Galleria Road Bioremediation Treatability Study Work Plan

Nevada Environmental Response Trust Site
Henderson, Nevada

PREPARED FOR

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LIST OF ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
ASTM	American Society for Testing and Materials
AWF	Athens Road Well Field
BEC	Basic Environmental Company, LLC
bgs	Below ground surface
BL	baseline
COH	City of Henderson
COPC	contaminants of potential concern
DO	dissolved oxygen
EC	electrical conductivity
EVO	emulsified vegetable oil
FS	Feasibility Study
ISB	in-situ bioremediation
ITRC	Interstate Technology & Regulatory Council
lbs/day	pounds per day
mg/L	milligrams per liter
mV	milliVolts
NAC	Nevada Administrative Code
NDEP	Nevada Division of Environmental Protection
NDWR	Nevada Division of Water Resources
NERT or Trust	Nevada Environmental Response Trust
NFG	National Functional Guidelines
NMR	Nuclear magnetic resonance
ORP	oxidation reduction potential
PLFA	phospholipid fatty acids
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
RAO	Remedial action objective
RI	Remedial Investigation
Site	Nevada Environmental Response Trust site
SWF	Seep Well Field
TDS	total dissolved solids
Tetra Tech	Tetra Tech, Inc.
TOC	total organic compound

Acronyms/Abbreviations	Definition
U.S. EPA	United States Environmental Protection Agency
UIC	Underground Injection Control
UMCf	Upper Muddy Creek Formation
UNLV	University of Nevada at Las Vegas
VFAs	volatile fatty acids
Work Plan	Galleria Road Bioremediation Treatability Study Work Plan
ZOI	zone of influence

CERTIFICATION

Galleria Road Bioremediation Treatability Study Work Plan

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

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: 10/6/17

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.

Description of Services Provided: Prepared Galleria Road Bioremediation Treatability Study Work Plan, Nevada Environmental Response Trust Site, Henderson, Nevada

Kyle S. Hansen

10/06/2017

Kyle Hansen, CEM
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Date

Nevada CEM Certificate Number: 2167
Nevada CEM Expiration Date: September 18, 2018

1.0 INTRODUCTION

On behalf of the Nevada Environmental Response Trust (NERT or Trust), Tetra Tech, Inc. (Tetra Tech) has prepared this Galleria Road Bioremediation Treatability Study Work Plan (Work Plan) for implementation of an in-situ bioremediation (ISB) treatability study in the Upper Muddy Creek Formation (UMCf) and alluvium (if saturated) at a location within the Eastside Study Area, which is northeast of the NERT site (Site), located in Clark County, Nevada (Figure 1). This Work Plan is being submitted to the Nevada Division of Environmental Protection (NDEP) under the Interim Consent Agreement effective February 14, 2011. The Work Plan presents a conceptual design for implementation of the ISB treatability study based on the current available data and provides details on pre-design activities to be conducted prior to final treatability test design.

1.1 PROJECT OBJECTIVES

This Work Plan is being conducted to support remedy selection as part of the Remedial Investigation and Feasibility Study (RI/FS). Currently, the Remedial Investigation (RI) is being conducted in four investigation sub-areas: the On-Site NERT RI Study Area; the Off-Site NERT RI Study Area; the Downgradient Study Area; and the Eastside Study Area. These investigation sub-areas are collectively referred to as the NERT RI Study Area (Figure 1).

Additional technical evaluation of location-specific remedial options is necessary to support remedy selection in the Eastside Study Area. Two separate, coordinated in-situ treatability studies will be performed along the northern portion of Eastside Study Area along Galleria Drive to evaluate the feasibility and effectiveness of these technologies to reduce contaminant mass flux at the mid-plume containment and mass removal boundary, which has been proposed as a remedial action objective (RAO). These studies are being performed in support of the proposed RAO to mitigate contaminant migration at the mid-plume boundary and to provide essential input for the future Feasibility Study (FS). These treatability studies will consist of application of ISB by Tetra Tech and Zero-Valent Iron Enhanced Bioremediation by Ramboll Environ. Conceptual locations of both treatability studies are presented in Figure 1.

The focus of this Work Plan is to present the activities associated with application of ISB performed by Tetra Tech, referred to herein as the treatability study. The overall objective of the treatability study is to demonstrate and evaluate the effectiveness of implementing ISB to reduce the contaminants present in the alluvium and UMCf that are migrating across the proposed mid-plume containment and mass removal boundary. This treatability study will build on the results of the previous ISB treatability study performed downgradient of the Athens Well Field (AWF) near the City of Henderson (COH) Bird Viewing Ponds and the on-going Seep Well Field (SWF) Area Bioremediation Treatability Study. However, unlike the studies that focused on the alluvium and more transmissive paleochannel deposits, this treatability study will primarily focus on the UMCf underlying the study location as well as alluvium, if saturated.

1.2 WORK PLAN ORGANIZATION

This Work Plan is organized as follows:

- **Introduction (Section 1.0):** Provides the primary objectives of the treatability study along with relevant background information, including site history, regional geology and hydrogeology, local geology and hydrogeology, and extent of contamination.
- **Technology Description (Section 2.0):** Provides an overview of bioremediation of perchlorate and provides a summary of previous and on-going ISB treatability studies.

- **Pre-Design Field and Laboratory Activities (Section 3.0):** Provides a description of the field and laboratory activities to be completed prior to implementing the treatability study to optimize and finalize the treatability study design.
- **Treatability Study Conceptual Design (Section 4.0):** Describes the conceptual design of the treatability study including objectives, evaluation of study locations, conceptual layout(s), and preliminary substrate injection design.
- **Effectiveness Monitoring Plan (Section 5.0)**: Presents the conceptual effectiveness monitoring program for the treatability study, including the field, analytical, and microbial groundwater monitoring and data validation requirements, as well as mass flux evaluations.
- **Access Agreement and Permitting (Section 6.0):** Summarizes access agreement and permitting requirements for treatability study implementation.
- **Reporting (Section 7.0):** Summarizes reporting related to design and execution of the pre-design field activities and treatability study.
- **Schedule (Section 8.0):** Summarizes the schedule for conducting the pre-design activities, treatability study, and associated reporting.
- **References (Section 9.0):** Lists the documents referenced in this Work Plan.

1.3 BACKGROUND

This section provides a summary of relevant background information for the NERT site and Eastside Study Area with emphasis on the area in proximity to the proposed mid-plume boundary. The information presented in this section was considered during the development of this Work Plan. As mentioned previously, NERT is conducting two treatability studies in adjacent areas to evaluate two remedial technologies to reduce perchlorate mass flux in this area to support one of the proposed Remedial Action Alternatives. The background information provided in the remainder of Section 1 was prepared by NERT and is repeated in this work plan as well as the Galleria Road Zero Valent Iron Treatability Study Work Plan for cost efficiency. Additional background information is available in the following documents:

- RI/FS Work Plan Addendum: Phase 3 Remedial Investigation prepared by Ramboll Environ (Ramboll Environ, 2017), the “Phase 3 RI Work Plan” and
- Remedial Investigation and Feasibility Study Work Plan, Revision 2 prepared by ENVIRON International Corporation (ENVIRON) (ENVIRON, 2014a), the “Phase 1 RI Work Plan”.

This section focuses on the Eastside Study Area since the treatability study is planned to be conducted there; however, the NERT site is discussed below as necessary to provide additional relevant context.

1.3.1 Site Description and Use

The Eastside Study Area covers approximately 2,527 acres and is located approximately 14 miles southeast of the City of Las Vegas and within the city limits of Henderson. It is located between Pabco Road and Lake Mead Parkway, northeast of the active industrial operations at the Black Mountain Industrial (BMI)[1] Complex and adjacent to primarily residential properties.

[1] The acronym “BMI” has been applied to several entities over the years. From 1941 until 1951 it referred to Basic Magnesium Incorporated; in 1951, a syndicate of tenants formed under the name of Basic Management, Inc. to provide utilities and other services at the complex; the group has also been known as Basic Metals, Inc., and at the present is called the Black Mountain Industrial complex.

The Eastside Study Area encompasses two subareas: the Eastside Sub-Area and the Northeast Sub-Area.

- The Eastside Sub-Area is approximately 1,983 acres and located east of Pabco Road, west of Lake Mead Parkway, and south of Galleria Drive. It was historically part of the BMI Common Area. Portions of the Eastside Sub-Area were historically used for the disposal of process wastewater generated at the neighboring BMI Complex.
- The Northeast Sub-Area is approximately 544 acres and is located north of Galleria Drive and encompasses much of the area currently occupied by the Chimera Golf Club, Tuscany Village, and other residential communities.

The BMI Complex, including the NERT site, was initially developed by the United States Government during World War II, under the Defense Plant Corporation, as a magnesium production facility. Facility construction began in 1941 under a contract with Basic Magnesium Incorporated (BMI) and the plant was operated from August 31, 1942 to November 15, 1944 in support of the war effort.

Starting in 1945, several companies began leasing portions of the complex from the U.S. Government. In 1949, ownership of a majority of the overall industrial complex was transferred to the State of Nevada's Colorado River Commission (CRC). In 1952, the five principal operating companies at the time (Western Electric Chemical Company [WECCO], Stauffer Chemical Company [Stauffer], U.S. Lime, Titanium Metals Corporation of America [TIMET], and Combined Metals Reduction Company [Combined Metals]) purchased operational facilities from the CRC. The CRC conveyed most of its remaining property to Basic Management Incorporated (Basic Management) as a new organization, which was owned by the five principal operating companies.

Basic Management was established to manage facilities and utilities common to all tenants at the complex, including water, power, sanitary sewers, and transportation. Areas used by Basic Management for general facility and utility operations are often referred to as the BMI Common Area.

The Eastside Sub-Area, which makes up the southern portion of the Eastside Study Area, was part of the BMI Common Area and was used for a variety of functions including industrial wastewater collection. Although much of the Eastside Sub-Area is currently vacant, portions of the area have been developed with residential, commercial, and public spaces, which is anticipated to expand throughout much of the Eastside Study Area within the next decade. Much of the Northeast Sub-Area was vacant prior to the construction of residential housing and a golf course in the late 1990s and early 2000s.

Process wastewaters generated by industrial operations within the BMI Complex were conveyed to the Upper BMI Ponds (located in the northern portion of the Eastside Sub-Area) via the Beta Ditch, which was an unlined ditch constructed circa 1941 or 1942. The Beta Ditch historically received a variety of wastes in addition to receiving storm water and non-contact cooling water. The Beta Ditch extended east of the NERT site to a siphon inlet/pond location on what is now TIMET property. The siphon inlet then transmitted flows from the western section of Beta Ditch under Boulder Highway to the eastern section of the Beta Ditch and subsequently to the Upper BMI Ponds (located within the Eastside Sub-Area) and Lower BMI ponds (located in the Downgradient Study Area to the northwest of the Eastside Sub-Area).

The Alpha Ditch was constructed in approximately 1943 to convey non-contact cooling water to the Las Vegas Wash and, possibly, the Lower BMI Ponds. Collection segments on the TIMET property directed flow north and northwest, joined, and then routed the combined flow northeast under Boulder Highway to the main segment of the Alpha Ditch.

1.3.2 Regulatory Background

Large portions of the Eastside Study Area have been the subject of numerous regulatory actions and environmental investigations (Ramboll Environ 2017). In 2006, Basic Remediation Company LLC (BRC) and other companies within the BMI complex executed a settlement agreement defining the framework for characterization and remediation of the BMI Common Areas and defined steps by which the remedial actions should be performed (NDEP 2006). BRC conducted soil and groundwater investigations and remediation activity (completed in 2014), which served as the basis for NDEP granting No Further Action (NFA) determinations on parcels comprising the Eastside Sub-Area. NDEP's NFA determinations were restricted to the upper 10 feet of the soil horizon and were consistent with proposed future land uses (BRC 2014). NDEP has directed the Trust to investigate the Eastside Sub-Area in order to evaluate the nature and extent of COPCs (i.e., perchlorate and chlorate) impacts to the subsurface as a result of migration from the NERT site, particularly in soil and the underlying groundwater (Ramboll Environ 2017b).

1.3.3 Physical Setting

Topographic elevation within the Eastside Study Area ranges from approximately 1,820 to 1,530 feet above mean sea level (amsl). The land surface across the Eastside Study Area generally slopes toward the north at a gradient of approximately 0.02 feet per foot (ft/ft). The developed portions of the Eastside Study Area have been modified by grading to accommodate structures, access roads, recreational spaces, and historical ponds and ditches.

1.3.4 Regional Geology

The Eastside Study Area is located within the Las Vegas Valley, which occupies a topographic and structural basin trending northwest-southeast and extending approximately 55 miles from near Indian Springs on the north to Railroad Pass on the south. The mountain ranges bounding the east, north, and west sides of the valley consist primarily of Paleozoic and Mesozoic sedimentary rocks, whereas the mountains on the south and southeast consist primarily of Tertiary volcanic rocks that overlie Precambrian metamorphic and granitic basement. The valley floor consists of deposits surrounded by more steeply sloping alluvial fan aprons derived from erosion of the surrounding mountains. Generally, the deposits grade finer with increasing distance from their source and with decreasing elevation.

