved containers. Solid waste materials were stored separately from liquid waste materials.

Soil was containerized onsite in plastic lined 20-cubic yard roll-off bins; asphalt and concrete cores were contained within two 55-gallon steel drums. Cuttings generated during the hydro-vacuum utility clearance that contained high volumes of liquid were placed in the plastic lined 20-cubic yard roll-off bins. Once the sediment was allowed to settle, the liquid was vacuumed from the surface and disposed of as liquid IDW.

The IDW containers were labeled to indicate contents, source, and date when accumulation began. All containers used to hold drilling-derived waste were secured at the drill site by closing and securing the lids. Solid materials, such as the used plastic sheeting, temporary well casings, and well screens were placed in separate 20-cubic yard roll-off bins. PPE and refuse generated during the drilling activities were containerized and disposed as solid waste in a licensed municipal landfill.

Soil cuttings contained in each of the roll-off bins were sampled for profiling purposes. One composite soil sample was collected from each roll-off bin. The samples were analyzed for the following analyses:

- VOCs by USEPA Method 8260B
- Semi-volatile organic compounds by USEPA Method 8270C

- Organochlorine pesticides by USEPA Method 8081A
- PCBs by USEPA Method 8082
- Resource Conservation and Recovery Act (RCRA) 8 Metals by USEPA Method 6010/6020
- Flashpoint ignitability by USEPA Method SW846 7.12
- pH by USEPA Method 9045D
- Asbestos by USEPA Method 800/R-93-116
- Perchlorate by USEPA Method 314.0
- Toxicity characteristic leaching procedure (TCLP) - Metals by USEPA Method by USEPA Method 1311 extraction/ USEPA Method 6010/6020
- TCLP - VOCs by USEPA Method 8260B
- Dioxins / Furans by USEPA Method 8290

The soil, asphalt, and concrete cores were determined to be non-hazardous waste and were subsequently disposed of at a non-hazardous waste facility. One roll-off bin from the first mobilization was disposed of at Las Vegas Paving Corporation. All remaining waste from the second and third mobilizations was disposed of at Apex Landfill, Las Vegas, Nevada. Plastic PVC (well casing material used for temporary wells) was steam cleaned onsite and disposed of at a municipal landfill. All remaining PVC not steam cleaned was disposed of at Apex landfill. Liquid IDW was transported from the Investigation Area and discharged to the GW-11 pond for onsite treatment in the GWETS.

3.3 FIELD VARIANCES

This section of the Report presents a summary of variances to the Unit 4 and 5 Buildings Investigation Work Plan and scope of work for each of the three mobilizations.

3.3.1 First Mobilization

A description of the variances to the Unit 4 and 5 Buildings Investigation Work Plan and scope of work for the first mobilization was presented in the First Mobilization Tech Memo and summarized below.

Shallow Soil Sampling

In an email from NDEP dated April 9, 2015, NDEP requested a conference call to discuss a few remaining questions/comments pertaining to the Work Plan. A conference call was scheduled for April 10, 2015 to discuss NDEP's remaining comments. One of the items discussed was NDEP's request to analyze for a broader list of analytes than proposed in the Work Plan. Specifically, NDEP requested the analysis of selected soil samples for asbestos, dioxins/furans, PCBs, and radionuclides. The discussion resulted in an expansion to the list of analytes presented in the Work Plan.

The additional soil sampling and analysis plan consisted of the collection of selected soil samples from the four soil boreholes advanced during the first mobilization to be analyzed for the following additional analyses:

- Asbestos by USEPA Method 600/R-93-116 and 600/M4-82-020
- Dioxins/furans by USEPA Method 8290
- PCBs by USEPA Method 8082
- Radionuclides by USEPA Method 9315, 9320, and US Department of Energy Method A-01-R

Tetra Tech planned to collect a total of 16 soil samples for the list of additional/supplemental analysis, which would have included four soil samples from each borehole at depths of 1, 2.5, 5, and 7.5 feet bgs. However, less than the planned number of samples were collected due to insufficient soil recovery from the slide hammer sampling tool. The following planned soil samples for the additional/supplemental analyses could not be collected:

- U4U5-1 – 7.5 feet bgs
- U4U5-3 – 1 foot bgs and 7.5 feet bgs
- U4U5-4 – 7.5 feet bgs

A total of 13 soil samples were analyzed for asbestos, dioxin/furans, PCBs, and radionuclides.

Soil Sampling During Drilling Activities

As described in the Work Plan, soil samples were planned for collection at 2.5-foot intervals in the vadose zone. Although every attempt possible was made to achieve this, there were some cases where this was not possible. A summary of the variances to the soil sampling plan presented in the Work Plan is outlined below:

- U4U5-1 – The soil samples collected at the 22.5 feet bgs interval for perchlorate, ammonia, hexavalent chromium, and chromium were lost in transit to the laboratory following sample delivery to the laboratory courier.
- U4U5-2 – Due to insufficient soil recovery at the 10 feet bgs interval, the prescribed soil sample from the 10-foot bgs was collected at 11 feet bgs.
- U4U5-3 – Due to insufficient soil recovery at a depth of 1-foot bgs, a soil sample could not be collected. Sampling continued at the next sample interval at 2.5 feet bgs.
- U4U5-4 – Due to insufficient soil recovery at 27.5 feet bgs, a soil sample could not be collected.

3.3.2 Second Mobilization

A description of the variances to the Unit 4 and 5 Buildings Investigation Work Plan and scope of work for the second mobilization presented in the First Mobilization Tech Memo is provided below.

3.3.2.1 Boreholes Based on Cracks, Sumps, and Trenches

As described in the Work Plan, in addition to the planned boreholes to be advanced along five transects during the second mobilization, additional boreholes would be placed in areas that were identified as potential conduits for contaminant migration to the subsurface, including cracks, sumps, and trenches. The following potential conduits were identified prior to the second mobilization:

- Five trenches aligned north to south in the Unit 4 basement were connected to a sump structure along the southwest corner of the basement. The surface of the easternmost trench was very rough and appeared to have been hand dug into the concrete; by contrast, the other trenches appeared to have been part of the basement floor form when it was poured.
    - Three boreholes were advanced through each of the five trenches, for a total of fifteen boreholes: U4U5-21, U4U5-22, U4U5-23, U4U5-24, U4U5-29, U4U5-30, U4U5-31, U4U5-32, U4U5-38, U4U5-39, U4U5-40, U4U5-41, U4U5-60, U4U5-61, and U4U5-62 (Figure 4).
        - Boreholes U4U5-21, U4U5-22, U4U5-23, U4U5-24, U4U5-29, U4U5-30, U4U5-31, U4U5-32, U4U5-38, U4U5-39, U4U5-40, and U4U5-41 were part of the originally proposed transects and were moved slightly to target the trenches, while boreholes U4U5-60, U4U5-61, and U4U5-62 were added to target the easternmost north-south trench.
- Four sumps were identified on the southwest and southeast corners of the Unit 4 basement floor. The sumps located closest to the east and west walls of the basement were reported by the Tenant to be part of a ventilation system and extended underneath the Unit 4 chlorinator building. Conductor casings were installed in the sumps and cemented in place as the sumps were filled with concrete. Drilling equipment was then advanced through the conductor casing into the subsurface. Eight boreholes were advanced

through or adjacent to the sumps (U4U5-45, U4U5-46, U4U5-47, U4U5-55, U4U5-56, U4U5-57, U4U5-58, and U4U5-59).

The locations of the boreholes advanced are shown on Figure 4.

3.3.2.2 Monitoring Well Installation

Following discussions with the Trust and NDEP, Tetra Tech recommended the installation of one permanent monitoring well during the second mobilization to provide comparison data to the discrete-depth groundwater sample from the temporary well. The monitoring well was designed to mirror the screened interval of the temporary well installed at 150 feet bgs in borehole U4U5-9. Following guidance from Ramboll Environ, the monitoring well installed at borehole U4U5-9 was designated M-241.

3.3.2.3 Borehole Depth Variations

The First Mobilization Technical Memorandum included recommendations to increase the depth of three of the second mobilization boreholes from 90 to 115 feet bgs. However, after subsequent discussions with the Trust and NDEP, it was determined that the depth of the boreholes would be increased to 150 feet bgs, with groundwater samples collected at approximately 50, 70, 90, 110, 130, and 150 feet bgs, soil samples collected at 10-foot intervals from below the water table to the total depth of the boring, and four boreholes would be advanced instead of three. The telescoping drilling and grouting approach, approved by the Trust and NDEP, was used to advance the 150-foot boreholes to minimize potential carry down of contaminants to zones below the Shallow WBZ.

The four boreholes that were increased in depth were U4U5-5, U4U5-9, U4U5-16, and U4U5-31 which provided samples crossgradient of the Unit 4 building, downgradient of the Unit 4 building, downgradient of the Unit 5 building, and directly below the center of the Unit 4 basement building, respectively.

3.3.2.4 Step-Out and Step-Down Boreholes

Tetra Tech, the Trust, NDEP, and USEPA met on October 12, 2016 to review data collected to date and discuss placement of step-out and step-down boreholes. At the time of the meeting, analytical results from 46 boreholes were available for review. To illustrate data collected to date, Tetra Tech prepared a series of three-dimensional visualizations to illustrate the distribution of perchlorate and hexavalent chromium in soil and groundwater. Additionally, an uncertainty analysis was presented, which illustrated areas where data uncertainty was greatest. The uncertainty analysis is a statistical calculation that was completed using an early version of the Earth Volumetric Studio (EVS) software called Environmental Visualization System. The data uncertainty analysis illustrated areas of data gaps to be filled for step-out boreholes as described in the Work Plan.

The statistical analysis revealed greater uncertainty in the upper 90 feet south of the Unit 4 and Unit 5 buildings and east of the Unit 5 building. Perchlorate and hexavalent chromium distribution uncertainty was also identified within the footprint of the Unit 5 building. Additionally, the analytical results of groundwater samples collected from the 150-foot boreholes indicated that perchlorate and hexavalent chromium concentrations were greatest in samples collected at 110-feet bgs.

During the October meeting, Tetra Tech recommended advancing additional boreholes as part of the second mobilization activities to provide further vertical and lateral characterization. In addition, NDEP requested that one boring be advanced to a depth of 250 feet. The agreed upon recommendations/requests are summarized below.

90-Foot Step-Out Boreholes

- Advance four step-out boreholes to 90 feet bgs (U4U5-67, U4U5-69, U4U5-71, and U4U5-73). The locations of these boreholes were positioned to address areas of greater lateral uncertainty identified by the EVS uncertainty analysis.

- Collect soil samples from these step-out boreholes at 2.5-foot intervals from ground surface to the water table and at 10-foot intervals below the water table to total depth.
- Collect discrete-depth groundwater samples from temporary wells within each step-out borehole at approximately 50, 70, and 90 feet bgs.

150-Foot Step-Down Boreholes

- Advance six step-down boreholes to a depth of 150 feet bgs (U4U5-64, U4U5-65, U4U5-66, U4U5-68, U4U5-70, and U4U5-72). These boreholes were positioned to increase vertical resolution of COPC distribution below 90 feet bgs. Boreholes U4U5-68, U4U5-70, and U4U5-72 were also positioned to address areas of greater lateral uncertainty identified by the EVS uncertainty analysis within the upper 90-foot zone.
- Collect soil samples at 2.5-foot intervals from ground surface to the water table from three of the step-down boreholes (U4U5-68, U4U5-70, and U4U5-72). Sample collection from above the water table from boreholes U4U5-64, U4U5-65, and U4U5-66 was not recommended because sufficient soil data were already collected from the vadose zone within the Unit 4 basement.
- Collect soil samples at 10-foot intervals below the water table to total depth from all six step-down boreholes (U4U5-64, U4U5-65, U4U5-66, U4U5-68, U4U5-70, and U4U5-72).
- Collect discrete-depth groundwater samples from temporary wells within each step-down borehole at general targeted depths of 50, 70, 90, 110, 130, and 150 feet bgs.
- Utilize telescoping sonic casing to advance the 150-foot step-down boreholes. The telescoping casing approach consisted of advancing 10-inch casing to a depth of 90 feet bgs, 9-inch casing to 110 feet bgs, 7-inch casing to 130 feet bgs, and 6-inch casing to 150 feet bgs.
- Install bentonite or cement/bentonite seals at 90, 110, and 130 feet bgs, and perform hydraulic competency tests to ensure a competent seal is in place prior to advancing the casing to the subsequent groundwater sampling interval.

250-Foot Extended Step-Down Borehole

- Advance one borehole to a depth of 250 feet bgs (U4U5-63). This borehole was designed to collect characterization data below a depth of 150 feet bgs. This borehole was advanced below the greatest perchlorate and hexavalent chromium concentrations observed at that point of the investigation.
- Collect soil samples from borehole U4U5-63 at 10-foot intervals below the water table. Soil sample collection from above the water table was not recommended because sufficient soil data were already collected from the vadose zone within the Unit 4 basement.
- Collect groundwater samples from temporary wells at general targeted depths of 50, 70, 90, 110, 130, 150, 200, and 250 feet bgs.
- Utilize telescoping sonic casing to advance the extended step-down borehole to a depth of 250 feet bgs. The telescoping casing approach for this borehole consisted of 10-inch casing to a depth of 90 feet bgs, 9-inch casing to 150 feet bgs, 7-inch casing to 200 feet bgs, and 6-inch casing to 250 feet bgs.
- Install bentonite or cement/bentonite seals at 90, 150, and 200 feet bgs and perform hydraulic competency tests to ensure a competent seal is in place prior to advancing the casing to the subsequent groundwater sampling interval.

3.3.2.5 Additional Analytical Testing

In November 2016, NERT approved expanding the analytical suite to support future remedial action analysis. All soil samples collected at 10-foot intervals and all groundwater samples (collected after the approval date) were analyzed for the following additional analyses:

- Nitrate and Sulfate by USEPA Method 300.0

- Chlorate by USEPA Method 300.1

3.3.2.6 Sample Collection Variances

As described in the Work Plan, soil samples were to be collected at 2.5-foot intervals in the vadose zone. Although every attempt was made to achieve this goal, there were some cases where this was not possible due to a lack of soil recovery from the borehole. These intervals are noted in the lithology logs provided in Appendix C.

As described in Section 3.2.5.1, soil samples were to be collected for the full suite of analyses at 10-foot intervals below the water table in step-out boreholes U4U5-67, U4U5-69, and U4U5-71. However, due to a chain-of-custody error, only nitrate, sulfate, and chlorate analyses were requested for the samples collected below the water table from these boreholes.

VOCs samples were collected but not analyzed from the temporary well installed at 50 feet bgs in borehole U4U5-26. Although the glass vials containing the sample were delivered to the laboratory, the vials were stored in a freezer and discovered broken the following day. There was no additional preserved sample available to complete the VOC analysis.

3.3.3 Third Mobilization

A description of the scope of work for the third mobilization was presented in the Second Mobilization Technical Memorandum (Tetra Tech, 2017) and is provided below.

3.3.3.1 Additional Analytical Testing

An expanded list of analyses for samples from monitoring wells installed within the Unit 4 basement (M-251-60, M-251-100, and M-252) was included to support the bench scale activities described in the Unit 4 Source Area In-Situ Bioremediation Treatability Study Bench-Scale Work Plan (Tetra Tech, 2017b) and for the development of the Unit 4 Source Area In-Situ Bioremediation Treatability Study Work Plan (Tetra Tech, 2018a). This expanded list of analyses included the following:

Geotechnical samples collected from well locations M-251/M-252 were also analyzed for the following, in addition to the planned analyses described in Section 3.2.5.3.2:

- ASTM D2216 Moisture Content
- ASTM D2937 Dry Bulk Density
- ASTM D854 Specific Gravity
- API RP40 Intrinsic Permeability
- EPA 9045 Soil pH
- Walkley-Black TOC
- Walkley-Black Fraction Organic Carbon
- ASTM D422 (sieve and hydrometer method) Grain Size Distribution

Soil samples collected from well locations M-251-60/M-251-100/M-252 were also analyzed for the following, in addition to the planned analyses described in Section 3.2.5.3.1:

- TOC by USEPA Method 9060
- pH by USEPA Method SW9045
- Sodium, potassium, calcium, and magnesium by USEPA Method SW6010B (soluble cation)
- Chloride, sulfate, and nitrate by USEPA Method E300/SW9056 (soluble anion)
- Carbonate and bicarbonate by USEPA Method E2320B (soluble anion)

- TDS by USEPA Method SM2540C (analysis to be prepared on water extracted and prepared per method SW9056)
- Metals by SW6020 USEPA Method (including arsenic, iron, manganese)

Groundwater samples collected from well locations M-251-60/M-251-100/M-252 were also analyzed for the following, in addition to the planned analyses described in Section 3.2.5.3.4:

- Chlorite by USEPA Method 300.1
- Dissolved methane by USEPA Method RSK175
- Volatile fatty acids by USEPA Method VFA-IC
- TOC by USEPA Method SM 5310B
- Sulfide by USEPA Method SM4500-S2-D
- Total phosphorus by USEPA Method 365.3
- Total nitrogen by USEPA Method 351.2
- Hardness by Calcium/Magnesium Calculation Method by USEPA Method SM 2340B
- Total chromium and manganese by USEPA Method 6010B
- Hexavalent chromium by USEPA Method 7199
- TDS by USEPA Method SM 2540C
- Alkalinity by USEPA Method SM 2320B
- Ferrous and ferric iron by USEPA Method SM 3500-Fe+3-D
- Nitrate and sulfate by USEPA Method 300.0
- Chloride by USEPA Method 9056
- Niobium, palladium, antimony, arsenic, selenium, thallium by USEPA Method 6020A
- Dissolved metals by USEPA Method 6010
- Microbial analysis by Microbial Insights

Tetra Tech collected bulk soil and groundwater samples for bench scale testing to be conducted by UNLV. A total of five sets of two 2-gallon samples consisting of soil composited from 10-foot sections of representative core were obtained from 72-112 feet below the Unit 4 basement floor.