1.3.5 Local Geology and Hydrogeology

The local geology and hydrogeology are currently defined by data collected from more than 1,100 borings and wells that have been installed by BMI/BRC and other neighboring parties over approximately the last 30 years in the Eastside Study Area. The following descriptions are summarized from BRC's Conceptual Site Model (BRC CSM) report (BRC 2007) as presented in the Phase 3 RI Work Plan (Ramboll Environ, 2017b). Additional hydrogeological investigation of the Eastside Study Area is planned as part of the Phase 3 RI Work Plan and additional focused investigation will be conducted as part of this treatability study (as described in Section 3). These investigations will further inform the understanding of the local geology and hydrogeology necessary to implement this treatability study.

1.3.5.1 Alluvium

The Eastside Study Area is located on Quaternary alluvial deposits (Qal or "alluvium") that slope north toward Las Vegas Wash. The alluvium consists of a reddish-brown heterogeneous mixture of well-graded sand and gravel with lesser amounts of silt, clay, and caliche. Clasts within the alluvium are primarily composed of volcanic material. Boulders and cobbles are common.

A major feature of the alluvial deposits is the stream-deposited sands and gravels that were laid down within paleochannels eroded into the surface of the Muddy Creek Formation during infrequent flood runoff periods. These deposits vary in thickness and are narrow and generally linear. These sand and gravel deposits exhibit higher hydraulic conductivity than the adjacent, well-graded deposits. In general, these paleochannels trend northeastward toward the Las Vegas Wash.

The thickness of the alluvial deposits ranges from approximately 20 feet to more than 50 feet beneath the Eastside Study Area. The alluvial soils identified in on-site borings include poorly sorted gravel, silty gravel, poorly sorted sand, well sorted sand, and silty sand. The thickness of the alluvium, as well as the top of the underlying Muddy Creek Formation, was mapped to locate these paleochannels.

1.3.5.2 Transitional (or Reworked) Muddy Creek Formation

Where present, Transitional Muddy Creek Formation (xMCf) is encountered at the base of the alluvium. The xMCf consists of reworked sediments derived from the Muddy Creek Formation, which is described below. Therefore, the xMCf appears similar to the Muddy Creek Formation but consists of reworked, less consolidated and indurated sediments.

1.3.5.3 Muddy Creek Formation

The Upper Muddy Creek Formation (UMCf) in the Las Vegas Valley consists of valley-fill deposits that are coarse-grained near mountain fronts and progressively finer-grained moving toward the center of the valley. Stratigraphic logs from historical borings indicate that, where encountered beneath the Eastside Study Area, the UMCf comprises fine-grained sediment composed of clay and silt interbedded with occasional thin layers of coarse-grained sediments of sand, silt, and gravel.

The contact between the alluvium and the UMCf is typically marked by the appearance of a well-compacted, moderate brown silt-to-sandy silt or stiff clay-to-sandy clay, except near the Las Vegas Wash where the contact is marked by gray-green to yellow-green gypsiferous clays and silts.

1.3.5.4 Hydrogeology

Depth to groundwater in the Eastside Study Area ranges from about 20 to 70 feet below ground surface (ft bgs) with the depth generally greatest in the southernmost portion of the Eastside Study Area, becoming shallower to the north (Ramboll Environ, 2017). The presumed direction of groundwater flow is generally toward the north-northwest on the east side of the Eastside Study Area and generally toward the north-northeast on the west side. These regional groundwater flow patterns may be influenced locally by lateral zones of coarser and more transmissive material (otherwise referred to as paleochannels) eroded into the underlying UMCf and/or hydraulic depressions created by pumping at the AWF located east of the Eastside Study Area along Galleria Drive.

NDEP has defined three water-bearing zones (WBZs) that are of interest in the BMI Complex[2]: the Shallow WBZ, which is defined by the first occurrence of groundwater in either the Qal, xMCf, or the UMCf where the xMCf is missing, is unconfined to partially confined, and is considered the “water table aquifer”; the Middle WBZ, which extends from approximately 90 to 300 feet bgs; and the Deep WBZ, which is defined as the contiguous WBZ that is generally encountered between 300 to 400 feet bgs (NDEP, 2009).

During previous investigations in the Eastside Sub-Area, the base of the Middle WBZ was considered to be 270 feet bgs (MWH, 2004). Within the Eastside Study Area, 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. Beneath the

[2] BRC reports have historically used two groundwater zones, a shallow unconfined WBZ (first encountered between 8 and 65 feet bgs) and a deeper confined WBZ (first encountered between 335 and 395 feet bgs) (BRC 2007). This Work Plan refers to WBZ using NDEP-defined nomenclature rather than the shallow and deep groundwater aquifers referenced in BRC’s reports.

southern portion of the Eastside Sub-Area, the first groundwater encountered occurs at depths of approximately 40 feet bgs or more and shallows northward, occurring near the ground surface at Las Vegas Wash within the Northeast Sub-Area (BRC, 2016). The water table occurs in the alluvium in the western part of the Eastside Sub-Area and predominantly in the UMCf near the northern boundary and eastern portion of the Eastside Sub-Area where the alluvium has become dewatered.

Based on the results of single-well hydraulic tests, implemented as rising head slug tests conducted at ten wells located within the Eastside Sub-Area in 2007, calculated hydraulic conductivity values ranged from approximately 0.8 to 60 feet per day (feet/day) in wells screened within the alluvium, and from approximately 0.06 to 0.5 feet/day in wells screened within the UMCf (Kleinfelder, 2007). A 48-hour constant discharge pumping test conducted in 1998 in test wells located along Galleria Road, approximately 1,700 feet due west of Pabco Road (near current extraction well ART-8A), concluded that permeabilities of the "channel-fill alluvium" ranged from 1,072-1,698 gallons per day per square foot (gpd/ft^2), transmissivities ranged from 39,666-66,000 gpd/ft, and storage coefficients ranged from 0.03 to 0.11 (Kerr-McGee, 1998). The field investigation presented in Section 4 is intended to provide location-specific hydrogeologic information to add to the understanding of hydraulic conductivities and groundwater velocities in the area of the proposed treatability study.

Investigations of the Middle WBZ within the Eastside Study Area and surrounding areas indicate that, with a few exceptions, a vertically upward hydraulic gradient exists between the Middle and Shallow WBZs with the magnitude of the vertical head difference generally increasing as depth increases. Additional data on vertical gradients within the Eastside Study Area and the proposed treatability study location will be collected as part of the Phase 3 RI and this Work Plan (as described in Section 3), respectively.

1.3.6 Existing Data Evaluation at the Proposed Mid-Plume Boundary

This section provides an evaluation of the current data in the vicinity of the proposed mid-plume boundary, specifically along Galleria Road in the Eastside Area, and discusses known data gaps along Galleria Road. Figure 2 shows a detailed view of the area in the vicinity of the proposed mid-plume boundary, along with recently sampled well locations. Data for recently sampled locations along Galleria Road are listed Appendix A in Table A-1, while data for additional wells in the vicinity of the proposed mid-plume boundary are listed in Appendix A in Table A-2.

1.3.6.1 Hydrogeology

Along Galleria Road, recently sampled wells are either cross-screened between the alluvium and the UMCf or screened in the UMCf. The depth to the UMCf along Galleria Road generally ranges from 30 to 40 ft bgs (Table A-1). However, local variations in UMCf contact topography may range from 25 to 60 ft bgs.

Depth to groundwater in the vicinity of the proposed mid-plume boundary is generally consistent with the range for the entire Eastside Area, though the range of depth to groundwater along Galleria Road is narrower, from about 26 to 59 ft bgs (Table A-1). Available shallow groundwater elevation data from 2015 and 2016 in the vicinity of the proposed mid-plume boundary are shown on Figure 3. 2016 data were collected by the Trust and TIMET, and 2015 data were collected by BRC. Additional 2016 data were also collected by AECOM in support of the Downgradient Study Area investigation. These data were used in conjunction with the NERT Phase 5 Transient Groundwater Flow Model (the Phase 5 model) interpretation of the Qal-UMCf contact (Ramboll Environ, 2016) to estimate the approximate saturated thickness of alluvium in the vicinity of the proposed mid-plume boundary. As discussed in the Phase 3 RI Work Plan, the alluvium has generally become dewatered near the northern boundary of the Eastside Area. Therefore, in many locations the first encountered groundwater exists within the UMCf (Ramboll Environ, 2017).

1.3.6.2 Soil

In 2009, BRC conducted an extensive soil investigation in the Eastside Study Area. Along Galleria Road, approximately 210 locations were sampled at multiple depths up to 20 feet below ground surface. While these data can be used to characterize the vadose zone in the area, the soil samples were not deep enough to characterize the saturated alluvium and the UMCf. Between 2004 and 2009, BRC also drilled soil borings in preparation for well installations. While the total depth sampled for each soil boring varied depending on the anticipated depth of the planned well, the maximum vertical extent of perchlorate contamination along Galleria Road is relatively consistent at approximately 80 ft bgs.

1.3.6.3 Groundwater Geochemistry

The field parameters, general chemistry, and metals analyses data from the ten monitoring wells along Galleria Road are shown in Table A-1. These data were collected by BRC and TIMET in 2014 and 2015, as well as AECOM on behalf of NERT in 2016. With the exception of MCF-05, which is screened in the Deep WBZ and has a much higher total dissolved solids content due to the presence of chloride salts, the geochemistry of the groundwater along Galleria Road is relatively consistent, with absolute concentrations of individual constituents trending with the total dissolved solids content. Additional analytical data from other wells in the vicinity of the proposed mid-plume boundary are summarized in Table A-2.

1.3.6.4 Data Gaps

In order to fully characterize the proposed field test area, additional geochemical data are necessary to address identified data gaps. Relevant data in the vicinity of the proposed field test area collected as part of the upcoming Phase 3 RI will be incorporated into future evaluations as it becomes available. However, additional geochemical data have also been identified as necessary to understand the full geochemical system in the area, including:

1. Characterization of the hydrogeology in greater detail and identification of preferential flow pathways.
2. Local assessment of vertical and horizontal distribution of perchlorate, chlorate, and other analytes to target remediation accordingly.
3. Local characterization of the baseline geochemical and biological conditions.

2.0 TECHNOLOGY DESCRIPTION

2.1 MICROBIOLOGY AND BIODEGRADATION OF PERCHLORATE

Perchlorate is the anionic component of ammonium perchlorate, a common ingredient in solid rocket fuel. Perchlorate salts are very soluble in water, (approximately 200,000 milligrams per liter [mg/L] for ammonium perchlorate and approximately 2,100,000 mg/L for sodium perchlorate) and do not adsorb very strongly to most soils.

Perchlorate also tends to be biologically stable under aerobic conditions or when there is a limited source of organic carbon. However, in the presence of a carbon substrate and after dissolved oxygen (DO) and nitrate have been depleted, perchlorate can act as an electron acceptor for anaerobic respiration. The first step in perchlorate biodegradation is carried out by the perchlorate reductase gene, wherein perchlorate is sequentially converted to chlorate and then to chlorite. A second gene, chlorite dismutase, further reduces the chlorite to chloride and oxygen (Interstate Technology & Regulatory Council [ITRC], 2008).

A variety of perchlorate-reducing bacteria have been isolated, with some of them being strict anaerobes, while others are facultative microbes. Generally, perchlorate-reducing microorganisms are known to be quite ubiquitous in the subsurface and are also quite versatile. As a result, successful groundwater treatment requires understanding of the chemical, geochemical, physical, geological, and hydrogeological conditions at a site, and then developing an appropriate engineered approach. Physical, geological, and hydrogeological conditions are usually fixed, and therefore, a successful remedial strategy relies on the modification and sustainment of the appropriate geochemical conditions to maintain perchlorate biodegradation. Favorable redox conditions that are appropriate for perchlorate biodegradation are less than 0 millivolts (mV) and generally in the 0 to -100 mV range. This range of redox is indicative of conditions wherein the aquifer is depleted of DO and nitrate is consumed, leaving perchlorate the next preferred electron acceptor as the respiratory source for native microorganisms (ITRC, 2008).

2.2 PREVIOUS BIOREMEDIATION APPLICATION

A groundwater bioremediation treatability study was performed by Tetra Tech, on behalf of the Trust, between April 2015 and September 2016 within the vicinity of the COH Water Treatment Facility, which is immediately upgradient of the Bird Viewing Preserve and mid-way between the Athens Road Well Field (AWF) and SWF. A treatability study results report, which summarized the laboratory bench-scale study, field carbon substrate injection design and details, and all the results and findings, was submitted in November 2016 and approved by NDEP on June 26, 2017 (Tetra Tech, 2016a). This section provides a brief summary of the findings of the treatability study.

The main elements of the treatability study included:

- (i) Single borehole dilution and slug tests to determine hydrogeologic characteristics of hydraulic permeability and groundwater velocity in the vicinity of the treatability study;
- (ii) Bench batch microcosm and column testing at University of Nevada at Las Vegas (UNLV);
- (iii) Installation of treatability study injection and monitoring wells;
- (iv) Two carbon substrate injection events; and
- (v) Periodic groundwater sampling, analyses, and evaluation of chemical, biochemical, and microbial parameters, which included a baseline sampling event followed by weekly, biweekly, and monthly groundwater sampling events.