Tetra Tech also collected two five-gallon plastic containers of water from monitoring wells M-253-100 and M-251-100. These containers were provided to UNLV for testing. The results of the additional analytical testing are provided in Appendix F of this Report and will be discussed separately in the Unit 4 Source Area In-Situ Bioremediation Treatability Study Report.

3.3.3.2 Sample Collection Variances

Tetra Tech planned to collect soil samples at 10-foot intervals below the water table to total depth at each of the permanent monitoring well boreholes. However, there was insufficient soil recovery for analytical sampling purposes between 53 to 103 feet bgs from well M-258.

4.0 RESULTS

This section of the Report provides a summary of the results of the investigation including lithology encountered, soil analytical results, discrete-depth groundwater analytical results, groundwater monitoring well analytical results, aquifer test results, and distribution of COPCs within the Investigation Area. Data generated during the investigation have also been evaluated through the development and application of 3DVA. The 3DVA framework plots of the distribution of perchlorate, hexavalent chromium, total chromium, chloroform, chlorate, and nitrate in soil and groundwater and TDS in groundwater are provided in Appendix H. The overall extent of contamination and associated human health risk for any constituent detected during the Unit 4 and 5 Buildings Investigation will be presented in the OU-1 and OU-2 RI Report and the subsequent Baseline Health Risk Assessments.

Three-dimensional visualizations of the distribution of perchlorate, hexavalent chromium, chloroform, chlorate, nitrate, and TDS are discussed in following sections. For reference, the lithologic contacts between the Qal and UMCf are included in the visualizations to show the relationship between lithology and the distribution of perchlorate, hexavalent chromium, chloroform, chlorate, nitrate, and TDS. The contact planes portrayed on the figures are based on the lithology encountered during the investigation.

4.1 LITHOLOGY ENCOUNTERED

The lithology encountered during the investigation consists of interlayered clay, silt, sand, and gravel of varying thicknesses, which is characteristic of Qal and UMCf deposits described in previous investigations. The Qal deposits consist primarily of sand and silty sand that transition into interbedded sandy silt and silt at the top of the UMCf. The UMCf underlies the alluvium within the Investigation Area and consists of interbedded coarse-grained and fine-grained sediments.

The contact between the base of the sandy alluvium and top of the UMCf in the Investigation Area is encountered at a depth of approximately 35 feet bgs. The first silty fine-grained facies of the uppermost first fine-grained sediment layer of the UMCf (UMCf-fg1), is encountered under the coarser sandy silt at a depth of approximately 75 feet bgs. The transition to the UMCf-fg1 is identified by predominately fine-grained materials, including silt, sandy silt, and clayey silt. Intervals of predominantly coarse-grained water-bearing sand and gravel and intervals of predominantly fine-grained silt and/or clay units were identified throughout the boreholes. A lithologic log for each borehole advanced is provided in Appendix C. Cross-sections that depict the lithology encountered are provided as Figures 7 and 8.

4.2 SOIL SAMPLING RESULTS

The soil analytical results from all boreholes are tabulated in Appendix F. Although these analytes are included in the tables and figures, discussion of contaminant distribution is reserved for the primary COPCs, perchlorate and hexavalent chromium, in Section 4.2.1. VOC samples collected from the interval that was cleared using hydro-vacuum utility clearance may be biased low due to potential disturbance of the interval by water, heat, and air flow from the hydrovac equipment, but a bias is not anticipated as the samples collected within the utility clearance interval showed little to no signs of disturbance. A summary of the COPCs detected above their respective NDEP LBCLs at a frequency greater than 10% is presented in ***Table 4*** and a summary of the soil concentration ranges of detected analytes is presented in ***Table 5***. For purposes of defining the COPCs that are present in this source area an exceedance frequency of 10% was selected. Any constituent present, but not detected above the LBCL greater than 10% of the time, is reported in Appendices F and G but not discussed in the report since the focus was to identify the constituents that pose the greatest threat to groundwater contamination at OU-1, OU-2, and OU-3. ***Table 4*** includes the NDEP LBCLs with dilution-attenuation factors (DAFs) of 1 and 20, as they are presented in the *User's Guide and Background Technical Document for the NDEP BCLs for Human Health for the BMI Complex and Common Areas* (NDEP, 2017). As described in the guidance document, "dilution-attenuation processes are physical, chemical, and biological processes that tend to reduce the eventual contaminant concentration at the receptor point". A DAF of 1 indicates that no dilution of COPC is anticipated between a sampling point and a receiving groundwater body, while a DAF of 20 indicates a 20-fold dilution over the same distance. DAFs are chosen based on site-specific factors and are presented here only as a comparison to the regulatory guidance documents. A summary of all soil COPC detections is provided in Appendix G.

Table 4 LBCL Exceedances

Analyte	LBCL (DAF 1)[a] mg/Kg	LBCL (DAF 20) mg/Kg	LBCL (DAF 1) Exceedances	LBCL (DAF 20) Exceedances	Total number of samples analyzed
Perchlorate	0.0155	0.31	1,469	1,251	1,510
Chlorate	1.03	20.6	307	183	411
Hexavalent Chromium	2	40	297	50	1,510
Nitrate (as N)	7	140	59	0	412
Chloroform	0.03	0.6	299	51	1,510
Iron	589	11,780	10	9	10
Manganese	52.2	1,044	62	4	62

Note:
DAF – dilution attenuation factor
LBCL – leaching-based basic comparison level
mg/Kg – milligrams per kilogram
[a] – The LBCLs are found in the table, "Nevada Division of Environmental Protection, Basic Comparison Levels" dated July 2017 with the exception of perchlorate, iron, and manganese which were re-calculated based on risk-based groundwater screening concentrations, in accordance with NDEP guidance.

Table 5 Concentration Range in Soil (mg/Kg)*

Analyte	Quaternary Alluvium (0-35 feet bgs)	Upper Muddy Creek formation (35-75 feet bgs)	Upper Muddy Creek formation (75-125 feet bgs)	Upper Muddy Creek formation (125-250 feet bgs)
Perchlorate	0.01 – 25,000	0.055 – 860	0.013 – 29,000	0.014 – 90
Chlorate	0.054 – 10,000	1.3 – 6,900	0.080 – 35,000	0.075 – 130
Total Chromium	0.13 – 760	2.1 – 200	14 – 170	23 – 110
Hexavalent Chromium	0.16 – 380	0.18 – 23	0.23 – 62	0.33 – 4.4
Nitrate (as N)	0.87 – 49	1.1 – 39	1.1 – 54	1.1 – 2.0
Chloroform	0.00083 – 1.0	0.0013 – 0.38	0.0011 – 5.8	0.0011 – 0.13
Iron	NS	14,000 – 21,000	10,000 – 20,000	18,000
Manganese	180 – 4,300	250 – 720	170 – 630	230 – 670

Note:
bgs – below ground surface
mg/Kg – milligrams per kilogram
NS – No samples collected
*Laboratory flags are not included on the summary table, but are provided in Appendix F.

In addition to the analytes summarized above, constituents with the following chemical classes were detected, but did not exceed their respective LBCLs at a frequency more than 10%: VOCs and metals. The distribution of these chemicals are summarized on the tables provided in Appendix F and Appendix G.

4.2.1 Contaminant Distribution

This section provides a general description of the vertical extent of contamination in soil within the Investigation Area. To be expected, the horizontal extent of contamination is more widespread than the Investigation Area and will be defined in the OU-1 and OU-2 RI Report. Although several constituents were detected above BCLs, this discussion will focus on the COPCs identified in the Work Plan that contribute to widespread soil contamination and those detected above their respective LBLC at a frequency greater than 10%. Section 4.5 provides a more thorough evaluation of the COPC plume configurations in soil under the Investigation Area. The soil analytical results from all Investigation Area boreholes are tabulated in Appendix F.

4.2.1.1 Perchlorate in Soil

Perchlorate is observed throughout the Investigation Area in both the Qal and UMCf (H-1 through H-5 in Appendix H). Perchlorate exceeded the LBCL throughout the Investigation Area in both the Qal and UMCf. In general, perchlorate concentrations exceeded the LBCL of 0.31 (mg/kg) (DAF 20) to a depth of up to 150 feet bgs and the LBCL of 0.0155 mg/kg (DAF 1) to a depth of up to 230 feet bgs. The perchlorate LBCL was calculated following the methodology of the 2017 NDEP LBCL calculation table using the risk-based groundwater screening level of 0.015 mg/L (NERT's RI groundwater screening level, the federal Interim Drinking Water Health Advisory, federal PRG).

4.2.1.2 Chlorate in Soil

Chlorate is observed throughout the Investigation Area in both the Qal and UMCf (Figures H-6 through H-10 in Appendix H). Chlorate exceeded the LBCL throughout the Investigation Area in both the Qal and UMCf. In general, chlorate concentrations exceeded the LBCL of 20.6 mg/kg (DAF 20) and 1.03 mg/kg (DAF 1) to a depth of up to 150 feet bgs.

4.2.1.3 Chromium in Soil

Chromium is observed throughout the Investigation Area in both the Qal and UMCf (Figures H-11 through H-15 in Appendix H). However, NDEP does not provide an LBCL for total chromium. A discussion of the distribution of hexavalent chromium in soil relative to the LBCL is provided in section 4.2.1.4.

4.2.1.4 Hexavalent Chromium in Soil

Hexavalent chromium is observed throughout the Investigation Area in both the Qal and UMCf (Figures H-16 through H-20 in Appendix H). Hexavalent chromium exceeded the LBCL throughout the Investigation Area in both the Qal and UMCf. In general, hexavalent chromium concentrations exceeded the LBCL of 40 mg/kg (DAF 20) to a depth of 113 feet bgs. Hexavalent chromium concentrations exceeded the LBCL of 2 mg/kg (DAF 1) to a depth of 115 feet bgs, with one additional exceedance at 130 feet bgs.

4.2.1.5 Nitrate in Soil

Nitrate is observed throughout the Investigation Area in both the Qal and UMCf (Figures H-21 through H-25 in Appendix H). Nitrate exceeded LBCL throughout the Investigation Area in both the Qal and UMCf. Nitrate concentrations did not exceed the LBCL of 140 mg/kg (DAF 20). Nitrate concentrations exceeded the LBCL of 7 mg/kg (DAF 1) to a depth of 123 feet bgs.

4.2.1.6 Chloroform in Soil

Chloroform is observed throughout the Investigation Area in both the Qal and UMCf (Figures H-26 through H-30 in Appendix H). Chloroform exceeded the LBCL throughout the Investigation Area in both the Qal and UMCf. In general, chloroform concentrations exceeded the LBCL of 0.6 mg/kg (DAF 20) to a depth of 113 feet bgs. Chloroform concentrations exceeded the LBCL of 0.03 mg/kg (DAF 1) to a depth of 130 feet bgs.

4.2.1.7 Iron in Soil

The collection of samples for iron analysis was limited to the borehole advanced for monitoring well M252, with the results to be used to support future remedial action analysis and design. Ten samples were collected between 53 and 135 feet bgs and analyzed for iron, all of which had detections above the LBCL of 589 mg/kg (DAF 1) and nine of which had detections above the LBCL of 11,780 mg/kg (DAF 20). The iron LBCL was calculated following the methodology of the 2017 NDEP LBCL calculation table using the 2017 risk-based groundwater iron BCL.

4.2.1.8 Manganese in Soil

The collection of samples for manganese analysis was limited to three boreholes (U4U5-73, U4U5-77, and M252) with the results to be used to support future remedial action analysis and design. Samples were collected from ground surface to 150 feet bgs, with most of the samples were collected from borehole U4U5-73 (37 samples). All of the samples had detections above the LBCL of 52.2 mg/kg (DAF 1), while only 4 had detections above the LBCL of 1,044 mg/kg (DAF 20). Those four samples were collected in the upper 15 feet of borehole U4U5-74. The manganese LBCL was calculated following the methodology of the 2017 NDEP LBCL calculation table using the 2017 risk-based groundwater manganese BCL.

4.3 GEOTECHNICAL SOIL TESTING RESULTS

As detailed in Section 3.2.5.3.2, a total of 63 soil samples were collected for grain size by sieve and Atterberg limits analyses from predefined depth intervals during the second and third mobilizations. Additionally, samples from pre-selected depth intervals during the third mobilization were analyzed for TOC, total porosity, and effective porosity. Sieve analysis was performed on 44 samples collected from the Qal, nine samples from the shallow UMCf (35 to 75 feet bgs), five samples from the middle UMCf (75 to 125 feet bgs), and two samples from the lower UMCf (125 to 250 feet bgs). Atterberg limits testing was conducted on 63 samples from the Qal, with five samples displaying plasticity; 45 samples from the shallow UMCf, with 30 samples displaying plasticity; 37 samples from the middle UMCf, with 32 samples displaying plasticity; and 26 samples from the lower UMCf, all of which displayed plasticity. Results for these analyses are provided as Appendix I and analyses are summarized below in ***Table 6***.

Table 6 Sieve Analysis and Atterberg Limits Summary

Geotechnical Parameter	Quaternary Alluvium (0-35 feet bgs)	Upper Muddy Creek Formation (35-75 feet bgs)	Upper Muddy Creek Formation (75-125 feet bgs)	Upper Muddy Creek Formation (125-250 feet bgs)
Course Gravel (%)	0 – 25.2	0 – 18.4	0 – 0	0
Fine Gravel (%)	0 – 35.5	0 – 17.3	0 – 15.1	0
Coarse Sand (%)	1.1 – 26.4	0.1 – 26.1	0 – 11	0

Geotechnical Parameter	Quaternary Alluvium (0-35 feet bgs)	Upper Muddy Creek Formation (35-75 feet bgs)	Upper Muddy Creek Formation (75-125 feet bgs)	Upper Muddy Creek Formation (125-250 feet bgs)
Medium Sand (%)	5.4 – 36.8	0.8 – 35.4	0 – 22.9	0
Fine Sand (%)	16.1 – 41	12.2 – 40.1	8 – 38	5 – 8
Fines (%)	5.6 – 63.8	5.8 – 67	19.3 – 92	92 – 95
Plastic Limit	30 – 55	24 – 50	25 – 49	26 – 56
Liquid Limit	46 – 69	27 – 104	50 – 150	38 – 110
Plasticity Index	11 – 25	0 – 77	25 – 83	11 – 63
Effective Porosity (%)	-	13.7 – 29.5	6.3 – 26.4	2.8 – 25.9
Porosity (%)	-	40.2 – 63.5	43 – 75.2	41.2 – 75.6
TOC	-	1.04 – 117	4.28 – 99.1	13 – 92.8

Note:
bgs – below ground surface

Results from laboratory geotechnical analyses were used to define soil classifications according to the USCS and are summarized in ***Table 7***. Soil classifications are grouped by depth, such that total count and percentage are based on the number of soil samples classified in a given depth within each column. A total of 49 soil samples were classified from the Qal (0-35 feet bgs), 35 samples were classified from the shallow UMCf (35-75 feet bgs), 34 soils were classified from the middle UMCf (75-125 feet bgs), and 26 soils were classified from the deep UMCf (125-250 feet bgs). Soil samples that were classified on the soil classification borderline, based on Atterberg limits results, were grouped with the more prevalent soil class observed in the given depth. One silt/elastic silt (ML/MH) soil was observed in the shallow UMCf and grouped with elastic silt (MH), one lean clay/fat clay (CL/CH) was observed in the middle UMCf and was grouped with fat clay (CH), one fat clay/elastic silt (CH/MH) was observed in the deep UMCf and grouped with MH, and one silt/lean clay (ML/CL) was observed in the deep UMCf and grouped with silt (ML).