2.2.1 Bioremediation Treatability Study Findings

As presented in the Groundwater Bioremediation Treatability Study Results Report (Tetra Tech, 2016a), groundwater in the study area was amenable to enhanced biodegradation of perchlorate and other electron acceptors and co-contaminants, such as chlorate and nitrate. The addition of a carbon substrate in the form of a slow-release emulsified vegetable oil (EVO) product provided a sustained reducing environment conducive to biodegrading perchlorate in the subsurface within the targeted area downgradient of the injection. Bioremediation was shown to be a promising remedial process at this location and has strong potential to be a component of the overall remedy. The results, findings, and lessons learned from the previous bioremediation treatability study will be used to optimize the design and application of the technology in other areas to maximize effective perchlorate destruction. Several of the key findings that were used to develop this treatability study approach include:

- The relatively high groundwater velocity flow rates (32 feet/day) and short residence time were not an impediment to enhanced perchlorate biodegradation. The field study indicated that a sustained anaerobic condition was created and maintained in the subsurface during the study.
- The carbon substrate that was selected for laboratory and field testing, EVO, proved to be effective in creating and sustaining reducing conditions in groundwater.
- During the course of the study, perchlorate concentrations decreased by over 90 percent in some of the monitoring wells. Perchlorate concentrations of non-detectable concentrations were achieved at one monitoring well location during the study.
- Maximum first-order perchlorate biodegradation rates in the field were determined to range from -0.25 day^{-1} to -0.51 day^{-1}. At these rates, perchlorate concentrations decreased very rapidly in groundwater. The estimate for mass removal ranged from 4.1 to 17.4 pounds per day (lbs/day) destruction of perchlorate through the study area.
- The higher total dissolved solids (TDS) concentrations (> 5,000 mg/L) in the area did not have an impact on the development of a microbial consortium with the ability to biodegrade perchlorate, nor did it appear to have an impact on acclimation time for perchlorate biodegradation.
- In both the laboratory and field studies, denitrification (nitrate biodegradation) occurred very rapidly and preferentially, compared to perchlorate biodegradation. Perchlorate biodegradation followed denitrification and, once initiated, the two reductive processes were observed to occur concurrently.
- Transient arsenic solubilization was observed but it did not appear to mobilize downgradient of the study area.
- An overall decrease in permeability with bioremediation was observed from periodic slug tests performed during the study, which was more pronounced in the last two events towards the end of the study.
    - Plausible causes include biomass buildup, oil adsorption, increase in alkalinity, and the formation of gas bubbles from biological activity.
    - Well redevelopment performed on the wells in the treatability study area indicates that relatively simple techniques can be adopted for permeability recovery that would enable periodic carbon substrate injections to be performed.

2.3 ON-GOING SEEP WELL FIELD TREATABILITY STUDY

A second treatability study is currently being performed in the vicinity of the SWF extraction system in accordance with the NDEP-approved Seep Well Field Area Bioremediation Treatability Study Work Plan (Tetra Tech, 2016b) (SWF Area Treatability Study). The overall objective of the SWF Area Treatability Study is to demonstrate the effectiveness of using ISB to reduce the flux of perchlorate mass that is migrating off-Site within the alluvium and is not currently being captured by the existing SWF extraction well network. The subject of this work plan, the Galleria Road Bioremediation Treatability Study, builds on the results and findings of the previous and on-going treatability studies including the use of geophysical surveys and nuclear magnetic resonance (NMR) logging, installation of a staggered injection well transect system, and construction of paired injection wells when the subsurface lithology suggests that this may improve injection coverage.

Pre-design activities for the SWF Area Treatability Study have been completed and its implementation is underway. As part of the pre-design, geophysical surveys, installation of soil borings and groundwater monitoring wells, groundwater sampling, aquifer testing, and bench-scale microcosm laboratory testing were completed between January and May 2017. Following the completion of the pre-design phase, twenty-five substrate injection wells (two transects, each of which are approximately 750 feet long) and an effectiveness monitoring network were installed in June 2017. Preliminary results from the on-going laboratory bench-scale studies currently being performed at UNLV have indicated that the addition of a slow-release carbon substrate, e.g., EVO, results in rapid bioremediation of nitrate and perchlorate in batch microcosms of treatability study area-specific media. One of the recommendations from the previous treatability study (described in Section 2.2), namely an evaluation of the sorption/desorption characteristics to soils, is currently being completed at UNLV. The first carbon substrate injection event began in the third week of August 2017 and is currently undergoing completion.

To achieve cost efficiencies, final results from the UNLV bench-scale testing, pre-design field activities, and effectiveness monitoring will be evaluated and applied to the design of the Galleria Road Bioremediation Treatability Study as appropriate. These include:

- Usefulness and accuracy of geophysics and NMR and their applicability;
- Laboratory sorption/desorption test results from bench-scale studies;
- Zone of influence (ZOI) of the carbon substrate injection(s) and longevity of the carbon substrate achieved; and
- Effectiveness of the application of a staggered configuration and paired injection well network, injection protocol and water distribution, downgradient influence of the injections, and any observed secondary geochemical impacts of the injections.

3.0 PRE-DESIGN FIELD AND LABORATORY ACTIVITIES

This section describes the various preliminary activities to be completed prior to the treatability study to gather relevant data and information required for final treatability study design. In general, these pre-design activites are consistent with those performed during previous treatability studies but will focus primarily on the UMCf, whereas previous pre-design activities focused on the alluvium. Specifically, the objectives of the pre-design activities include:

- Characterize the lithology in sufficient detail to refine conceptual injection well spacing;
- Identify preferential flow pathways in order to better target injections;
- Assess localized vertical and horizontal distribution of perchlorate to target remediation accordingly; and
- Accurately identify groundwater flow directions and rates to design injection wells and perform injections to best address perchlorate migration in the vicinity of the proposed mid-plume RAO boundary.

To gather the appropriate data to meet the objectives of the work, several key pre-design field activities will be conducted and evaluated, including soil boring and monitoring well installation, soil and groundwater sampling, single borehole dilution, and slug tests. Each of these activities and their purpose are presented in this section. In addition, the relevant results associated with the forthcoming Phase 3 RI will be evaluated and incorporated into the final design as applicable data become available.

3.1 FIELD ACTIVITIES

All field work described herein will be conducted in general accordance with the existing Field Sampling Plan, Revision 1 (ENVIRON, 2014b). Tetra Tech, on behalf of NERT, will prepare and submit all required applications and obtain required permits prior to the installation of any soil borings, injection wells, and monitoring wells. Once approval is granted, an underground utility survey will be performed before drilling commences. All wells will be drilled in accordance with the Nevada Division of Water Resources (NDWR) requirements, following submittal of a Notice of Intent to Drill.

3.1.1 Access Agreement

Due to the off-site location of the preliminary field activities and treatability study (further described in Section 4.0), the Trust will acquire access and user agreements for all field activities and treatability study activities (including injections and monitoring) from Basic Environmental Company, LLC (BEC). Access requirements are further discussed in Section 6.0.

3.1.2 Utility Clearance

Tetra Tech will contact USA North Utility Locating Services, review available utility maps, and retain the services of a geophysical locator to check for underground utility lines prior to advancing the borings. Boring locations may be adjusted in the field based on the findings of the utility clearance activities to avoid existing utilities, structures, or other features. Prior to drilling, each location will also be cleared to a depth of 5 feet below ground surface (bgs) either by hand augering or air knife operations.

3.1.3 Geophysics

Surface geophysical surveys will be performed as a cost-effective way to adjust horizontal and vertical placement of soil borings and monitoring wells as well as the dimensions and orientation of the field test. One of the lessons learned during previous treatability studies (Tetra Tech, 2016a) was that improved definition of preferential flow pathways and paleochannel morphology was needed prior to implementation of the field tests.

Time domain electromagnetic (TDEM) soundings will be utilized to characterize the top of the UMCf and identify potential preferential flow pathways associated with paleochannels in the vicinity of the proposed field test area. The TDEM method has been used to successfully identify paleochannels in the UMCf in the Eastside Area (GEOVision, 2003) including portions of the paleochannel that is mapped within the proposed field test area. However, the transect lines from the 2003 geophysical survey were located too far south to be of direct use for the purposes of this study. The results of the geophysical surveys will be used to refine appropriate locations for boreholes and monitoring wells to further characterize the subsurface conditions within the field test area. Soil borings will be advanced for additional characterization of the field test area and to confirm the geophysical survey interpretations (see Section 3.1.4).

3.1.4 Soil Borings and Monitoring Wells

As described in Section 1.1, the primary objective of the treatability study is to evaluate extension of the ISB methods, previously implemented in the alluvium (discussed in Sections 2.2 and 2.3), in order to address contaminant mass in the UMCf in the Eastside Study Area near Galleria Road. This will help determine the effectiveness of ISB to support the RAO to mitigate contaminant migration at the proposed mid-plume boundary. As described in Section 1.5.4, the water table generally occurs within the UMCf near the northern and eastern portions of the Eastside Study Area, where the alluvium has become dewatered. A review of available information indicates that the water table is in the uppermost portion of the UMCf in the vicinity of the proposed bioremediation treatability study location. Therefore, soil and groundwater sampling and analysis efforts will focus on the UMCf. However, evaluation will also be conducted to confirm the lack of saturated alluvium present within the treatability study area. If there is saturated alluvium within treatability study area, then both pre-design and treatability study phases will also include the alluvium as an additional focus of investigation and remediation.

Based on evaluation of relevant soil boring data from areas outlined in the Draft RI/FS Work Plan Addendum: Phase 3 RI (Ramboll Environ, 2017), soil borings will be advanced at strategic locations throughout the treatability study area and extend to approximately 120 feet bgs (similar to the proposed depths in the forthcoming Phase 3 RI). These soil borings will also be completed as monitoring wells to better characterize the study area and allow for selection of the best location for the bioremediation treatability study. A minimum of five soil borings will be installed throughout the treatability study area, although the final locations, quantity, and depths of soil borings and monitoring wells will be determined using the results from borings/monitoring wells installed as part of the Phase 3 RI that are near the treatability study area. Approximate locations of the soil borings/monitoring wells are presented in Figure 4.

The purpose of the soil borings will be to obtain area-specific lithological information, physical parameters, and contaminant concentrations. Soil samples for laboratory analysis will be collected on approximately 10 foot intervals from the top of the water table to the base of the boring (approximately 120 ft bgs). Analysis of these samples will support estimates of the mass of perchlorate and chlorate in the uppermost UMCf prior to implementing ISB. Additionally, during boring installation, soil will be collected and transported to the UNLV for use in the laboratory bench tests (described in Section 3.2).

Tetra Tech will retain a Nevada licensed drilling contractor to advance the soil borings using rotosonic drilling methods to allow for the collection of continuous soil cores for accurate lithologic logging and sampling. Before the drill rig mobilizes to each selected soil boring location, down-hole drilling equipment will be cleaned with a high-pressure, high-temperature water spray to avoid potential cross-contamination. The continuous soil cores will be logged by the on-site geologist from ground surface to total depth using the Unified Soil Classification System.

The drilling contractor will decontaminate soil collection equipment between samples. Soil samples for laboratory analysis will be collected in laboratory-supplied containers, labeled, placed in plastic bags, and stored in a cooler on ice for transport to the project analytical laboratory. Upon reaching groundwater, two undisturbed soil samples will be collected using a Shelby tube, or similar collection device, from each borehole from representative lithological units, for physical parameter analysis including moisture content, porosity, and soil density. Selected soil samples from within the UMCf will also be analyzed for soil grain size distribution. Soil samples from the UMCf will be analyzed for a variety of chemical and biochemical parameters, such as the ones listed in ***Table 1***. Depth-discrete groundwater samples may also be collected from select boreholes within the alluvium, just above the top of the UMCf, and within the UMCf to vertically profile the perchlorate extent.

Table 1 Example Soil Sampling Protocol

Parameter	Analytical Method	Purpose
Perchlorate	E314.0	Estimate mass of perchlorate in saturated soil
Chlorate	E314.0	Estimate mass of chlorate in saturated soil
TOC	SM5310B	Estimate available natural organic carbon
Soil pH	SW846 9045C	Assess geochemical conditions
Soluble Cations and Anions[1,2]	Notes 1 and 2	Assess salt loading
TDS[2]	SM2540C	Assess salt loading
Dissolved Metals[3]	SW 846 6010/6020	Assess potential secondary impacts of treatment
Total Kjeldahl Nitrogen	Modified EPA Method 351.2	Evaluate potential nutrient availability in soil
Total Phosphorus	EPA 6010B	Evaluate potential nutrient availability in soil
PLFA	Microbial Insights Method	Examine native/natural microbial characteristics
Perchlorate Reductase Gene	Microbial Insights Method	Examine native/natural microbial perchlorate degradation characteristics

Acronyms and Abbreviations:

PLFA: Phospholipid Fatty Acids
TDS: Total dissolved solids
TOC: Total organic carbon

Notes:

1. Cations include sodium, potassium, calcium, and magnesium (Method SW6010). Anions include chloride, sulfate, nitrate (Method E300.0), carbonate, and bicarbonate (Method SM2320B).
2. Analysis to be performed on water extract prepared per method SW9056.
3. Metals include arsenic, chromium, iron, and manganese.

Monitoring wells will be installed at each soil boring location to evaluate the horizontal and vertical extent of perchlorate and other key parameters within the treatability study area to help optimize the design and effectiveness of the treatability study. All soil borings will be converted to permanent monitoring wells, some or all of which may be installed as paired wells with separate screened intervals in targeted zones of the alluvium (if saturated) and throughout the UMCf to evaluate the perchlorate concentration and hydraulic gradient changes with depth. Decisions regarding which and how many locations will consist of paired wells will be based on review of the results of soil borings installed during the forthcoming Phase 3 RI and evaluation of the soil cores and lithology encountered during the treatability study soil boring field activities.

Most wells will be constructed using 2-inch schedule 40 polyvinyl chloride (PVC) casing and screened with 2-inch diameter slotted PVC well screen. Up to two wells will be installed with 4-inch diameter schedule 40 PVC casing and screened with 4-inch diameter slotted PVC well screen; these wells will be used for borehole dilution testing. An appropriate sand filter pack will be installed in the annular space around the well screens and extend up to two feet above the top of the screen intervals. The remainder of the annular space will be backfilled with two feet of hydrated bentonite, followed by neat cement grout. The total well depth, slot size, filter pack, and length of the well screens will be determined in the field based on the lithology and depth to groundwater. Wells will be completed with flush-mounted, tamper-resistant (locked), traffic-rated well boxes, at an elevation approximately one-half inch above grade.

Following the completion of well construction, but no sooner than 24 hours after well construction is compete, Tetra Tech will develop each of the newly installed wells. A surge block and bailer will be used to swab and surge the filter pack and remove sediment from the well. This process will be followed by pumping with a submersible pump to purge the well of fine-grained sediment. Well development will be considered complete when three to ten casing volumes of water have been removed from the well, and index parameters consisting of pH, specific conductivity, turbidity, and temperature are stable (pH within 0.1 and other parameters within 10 percent) over three consecutive measurements. All index parameter readings will be recorded by Tetra Tech on well development logs.

Following well development, groundwater will be sampled and analyzed for a variety of field and laboratory parameters (described in more detail in Section 5.2) to establish baseline conditions for final treatability study design. Collected groundwater will be transported to UNLV and used in the bench studies described in Section 3.2.

Following installation of all groundwater monitoring wells, a land surveyor will survey the horizontal coordinates of each well relative to North American Datum 83 with an accuracy of 0.1 foot, and the elevation of the ground surface and top of well casing measuring point relative to North American Vertical Datum 88 with accuracies of 0.1 foot and 0.01 foot, respectively.

3.1.5 Single-Borehole Dilution Test

A single-borehole dilution test will be performed in the two newly installed 4-inch monitoring wells to evaluate volumetric flow in the UMCf within the treatability study area. Single-borehole dilution tests consist of mixing a tracer compound into the groundwater in a well and then observing the decline in tracer concentration in the well as a function of time using downhole instruments (e.g., Pitrak et al., 2007). The decline in tracer concentration in the well is due to dilution by volumetric groundwater flow and the results will be used to estimate groundwater velocity in the immediate vicinity of the well.

Tracers used in single-borehole dilution tests are typically chloride or bromide salts, or fluorescent dyes. During the prior bioremediation treatability studies' preliminary testing activities, distilled water was successfully used as the tracer in five monitoring wells. Recent water quality results indicate that groundwater near the proposed treatability study location has a specific conductance generally ranging from 8,000 to 38,000 microsiemens per centimeter (AECOM, 2017). The fairly high specific conductance would support the potential use of distilled water as a tracer. Water samples collected after well installation will therefore be analyzed for major cations and anions to confirm the suitability of distilled water as a tracer prior to use. If the specific conductance is low enough that distilled water would not serve as an appropriate tracer, other appropriate tracers will be evaluated.

Results of the single-borehole dilution tests will be used to determine appropriate flow rates to be used in the field test design. All results will be provided in a final report which is further described in Section 7.0.

3.1.6 Slug Tests

Slug tests will be performed in newly installed wells (including any installed during the forthcoming Phase 3 RI that are near or within the treatability study location) and existing wells (e.g, MCF-06B, and MCF-06C, DBMW-7) to estimate location-specific aquifer hydraulic conductivity within the field test area and to confirm the results of the borehole dilution tests described in Section 3.1.5. The slug tests will be performed in general accordance with American Society for Testing and Materials (ASTM) Standard D4044-96 (ASTM International, 2008). Prior to conducting each slug test, the water level in the well will be measured manually with an electronic water level probe to determine the static groundwater level. An electronic pressure transducer/data logger will then be suspended in the well, and water levels will be monitored manually until static conditions are reestablished. A falling-head test will then be conducted by smoothly lowering a length of weighted and sealed PVC pipe (slug) into the well, securing it in place above the transducer, and recording the rate of water level decline. Once static conditions are reestablished, a rising-head test will be conducted by removing the slug and allowing the water level to again recover to static conditions while recording the rate of recovery. Barometric pressure changes during testing will be monitored and recorded using a pressure transducer placed above the water table.

At the end of each test, the pressure transducer will be removed from the well and the water level displacement data will be downloaded to a laptop computer and corrected for barometric pressure effects. The corrected data will be interpreted using AQTESOLV for Windows (Duffield, 2014) or similar aquifer test analysis software. If possible, both the falling-head and rising-head data will be analyzed to cross-check the interpretation results.

3.1.7 Nuclear Magnetic Resonance Logging

Nuclear magnetic resonance (NMR) logging will be performed in the newly installed wells and select existing monitoring wells (e.g., MCF-06A-R, MCF-06B, and MCF-06C, DBMF-7) to further delineate any localized preferential flow pathways. This method was used successfully at the SWF Area Treatability Study to identify higher-transmissivity zones within the adjacent geologic material. This technology can be used in open or PVC-cased wells to provide high-resolution downhole estimates of hydraulic conductivity, total water content, total and mobile porosity, and relative pore-size distributions below the water table (Walsh et al, 2013). Above the water table, NMR provides volumetric water content measurements. The specific tool used will depend on the diameter of the well, because larger diameter wells require a larger tool that has a larger radius of investigation. All tools are expected to provide a measurement approximately every 1.5 to 2 feet of depth. The high-resolution estimates of hydraulic conductivity will be compared to the lithologic logs and aquifer testing results for each well to assess the possibility of preferential flow.

3.1.8 Management of Investigation-Derived Wastes

Investigation-derived waste generated during the soil and groundwater investigation will be managed according to applicable state, federal, and local regulations and as described in Field Sampling Plan, Revision 1 (ENVIRON, 2014b).

The investigation-derived waste that will be generated during the environmental investigation includes soil cuttings, personal protective equipment, equipment decontamination water, and groundwater generated during depth-discrete groundwater sampling and well development. Investigation-derived soil waste will be accumulated in plastic-lined roll-off bins. Solids will be characterized by collecting representative samples, as necessary, to determine disposal options. Depending upon the size of the container and quantity of material, one sample may be sufficient for characterization, or several samples may be composited in the field. Generally, a minimum of one sample will be collected for each 10 cubic yards of solid waste or each roll-off bin. Waste sample analysis will be determined by the receiving waste facility's analysis requirements. Waste water generated during purging or decontamination activities will be temporarily stored in 55-gallon drums and/or 500-gallon totes and transferred into the GW-11 Pond. Drums, bins, and tanks will be labeled with “pending analysis” labels, the date accumulation began, contents, source, and contact information, and stored in a designated area. Management of investigation-derived waste will comply with the requirements of the access agreement.

3.1.9 Health and Safety

Fieldwork will be conducted in accordance with an Activity Hazard Analysis and other elements of the Site-wide Health and Safety Plan (Tetra Tech, 2015), which addresses potential chemical and physical hazards associated with the treatability study. It is anticipated that modified Level D personal protective equipment will be required for all field activities.

3.2 LABORATORY STUDIES

Bench-scale laboratory studies performed in connection with the previous bioremediation treatability study (Section 2.2) and on-going SWF Area Treatability Study (Section 2.3) have provided significant data on the biodegradation potential of perchlorate and other electron acceptors using EVO as the carbon substrate. The on-going EVO sorption/desorption laboratory testing for the SWF Area Treatability Study will provide additional information on the potential longevity of the carbon substrate. Based on a proposed ISB pilot study slated for the LVW during a similar timeframe, only one set of laboratory studies will be performed for both these areas, presuming soil lithological and geochemical characteristics are similar. Secondly, because this treatability study is focused on the UMCf, limited and targeted laboratory studies will be performed as follows:

- **(i) Short-term batch microcosm perchlorate biodegradation tests** will be performed using soil and groundwater from the alluvium and UMCf collected during pre-design activities. Batch tests will confirm the applicability of EVO to the soil and groundwater that will likely be encountered in the vicinity of the Galleria Road Bioremediation Treatability Study and provide an estimate of the acclimation time and perchlorate biodegradation rates. In addition to EVO, soluble substrate(s) will also be evaluated in batch microcosms for specific application to the UMCf soil and groundwater because the chemical, lithological, and hydrogeological characteristics of this zone are different from the alluvium and, therefore, warrant testing using soluble as well as slow-release substrates.
- **(ii) EVO sorption/ desorption tests** on soil and groundwater from the UMCf will be performed to understand the interactions of site-specific soil with the carbon substrate (which could include modifications and variations of EVO with additives), including substrate movement and how it desorbs over time, to support biodegradation. On-going laboratory sorption/desorption tests for the SWF Area Treatability Study are focusing on the alluvium; the proposed testing for this treatability study will focus on the UMCf.

4.0 TREATABILITY STUDY CONCEPTUAL DESIGN

This section describes the conceptual design for the treatability study, which includes specific objectives, details of the conceptual treatability study location, conceptual injection and monitoring well layout, and preliminary substrate design. The treatability study design, as well as the effectiveness monitoring program (described in Section 5.0), may be modified or refined based on the results of the forthcoming Phase 3 RI and/or pre-design field and laboratory activities described in Section 3.0.

Although this treatability study focuses on the UMCf, the findings and lessons learned (described in Sections 2.2 and 2.3) from previous treatability studies that focused on the alluvium could also be applied to this Galleria Road Bioremediation Treatability Study to optimize the design and application of in situ bioremediation. For example, the evaluations of biomass growth, permeability changes, and arsenic solubilization are all components to previous studies that will be relevant to the Galleria Road Bioremediation Treatability Study. Unique attributes to this study include the application of in situ bioremediation to the UMCf, which will likely require closer injection well spacings and variations to carbon donor types (EVO, soluble substrate, or combination) and quantities.

4.1 OBJECTIVES

As explained in Section 1.1, the overall objective of the treatability study is to demonstrate and evaluate the effectiveness of implementing ISB to reduce the contaminants present in the UMCf (and alluvium, if saturated) that are migrating across the proposed mid-plume containment and mass removal boundary. More detailed objectives of the treatability study are to accomplish the following:

- Evaluate the feasibility and effectiveness of implementing ISB in the UMCf (and alluvium, if saturated) to reduce the perchlorate mass flux that is migrating across the proposed mid-plume containment and mass removal boundary (the location of the proposed mid-plume RAO boundary);
- Estimate the lateral subsurface influence achieved in the UMCf (and alluvium, if saturated) during the treatability study;
- Estimate the ZOI for substrate and biodegradation achievable in the UMCf (and alluvium, if saturated) during the treatability study;
- Estimate or extrapolate the longevity of the carbon substrate and frequency of carbon substrate replenishment required to reduce perchlorate contamination immediately downgradient of the treatability study injection transect; and
- Provide critical information applicable to the remedial alternatives evaluation in the forthcoming FS.

4.2 FIELD STUDY LOCATION

As shown in Figure 1, the proposed area for the treatability study is immediately north of Galleria Road, with the location selected to be west of a presumed paleochannel (as seen in Figure 5). This location was selected due to accessibility and the presence of elevated perchlorate concentrations in the UMCf at concentrations generally around 5,000 μg/L. As described in Section 1.5.4, the water table occurs in the alluvium in the western part of the Eastside Study Area and then in the UMCf near the northern boundary and eastern portion of the Eastside Study Area, where the alluvium has become dewatered (Ramboll Environ, 2017). A review of available information from the proposed treatability study location indicates that the water table appears to be within the uppermost UMCf in monitoring well DBMW-6, which is located approximately 200 feet west of the proposed bioremediation treatability study. Therefore, application of ISB is focusing on the UMCf. However, if pre-design results indicate the presence of saturated alluvium that requires treatment, the treatability study will also include injection wells screened within the alluvium.

4.3 CONCEPTUAL LAYOUT

This section describes the injection wells and supplemental monitoring well network that will be installed to evaluate the effectiveness of the ISB treatability study. The conceptual layout of the pre-design monitoring wells (discussed in Section 3.1.4) along with the conceptual injection and monitoring well locations is provided in Figure 5. The required access agreement (discussed in Section 6.0) will be in place prior to initiating field activities. Once access is granted, an underground utility survey will be performed before drilling commences. All wells will be drilled in accordance with the NDWR requirements. Drilling, well installation, and well development procedures are provided in the Field Sampling Plan, Revision 1 (ENVIRON, 2014b).

4.3.1 Injection Well Layout

The final number, location, layout, and orientation of the injection wells will be determined after completion of the pre-design field activities described in Section 3.0 and review of the results from the forthcoming Phase 3 RI. However, the injection well layout will be configured to intersect perchlorate-contaminated groundwater flowing through the treatability study location. Based on results from previous investigations, there may be considerable heterogeneity in the lithology within relatively short distances in both the UMCf and the alluvium, which may result in flow pathways and transport of organic carbon during injections being non-uniform. As a result, the results from the pre-design investigation, including evaluation of the potential preferential flow zones within the UMCf (and the alluvium, if saturated), will be used to focus both injection and groundwater monitoring well screen intervals appropriately. If multiple preferential flow zones with elevated perchlorate concentrations are encountered within the UMCf, multiple wells or screened intervals may be used to target such flow zones.