Table 7 Soil Classification in Accordance with USCS

Soil Types	Quaternary Alluvium (0-35 feet bgs)	Upper Muddy Creek Formation (35-75 feet bgs)	Upper Muddy Creek Formation (75-125 feet bgs)	Upper Muddy Creek Formation (125-250 feet bgs)
CH (fat clay)	0	6 (17.1%)	18 (52.9%)	6 (23.1%)
CL (lean clay)	0	3 (8.6%)	0	0
MH (elastic silt)	4 (8.2%)	16 (45.7%)	14 (41.2%)	17 (65.4%)

Soil Types	Quaternary Alluvium (0-35 feet bgs)	Upper Muddy Creek Formation (35-75 feet bgs)	Upper Muddy Creek Formation (75-125 feet bgs)	Upper Muddy Creek Formation (125-250 feet bgs)
ML (silt)	3 (6.1%)	4 (11.4%)	1 (2.9%)	3 (11.5 %)
SM (silty sand)	24 (49.0%)	3 (8.6%)	1 (2.9%)	0
SP-SM (poorly graded sand/silty sand)	13 (26.5%)	1 (2.9%)	0	0
SW-SM (well graded sand/silty sand)	5 (10.2%)	2 (5.7%)	0	0
Note: bgs – below ground surface				

4.4 GROUNDWATER SAMPLING RESULTS

As detailed in Section 3.2.5, a total of 348 groundwater samples were collected from both permanently installed monitoring wells and from discrete-depth temporary groundwater monitoring wells. The results of the groundwater results obtained from permanent monitoring wells and discrete-depth groundwater sampling from temporary monitoring wells are presented below. For purposes of defining the COPCs that are present in this source area an exceedance frequency of 10% was selected. Any constituent present, but not detected above the LBCL greater than 10% of the time, is reported in Appendices F and G.

4.4.1 Permanent Monitoring Well Groundwater Results

The depth to groundwater was measured at all newly installed monitoring wells prior to sampling the wells. ***Table 8*** provides a summary of the depth to groundwater and groundwater elevation data collected.

Table 8 Groundwater Depth/Elevations

Well Identification	Depth to Groundwater (feet bgs)	Groundwater Elevation (feet above msl)
Shallow WBZ – Screen Completions (60-70 feet bgs)		
M-247-60	34.10	1779.12
M-249-60	39.60	1773.57
M-251-60	34.90	1773.47
M-253-60	35.91	1775.54
M-255-60	41.75	1771.04
M-256-60	40.99	1770.81
M-259-60	42.00	1770.27
Middle WBZ – Screen Completions (100-110 feet bgs)		
M-247-100	34.62	1778.64

Well Identification	Depth to Groundwater (feet bgs)	Groundwater Elevation (feet above msl)
M-249-100	40.30	1772.84
M-251-100	34.10	1774.14
M-253-100	35.76	1775.80
M-255-100	46.82	1765.68
M-256-100	41.65	1770.19
M-259-100	42.45	1769.81
Deep WBZ – Screen Completions (140-150 feet bgs)		
M-241	37.45	1774.92
M-248	32.46	1781.04
M-250	34.78	1778.13
M-252	40.18	1768.10
M-254	31.23	1780.63
M-257	47.62	1764.35
M-258	42.61	1769.98

Note:
bgs – below ground surface
msl – mean sea level

Groundwater elevations and potentiometric surface maps are provided in Figures 9, 10, and 11. Figure 9 illustrates the potentiometric surface for monitoring wells installed to approximately 70 feet bgs, showing that the groundwater flow direction is generally from the south to the north with a gradient of approximately 0.014 feet/foot. Figure 10 illustrates the potentiometric surface for monitoring wells installed to approximately 110 feet bgs, showing that the groundwater flow direction is generally from the south to the north with a gradient of approximately 0.018 feet/foot. Figure 11 illustrates the potentiometric surface for monitoring wells installed to approximately 150 feet bgs, showing that the groundwater flow direction is generally from the southwest to the northeast with a gradient of approximately 0.022 feet/foot. Discussion of the groundwater flow velocities are provided in Section 4.5.4.3.

Groundwater samples were collected from each monitoring well that was installed during the investigation, as described in Section 3.2.5.3.4. Following installation of the monitoring wells, the depth to groundwater stabilized between approximately 28 and 42 feet bgs. A discussion of the analytical results is provided in Section 4.4.3 and tabulated in Appendix F. A summary of the COPCs detected above their respective BCL at a frequency of more than 10% is presented in ***Table 9*** And a summary of the range of concentrations from the groundwater samples is presented in ***Table 10***.

Table 9 BCL Exceedances in Groundwater from Permanent Wells

Analyte	BCL (mg/L)	BCL Exceedances	Total number of samples analyzed
Chromium, Hexavalent	0.000134	28	28

Analyte	BCL (mg/L)	BCL Exceedances	Total number of samples analyzed
Perchlorate	0.015[a]	23	24
Chlorate	1	24	28
Chloroform	0.000219	20	24
Arsenic	0.01	20	28
1,2,3-Trichloropropane	0.00000224	14	24
Nitrogen, Ammonia (as N)	0.209	8	24
Magnesium	189	1	4
Formaldehyde	0.000432	4	24
Strontium	20	4	28
Nitrate (as N)	53.4	3	28
Thorium-228	0.14*	8	24
Thorium-230	0.05*	21	24

Note:
BCL – basic comparison level
mg/L – milligrams per liter
* - Thorium concentrations are presented in pCi/L
[a] - Federal Interim Drinking Water Health Advisory and federal Preliminary Remediation Goal

Table 10 Concentration Range in Groundwater from Permanent Wells (mg/L)*

Analyte	Shallow – Screen Completions (60-70 feet bgs)	Middle – Screen Completions (100-110 feet bgs)	Deep – Screen Completions (140-150 feet bgs)
Hexavalent Chromium	0.026 – 3.3	0.04 – 97	0.004 – 0.042
Total Chromium	0.057 – 2.3	0.037 – 97	0.013 – 0.042
Perchlorate	0.61 – 220	3.8 – 6,600	0.0086 – 8.8
Chlorate	5.6 – 540	13 – 32,000	ND (0.010) – 17
Chloroform	0.0024 – 0.13	0.00056 – 8.3	ND (0.00025) – 0.010
Arsenic	ND (0.010) – 0.13	ND (0.020) – 0.02	0.01 – 0.021
Phosphorus	ND (0.025) - 0.19	ND (0.025) – 0.14	ND (0.025) – 0.074
1,2,3-Trichloropropane	ND (0.0000025) – 0.0000031	ND (0.0000025) 0.00046	ND (0.0000025) – 0.000026
Nitrogen, Ammonia (as N)	0.18 – 0.50	ND (0.10) – 0.27	ND (0.10)
Aluminum	ND (0.050) – 1.4	ND (0.050) – ND (0.25)	ND (0.050) – 0.17
Magnesium	0.074 – 12.0	23.0 – 1,100	13.0 – 21.0
Formaldehyde	ND (0.0050)	ND (0.0050) – 2.0	ND (0.0050)
Strontium	0.49 – 3.5	0.90 – 72.0	0.94 – 1.3
Nitrate	0.31 – 2.6	1.6 – 58	0.44 – 1.7
TDS	1,600 – 3,000	710 – 50,000	550 – 620
Thorium-228[1]	0.0679 – 0.397	0.174 – 1.49	0.0259 – 0.159
Thorium-230[1]	0.127 – 0.349	0.167 – 1.84	0.0527 – 0.352

Note:
bgs – below ground surface
mg/L – milligrams per liter
ND – Not detected
*Laboratory flags are not included on the summary table, but are provided in Appendix F.
[1] Thorium concentrations are presented in pCi/L.

In addition to the analytes summarized above, additional VOCs were detected in groundwater but did not exceed their respective BCLs at a frequency greater than 10%. These VOCs are documented on the tables provided in Appendix F and the exceedances are summarized in Appendix G.

4.4.2 Discrete-depth Groundwater Results

Discrete-depth groundwater samples were collected from 77 boreholes that were not advanced for the installation of a permanent groundwater monitoring well, as described in Section 3.2.5.1.3. Groundwater was first encountered at depths between 30 and 47.5 feet bgs. Following installation of the temporary wells, depth to groundwater stabilized between approximately 37.5 and 43 feet bgs. The discrete-depth analytical results are tabulated in Appendix F. For purposes of discussion, this subsection presents the distribution of those constituents that were detected above their respective BCL at a frequency greater than 10%. Due to the use of a bailer to collect water samples (consistent with the NDEP-approved FSP) the results of VOC samples collected from temporary wells may be biased low. However, extreme care was taken not to significantly agitate groundwater during the sample collection process. A summary of the COPCs detected above their respective BCL at a frequency of more than 10% is presented in ***Table 11*** and a summary of the range of concentrations from the discrete-depth groundwater samples is presented in ***Table 12***.

Table 11 BCL Exceedances in Groundwater from Temporary Wells

Analyte	BCL mg/L	BCL Exceedances	Total number of samples analyzed
Perchlorate	0.015[a]	319	320
Hexavalent Chromium	0.000134	309	318
Chloroform	0.000219	306	318
Bromodichloromethane	0.000133	69	318
Chlorate	1	102	107
Manganese	0.801	2	6

Note:
BCL – basic comparison level
mg/L – milligrams per liter
[a] - Federal Interim Drinking Water Health Advisory and federal Preliminary Remediation Goal

Table 12 Concentration Range in Groundwater from Temporary Wells (mg/L)*

Analyte	Quaternary Alluvium (0-35 feet bgs)	Upper Muddy Creek Formation (35-75 feet bgs)	Upper Muddy Creek Formation (75-125 feet bgs)	Upper Muddy Creek Formation (125-250 feet bgs)
Perchlorate	2.7 – 2,900	0.92 – 3,500	1.4 – 6,700	0.057 – 570
Hexavalent Chromium	0.013 – 12.0	0.001 – 42.0	0.00028 – 110	0.00035 – 9.7
Total Chromium	0.078 – 12.0	0.012 – 38.0	0.013 – 110	0.032 – 8.9
Chloroform	0.0028 – 1.6	0.002 – 3.7	0.00097 – 7.8	0.00026 – 0.56

Analyte	Quaternary Alluvium (0-35 feet bgs)	Upper Muddy Creek Formation (35-75 feet bgs)	Upper Muddy Creek Formation (75-125 feet bgs)	Upper Muddy Creek Formation (125-250 feet bgs)
Bromodichloromethane	0.00027 - 0.00053	0.00025 – 0.00065	0.00026 – 0.025	0.00038
Chlorate	1,900 – 3,200	7.4 – 3,200	2.5 – 22,000	0.072 - 3,100
Manganese	NA	0.028 – 0.10	NA	0.25 – 6.0
TDS	3,100 – 13,000	430 – 24,000	890 – 48,000	630 – 6,400
Nitrate	0.630 - 8.10	0.900 - 25.0	0.510 - 44.0	0.470 - 3.70

Note:
bgs – below ground surface
mg/L – milligrams per liter
*Laboratory flags are not included on the summary table, but are provided in Appendix F.

In addition to the analytes summarized above, other VOCs were detected, but did not exceed their respective BCL at a frequency greater than 10%. These VOCs are documented on the tables provided in Appendix F and the exceedances are summarized in Appendix G.

4.4.3 Contaminant Distribution in Groundwater

This section provides a general description of the vertical extent of contamination in groundwater within the Investigation Area. To be expected, the horizontal extent of groundwater contamination is more widespread than the Investigation Area and will be defined in the OU-1 and OU-2 RI Report. Although several constituents were detected above the groundwater BCLs, this discussion will focus on the COPCs that contribute to widespread groundwater contamination as portrayed in the Annual Remedial Performance Reports. Section 4.5 provides a more thorough evaluation of groundwater under the Investigation Area.

4.4.3.1 Perchlorate in Groundwater

Perchlorate exceeded the NERT's RI groundwater screening level (federal Interim Drinking Water Health Advisory and federal PRG) of 0.015 (mg/L) throughout most of the Investigation Area. Although perchlorate was detected in groundwater within the Qal at concentrations as great as 2,900 mg/L and in the upper saturated interval of the UMCf as great as 3,500 mg/L, the highest concentrations of perchlorate (as great as 6,700 mg/L) were detected in the lower saturated interval of the UMCf. Perchlorate was detected above the NERT's RI groundwater screening level as deep as 242 feet bgs, in borehole U4U5-63. Perchlorate concentrations in soil in borehole U4U5-63 were non-detect at 240 feet bgs, indicating that the perchlorate detected in groundwater at 242 feet bgs may have been due to carry down during drilling. As can be seen on Figures H-31 through H-35, the greatest perchlorate concentrations in groundwater were observed below and downgradient of the Unit 4 Building in the UMCf at approximately 95 to 120 feet bgs. A limited number of groundwater samples collected below the Unit 5 Building confirmed a similar distribution pattern, albeit, perchlorate concentrations were approximately an order of magnitude lower.

4.4.3.2 Chlorate in Groundwater

Chlorate was detected in groundwater within the Qal and the upper saturated interval of the UMCf in the Investigation Area above the BCL of 1 mg/L and was detected at concentrations as great as 3,200 mg/L. Chlorate at concentrations as great as 32,000 mg/L were detected in the lower saturated interval of the UMCf. Chlorate concentrations generally decrease with depth below approximately 130 feet bgs. As was observed with perchlorate, the greatest concentrations were observed below and downgradient of the Unit 4 Building within the UMCf between 95 and 120 feet bgs (Figures H-36 through H-40).

4.4.3.3 Total Chromium in Groundwater

Chromium is observed in groundwater throughout the Investigation Area in both the Qal and UMCf (Figures H-41 through H-45 in Appendix H). However, NDEP does not provide a BCL for total chromium. However, concentrations of total chromium exceeded the US EPA Maximum Contaminant Level of 100 ug/L to depths of 192 feet bgs in the lower saturated interval of the UMCf. A discussion of the distribution of hexavalent chromium in groundwater relative to the BCL is provided in section 4.4.3.4.

4.4.3.4 Hexavalent Chromium in Groundwater

The distribution of hexavalent chromium concentrations in groundwater is similar to the distribution of perchlorate concentrations in groundwater. Hexavalent chromium concentrations exceeded the groundwater BCL of 0.000134 mg/L throughout much of the Investigation Area. Hexavalent chromium was detected in groundwater within the Qal and the upper saturated interval of the UMCf at concentrations as great as 42 mg/L. Hexavalent chromium at concentrations as great as 110 mg/L was detected in the lower saturated interval of the UMCf. Similar to the observed groundwater perchlorate distribution with depth, hexavalent chromium concentrations generally decrease with depth below approximately 130 feet bgs. Hexavalent chromium was detected above the groundwater BCL as deep as 150 feet bgs. The greatest concentrations were observed below and to the west of the Unit 4 Building within the UMCf from 60 to 120 feet bgs (Figures H-46 through H-50).

4.4.3.5 TDS in Groundwater

TDS in groundwater within the Qal and the upper saturated interval of the UMCf reached concentrations as great as 24,000 mg/L. TDS reached concentrations as great as 48,000 mg/L in the lower saturated interval of the UMCf. TDS concentrations generally decrease with depth below approximately 130 feet bgs. The greatest concentrations were observed below and downgradient of the Unit 4 Building, as well as downgradient of the region between the Unit 4 and 5 Buildings within the UMCf from 95 to 120 feet bgs (Figures H-51 through H-55).

4.4.3.6 Nitrate in Groundwater

Nitrate (as N) in groundwater within the Qal and the upper saturated interval of the UMCf reached concentrations as great as 25 mg/L. Nitrate reached concentrations as great as 65 mg/L in the lower saturated interval of the UMCf. Nitrate concentrations generally decrease with depth below approximately 130 feet bgs. Nitrate concentrations were below the groundwater BCL of 53.4 mg/L in every sample collected, with the exception of the samples collected from M-251-100 (58 and 65 mg/L) and M-256-100 (54 mg/L). The greatest concentrations were observed below and downgradient of the Unit 4 Building within the UMCf between 85 and 110 feet bgs (Figures H-56 through H-60).

4.4.3.7 Chloroform in Groundwater

Chloroform in groundwater within the Qal and the upper saturated interval of the UMCf reached concentrations as great as 0.66 mg/L. Chloroform reached concentrations as great as 8.3 mg/L in the lower saturated interval of the UMCf. Chloroform concentrations exceeded the groundwater BCL of 0.000219 mg/L at all groundwater sample locations. Similar to the observed groundwater perchlorate distribution with depth, chloroform concentrations generally decrease with depth below approximately 110 feet bgs. Chloroform was detected above the groundwater BCL as deep as 242 feet bgs. The greatest concentrations were observed below and downgradient of the Unit 4 Building within the UMCf between 95 and 110 feet bgs (Figures H-61 through H-65).