The proposed injection layout should be sufficient to take into account subsurface variability as well as the general effectiveness of bioremediation at remediating perchlorate-contaminated groundwater in the UMCf. As a result, the injection transect could be installed in a single row or multiple staggered rows to address the impacts of heterogeneity and non-uniform flow, which could provide overlap and better distribution of the injected carbon substrate to curtail the potential for perchlorate breakthrough. The results of the on-going SWF Area Treatability Study will provide additional information and data that will assist the final design of injection well transects and possible implementation of a staggered well network, if beneficial. For this treatability study, up to 15 injection wells will be installed along an injection well transect line to target contamination in the UMCf (Figure 5). The final spacing will be selected to optimize subsurface distribution to account for variability and non-uniform groundwater flow and lithology by improving contact of carbon substrate with perchlorate in the saturated matrix. Results of the Phase 3 RI and pre-design activities, proposed bench-scale tests, and on-going SWF Area Treatability Study will also be used to finalize the injection system network to most appropriately address the mass flux of perchlorate in the vicinity of the treatability study location.

If pre-design results indicate a saturated alluvium is present within the treatability study area, it will be addressed separately from the UMCf, as far as the injection well system is concerned, due to their difference in lithological characteristics. This includes the spacing, configuration, number of wells, and well design. If the alluvium is saturated in the treatability study area, up to seven injection wells will be installed to target contamination in the alluvium. As previously explained for the UMCf injection wells, the exact number and spacing of the alluvium injection wells, number of transects, and transect layout will be finalized based on the results of the preliminary field activities described in Section 3.0, as well as the results of the SWF treatability study, as appropriate, particularly pertaining to the alluvium.

Injection wells will be constructed of either 2-inch or 4-inch schedule 40 PVC casing and screened with slotted PVC well screen (similar to pre-design monitoring wells discussed in Section 3.1.4). The total well depth, size, slot size, filter pack, and length of the well screens will be determined in the field based on the lithology, depth to groundwater, and to target preferential flow zones identified in pre-design activities. The slot size and filter pack may be adjusted based on the results of the soil physical parameter analyses. Paired wells may be used to separate screened intervals within the multiple preferential flow zones if identified in the UMCf during pre-design activities, as well to also perform targeted injections into the alluvium, if saturated. Injections wells may also be installed in a phased approach to evaluate optimal injection spacing in the UMCf. Wells will be completed with flush-mounted, tamper-resistant (locked), traffic-rated well boxes, at an elevation approximately one-half inch above grade. Following the completion of well construction, but no sooner than 24 hours after well construction is complete, Tetra Tech will develop each of the newly installed wells.

4.3.2 Effectiveness Monitoring Wells

A monitoring well network, consisting of both upgradient and downgradient monitoring wells, will be required to evaluate treatability study effectiveness and will be a key component of the final remedy. Upgradient monitoring wells will be used to determine the perchlorate concentrations in groundwater that are migrating into the treatability study area. Downgradient monitoring wells will be installed at strategic locations downgradient of the injection well transects to monitor for treatment effectiveness. Details on the effectiveness monitoring program are presented in Section 5.0.

To the extent possible, monitoring wells that are installed as part of the Phase 3 RI that are in the vicinity of the treatability study will be incorporated in the effectiveness monitoring well network. Monitoring wells installed as part of the pre-design phase will also be incorporated into the effectiveness monitoring program. Based on pre-design results and final treatability study layout, up to an additional nine monitoring wells may be required at locations directly in-line and offset from the injection wells at varying distances upgradient and downgradient of the injection well transects, as shown in Figure 5. The exact number and location of effectiveness monitoring wells may be modified based on the results of the pre-design activities (such as slug tests, single borehole tests, NMR profiling, estimations of groundwater velocity, and other geological characteristics in the area).

Monitoring wells will be constructed of 2-inch schedule 40 PVC casing and screened with 2-inch diameter slotted PVC well screen, as discussed in Section 3.1.4. The slot size and filter pack may be adjusted based on the results of the soil physical parameter analyses. The depth of the well and length of well screen will be determined in the field, based on lithology and results of pre-design investigations, to locate any preferential flow zones within the UMCf (e.g., NMR profiles). Dual-nested or paired monitoring wells may be used to separate screened intervals in the UMCf, if conditions warrant, as well as to monitor the alluvium if saturated. Wells will be completed with flush-mounted, tamper-resistant (locked), traffic-rated well boxes at an elevation approximately one-half inch above grade. As discussed in Section 3.1.4, following the completion of well construction, but no sooner than 24 hours after well construction is compete, Tetra Tech will develop each of the newly installed wells.

4.4 PRELIMINARY INJECTION DESIGN

This section presents the preliminary injection design for injections of carbon substrate, water for chemical make-up, and distribution water for the treatability study. Results of the previous bioremediation treatability study (Section 2.2) have provided preliminary findings on the longevity of each carbon substrate injection event, lateral and downgradient coverage or influence of the injections, and impact of the distribution water. These findings have been incorporated into the conceptual injection design for both carbon substrate injections and follow-up distribution water. As the results from the on-going SWF Area Bioremediation Treatability Study (Section 2.3) are evaluated, these findings will be also be incorporated into the final design of the Galleria Road Bioremediation Treatability Study (as appropriate). All required permits (discussed in Section 6.0) will be obtained prior to treatability study activities.

4.4.1 Carbon Substrate Injections

Prior to actual carbon substrate injections, slug tests will be performed on a select number of the injection wells and monitoring wells to determine pre-injection hydraulic conditions. As required, step-rate injection tests may be performed prior to carbon substrate injections to establish well injection rates and pressures in the injection wells. Slug tests will be performed periodically throughout the treatability study as they have been shown to provide valuable information on subsurface conductivity changes following carbon substrate injections as described in Section 2.2.

The carbon substrate will be pressure-injected into injection wells using a mobile injection system, consisting of a tanker or trailer unit with a manifold piping system and hoses supplied with valves and regulators for controlling and monitoring rates of injection. Prior to each injection, the injection solution will be prepared in a truck-mounted batch tank using water for dilution of the carbon substrate (generally diluted at a ratio of 1:4 parts of carbon substrate to water, but could be increased for the finer soils expected in the UMCf). The injection solution will be prepared by thoroughly mixing the carbon substrate, additional amendments such as micronutrients, and water in the trailer-mounted mixing tank. The injection solution will then be pressure-injected into the injection wells through a manifold with hoses equipped with quick disconnect fittings. Pressure gauges and a flow totalizer will be used to monitor the pressure and flow rates during injection at each injection well.

Following completion of pre-design activities, final carbon substrate quantities and projected frequency of the injections for the treatability study will be estimated for the remediation of the UMCf and alluvium (if saturated).

Based on the previous treatability studies, up to three separate injection events may be required during the treatability study timeframe. However, the final substrate type (EVO, soluble substrate, or combination of the two), quantity, and frequency of injection events will be determined based on the following:

- Results and findings of the pre-design activities outlined in Section 3.0 (including both field activities and UNLV laboratory studies);
- Chemistry and geochemistry of the groundwater;
- Lithological and soil characteristics of the UMCf and the alluvium;
- Results and findings of the previous and on-going treatability studies; and
- Stoichiometric requirements for the carbon substrate based on the mass of perchlorate and other electron acceptors that will migrate through the treatability study area.

4.4.2 Distribution Water

Distribution water is an important component of the injection process to improve subsurface distribution of the amendments within the injection well transect. This feature of the bioremediation design is important because it improves the distribution of the carbon substrate to create a more complete treatment zone. As a result, a designated quantity of water (determined based on results from the pre-design field and laboratory activities described in Section 3.0) will be injected into each injection well either with, or following injections.

Based on the results observed during the previous COH treatability study, it is believed that considerable quantities of distribution water will likely be required to obtain enhanced distribution of the carbon substrate in the UMCf in vicinity of the injection wells, based on the pore volume of the saturated soils in the vicinity. Preliminary findings also indicate that alternating the chase water between wells or injecting into alternatively spaced wells could provide better distribution of carbon substrate. Results and lessons learned from the upcoming injections associated with the SWF Area Treatability Study will be incorporated into the final distribution water protocol for the Galleria Road Bioremediation Treatability Study.

There are two choices for available water sources to be used as distribution water during the injections for the Galleria Road Bioremediation Treatability Study. Specifically, these include COH water obtained from a nearby hydrant or extraction of groundwater from nearby injection and/or monitoring wells. It should be noted that for the previous treatability study near the COH water treatment facility, hydrant water was used as the source for distribution water, while the SWF Area Treatability Study used extracted water from upgradient monitoring wells in the immediate vicinity of the treatability study. A series of injection and subsequent monitoring events will be performed for the SWF Area Treatability Study prior to injections performed as part of this Galleria Road Bioremediation Treatability Study. As a result, lessons learned from each treatability study on the advantages and disadvantages of each water source, as well as pre-design results from the Galleria Road Bioremediation Treatability Study Area, will be evaluated to determine the optimal water source for this treatability study.

4.5 HEALTH AND SAFETY

Fieldwork will be conducted in accordance with an Activity Hazard Analysis and other elements of the Site-wide Health and Safety Plan (Tetra Tech, 2015), which addresses potential chemical and physical hazards associated with the treatability study. It is anticipated that modified Level D personal protective equipment will be required for all field activities.

5.0 EFFECTIVENESS MONITORING PLAN

This section describes the conceptual groundwater monitoring program to determine treatment effectiveness during the treatability study, which is generally consistent with those performed during previous treatability studies. The effectiveness monitoring program for this treatability study has been enhanced to included periodic slug testing during the treatability study based on the findings and lessons learned from the previous studies (described in Section 2.2 and 2.3). In addition to groundwater monitoring, soil gas sampling has also been included due to the proximity of residential areas in the vicinity of Galleria Road.

5.1 GROUNDWATER SAMPLING PROCEDURES

General groundwater sampling activities will follow the guidance of the Field Sampling Plan, Revision 1 (ENVIRON, 2014b). Prior to groundwater sample collection, groundwater levels will be gauged in all wells for use in potentiometric contouring. Groundwater samples will be collected using low-flow purging and sampling techniques. During low-flow purging of the wells, a pump capable of purging between approximately 0.1 to 0.13 gallons per minute will be used to minimize drawdown and induce inflow of fresh groundwater. The pump discharge water will be passed through a flow-through cell field water analyzer for continuous monitoring of field parameters (temperature, pH, turbidity, electrical conductivity, DO, and oxidation reduction potential). Field parameters will be monitored and recorded on field sampling forms during purging. The wells will be sampled when purging is complete, which is when the field parameter readings and water levels have stabilized. Per NDEP letter dated June 27, 2016, field-filtering of water samples for perchlorate analysis will not be required. Filtering for dissolved metals and hexavalent chromium analyses will be conducted in the field using a 0.45-micron filter.

5.2 EFFECTIVENESS MONITORING

Groundwater samples will be collected from all injection and monitoring wells in the vicinity of the treatability study to establish baseline conditions prior to the injections. After injections have occurred, groundwater samples will be periodically collected from the upgradient and downgradient monitoring wells. A variety of field, laboratory, and microbial parameters that may be evaluated during the study are listed in ***Table 2***, which presents the parameters, associated methods, and purpose. Effectiveness monitoring wells will include newly installed monitoring wells as well as select monitoring wells that are either existing or will be installed during the Phase 3 RI and/or pre-design phase described in Section 3.0. The actual frequency of sampling, selected wells, and specific parameters to be sampled during each individual event will be adjusted based on the results from treatability study effectiveness monitoring events. Specialized microbial analyses, namely, PLFA analyses and the presence of the perchlorate reductase gene, will be determined via the employment of Bio-Traps® in select wells during the study. In addition, slug tests will be repeated periodically during the treatability study to examine any changes in hydraulic conductivity as a result of carbon injections and geochemical processes. Finally, soil gas monitoring may also be performed to evaluate sulfide and methane that may be produced as a result of on-going biological processes.

Table 2 Example Groundwater Effectiveness Monitoring Sampling Protocol

Parameter	Analytical Method	Purpose
Field Parameters		
EC	Field Meter	Assess geochemical conditions
pH	Field Meter	
DO	Field Meter	
ORP	Field Meter	
Temperature	Field Meter	
Turbidity	Field Meter	
Perchlorate	E314	Assess treatment effectiveness
TOC	SM5310B	Assess carbon substrate distribution in the aquifer
TDS	SM2540C	Assess any impact of salts on delayed or slower perchlorate biodegradation in the flow-through mode
Alkalinity	SM2320B	Assess geochemical conditions
Hexavalent Chromium	SW846 7199	Assess secondary impacts of treatment
Nitrate	E300.0	Assessment of nitrate as the most likely competing electron acceptor and carbon substrate consumer
Sulfate	E300.0	Assessment of sulfate as an electron acceptor and potential carbon substrate consumer
Sulfide	HACH Method 8131	Examine secondary geochemical impacts
Total Nitrogen	E351.2	Examine the need for micronutrients
Total Phosphorus	E365.3	Examine the need for micronutrients
Ferrous Iron	HACH Field Kit	Assess effect of reducing conditions on iron
Manganese	SW846 6010B	Assess potential for biologically driven dissolution of manganese
Methane	EPA Method RSK175	Examine secondary geochemical impacts
Dissolved Metals[(1)]	SW6010/6020	Assess secondary impacts of treatment (includes arsenic)
VFAs	BF-MB-009, Rev 3	Surrogate carbon substrate assessment
Chlorate/Chlorite	E300.1	Assess treatment effectiveness and examination as intermediate by-product of perchlorate biodegradation
Chloride	E300.0	Potential estimation of conservative end-product of biodegradation
PLFA	Microbial Insights Method	Examine microbial response to carbon substrate addition
Perchlorate Reductase Gene	Microbial Insights Method	Examine microbial response to carbon substrate addition

Acronyms and Abbreviations:

EC: Electrical conductivity
DO: Dissolved Oxygen
ORP: Oxidation-reduction potential
PLFA: Phospholipid Fatty Acids
TOC: Total organic carbon
TDS: Total dissolved solids
VFAs: Volatile Fatty Acids

Notes:

(1) Metals include arsenic, chromium, iron, and manganese.