4.5 INVESTIGATION AREA CONTAMINANT DISTRIBUTION

This section builds upon the data previously presented in Section 4.4 and presents a discussion of the distribution of select COPCs based on the analytical results from the Unit 4 and 5 Buildings Investigation. The discussion focuses on those COPCs identified in the Work Plan (perchlorate, chromium, hexavalent chromium, chloroform, and TDS) and those identified as widely distributed during implementation of the investigation (chlorate and nitrate). Ultimately, the RI Report for OU-1 and OU-2 will provide a comprehensive analysis of the extent of contamination of all constituents across the Site originating from the Investigation Area. While the presence of perchlorate, chlorate, chromium, hexavalent chromium, TDS, and nitrate in the environment are believed to have been released during former manufacturing operations at the Unit 4 and 5 Buildings, the origin of chloroform is unknown. No written records documenting the use of chloroform in manufacturing operations have been identified by the Trust or its consultants. The sources and presence of chloroform will be more thoroughly discussed in the RI Report for OU-1 and OU-2.

4.5.1 COPC Plume Configuration in Soil

The configuration of the plumes for the contaminants identified in the prior subsections are described for soil in the following subsections. This analysis was completed using 3DVA and the supporting graphics are presented in Appendix H. Estimates of COPC mass that are presented in this section are based on calculations described in more detail in Section 4.5.3.

4.5.1.1 Perchlorate in Soil

Figure H-2 (Appendix H) displays a three-dimensional (3-D) representation of the highest perchlorate concentrations in soil above and below the water table. As illustrated in the greater than 10 mg/kg visualization, the perchlorate plume has 2 discrete lobes along the southern portion of the Unit 4 Building. Perchlorate concentrations in the uppermost lobe drop below 10 mg/kg at approximately 50 feet bgs (about 1760 feet mean sea level [MSL]) and then increase again above 10 mg/kg at approximately 80 feet bgs (about 1730 feet MSL). This geometry is also visible in the cross sectional slices presented in Figure H-3. When examining the plume shape at concentrations greater than 100 and 1,000 mg/kg, two discrete highly-concentrated perchlorate bodies are visible. Based on the distribution of perchlorate in the subsurface it appears that substantial perchlorate mass is retained in the vadose zone and a second, and even greater mass of perchlorate, is present from 80 to 120 feet bgs. This perchlorate distribution is also visible in Figures H-4 and H-5 which display cross sections through the center of the Unit 4 and 5 Buildings. The most notable difference at the north end of the Unit 4 Building is that perchlorate concentrations remain above 10 mg/kg to a depth of approximately 150 feet bgs.

Given the high specific gravity of sodium perchlorate, it is likely that the sodium perchlorate brine vertically migrated into the subsurface, driven by gravity, and accumulated on top of the finer-grained grain sediment of the UMCf. As illustrated in Figure 8, the UMCf transitions from sandy silt to predominantly a silty clay at a depth of approximately 80 feet bgs which appears to have prohibited significant downward migration beyond 150 feet bgs. However, soil samples indicate the presence of perchlorate above its LBCL to a depth of 242 feet bgs. The vertical extent of high perchlorate concentrations is best illustrated with the geologic conditions in cross sections on Figure H-4.

Based on the 3D distribution of perchlorate in soil, the centroid of mass of perchlorate in the Qal is located near the southeast corner of the Unit 4 basement (828,366E, 26,717,262N Nevada State Plane coordinates, WGS84) at an approximate depth of 24 feet bgs. The centroid of perchlorate mass in soil within the UMCf is located near the northeast corner of the Unit 4 basement (828,320E, 26,717,422N Nevada State Plane coordinates, WGS84) at an approximate depth of 88 feet bgs. The variances in the perchlorate mass centroid in soil is likely attributable to micro-migration pathways present in the subsurface. Based on soil data, the perchlorate mass in the Investigation Area was estimated to be 103,000 pounds in the Qal and 581,000 pounds in the UMCf. These mass estimates are based on the current understanding of the distribution of perchlorate in the Investigation Area.

4.5.1.2 Chlorate in Soil

Figure H-7 (Appendix H) displays a 3-D representation of elevated chlorate concentrations in soil above and below the water table. The chlorate plume is present in shallow soil (10-40 feet bgs) at the highest concentrations (greater than 5,000 mg/kg) to the west of the Unit 4 Building and in the southwest corner of the Unit 4 Building basement. Soil concentrations of chlorate west of the Unit 4 Building drop below 50 mg/kg at approximately 50 feet bgs (about 1,760 feet MSL) but chlorate concentrations are present above 500 mg/kg in the area north of the Unit 4 Building at 50 feet bgs (Figure H-8). From 80 feet bgs (approximately 1,730 feet MSL) to a depth of approximately 120 feet bgs, chlorate is present in soil at concentrations greater than 1,000 mg/kg in a southwest-northeast trending zone extending from west of the Unit 4 Building to the northwest of the Unit 5 Building. Below 120 feet bgs, concentrations of chlorate in soil decrease to generally less than 5 mg/kg.

Based on the distribution of chlorate in the subsurface, it appears that substantial chlorate mass is retained in the vadose zone, primarily west of the Unit 4 basement and that a second, greater mass of chlorate, is present from 80 to 120 feet bgs (See cross-sectional figures H-9 and H-10). Similar to the perchlorate discussion above, it is likely that chlorate migrated vertically into the subsurface and accumulated on top of the finer-grained sediment of the UMCf. As illustrated in Figure 8, the UMCf transitions from sandy silt to predominantly a silty clay at a depth of approximately 80 feet bgs, which appears to have prohibited significant downward migration beyond 150 feet bgs. However, soil samples indicate the presence of chlorate above its LBCL to a depth of 150 feet bgs, the deepest that a sample was collected and analyzed for chlorate. The vertical extent of high chlorate concentrations is best illustrated with the geologic conditions in cross sections on Figure H-9.

Based on the 3-D distribution of chlorate in soil, and similar to the centroid mass of perchlorate, the centroid of mass of chlorate in the Qal is located near the southeast corner of the Unit 4 basement (828,169E, 26,717,257N Nevada State Plane coordinates, WGS84) at an approximate depth of 25 feet bgs. The centroid of chlorate mass in soil within the UMCf is located north of the Unit 4 basement (828,257E, 26,717,396N Nevada State Plane coordinates, WGS84) at an approximate depth of 89 feet bgs. Based on soil data, the chlorate mass in the Investigation Area was estimated to be 577,000 pounds in the Qal and 3,300,000 pounds in the UMCf. These mass estimates are based on the current understanding of the distribution of chlorate in the Investigation Area.

4.5.1.3 Chromium in Soil

The locations of the chromium in soil data collected during the Unit Buildings 4 and 5 investigation is presented in Figure H-11 (Appendix H). The distribution of chromium in soil as determined by the 3-D model is shown in Figure H-12 with horizontal and vertical cross sections presented in Figures H-13, H-14 and H-15. Chromium is present in the soils beneath the Investigation Area in shallow soil (10-40 feet bgs) at the highest concentrations (exceeding 100 mg/kg in some areas) immediately west of and east of the Unit 4 Building basement (Figure H-13). Soil concentrations of chromium decrease to below 50 mg/kg at approximately 50 feet bgs (about 1.760 feet MSL) but increase again to above 50 mg/kg between 80 and 120 feet bgs in an area beneath the Unit 4 Building basement (Figures H-13, H-14 and H-15). A lobe of chromium at concentrations above 100 mg/kg is present between 60 to 70 feet bgs below the western side of the Unit 5 building basement (Figure H-14). Below 120 feet bgs, concentrations of chromium in soil decrease to generally less than 50 mg/kg.

The locations and depth intervals containing the highest concentrations of chromium in soil appear consistent with a conceptual model in which brine solutions with elevated concentrations of chromium entered the soil near the western and eastern edges of the Unit 4 basement (Figure H-14). The chromium likely migrated vertically downward as part of a density-driven brine flow, accumulating on top of and into the finer-grained sediment of the UMCf until the soil type transitions from sandy silt to predominantly a silty clay at a depth of approximately 80 feet bgs. This lithologic change appears to have prohibited significant downward migration of chromium beyond 150 feet bgs. The vertical extent of high chromium concentrations is best illustrated with the geologic conditions in cross sections on Figure H-14 and H-15.

Based on the 3-D distribution of chromium in soil, the centroid of mass of chromium in the Qal is located near the center of the western edge of the Unit 4 basement (828,414E, 26,717,346N Nevada State Plane coordinates, WGS84) at an approximate depth of 19 feet bgs. The centroid of mass of soil chromium in the UMCf is located north of the northern side of the Unit 4 basement (828,390E, 26,717,348N Nevada State Plane coordinates, WGS84) at an approximate depth of 101 feet bgs. Based on soil data, the chromium mass in the Investigation Area was estimated to be 52,100 pounds in the Qal and 358,000 pounds in the UMCf. These mass estimates are based on the current understanding of the distribution of chromium in the Investigation Area.

4.5.1.4 Hexavalent Chromium in Soil

The locations of the hexavalent chromium in soil data collected during the Unit Buildings 4 and 5 investigation is presented in Figure H-16 (Appendix H). The distribution of hexavalent chromium in soil as determined by the 3-D model is shown in Figure H-17 with horizontal and vertical cross sections presented in Figures H-18, H-19 and H-20. Hexavalent chromium is present in the soils beneath the Investigation Area in shallow soil (10-40 feet bgs) at the highest concentrations (exceeding 100 mg/kg in some areas) immediately west of and east of the Unit 4 Building basement (Figure H-18). Soil concentrations of hexavalent chromium decrease to below 5 mg/kg at approximately 50 feet bgs (about 1.760 feet MSL) but increase again to above 50 mg/kg between 80 and 120 feet bgs in an area beneath the Unit 4 Building basement (Figures H-18, H-19 and H-20). Below 120 feet bgs, concentrations of hexavalent chromium in soil decrease to generally less than 0.20 mg/kg.

The locations and depth intervals containing the highest concentrations of hexavalent chromium in soil appear consistent with a conceptual model in which brine solutions with elevated concentrations of hexavalent chromium entered the soil near the western and eastern edges of the Unit 4 basement (Figure H-19). The hexavalent chromium likely migrated vertically downward as part of a density-driven brine flow, accumulating on top of and into the finer-grained sediment of the UMCf until the soil type transitions from sandy silt to predominantly a silty clay at a depth of approximately 80 feet bgs. This lithologic change appears to have prohibited significant downward migration of hexavalent chromium beyond 150 feet bgs. The vertical extent of high hexavalent chromium concentrations is best illustrated with the geologic conditions in cross sections on Figure H-19 and H-20.

Based on the 3-D distribution of hexavalent chromium in soil, the centroid of mass of hexavalent chromium in the Qal is located near the center of the western edge of the Unit 4 basement (828,175E, 26,717,289N Nevada State Plane coordinates, WGS84) at an approximate depth of 21 feet bgs. The centroid of mass of soil hexavalent chromium in the UMCf is located north of the northern side of the Unit 4 basement (828,214E, 26,717,416N Nevada State Plane coordinates, WGS84) at an approximate depth of 94 feet bgs. Based on soil data, the hexavalent chromium mass in the Investigation Area was estimated to be 1,600 pounds in the Qal and 15,600 pounds in the UMCf. These mass estimates are based on the current understanding of the distribution of hexavalent chromium in the Investigation Area.

4.5.1.5 Nitrate in Soil

Figure H-21 (Appendix H) illustrates the distribution of data collected for nitrate in soil during the Unit 4 and 5 Investigation. Figure H-22 displays a 3-D representation of the highest nitrate concentrations in soil above and below the water table. The 3-D representation and cross sections for the same 3-D model (Figures H-23, H-24 and H-25) show that the low data density combined with the data variability spatially results in a discontinuous distribution. The nitrate concentrations range from 0.87 to 54 mg/kg. In a general sense, concentrations of nitrate are highest approximately at the water table (33 feet bgs or 1,780 feet MSL) north and east of the Unit 5 Building, and at a depth of approximately 90 feet bgs beneath, downgradient, and west of the Unit 4 Building. Since collection of nitrate data was added to support the Unit 4 Source Area In-Situ Bioremediation Treatability Study, there is limited data available. While the low data density directly limits the conclusions that can be drawn about the distribution of nitrate, this was not a goal of this investigation. Boreholes tended to have greater correlation from sample to sample vertically than with other boreholes nearby, causing the 3-D representation to have a columnar appearance (Figure H-22). Based on soil data, the nitrate mass in the Investigation Area was estimated to be 2,160 pounds in the Qal and 8,070 pounds in the UMCf. These mass estimates are based on the current understanding of the distribution of nitrate in the Investigation Area.

4.5.1.6 Chloroform in Soil

Chloroform in soil data collected during the Unit 4 and 5 investigation is presented in Figure H-26. The results of the 3-D visualization model are shown in Figure H-27 as a series of horizontal slices in Figure H-28 and in cross-section in Figures H-29 and H-30. Chloroform is present in the Qal primarily around and beneath the Unit 4 basement. Areas of elevated concentrations are present west of the basement, east of the basement and near the southeast corner of the basement to a depth of approximately 40 feet (Figure H-27). Additional areas of elevated soil chloroform concentrations are present beneath the Unit 5 Building in the Qal. Near the water table and the contact with the top of the UMCf, concentrations of chloroform decrease to less than 0.1 mg/kg. Beneath and northwest of the Unit 4 basement, soil concentrations of chloroform increase to greater than 2 mg/kg between 80 and 120 feet bgs. A second area of elevated concentrations is also present beneath and north of the Unit 5 Building. The 3-D iso-concentration shells shown in Figure H-27 and the cross sections shown in Figures H-29 and H-30 indicate the vertical and horizontal distributions of these "hot spots."

Based on the available soil data, the chloroform mass in the Investigation Area was estimated to be 13 pounds in the Qal and 880 pounds in the UMCf. These mass estimates are based on the current understanding of the distribution of chloroform in the Investigation Area.

4.5.2 COPC Plume Configuration in Groundwater

The configuration of the soil plumes for the contaminants identified in the prior subsections are described for groundwater in the following subsections. This analysis was completed using 3DVA and the supporting graphics are presented in Appendix H.

4.5.2.1 Perchlorate in Groundwater

Figures H-31 to H-35 (Appendix H) show the distribution of perchlorate in groundwater in the Investigation Area. Figure H-32 displays a 3-D representation of the areas containing elevated perchlorate concentrations in groundwater. Immediately below the water table, perchlorate is highest in concentration in an area between the northern edge of the Unit 4 Building and the wells along the downgradient line of borings to the north. A small zone of elevated concentration is also present near the northeast corner of the model block. Perchlorate concentrations in groundwater increase with depth as seen in Figure H-33, reaching the zone of highest mass between approximately 80 and 120 feet bgs, as seen in Figure H-32 at concentrations greater than 100 and 1,000 mg/L. Below this depth interval, concentrations decrease until they are generally less than 10 mg/L at depths below 140 feet bgs, as shown in the cross sections presented in Figures H-34 and H-35. One exception to this is the groundwater sample collected from U4U5-31 at 140 feet bgs which contained perchlorate at 570 mg/L. This concentration appears to be isolated, and not typical of other concentrations from this depth interval in the rest of the Investigation Area.

Similar to the distribution of perchlorate in soil, the elevated groundwater concentrations of perchlorate at depth suggest that the density of sodium perchlorate led to the downward migration of perchlorate in brine into the UMCf to a depth of approximately 80-120 feet bgs. Later flow of groundwater through the subsurface may have diluted or flushed the perchlorate from the shallow intervals, particularly in the depth interval around 70 feet bgs, stranding the deeper intervals with higher concentrations that have not yet been flushed by the throughflow of regional groundwater. The remaining elevated groundwater concentrations may be due to these zones being finer-grained and lower permeability or possibly just hydraulically isolated from the higher permeability zones through which more of the flushing occurred.

Consistent with the Work Plan, mass estimates of perchlorate in groundwater were not performed since the total perchlorate mass had already been calculated using the perchlorate soil data set (which would include that portion dissolved in groundwater).

4.5.2.2 Chlorate in Groundwater

The distribution of chlorate in groundwater beneath the Unit 4 and 5 Investigation Area is depicted in Figures H-36 to H-40 (Appendix H). Figure H-37 contains a 3-D representation of the areas containing elevated chlorate concentrations in groundwater. Chlorate is generally highest in concentration in an area underneath and north of the Unit 4 Building basement. The highest concentrations are present between approximately 80 and 120 feet bgs, as seen in Figure H-38 at concentrations greater than 2,000 mg/L. Below this depth interval, concentrations decrease until they are generally less than 100 mg/L at depths below 140 feet bgs, as shown in the cross sections presented in Figures H-39 and H-40.