5.3 MASS FLUX EVALUATION

In conjunction with groundwater monitoring, a groundwater model will be developed to assess the effectiveness of the treatability study. The objective of the groundwater modeling is to calculate the groundwater flux through the injection well transects before and after injection. The groundwater model results will be used to estimate the amount of perchlorate mass destroyed and amount of perchlorate mass that remains in the subsurface after the treatability study is completed. Specifically, the groundwater model for this Work Plan will be based on the Phase 6 Ramboll Environ groundwater flow and transport model (Phase 6 Model), which is scheduled to be completed by March 2018. The Phase 6 model will be modified to focus on the treatability study area by using grid refinement and site-specific material properties measured by field techniques and laboratory analyses, such as geophysics, NMR, slug tests, and physical properties. Once constructed, the modified groundwater model will be calibrated to the groundwater response to injections conducted during this study. Then, this model will be used to calculate groundwater flux through injection well transects to ultimately estimate perchlorate mass destroyed or left in place by the treatability study.

5.4 DATA VALIDATION

All treatability study field samples and field quality assurance/quality control (QA/QC) samples will be evaluated for quality and usability. Field QA/QC samples include equipment blanks, field blanks, field duplicates, and matrix spike/matrix spike duplicates. The QA/QC samples will provide information on the effects of sampling procedures and assess sampling contamination, laboratory performance, and matrix effects.

The current guidance described in the NDEP *Data Verification and Validation Requirements - Supplement April, 2009* states that “all data collected at the BMI Complex and Common Areas should be validated at least to Stage 2B…In addition, at least 10% of all data within a DVSR should be validated to Stage 4”. However, laboratory analytical data from treatability study activities will be verified and validated to Stage 2A in accordance with recommendations made to NERT concerning end-use of data. The intended use of data is to support technology selection in the forthcoming FS. Per the January 11, 2017 email from Weiquan Dong, NDEP accepts the recommendation and is currently in the process of revising the existing guidance.

The analytical data will be evaluated for QA/QC based on the following documents: *Quality Assurance Project Plan (QAPP),* Revision 1, July 18, 2014; NDEP *Revised Guidance on Qualifying Data due to Blank Contamination for the BMI Complex and Common Areas*, January 5, 2012; *National Functional Guidelines (NFG) for Inorganic Superfund Data Review, August 2014*; *National Functional Guidelines (NFG) for Superfund Organic Methods Data Review, August 2014;* and individual United States Environmental Protection Agency (US EPA) and laboratory methods, based on the logic contained in the NFG.

6.0 ACCESS AND PERMITTING REQUIREMENTS

Both an access agreement and multiple permits will be required prior to performing pre-design and/or injection activities associated with this treatability study. This section presents a summary of the access and permit requirements that will likely be required for the implementation of the activities described in this Work Plan.

6.1 ACCESS NEGOTATIONS

Due to the off-site location of the treatability study, the Trust will acquire land use authorization for all field activities. As described in Section 4.2, the proposed area for the pre-design and treatability study is located on land owned by BEC. As a result, Tetra Tech, on behalf of NERT, will prepare all required applications for access to this parcel in coordination with the Trust's attorneys. It should be noted that the treatability study location may be adjusted based on conditions prescribed by BEC.

6.2 PERMITTING

There will be a series of permits required for the various activities that are being proposed as part of the treatability study. In addition to the permits described herein, a review of other potential permitting requirements was conducted. Based on project design, several regulatory requirements likely will not apply. A review of installation activities associated with the pre-design and treatability study phases indicates that the soil disturbance will be less than 0.25 acres; therefore, a dust control permit will not be required. Authorization under the construction stormwater general permit administered by NDEP is not anticipated because cumulative disturbances are not expected to exceed one acre. Lastly, there will be no wastewater discharges from well operation.

6.2.1 Well Installation Permitting

Both pre-design and treatability study activities will require a Nevada Administrative Code (NAC) 534.441 Monitor Well Drilling Waiver and a NAC 534.320 Notice of Intent Card prior to installation of monitoring wells associated with the pre-design phase and injection and monitoring wells as part of the treatability study. The Monitoring Well Drilling Waiver also requires a completed, signed, and notarized Affidavit of Intent to Abandon a Well as an attachment. As required, all injection and monitoring wells will be drilled by a licensed well driller pursuant to Nevada Revised Statutes 534.160 and will be constructed pursuant to NAC Chapter 534 – Underground Water and Wells. To the extent that any injection and monitoring wells associated with this treatability study are to be abandoned, they would be done so in accordance with the provisions contained in NAC 534.4365 and all other applicable rules and regulations for plugging wells in the State of Nevada.

6.2.2 NDEP – Underground Injection Control Program

The treatability study will require an underground injection control (UIC) permit for the injection of the carbon substrate and amendments into the saturated subsurface. Specifically, an application for a Class V General Permit for Long-Term Remediation UIC permit will be required. The UIC long-term general permit falls under NAC 445A. The permit application requires completion of UIC Form U200 – Permit Application and UIC Form U210 – Notice of Intent.

6.2.3 Water Appropriations Permit

Pursuant to Nevada Revised Statutes 533.335 and 533.437, an application for a Permit to Appropriate the Public Waters of the State of Nevada for Environmental Purposes (Water Appropriation Permit) may be required to support the extraction of groundwater from nearby injection or monitoring wells to be used as distribution water during injections. The need for the water appropriations permit will be determined following the detailed evaluation of the source for distribution water, which will include an assessment of the lessons learned from each treatability study on the advantages and disadvantages of each water source, as well as pre-design results from the Galleria Road Bioremediation Treatability Study Area.

7.0 REPORTING

Monthly status updates will be provided to the Trust and NDEP summarizing the progress and results of the pre-design field activities, laboratory studies, and the treatability study.

Following completion of the pre-design phase described in Section 3.0, a pilot study work plan addendum will be prepared for NDEP and US EPA review. The pilot study work plan addendum will include the following:

- Summary of pre-design field activities, including presentation of soil boring logs, well construction diagrams, cross-sections, single borehole dilution tests, and slug tests.
- Analytical results summary of soil, groundwater, and surface water samples collected during the predesign field activities.
- Preliminary summary and application of bench testing results.
- Final pilot study design, including injection and monitoring well layout, targeted treatment depths and intervals in the alluvium and UMCf, injection protocol for carbon donor and distribution water source, and finalized effectiveness monitoring program.
- Schedule of pilot study activities, including implementation, anticipated injection intervals, monitoring, and reporting.

Following completion of the treatability study, a final Galleria Road Bioremediation Treatability Study Report will be prepared and submitted for NDEP and US EPA review. This report will summarize the treatability study activities and present the results of reducing perchlorate concentrations in groundwater in the vicinity of the treatability study location. This report will include:

- Summary of pre-design field activities, including presentation of soil boring logs, well construction diagrams, cross-sections, soil and groundwater analytical results, single borehole dilution tests, and slug tests;
- Summary and application of bench-scale testing results;
- Final treatability study design, including injection and monitoring well layout, targeted treatment depths and intervals in the alluvium (if saturated) and UMCf, injection protocol for carbon donor and distribution water source, and finalized effectiveness monitoring program;
- Evaluation of effectiveness in reducing perchlorate-contaminated groundwater within the treatability study area, including an estimate of the perchlorate mass reduction during the treatability study timeframe;
- Estimation of perchlorate degradation kinetics that were attainable in the field from trend graphs of individual monitoring wells; and
- Determination of the technology’s feasibility and effectiveness for full-scale application and other relevant components required for proper evaluation in the FS.

8.0 SCHEDULE

A general schedule for the primary deliverables and activities associated with implementing the pre-design and treatability study activities is presented in ***Table 3***. This schedule is contingent upon Trust, NDEP, and US EPA approval of this Work Plan, Trust approval of funding and notice to proceed, completion of access agreements, and obtaining all necessary permits. Tetra Tech will coordinate with Ramboll Environ to gain efficiencies where appropriate, such as collection of background and pre-design data, well installations, and report preparation.

Table 3 Preliminary Project Schedule

Task/Milestone	Estimated Start Date	Estimated Completion Date
Pre-Design Field Activities	January 2018	June 2018
Laboratory Bench-Scale Tests	February 2018	June 2018
Treatability Study Implementation (Installation, Injection Event, and Effectiveness Monitoring)	July 2018	June 2019
Reporting	July 2019	September 2019

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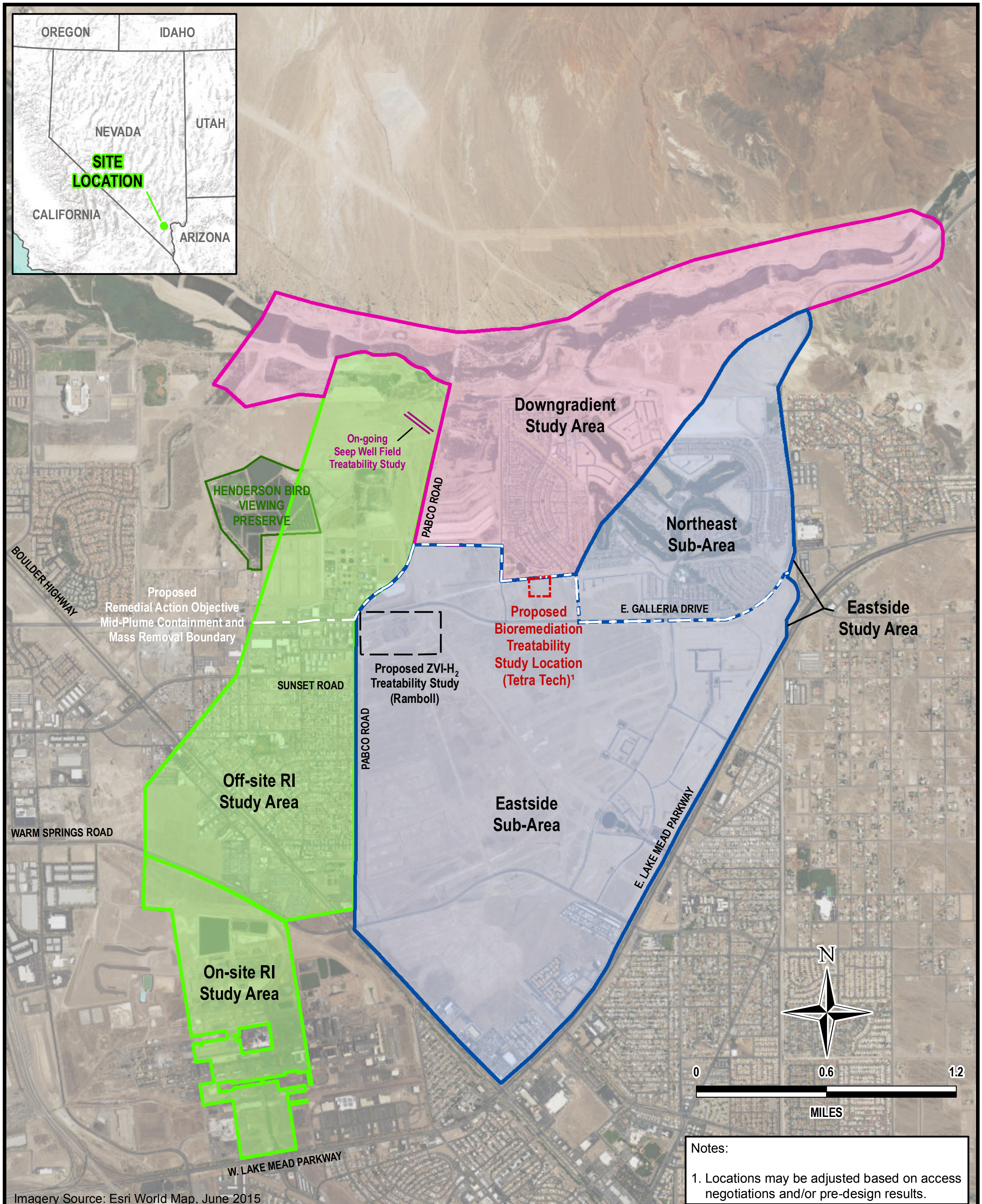
Figures



Notes:

1. Locations may be adjusted based on access negotiations and/or pre-design results.

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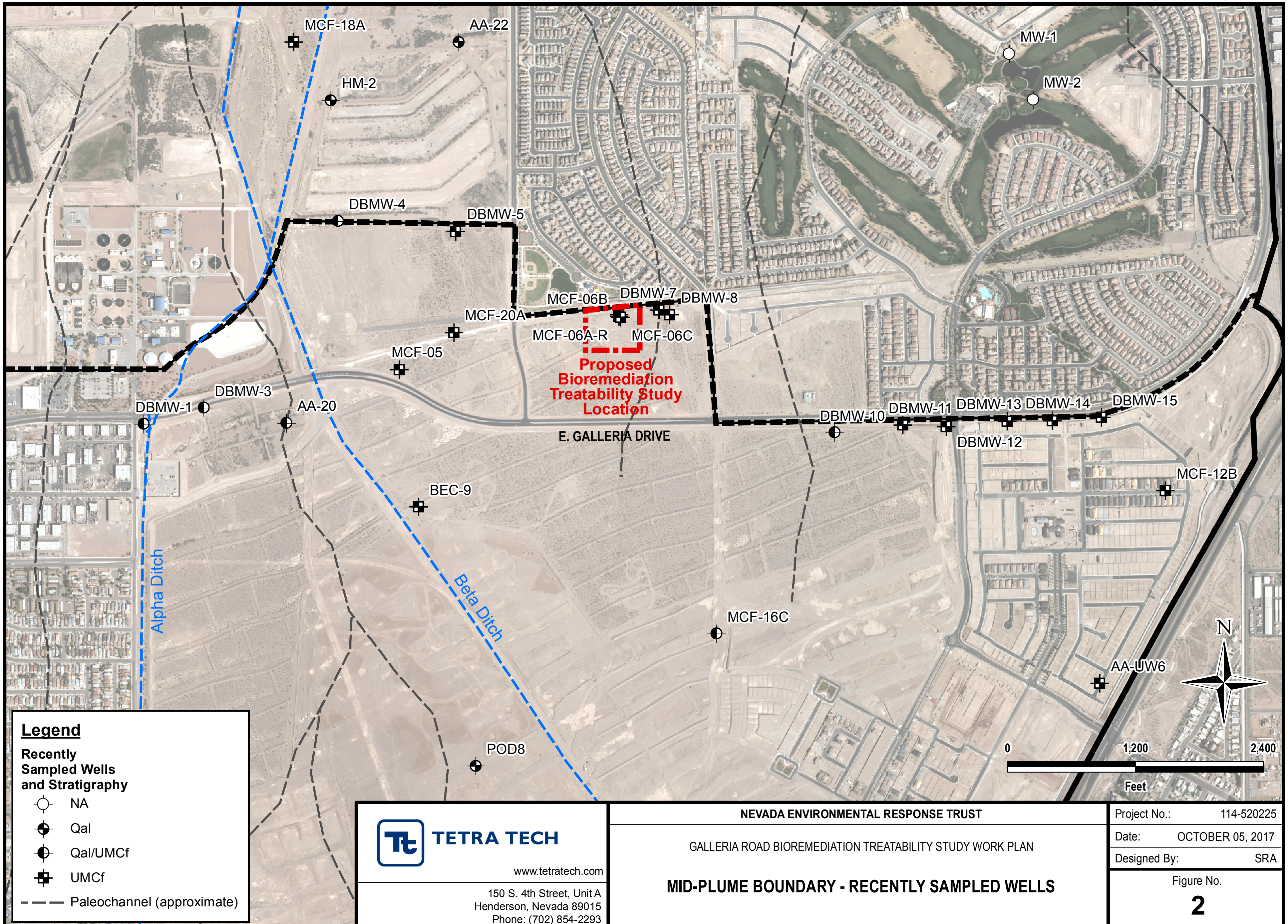
NEVADA ENVIRONMENTAL RESPONSE TRUST

GALLERIA ROAD BIOREMEDIATION TREATABILITY STUDY WORK PLAN

SITE LOCATION

Project No.:	114-520225
Date:	OCTOBER 04, 2017
Designed By:	SRA
Figure No.	1



\\TTS100FS1\PROJECTS\NERT\GIS FIGURE DATABASE\MXD\GR_RD_WP\FIGURE2.MXD

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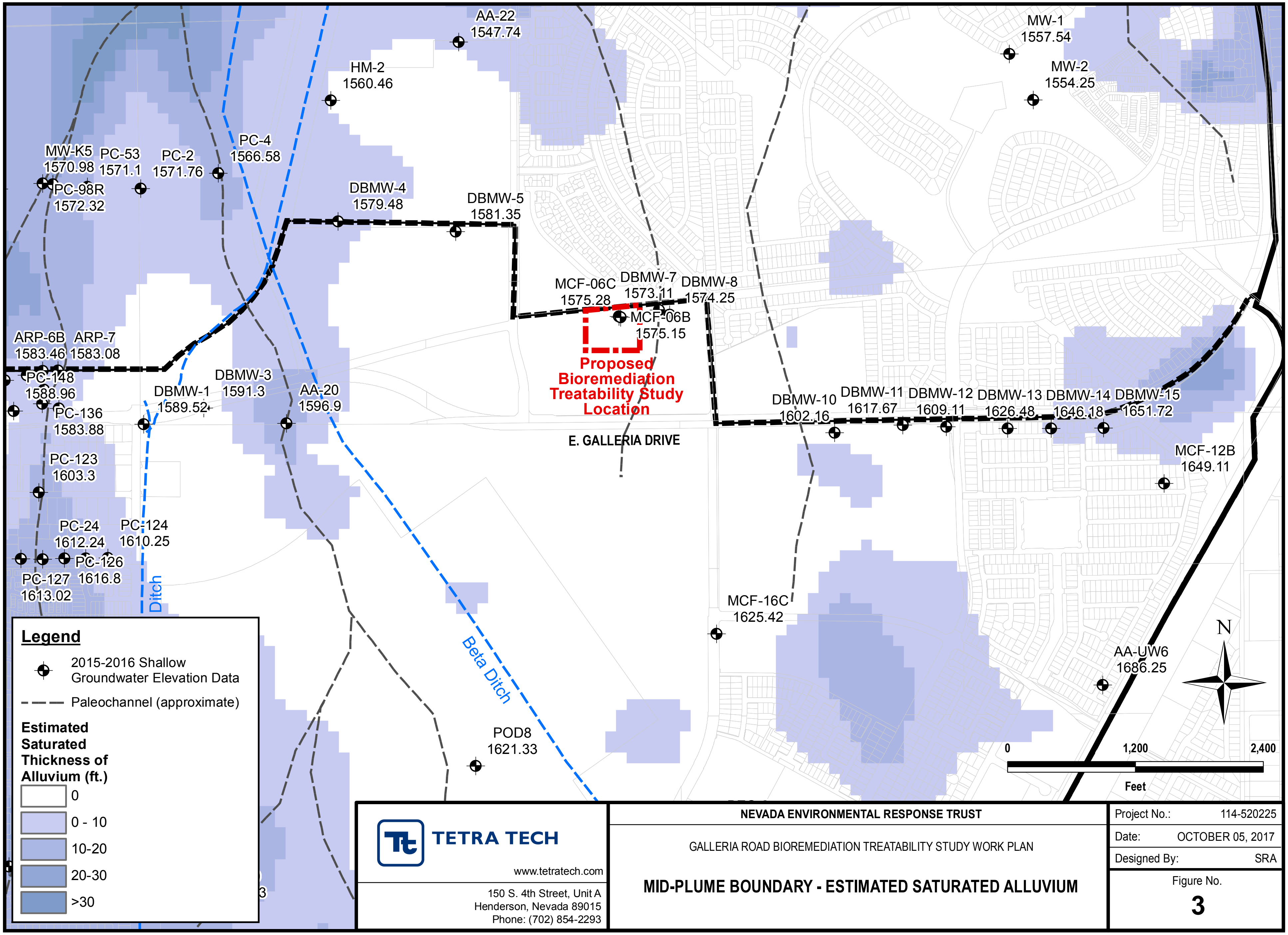
NEVADA ENVIRONMENTAL RESPONSE TRUST	Project No.: 114-520225
GALLERIA ROAD BIOREMEDIATION TREATABILITY STUDY WORK PLAN	Date: OCTOBER 05, 2017
	Designed By: SRA
MID-PLUME BOUNDARY - RECENTLY SAMPLED WELLS	Figure No. 2



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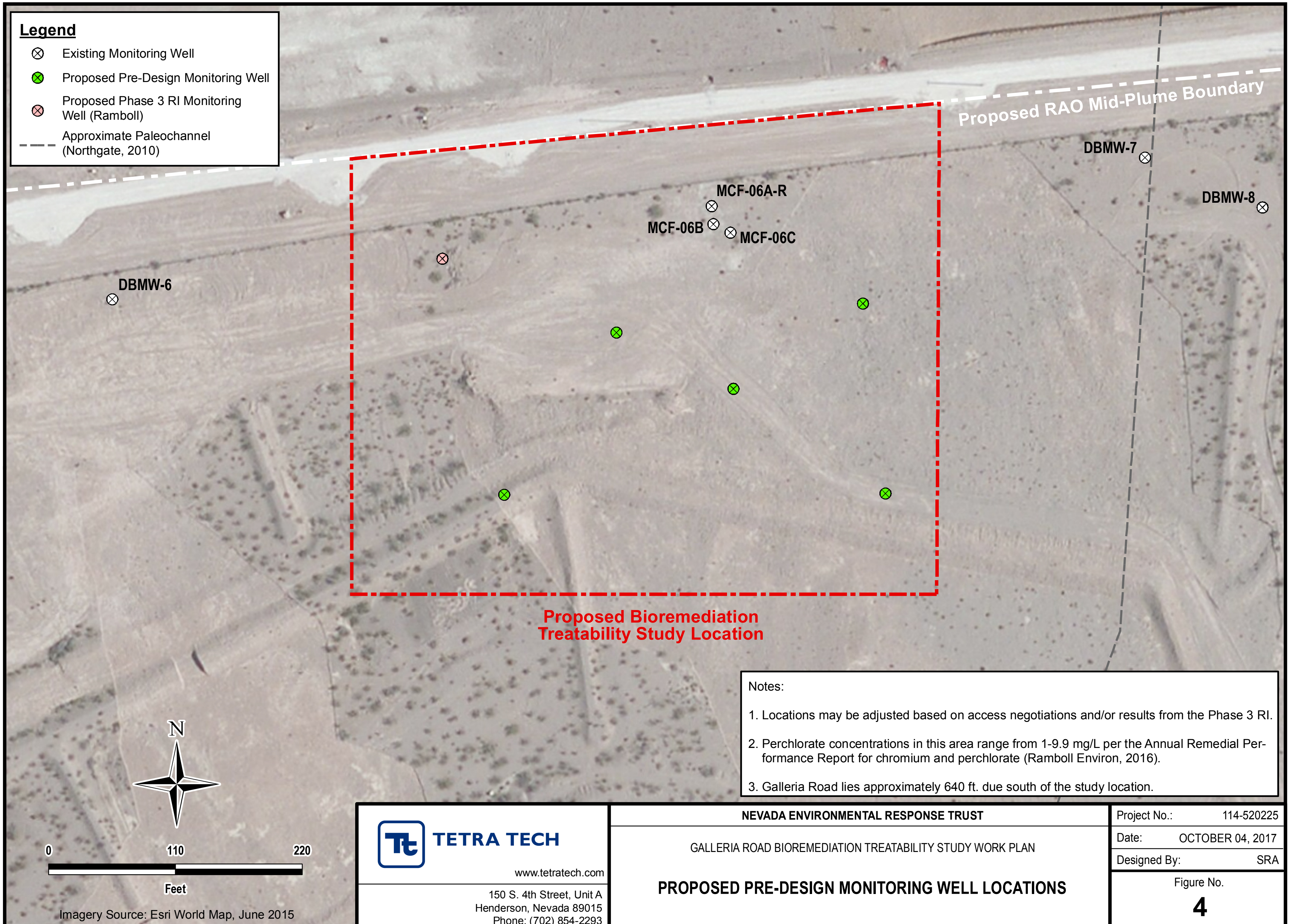
GALLERIA ROAD BIOREMEDIATION TREATABILITY STUDY WORK PLAN

MID-PLUME BOUNDARY - ESTIMATED SATURATED ALLUVIUM

Project No.:	114-520225
Date:	OCTOBER 05, 2017
Designed By:	SRA
Figure No.	3

\\TTS100FS1\PROJECTS\NERT\GIS FIGURE DATABASE\MXD\GR_RD_WP\FIGURE3.MXD



Notes:

1. Locations may be adjusted based on access negotiations and/or results from the Phase 3 RI.
2. Perchlorate concentrations in this area range from 1-9.9 mg/L per the Annual Remedial Performance Report for chromium and perchlorate (Ramboll Environ, 2016).
3. Galleria Road lies approximately 640 ft. due south of the study location.