As seen in the distributions of perchlorate, and the distribution of chlorate in soil, the elevated concentrations of chlorate in groundwater below the top of the UMCf suggests that the density of the brine containing chlorate led to downward migration into the UMCf to a depth of approximately 80-120 feet bgs. Later flow of groundwater through the subsurface may have diluted or flushed the chlorate from the shallow intervals, stranding chlorate in the deeper intervals. The remaining elevated concentrations may be due to these zones being finer-grained and lower permeability or possibly just hydraulically isolated from the higher permeability zones through which more of the flushing occurred.

Consistent with the Work Plan, mass estimates of chlorate in groundwater were not performed since total chlorate mass had already been calculated using the chlorate in soil data set (which would include that portion dissolved in groundwater).

4.5.2.3 Chromium in Groundwater

The distribution of chromium in groundwater beneath the Unit 4 and 5 Investigation Area is depicted in Figures H-41 to H-45 (Appendix H). Figure H-42 contains a 3-D representation of the areas containing elevated chromium concentrations in groundwater. Concentrations of chromium from 50-120 feet bgs are projected to be generally highest in concentration in an area northwest of the Unit 4 Building basement, where the sample with the highest concentration was collected (U4U5-22 from 77-82 feet bgs contained a chromium concentration of 110 mg/L). The highest concentrations are generally present between approximately 50 and 120 feet bgs (1,780 to 1,690 feet MSL), as seen in Figure H-43 where concentrations north and west of the Unit 4 basement are projected to be greater than 50 mg/L. Below this depth interval, concentrations decrease until they are generally less than 1 mg/L at depths below 140 feet bgs, as shown in the cross sections presented in Figures H-44 and H-45.

As seen in the distributions of perchlorate and chlorate, and the distribution of chromium in soil, the elevated concentrations of chromium in groundwater below the top of the UMCf suggests that the density of the brine containing chromium led to downward migration into the UMCf to a depth of approximately 80-120 feet bgs. Later flow of groundwater through the subsurface may have diluted or flushed the brine from the shallow intervals, stranding chromium in the deeper intervals. The remaining elevated concentrations may be due to these zones being finer-grained and lower permeability or possibly hydraulically isolated from the higher permeability zones through which more of the flushing occurred.

Consistent with the Work Plan, mass estimates of chromium in groundwater were not performed since total chromium mass had already been calculated using the soil data set (which would include that portion dissolved in groundwater).

4.5.2.4 Hexavalent Chromium in Groundwater

The distribution of hexavalent chromium in groundwater beneath the Unit 4 and 5 Investigation Area is depicted in Figures H-46 to H-50 (Appendix H). Figure H-47 contains a 3-D representation of the areas containing elevated hexavalent chromium concentrations in groundwater. Shallow (< 70 feet bgs) concentrations of hexavalent chromium are projected to be generally highest in concentration in an area northwest of the Unit 4 Building basement. In the 80-120 foot bgs depth interval, the highest concentrations of hexavalent chromium are present along the center of the northern edge of the Unit 4 Building basement where the sample with the highest concentration was collected (U4U5-22 from 77-82 feet bgs contained a hexavalent chromium concentration of 110 mg/L). The highest concentrations are generally present between approximately 80 and 120 feet bgs (1,730 to 1,690 feet MSL), as seen in Figure H-48 where concentrations north and west of the Unit 4 basement are projected to be greater than 50 mg/L. Below this depth interval, concentrations decrease until they are generally less than 1 mg/L at depths below 140 feet bgs, as shown in the cross sections presented in Figures H-49 and H-50.

As seen in the distributions of perchlorate and chlorate, and the distribution of hexavalent chromium in soil, the elevated concentrations of hexavalent chromium in groundwater below the top of the UMCf suggests that the density of the brine containing hexavalent chromium led to downward migration into the UMCf to a depth of approximately 80-120 feet bgs. Later flow of groundwater through the subsurface may have diluted or flushed the brine from the shallow intervals, stranding hexavalent chromium in the deeper intervals. The remaining elevated concentrations may be due to these zones being finer-grained and lower permeability or possibly hydraulically isolated from the higher permeability zones through which more of the flushing occurred.

Consistent with the Work Plan, mass estimates of hexavalent chromium in groundwater were not performed since total hexavalent chromium mass had already been calculated using the soil data set (which would include that portion dissolved in groundwater).

4.5.2.5 TDS in Groundwater

TDS was measured in groundwater samples collected during the investigation of the Unit 4 and 5 building subsurface and the sample locations and corresponding TDS concentrations are shown in Figure H-51. There is generally good correlation between TDS and the concentration distributions of perchlorate, chlorate and hexavalent chromium in groundwater within the investigation area. TDS is a composite representation of all the dissolved chemical species in water, which include the major COPCs. TDS concentrations immediately below the water table and near the contact between the Qal and the UMCf are typically less than or near 5,000 mg/L (Figure H-53). The highest concentrations are detected at the northwest corner of the Unit 4 building in this depth interval. TDS concentrations begin to increase significantly around 80 feet bgs; the groundwater beneath the center of the northern edge of the Unit 4 Building basement at 93 feet bgs (1,720 feet MSL) is projected to have TDS concentrations over 20,000 mg/L (Figure H-55). The high TDS concentration plume is projected to extend northeast to the area north of Unit 5 where TDS was measured in M-256 at 40,000 mg/L at a depth of 100 to 110 feet bgs. Below approximately 130 feet bgs, TDS concentrations decrease to less than 2,000 mg/L.

Based on the 3-D distribution of TDS in groundwater, the centroid of mass of total-dissolved solids is located north of the Unit 4 basement (828,273E, 26,717,382N Nevada State Plane coordinates, WGS84) at an approximate depth of 93 feet bgs (1,720 feet MSL). Based on groundwater TDS data, the TDS mass in the Investigation Area was estimated to be 12,450,000 pounds. This mass estimate is based on the current understanding of the distribution of TDS in the Investigation Area.

4.5.2.6 Nitrate in Groundwater

The distribution of nitrate in groundwater displays a higher degree of spatial continuity than is observed in the soil data. Nitrate was measured in groundwater samples collected during the investigation of the Unit 4 and 5 Building subsurface and the sample locations and corresponding nitrate concentrations are shown in Figure H-56. Nitrate concentrations immediately below the water table to a depth of approximately 80 feet bgs are typically between 0.5 and 5 mg/L (Figure H-58). Nitrate concentrations increase significantly around 80 feet bgs; the groundwater beneath the center of the northern edge of the Unit 4 Building basement at 93 feet bgs (1,720 feet MSL) is projected to have nitrate concentrations over 20 mg/L and extends north (Figure H-60). Below approximately 130 feet bgs, nitrate concentrations decrease to less than 4 mg/L (Figure H-58).

Consistent with the Work Plan, mass estimates of nitrate in groundwater were not performed since total nitrate mass had already been calculated using the soil data set (which would include that portion dissolved in groundwater).

4.5.2.7 Chloroform in Groundwater

The distribution of chloroform in groundwater beneath Investigation Area is depicted in Figures H-61 to H-65 (Appendix H). Figure H-62 contains a 3-D representation of the areas containing elevated chloroform concentrations in groundwater. Shallow (< 70 feet bgs) concentrations of chloroform are projected to be generally highest in concentration in an area north of the Unit 4 Building basement. The groundwater sample collected from boring U4U5-29 from 27.5 to 32.5 feet bgs contained a chloroform concentration of 1.6 mg/L. The highest chloroform concentrations are generally present between approximately 80 and 120 feet bgs (1,730 to 1,690 feet MSL). In the 80-120 foot bgs depth interval, the highest concentrations of chloroform are present along the center of the northern edge of the Unit 4 Building basement where the sample with the highest concentration was collected. The groundwater samples collected from the boring for monitoring well M-251-100 from 92.5 to 102.5 feet bgs contained a chloroform concentration of 8.3 mg/L. Chloroform concentrations decrease below 120 feet bgs until they are generally less than 0.02 mg/L at depths below 140 feet bgs, as shown in the cross sections presented in Figures H-64 and H-65.

Mass estimates of chloroform in groundwater were not performed since total chloroform mass had already been calculated using the soil data set (which would include that portion dissolved in groundwater).

4.5.3 Mass Estimates

In addition to providing the distribution of COPCs in the vadose zone and saturated zone, as illustrated in the 3DVA graphics in Appendix H, the EVS software algorithm can also provide estimates of the constituent mass in the Investigation Area from soil samples collected in the vadose zone and saturated zone. These mass estimates, introduced in previous sections, are based on the current understanding of the distribution of the constituents in the Investigation Area and were calculated using soil analytical data only, except for TDS. Descriptions of the procedures used to prepare the mass estimates, including TDS, are provided below. These estimates provide the best approximation of the contaminant mass in this source area using EPA-approved analytical methods. Recently, UNLV identified the presence of micro-crystals within the soil matrix that might account for contaminant mass that isn't measured using the current analytical methodology. As such, the mass estimates provided herein might underestimate the quantity of contaminant mass present. However, additional evaluation is warranted before any changes are made to the mass estimates provided in this section.

Consistent with the Work Plan, the mass estimates previously calculated from the Second mobilization data, and the RI Study Area Mass Estimate and Extended Performance Metrics Technical Approach (Ramboll, 2017b), the mass of each parameter (except for TDS) was calculated using kriging to produce a mass estimate over a regular grid from the soil data. The approach used was slightly improved from that specified in the RI Study Area Mass Estimate technical approach, due to the higher degree of data density in the Investigation Area than is available elsewhere. Differences in the approach include: 1) mass estimates were performed using soil concentrations directly, rather than converting to groundwater concentrations first, as this functionality is a direct calculation within the EVS software; 2) the approach of kriging to a regular grid was used for all subsurface units including the vadose and saturated zones due to the sufficient data density available; and 3) the numerical 3DVA grid used to generate the visualization and mass estimates utilized cell dimensions that were finer (approximately 5 feet in width in plan view, by 1 foot vertically), and therefore provides higher resolution. A key input parameter under this approach is the 50 percent bulk dry density, which was estimated to be 1.5 grams per cubic centimeter based on site-specific soil data collected during the third mobilization. This value correlates well with site soil data previously collected from the Ammonium Perchlorate Area, located north of the Investigation Area.

The mass estimate for TDS, for which soil data is not available, was prepared using the groundwater analytical data. In this case, a key input parameter is the porosity of the saturated soil in the UMCf which was estimated to be 0.512 above 90 feet bgs and 0.579 below 90 feet bgs, based on geotechnical laboratory data collected during the Unit 4 and 5 investigation. The depth of 90 feet bgs was selected after examination of the depth-vs-porosity relationship, which suggested that different porosity conditions were present above and below that depth. The porosity values of 0.512 and 0.579 were then calculated by averaging the geotechnical laboratory data from above and below 90 feet bgs. The kriging process was applied to the groundwater data using the equivalent tool in EVS which additionally takes the porosity into account in the calculations. The "volumetrics" module was again used to sum the mass of each COPC using the 3-dimensional interpolation performed for the 3DVA visualization. The mass estimates of each COPC are presented in ***Table 13***.

Table 13 COPC Mass Estimates

Analyte	Qal Mass Estimates		UMCf Mass Estimates		Total Mass Estimates
	Nominal	Statistical Range[1]	Nominal	Statistical Range[1]	Nominal
Perchlorate	103,000	53,000 – 208,000	581,000	221,000 – 1,621,000	684,000
Chlorate	577,000	202,000 – 1,744,000	3,300,000	1,020,000 – 11,100,000	3,877,000
Chromium	52,100	45,400 – 60,000	358,000	300,000 – 428,000	410,100
Hexavalent Chromium	1,600	840 – 3,000	15,600	6,200 – 41,100	17,200
Chloroform	13	8 – 24	880	350 – 2,300	893
Nitrate	2,160	876 – 5,416	8,070	3,248 – 20,344	10,230
TDS[2]	-	-	12,450,000	10,010,000 – 15,500,000	12,450,000

Note:
Mass estimates are reported in units of pounds.
[1] Statistical Range is based on the upper and lower bounding mass estimates using an 80% confidence level (80% min and 80% max, as discussed below).
[2]TDS estimates are calculated using groundwater data; all other estimates were calculated using soil data.

EVS uses the 3D geostatistical interpolation and extrapolation "kriging" process to create a block model of the concentration of the contaminant at each of the numerical nodes within the block. In the Investigation Area, this block consisted of a grid of approximately 3.67 million nodes. The kriging process was performed using the kriging parameterization that was automatically calculated by the EVS algorithms, then adjusting them to use a "zero nugget". A "zero nugget" forces the distribution of estimated mass to match that of the concentrations observed in the input dataset where the grid nodes are coincident and to encourage interconnectivity between samples of similar concentration. This ensures that the distribution will accurately represent the concentrations measured in the samples collected at the Site. The volumetrics module is then used to perform an integration of both the soil volume and chemical mass that are within the model block. The results of the integration are displayed in a module output window.

In addition to the predicted mass estimates calculated by the software, the geostatistics associated with the kriging process produce estimates for the statistical distribution cases in which the mass estimate, based on the concentration at each model node, is less than a certain mass at the 80% confidence level (80% Max) and greater than a certain mass at the 80% confidence level (80% Min). These are calculated by determining the associated standard deviation at every node in the model, then calculating the value such that 80% of the time, the actual values will fall below the maximum value for that concentration and standard deviation. This process is repeated for every node in the model. This method produces high and low estimates of the mass while accounting for the uncertainty associated with the interpolation method, resulting in a form of bounds for the mass estimates in the model block, as shown above in ***Table 13***.

4.5.4 Aquifer Testing Results

This section provides the results of aquifer testing described in Section 3.2.7.

4.5.4.1 Slug Testing

A total of 10 slug tests were conducted to determine the hydraulic parameters laterally and vertically within the UMCf in the Unit 4 and 5 Investigation Area. Monitoring wells were selected across the Investigation Area and at a variety of depth completion intervals to obtain a representative dataset throughout the Investigation Area. A summary of the slug test results is provided in ***Table 14*** (at the end of this section) which includes the well identification, well screen interval, test identification, hydraulic conductivity, transmissivity, thickness, and soil description within the screen interval. Graphical outputs of the Bouwer and Rice solutions produced by AQTESOLV for each test are provided in Appendix J-1. “Slug in” and “Slug out” values for transmissivity and hydraulic conductivity were averaged to provide a single value for each well.

Hydraulic conductivity values for the intervals of the UMCf where the monitoring wells are screened are within the typical range for clay, silt, and silty sand (Johnson Screens, 2007). Hydraulic conductivity values ranged from 5.71 x 10^{-3} feet per day at monitoring well M-253-100 to 5.71 x 10^{-1} feet per day at monitoring well M-253-60.

4.5.4.2 Specific Capacity Testing

A total of three specific capacity tests were conducted to corroborate the hydraulic parameters determined by slug tests and calculate specific capacity. The tests were conducted at monitoring wells M-251-60, M-251-100, and M-252. The monitoring well cluster within the Unit 4 basement was selected for specific capacity testing due to its proximity to greater perchlorate and hexavalent chromium concentrations in the vicinity. The wells were selected based on their proximity to one another as a monitoring well cluster and the ability to provide data across all of the completion intervals that were targeted during the investigation.

Results are summarized in ***Table 15*** (at the end of this section), which includes well identification, well screen interval, specific capacity, average flow rate, drawdown, transmissivity, and hydraulic conductivity. Graphical output of the Theis and Hantush solutions produced by AQTESOLV including the displacement data versus time matched to the type curve are provided in Appendix J-2. Overall, transmissivity and hydraulic conductivity values for M-251-60, M-251-100, and M-252 are consistent with the slug test results. These values are within acceptable order of magnitude, and hydraulic conductivities are within the typical range for clay, silt, and silty sand (Johnson Screens, 2007).

4.5.4.3 Average Groundwater Velocity

The average groundwater velocity was estimated from the hydraulic conductivity determined from slug testing, the effective porosity, and the hydraulic gradient. Average groundwater velocity, is derived from a combination of Darcy's Law and the velocity equation of hydraulics, as follows.

$$V_x = \frac{Ki}{n_e}$$

Where *V_x is average groundwater velocity (feet/day)*
K is hydraulic conductivity (feet/day)
i is hydraulic gradient (feet/feet)
n_e is effective porosity (%)

Average groundwater velocity values for the UMCf intervals in which the monitoring wells are screened were calculated as:

- 2.08×10^{-2} feet/day, or approximately 7.6 feet/year in the shallow zone,
- 3.26×10^{-3} feet/day, or approximately 1.2 feet/year in the intermediate zone, and
- 4.13×10^{-3} feet/day, or approximately 1.3 feet/year in the deep zone.

Average groundwater velocity values are summarized in ***Table 16***.

Table 14 Slug Testing Results

Well Identification	Screen Interval (feet bgs)	Test Date	Test Identification (Type)	Transmissivity ($feet^2$/day)	Transmissivity Average ($feet^2$/day)	Hydraulic Conductivity (feet/day)	Hydraulic Conductivity Average (feet/day)	Thickness* (feet)	USCS Description (Screen Interval)
M-251-60	52.5 - 62.5	11/21/2017	M-251-60_SLUG IN	3.69E-01	3.71E-01	2.95E-02	2.97E-02	12.5	SM, ML, CL
		11/21/2017	M-251-60_SLUG OUT	3.74E-01		2.99E-02		12.5	
M-251-100	92.5 - 102.5	11/22/2017	M-251-100_SLUG IN	7.68E-01	7.79E-01	6.07E-02	6.16E-02	12.7	ML, CL
		11/22/2017	M-251-100_SLUG OUT	7.90E-01		6.24E-02		12.7	
M-252	132.5 - 142.5	11/27/2017	M-252_SLUG IN	3.86E-02	3.96E-02	3.86E-02	3.96E-02	12.5	ML, CL
		11/28/2017	M-252_SLUG OUT	4.06E-02		4.06E-02		12.5	
M-253-60	60 - 70	11/20/2017	M-253-60_SLUG IN	7.35E+00	7.42E+00	5.65E-01	5.71E-01	13.0	SP, SM, SC
		11/20/2017	M-253-60_SLUG OUT	7.49E+00		5.76E-01		13.0	
M-253-100	100 - 110	11/22/2017	M-253-100_SLUG IN	8.19E-02	7.71E-02	6.07E-03	5.71E-03	13.5	ML, CL
		11/22/2017	M-253-100_SLUG OUT	7.22E-02		5.35E-03		13.5	
M-254	138.5 - 148.5	11/27/2017	M-254_SLUG IN	3.36E-01	2.83E-01	2.25E-02	1.90E-02	14.9	CL, ML
		11/27/2017	M-254_SLUG OUT	2.29E-01		1.54E-02		14.9	
M-255-60	60.5 - 70.5	11/28/2017	M-255-60_SLUG IN	6.44E+00	6.88E+00	5.15E-01	5.50E-01	12.5	SC, SM
		11/28/2017	M-255-60_SLUG OUT	7.33E+00		5.86E-01		12.5	
M-255-100	100 - 110	11/29/2017	M-255-100_SLUG IN	3.62E-01	2.95E-01	2.83E-02	2.30E-02	12.8	ML, CL
		11/29/2017	M-255-100_SLUG OUT	2.27E-01		1.78E-02		12.8	

Well Identification	Screen Interval (feet bgs)	Test Date	Test Identification (Type)	Transmissivity (feet^2/day)	Transmissivity Average (feet^2/day)	Hydraulic Conductivity (feet/day)	Hydraulic Conductivity Average (feet/day)	Thickness* (feet)	USCS Description (Screen Interval)
M-256-60	60 - 70	11/21/2017	M-256-60_SLUG IN	8.29E-01	8.17E-01	6.63E-02	6.54E-02	12.5	SM, SC
		11/21/2017	M-256-60_SLUG OUT	8.05E-01		6.44E-02		12.5	
M-256-100	100-110	11/29/2017	M-256-100_SLUG IN	5.36E-01	4.21E-01	4.28E-02	3.37E-02	12.5	ML, CL
		11/29/2017	M-256-100_SLUG OUT	3.06E-01		2.45E-02		12.5	

Note:
SP – poorly graded sand
SM – silty sand
SC - clayey sand
ML – silt
CL – clay
bgs – below ground surface
*thickness is screen interval plus filter pack above or below screen

Table 15 Constant Rate Testing Results Summary

Well Identification	Screen Interval (feet bgs)	Test Date	Specific Capacity (gpm/feet)	Transmissivity (feet^2/day)	Hydraulic Conductivity (feet/day)	Average Flow Rate (gpm)	Drawdown (feet)	Thickness* (feet)	USCS Description (Screen Interval)
M-251-60	52.5 - 62.5	12/6/2017	0.005	3.01E-01	2.4E-02	0.12	25.15	12.5	SM, ML, CL
M-251-100	92.5 - 102.5	12/13/2017	0.010	1.02E+00	8.1E-02	0.08	8.29	12.5	ML, CL
M-252	132.5 - 142.5	12/12/2017	0.003	1.12E-01	9.0E-03	0.10	36.23	12.5	ML, CL

Note:
gpm – gallons per minute
SM – silty sand
ML – silt
CL – clay
Q – flow rate
bgs – below ground surface
*thickness is screen interval plus filter pack above or below screen

Table 16 Average Groundwater Velocity Results Summary

Unit	Screen Total Depth (feet bgs)	Hydraulic Conductivity[1] (feet/day)	Gradient (feet/feet)	Effective Porosity[2] (%)	Average Groundwater Velocity (feet/day)	Average Groundwater Velocity (feet/year)
Shallow	70	$3.04X10^{-1}$	0.014	20.5	$2.08X10^{-2}$	7.6
Intermediate	110	$3.10X10^{-2}$	0.018	17.1	$3.26X10^{-3}$	1.2
Deep	150	$2.93X10^{-2}$	0.022	15.6	$4.13X10^{-3}$	1.5

Note:
[1] – average of hydraulic conductivity values per unit
[2] – geometric mean of effective porosity per unit
bgs – below ground surface

4.6 DATA VALIDATION

In accordance with the Work Plan, a data validation summary report (DVSR) was generated following the completion of the third mobilization. The DVSR report summarized the quality assurance/quality control (QA/QC) evaluation of the data according to precision, accuracy, representativeness, completeness, comparability, and sensitivity relative to the project data quality objectives. It provided a quantitative and qualitative assessment of the data and identifies potential sources of error, uncertainty, and bias that may affect the overall usability. The DVSR was submitted to NDEP on July 31, 2018 (Tetra Tech, 2018b). Following comments from NDEP, the DVSR was revised and resubmitted to NDEP on January 23, 2019. The DVSR was subsequently approved by NDEP on February 21, 2019 with comments for the administrative record.

The laboratory analytical data were verified and validated in accordance with procedures described in the NDEP Data Verification and Validation Requirements - Supplement April 2009 established for the BMI Plant Sites and Common Areas Projects, Henderson, Nevada (NDEP, 2009) and with correspondence from NDEP personnel. The analytical data were evaluated for QA/QC based on the following documents: Quality Assurance Project Plan, Revision 1 (ENVIRON, 2014b); Quality Assurance Project Plan, Revision 2 (RAMBOLL Environ, 2017); NDEP Revised Guidance on Qualifying Data due to Blank Contamination for the BMI Complex and Common Areas, (NDEP, 2012); National Functional Guidelines for Inorganic Superfund Data Review, (USEPA, 2014a); National Functional Guidelines for Superfund Organic Methods Data Review, (USEPA, 2014b); National Functional Guidelines for High Resolution Superfund Methods Data Review, (USEPA, 2016); National Functional Guidelines for Inorganic Superfund Methods Data Review, (USEPA, 2017a); National Functional Guidelines for Superfund Organic Methods Data Review, (USEPA, 2017b); and the USEPA SW-846 Third Edition, Test Methods for Evaluating Solid Waste, including Updates I, II, IIA, IIB, III, and IV (USEPA, 1996). The project QAPP was updated during implementation of the Work Plan. All validation was performed in accordance with the QAPP, and other references, in place at time of validation. All samples were validated to Stage 2A using Automated Data Review (ADR) software. Additionally, 90 percent of the soil and groundwater data were validated to Stage 2B and 10 percent to Stage 4. Field quality blanks were validated to Stage 2A only.

5.0 CONCLUSIONS

While this report was limited to presenting the data from the Investigation Area and the forthcoming OU-1 and OU-2 RI Report will discuss/evaluate how the Investigation Area data and data from other portions of OU-1 and OU-2 tie together, the objectives of the investigation as stated in the Work Plan have been met. As outlined in the Work Plan, the specific goals of the investigation included the following:

- Collect sufficient soil and groundwater data to provide scale-appropriate data density for characterization of the nature and extent of perchlorate, hexavalent chromium, and other contaminants in the vadose zone and shallow groundwater within the Investigation Area;
- Estimate the mass of perchlorate and hexavalent chromium in the vadose zone and shallow groundwater in the Investigation Area;
- Evaluate potential migration pathways and the velocity of perchlorate and hexavalent chromium migration in shallow groundwater in the Investigation Area; and
- Evaluate the potential contribution of perchlorate and hexavalent chromium in the Investigation Area to the previously identified Site-wide shallow groundwater plume.

The first and second goals of the investigation were achieved, with more than sufficient data collected to provide characterization of the COPCs in the vadose zone and groundwater of the Investigation area. By utilizing three-dimensional visualization techniques, the data has been used to clearly define the extent and distribution of COPCs in the figures provided in this report. Additionally, sufficient data was collected to meet the second goal and calculate the estimated mass of not only perchlorate and hexavalent chromium in the Investigation Area, but other COPCs, including chlorate, chloroform, TDS, and nitrate.

As discussed previously, it was determined that the third and fourth goals could only be accomplished within the larger scope of the RI. Given the broad extent of elevated COPCs in soil and groundwater across the Site, the extent of contamination cannot be determined as part of the Unit 4 and 5 Buildings investigation alone; however, the RI Report for OU-1 and OU-2 will define the limits of COPC impacts. Nevertheless, the source investigation does define the vertical extent of COPC impacts such that source control and reduction actions can be evaluated in the Feasibility Study. Therefore, although the third and fourth bullets listed above were goals of the investigation outlined in the Work Plan, achievement of these goals including data interpretation and conclusions of the Unit 4 and 5 building area will be incorporated in the RI Report. The contaminant mass was estimated using the data collected during the source characterization as was presented in Section 4.5.3. The largest contaminant mass estimated was for chlorate followed by perchlorate, total chromium, hexavalent chromium, nitrate, and chloroform (in descending order).

As described in this report, soil and groundwater beneath the Unit 4 building appear to be a source of perchlorate, hexavalent chromium, chlorate, chloroform, TDS, and nitrate to groundwater. Soil and groundwater beneath the Unit 5 building also appears to be a source of COPCs to groundwater but, the magnitude of contributions to groundwater is much lower than below the Unit 4 building. The dataset obtained through this investigation is sufficient to characterize the nature and extent of these COPCs within the Investigation Area and there are no additional data gaps to be addressed. The dataset is suitable to support future source area treatability testing and development of source control and containment remedial alternatives to be considered in the forthcoming Feasibility Study for OU-1 and OU-2.

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Figures

\\GEOS051FS1\GEOL\VOL1\PROJECTS\DATA\NERT\M02\FEBRUARY MEETING\FIGURES\FIGURE01_SITELOCATION.MXD

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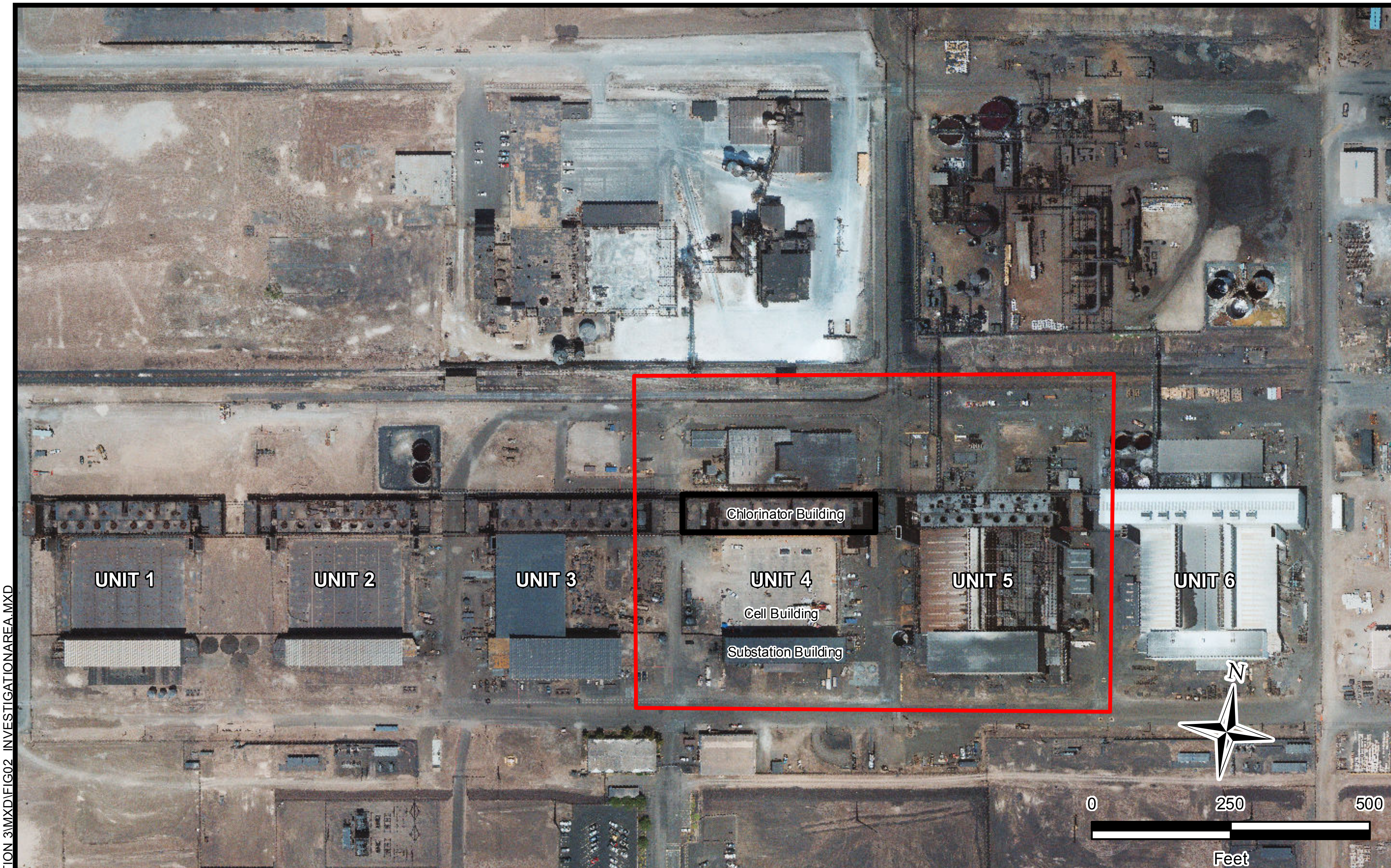
NEVADA ENVIRONMENTAL RESPONSE TRUST

UNIT 4 AND 5 BUILDINGS INVESTIGATION SOURCE AREA CHARACTERIZATION REPORT
HENDERSON, NEVADA

SITE LOCATION

Project No.:	114-520225
Date:	AUGUST 21, 2019
Designed By:	ES
Figure No.	1



Legend

Investigation Area

Imagery Source: Aerotech Mapping, August 2016.

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NEVADA ENVIRONMENTAL RESPONSE TRUST SITE

UNIT 4 AND 5 BUILDINGS INVESTIGATION SOURCE AREA CHARACTERIZATION REPORT
HENDERSON, NEVADA

UNIT 4 & 5 INVESTIGATION AREA

Project No.:	117-7502018
Date:	SEPTEMBER 05, 2018
Designed By:	MRB
Figure No.	2

T:\NERT\M02\MOBILIZATION 3\MXD\FIG02_INVESTIGATIONAREA.MXD

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NEVADA ENVIRONMENTAL RESPONSE TRUST SITE

UNIT 4 AND 5 BUILDINGS INVESTIGATION SOURCE AREA CHARACTERIZATION REPORT
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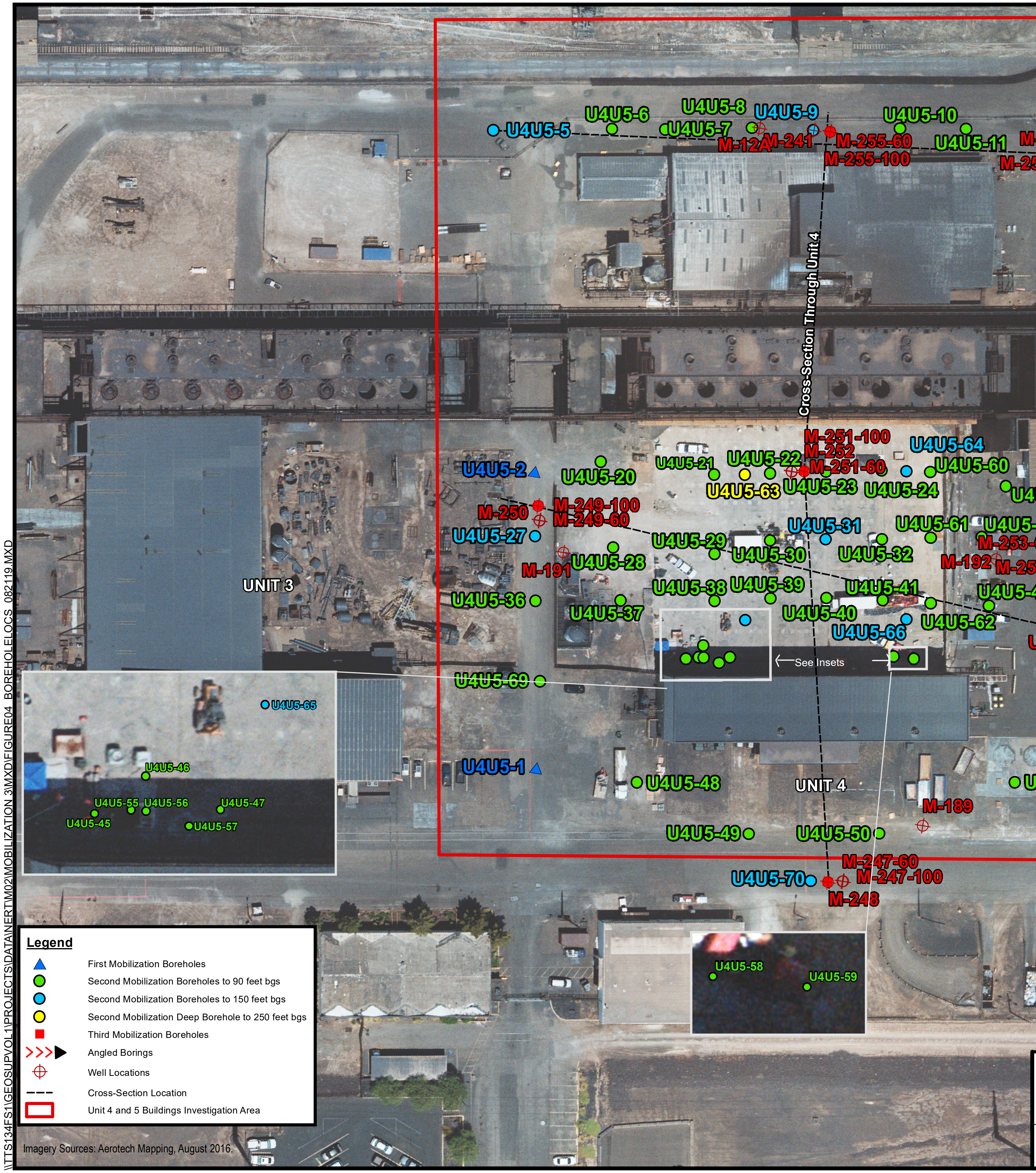
PROPOSED BOREHOLE TRANSECT LOCATIONS
MARCH 30, 2015 WORK PLAN

Project No.:	117-7502018
Date:	SEPTEMBER 05, 2018
Designed By:	MRB
Figure No.	3

T:\NERT\M02\MOBILIZATION 3\MXD\FIGURE03_BOREHOLETRANSECTLOCS.MXD



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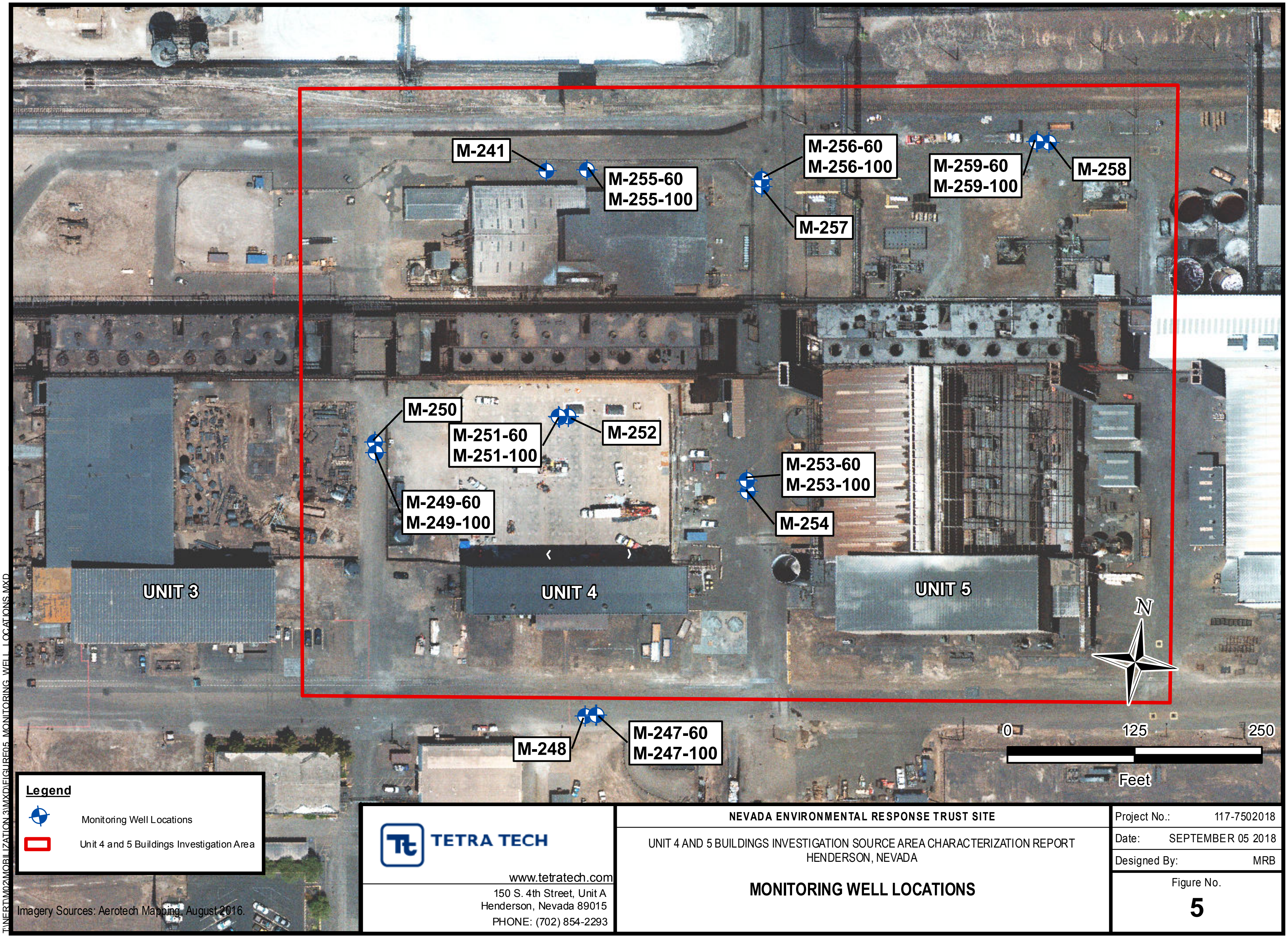
UNIT 4 AND 5 BUILDINGS INVESTIGATION SOURCE AREA CHARACTERIZATION REPORT
HENDERSON, NEVADA

BOREHOLE LOCATIONS

Project No.:	117-7502018
Date:	AUGUST 21, 2019
Designed By:	MRB
Figure No.	4



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NEVADA ENVIRONMENTAL RESPONSE TRUST SITE

UNIT 4 AND 5 BUILDINGS INVESTIGATION SOURCE AREA CHARACTERIZATION REPORT
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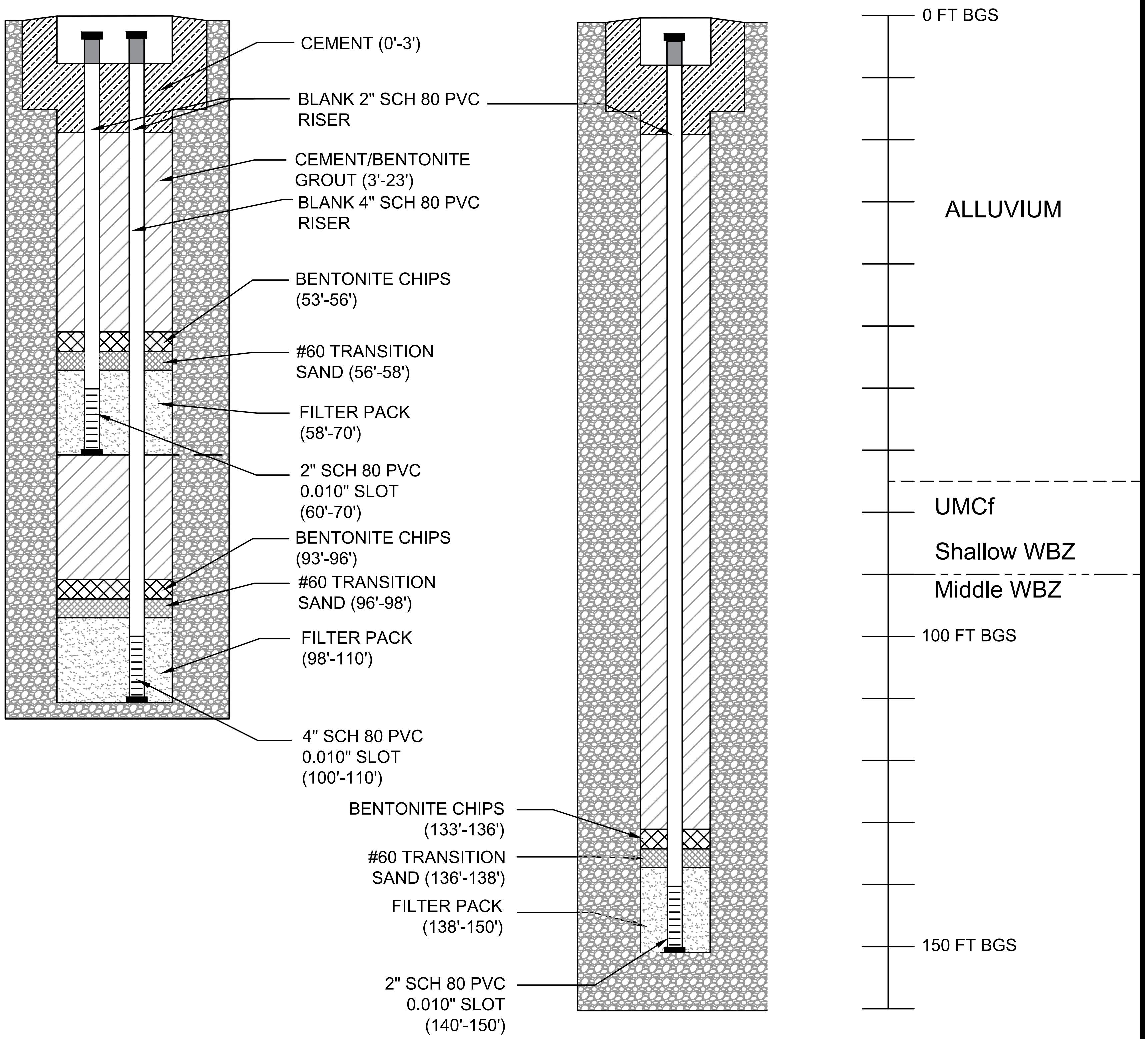
MONITORING WELL LOCATIONS

Project No.:	117-7502018
Date:	SEPTEMBER 05 2018
Designed By:	MRB
Figure No.	5



LEGEND

FT BGS	FEET BELOW GROUND SURFACE
WBZ	WATER BEARING ZONE
UMCf	UPPER MUDDY CREEK FORMATION

NOTES:

1. ACTUAL WELL CASING / SCREEN DEPTH, SLOT SIZE, SEAL INTERVALS, ETC. WERE BASED ON FIELD DATA AND CONDITIONS.
2. SCALED TO APPROXIMATE DEPTH.
3. BOREHOLE DIAMETER 12 INCHES.

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NEVADA ENVIRONMENTAL RESPONSE TRUST SITE

UNIT 4 AND 5 BUILDINGS INVESTIGATION SOURCE AREA CHARACTERIZATION REPORT
HENDERSON, NEVADA

TYPICAL MONITORING WELL DESIGN

Project No.:	117-7502018
Date:	MARCH 16, 2018
Designed By:	JX
Figure No.	6

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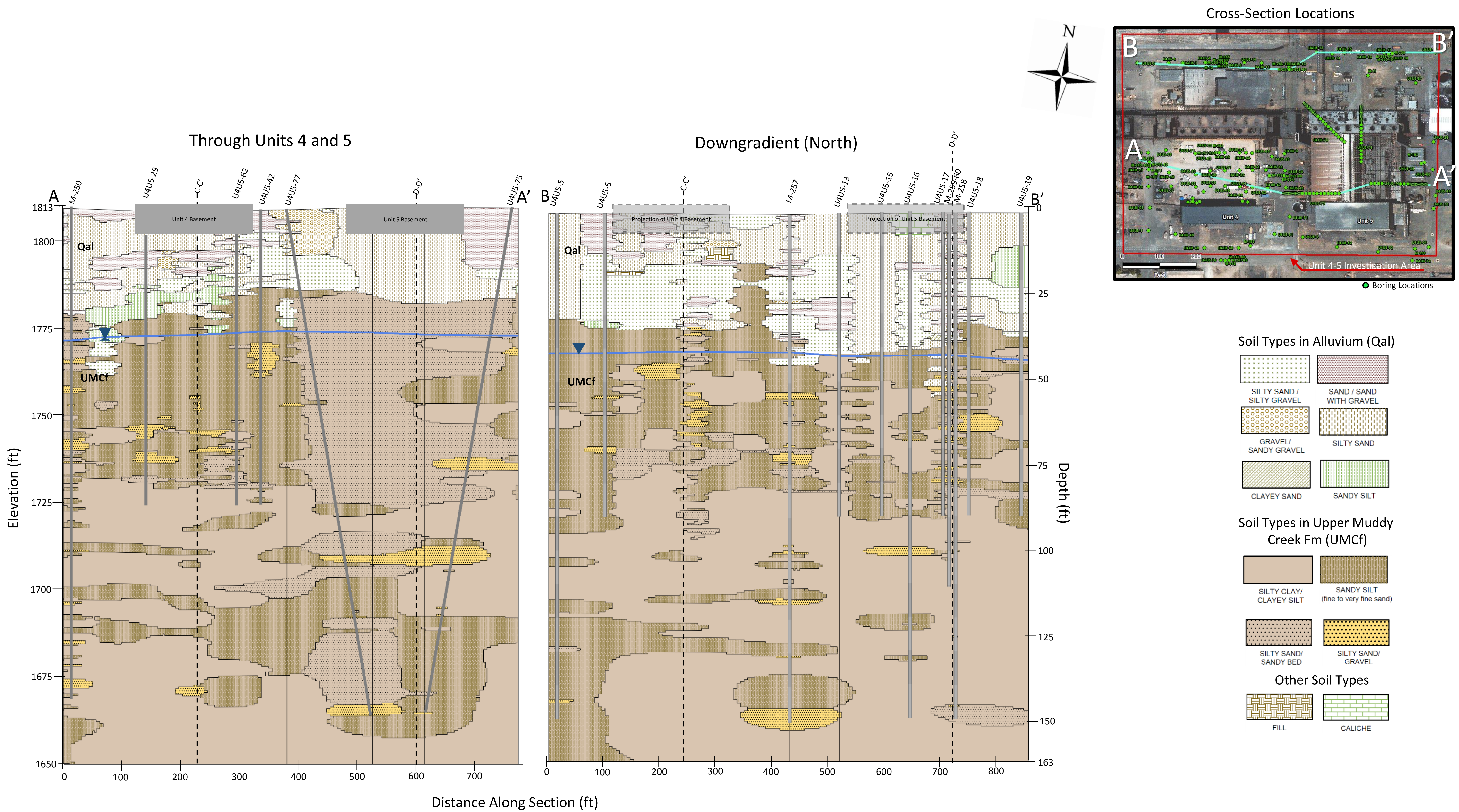

\\Ts134fs1\geosurvol1\PROJECTS\DATA\NERT\M02\Mobilization 3\Powerpoint Figures\Fig 8 – Lithology Sections EW

Notes:
1. Vertical exaggeration: 6:1.
2. Sections are shown looking North.
3. Data interpolation truncated below 163 ft bgs (below ground surface) due to insufficient data.
4. Ground surface elevation is assumed to be 1,813 ft amsl (above mean sea level) for the purposes of illustrated depth.
5. M-250 Monitoring well location and designation.
6. U4U5-29 Borehole location and designation.

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NEVADA ENVIRONMENTAL RESPONSE TRUST SITE
UNIT 4 AND 5 BUILDINGS INVESTIGATION SOURCE AREA CHARACTERIZATION REPORT
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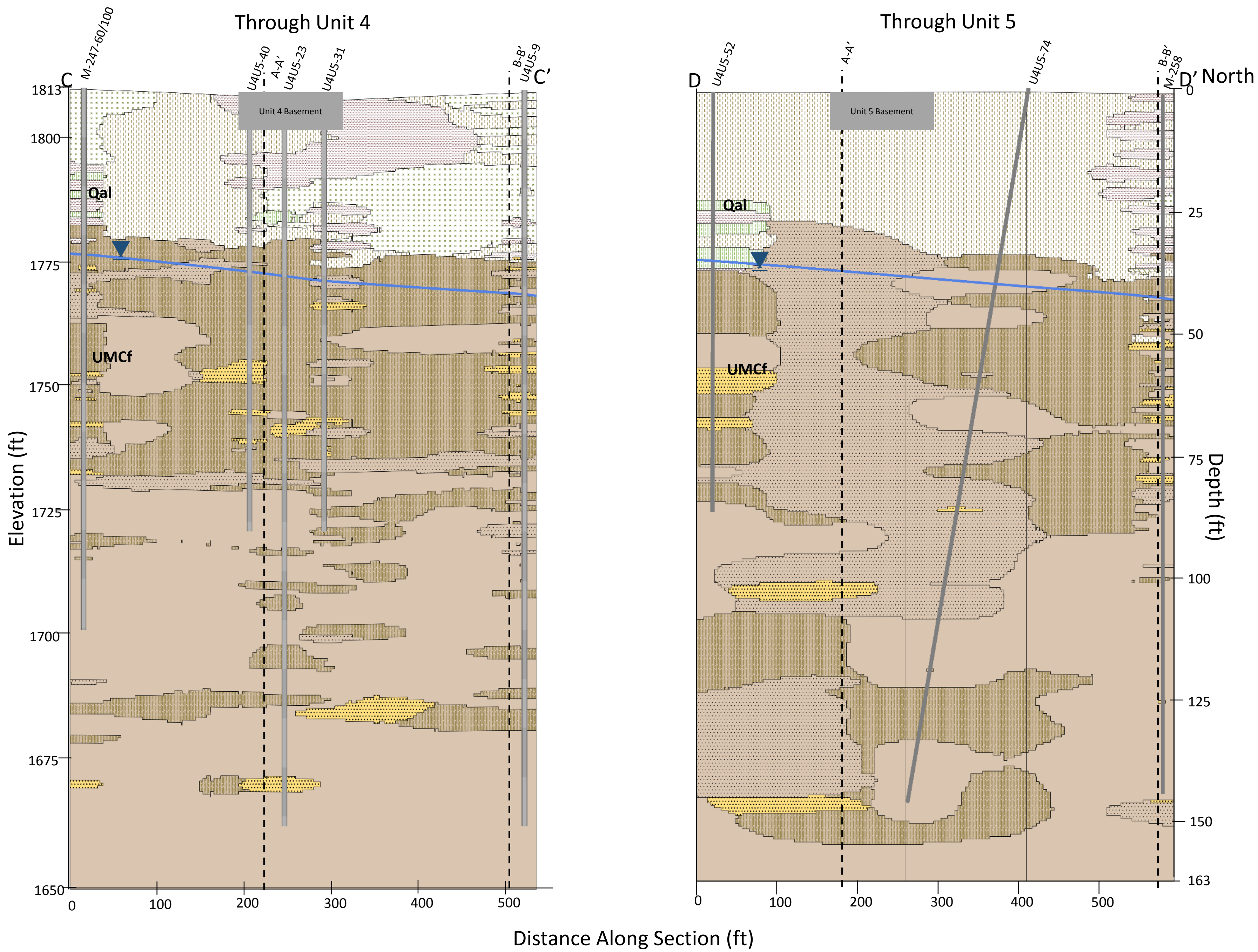
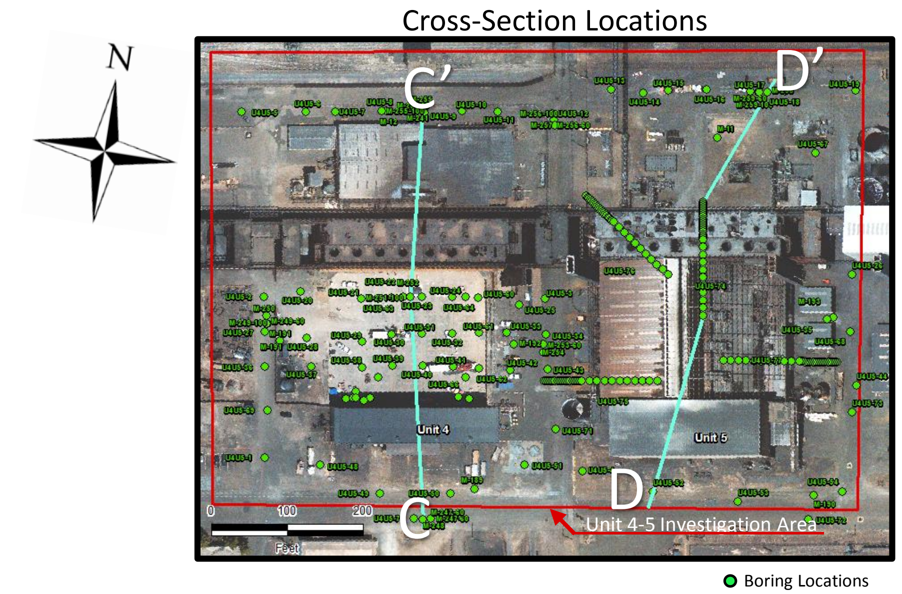
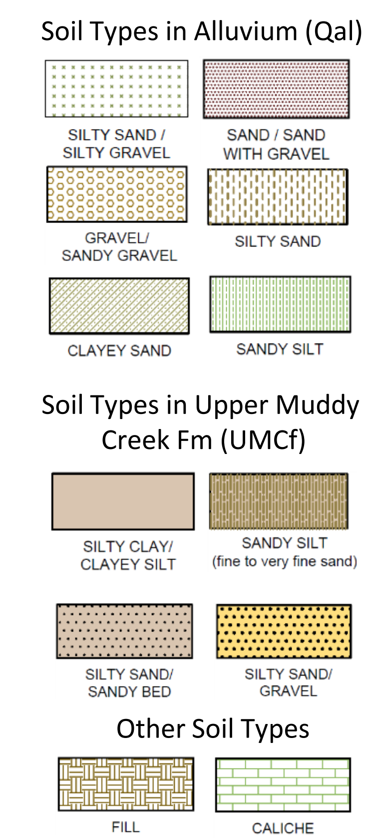
2D VISUALIZATION EAST-WEST CROSS SECTIONS OF LITHOLOGY, UNITS 4 AND 5

Project No.:	117-7502018
Date:	September 4, 2018
Designed By:	MRB
Figure No.	7







Notes:

1. Vertical exaggeration: 6:1.
2. Sections are shown looking West.
3. Data interpolation truncated below 163 ft bgs (below ground surface) due to insufficient data.
4. Ground surface elevation is assumed to be 1,813 ft amsl (above mean sea level) for the purposes of illustrated depth.
5. M-250 Monitoring well location and designation.
6. U4U5-29 Borehole location and designation.

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NEVADA ENVIRONMENTAL RESPONSE TRUST SITE

UNIT 4 AND 5 BUILDINGS INVESTIGATION SOURCE AREA CHARACTERIZATION REPORT
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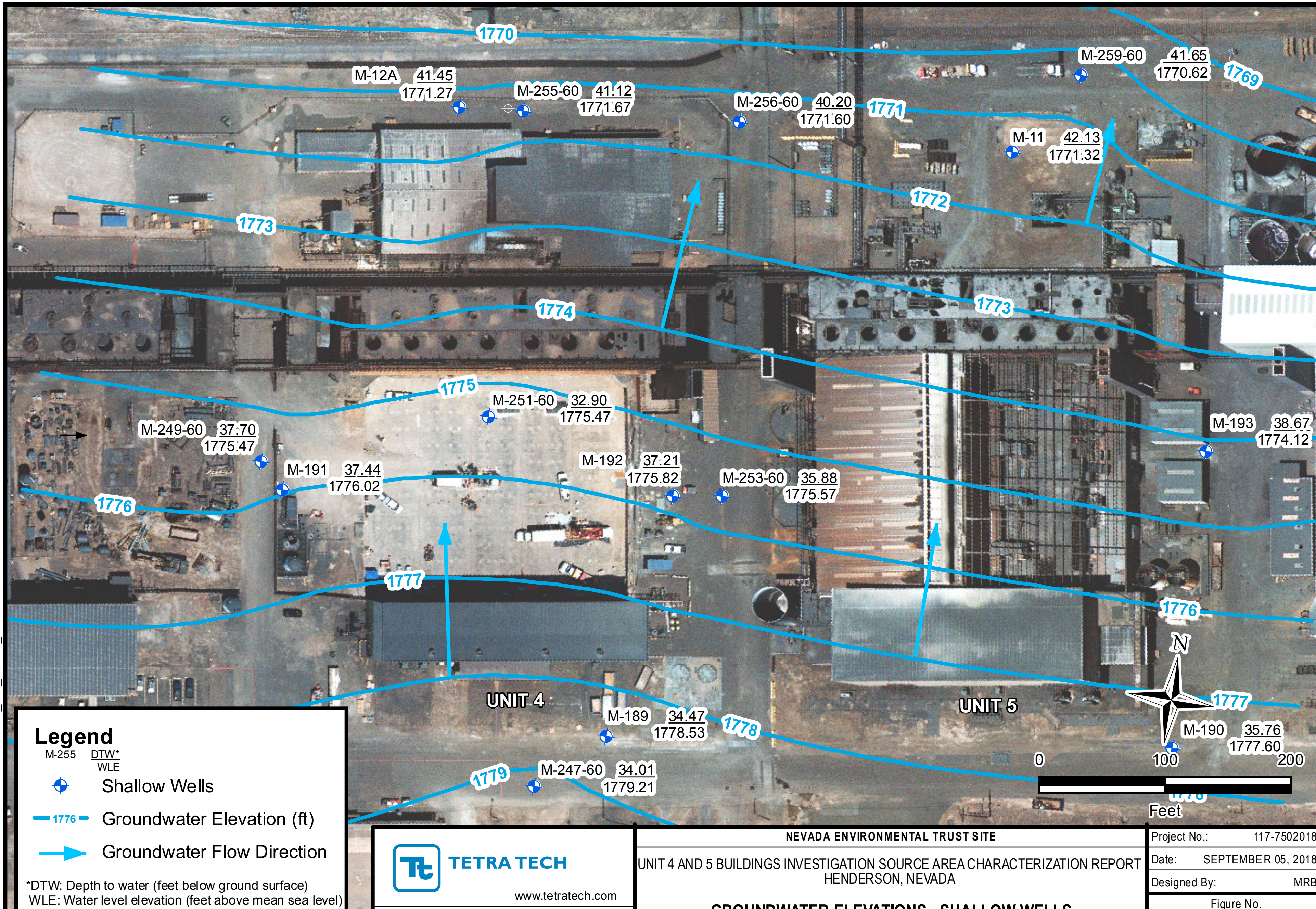
2D VISUALIZATION NORTH-SOUTH CROSS SECTIONS OF LITHOLOGY, UNITS 4 AND 5

Project No.:	117-7502018
Date:	September 4, 2018
Designed By:	MRB
Figure No.	8



Imagery Sources: Esri World Map, June 2015; Aerotech Mapping, August 2016

T:\NERT\M02\MOBILIZATION 3\MXD\FIG_WT_MOB3_SHALLOW.MXD

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NEVADA ENVIRONMENTAL TRUST SITE

UNIT 4 AND 5 BUILDINGS INVESTIGATION SOURCE AREA CHARACTERIZATION REPORT
HENDERSON, NEVADA

GROUNDWATER ELEVATIONS - SHALLOW WELLS

Project No.:	117-7502018
Date:	SEPTEMBER 05, 2018
Designed By:	MRB
Figure No.	9

T:\NERT\M02\MOBILIZATION 3\MXD\FIG_WT_MOB3_INTERMEDIATE.MXD

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NEVADA ENVIRONMENTAL RESPONSE TRUST SITE

UNIT 4 AND 5 BUILDINGS INVESTIGATION SOURCE AREA CHARACTERIZATION REPORT
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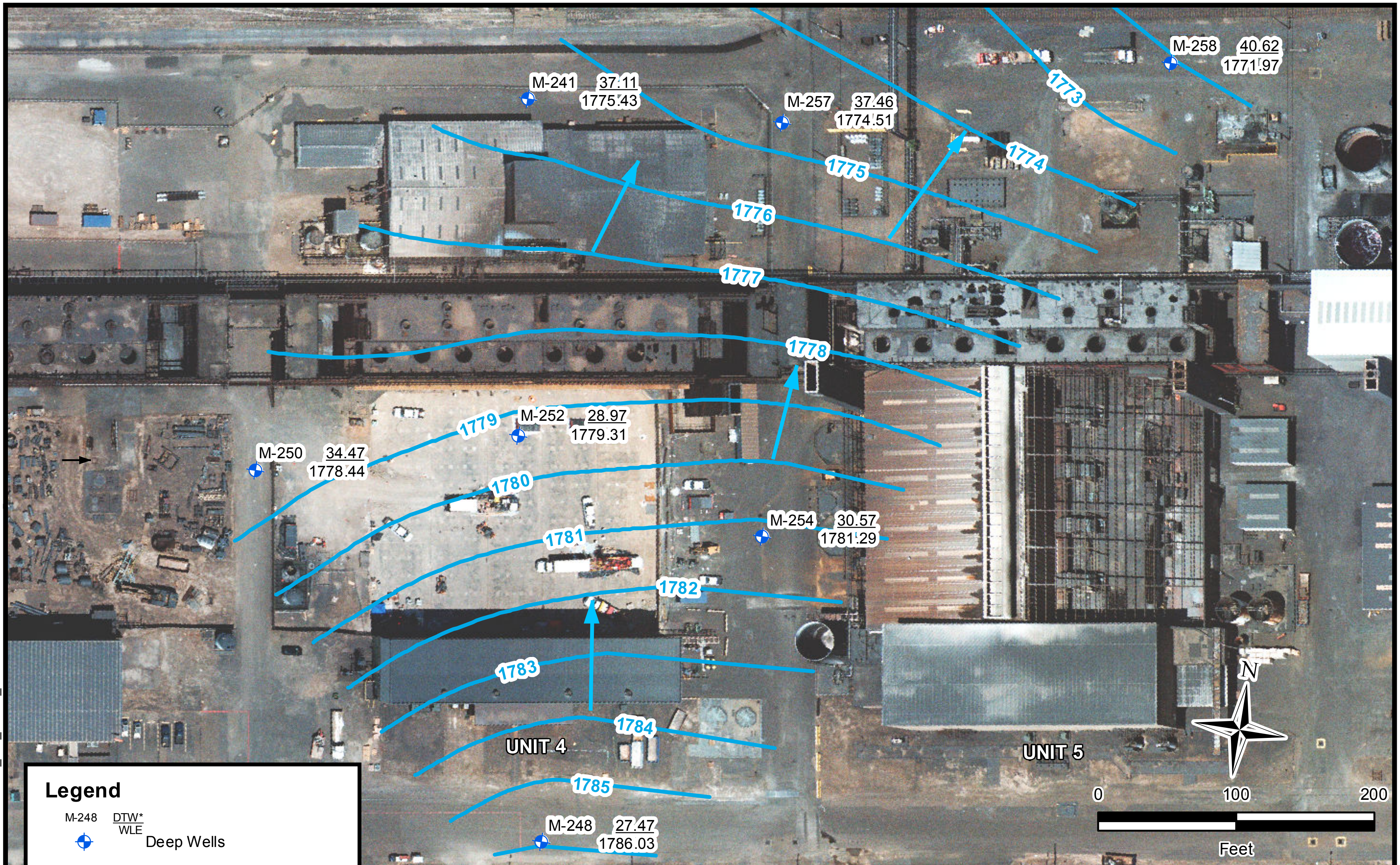
GROUNDWATER ELEVATIONS - INTERMEDIATE WELLS

Project No.:	117-7502018
Date:	SEPTEMBER 05, 2018
Designed By:	MRB
Figure No.	10



Legend

M-248 DTW*/WLE Deep Wells

1776 Groundwater Elevation (ft)

Groundwater Flow Direction

*DTW: Depth to water (feet below ground surface)
WLE: Water level elevation (feet above mean sea level)

Imagery Sources: Aerotech Mapping, August 2016.

T:\NERT\M02\MOBILIZATION 3\MXD\FIG_WT_MOB3_DEEP.MXD

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NEVADA ENVIRONMENTAL RESPONSE TRUST SITE

UNIT 4 AND 5 BUILDINGS INVESTIGATION SOURCE AREA CHARACTERIZATION REPORT
HENDERSON, NEVADA

GROUNDWATER ELEVATIONS - DEEP WELLS

Project No.: 117-7502018

Date: SEPTEMBER 05, 2018

Designed By: MRB

Figure No.

11