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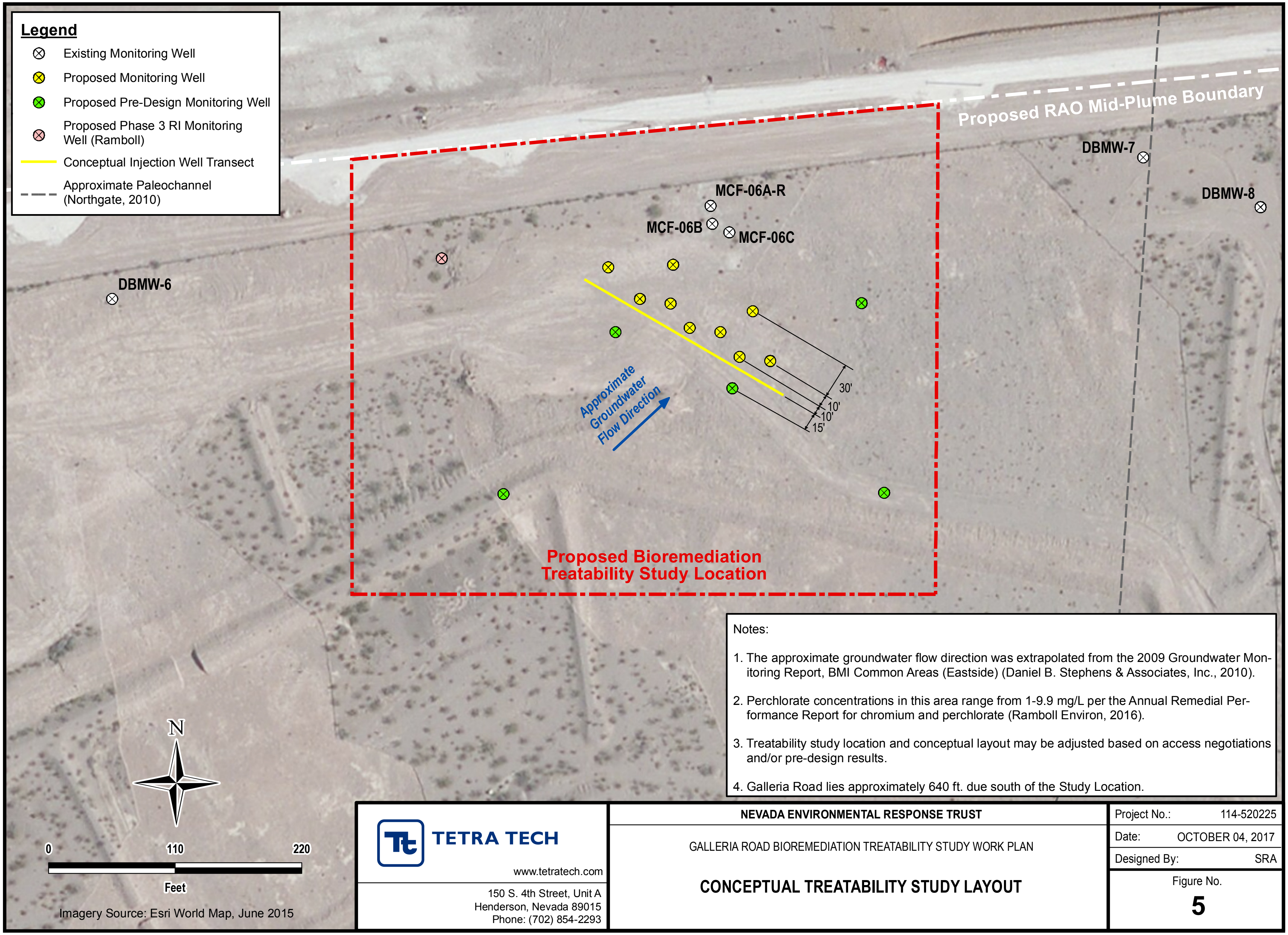
NEVADA ENVIRONMENTAL RESPONSE TRUST

GALLERIA ROAD BIOREMEDIATION TREATABILITY STUDY WORK PLAN

PROPOSED PRE-DESIGN MONITORING WELL LOCATIONS

Project No.:	114-520225
Date:	OCTOBER 04, 2017
Designed By:	SRA
Figure No.	4

\\TTS100FS1\PROJECTS\NERT\GIS FIGURE DATABASE\MXD\GR_RD_WP\FIGURE4.MXD



Notes:

1. The approximate groundwater flow direction was extrapolated from the 2009 Groundwater Monitoring Report, BMI Common Areas (Eastside) (Daniel B. Stephens & Associates, Inc., 2010).
2. Perchlorate concentrations in this area range from 1-9.9 mg/L per the Annual Remedial Performance Report for chromium and perchlorate (Ramboll Environ, 2016).
3. Treatability study location and conceptual layout may be adjusted based on access negotiations and/or pre-design results.
4. Galleria Road lies approximately 640 ft. due south of the Study Location.

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GALLERIA ROAD BIOREMEDIATION TREATABILITY STUDY WORK PLAN

CONCEPTUAL TREATABILITY STUDY LAYOUT

Project No.:	114-520225
Date:	OCTOBER 04, 2017
Designed By:	SRA
Figure No.	5

Appendix A
Existing Data at the Proposed Mid-Plume Boundary

TABLE A1: DATA SUMMARY ALONG GALLERIA ROAD, 2014-2016

Nevada Environmental Response Trust Site

Henderson, Nevada

Chemical Group	Chemical	Unit	DBMW-1	DBMW-3	AA-20	MCF-05	DBMW-10	DBMW-11	DBMW-12	DBMW-13	DBMW-14	DBMW-15
Physical	Depth to Groundwater	ft bgs	34 - 35	26 - 32	29	42	59	42 - 47	52 - 57	43 - 49	32 - 40	32 - 39
	Depth to UMCf	ft bgs	40	31	27	25	60	30	30	30	36	36
	Screen Interval	ft bgs	19 - 49	19 - 39	10 - 30	220 - 230	55 - 75	45 - 75	45 - 75	45 - 75	35 - 65	40 - 65
Field	Conductivity	µS/cm	--	8900 - 13000	7100 - 9300	--	3500 - 3600	8500 - 15000	8200 - 9500	9600 - 12000	6500 - 9900	5900 - 12000
	Dissolved Oxygen	mg/L	4.7 - 6.5	4.5	6.3	1.9	--	--	--	--	--	--
	Field Conductivity	µS/cm	7900	--	7300	74000	--	--	--	--	--	--
	Field pH	SU	7.1	--	7.2	9.3	--	--	--	--	--	--
	Iron, Ferrous	mg/L	0	0	0	--	--	--	--	--	--	--
	Oxidation Reduction Potential	mV	12 - 49	69	42 - 63	120	--	--	--	--	--	--
	Temperature	deg c	20 - 26	22	23 - 25	24	--	--	--	--	--	--
	Turbidity	NTU	0.56 - 1.0	1.0	0.18 - 52	420	--	--	--	--	--	--
	pH	SU	7.4	5.3 - 7.7	5.9 - 7.4	--	5.2 - 5.5	5.3 - 7.0	5.2 - 6.4	5.5 - 5.8	4.8 - 5.9	6.4 - 7.2
General Chemistry	Alkalinity	mg/L	--	64	78 - 82	--	68 - 96	68	74 - 170	130 - 6000	50 - 95	130
	Alkalinity, Bicarbonate [As CaCO3]	mg/L	--	64	78 - 82	--	68 - 96	68	74 - 170	130 - 6000	50 - 95	130
	Alkalinity, Carbonate [As CaCO3]	mg/L	--	0.54	0.54	--	0.54	0.54	0.54	0.54 - 14	0.54	0.54
	Anion Cation Balance Difference	percent	--	-8.8 - 0.15	-0.37 - 2.3	--	-5.9 - 0.78	-3.3 - -1.1	-6.6 - -0.38	-9.9 - 6.9	-16 - -3.8	-11 - 50
	Bromide	mg/L	5.0	0.36 - 2.4	0.41 - 2.5	13 - 25	0.63 - 0.64	0.13 - 0.15	0.49 - 2.0	1.9 - 6.0	0.48 - 0.84	0.24 - 0.97
	Bromine	mg/L	--	0.72 - 4.8	0.82 - 2.8	--	1.3	0.050 - 0.30	0.98 - 4.0	3.8 - 12	0.050 - 1.7	0.48 - 1.9
	Chlorate	mg/L	22	47 - 49	28 - 30	0.50 - 2.0	0.34 - 0.50	28 - 31	13 - 25	17 - 24	0.10 - 13	1.4 - 5.9
	Chloride	mg/L	1100	1800	970 - 1000	19000 - 27000	320 - 330	2000	1100 - 1900	2000 - 2100	600 - 800	550
	Chlorine	mg/L	--	3600	1900	--	640 - 660	3400 - 4000	2200 - 3800	4000 - 4400	1200 - 2200	340 - 1100
	Dissolved Solids (total)	mg/L	5900 - 6000	8300 - 8600	5200 - 6100	76000 - 120000	2100 - 2200	9900	6400 - 9800	7300 - 8500	5600 - 7100	7700
	Fluoride	mg/L	--	0.18	0.35 - 0.40	--	0.43 - 0.65	0.17	0.11 - 0.22	0.073 - 0.10	0.20 - 0.34	0.59
	Hydroxide alkalinity	mg/L	--	0.54	0.54	--	0.54	0.54	0.54	0.54 - 14	0.54	0.54
	Nitrate	mg/L	--	15	7.7 - 8.9	--	12	21	15 - 24	26 - 27	11 - 15	11
	Nitrite	mg/L	--	1.5	0.15 - 1.5	--	0.60	0.60 - 1.5	1.5	1.5	0.15 - 0.60	0.60 - 1.5
	Orthophosphate	mg/L	--	0.39	0.39 - 0.46	--	0.078	0.16 - 0.39	0.16 - 0.39	0.39 - 0.88	0.078 - 0.20	0.16 - 0.39
	Perchlorate	mg/L	7.6 - 9.0	8.3 - 9.8	3.8 - 34	0.095 - 0.63	0.34 - 0.36	13 - 15	--	12 - 20	5.4 - 13	3.4 - 4.7
	Sulfate	mg/L	--	3900	2700 - 2800	--	980 - 1000	4300	3000 - 4400	2300 - 2400	3000 - 4500	4900
Metals	Aluminum	mg/L	0.22 - 0.45	0.17 - 1.7	0.065 - 0.45	--	1.0 - 1.2	0.17 - 0.55	0.31 - 17	21 - 40	7.3 - 13	5.0 - 26
	Antimony	µg/L	37 - 75	8.4 - 75	8.4 - 75	--	8.4	8.4	8.4	8.4	8.4	8.4
	Arsenic	mg/L	0.099 - 0.13	0.10 - 0.14	0.10 - 0.14	--	0.059 - 0.064	0.0059 - 0.054	0.042 - 0.075	0.056 - 0.081	0.10 - 0.16	0.13 - 0.26
	Barium	µg/L	21 - 42	14 - 42	13 - 42	--	19 - 32	26 - 27	15 - 170	240 - 410	94 - 170	71 - 340
	Beryllium	µg/L	2.8 - 5.7	1.8 - 5.7	1.8 - 5.7	--	1.8	1.8	1.8	1.8 - 1.9	1.8	1.8
	Boron	mg/L	2.9 - 3.3	4.0 - 4.7	2.6 - 2.9	--	1.0 - 1.1	1.9 - 3.6	2.0 - 3.8	3.8	3.9 - 4.3	3.8 - 5.5
	Cadmium	µg/L	3.4 - 6.7	0.50 - 6.7	0.50 - 6.7	--	0.50	0.50	0.50 - 0.61	0.50 - 0.66	0.50	0.50
	Calcium	mg/L	610 - 710	560 - 640	610 - 680	--	220 - 230	590	590 - 670	830	440 - 590	490

TABLE A1: DATA SUMMARY ALONG GALLERIA ROAD, 2014-2016

Nevada Environmental Response Trust Site

Henderson, Nevada

Chemical Group	Chemical	Unit	DBMW-1	DBMW-3	AA-20	MCF-05	DBMW-10	DBMW-11	DBMW-12	DBMW-13	DBMW-14	DBMW-15
Metals	Chromium (total)	µg/L	55 - 110	92 - 110	34 - 90	25 - 110	13 - 14	58 - 72	61 - 65	54 - 72	34 - 56	19 - 47
	Chromium VI	µg/L	60 - 70	69 - 70	30 - 41	1.0 - 2.0	12	54 - 61	39 - 59	23 - 24	21 - 51	12 - 20
	Cobalt	µg/L	27 - 54	1.1 - 54	1.1 - 54	--	1.1	1.1	1.1 - 5.7	7.5 - 13	2.5 - 4.5	1.4 - 8.4
	Copper	µg/L	21 - 42	3.4 - 42	3.7 - 42	--	2.3 - 3.4	2.3 - 4.5	3.4 - 18	36 - 40	8.5 - 15	6.3 - 38
	Hardness (total)	mg/L	--	3400 - 3500	2600 - 2700	--	900 - 950	3200 - 4700	3100 - 4900	3100 - 3800	2000 - 2600	2300 - 2800
	Iron	mg/L	0.13 - 0.26	0.25 - 2.0	0.11 - 0.26	--	0.16 - 1.4	0.28 - 0.54	0.29 - 16	18 - 32	6.2 - 11	4.2 - 25
	Lead	µg/L	11 - 32	1.4 - 40	0.98 - 28	--	0.87 - 1.3	0.87 - 1.6	0.87 - 9.7	14 - 21	5.0 - 8.1	3.0 - 14
	Lithium	mg/L	0.44 - 0.51	0.52 - 0.69	0.33 - 0.44	--	0.16	0.59 - 1.4	0.67 - 1.3	0.58 - 0.72	0.39 - 0.42	0.33 - 0.49
	Magnesium	mg/L	260 - 300	400 - 450	220 - 260	--	84 - 90	780	410 - 790	430	210 - 230	260
	Manganese	µg/L	10 - 20	4.4 - 37	4.4 - 20	--	5.1 - 35	7.2 - 11	7.1 - 430	530 - 890	130 - 230	82 - 480
	Mercury	µg/L	0.027 - 0.13	0.027	0.027 - 0.15	--	--	--	--	--	--	--
	Molybdenum	mg/L	0.75 - 0.87	1.8 - 2.8	0.63 - 0.78	--	0.023 - 0.026	0.064 - 0.12	0.062 - 0.14	0.11 - 0.14	0.077 - 0.15	0.14 - 0.19
	Nickel	µg/L	26 - 51	3.4 - 51	3.5 - 51	--	2.1 - 4.0	2.1 - 5.8	4.0 - 18	28 - 36	6.2 - 12	4.9 - 27
	Phosphorus (total)	mg/L	0.14 - 0.28	0.28	0.14 - 0.28	--	--	--	--	--	--	--
	Potassium	mg/L	47 - 65	100 - 160	33 - 41	--	46 - 50	590	190 - 410	160	100 - 120	120
	Selenium	mg/L	0.13	0.12 - 0.23	0.068 - 0.13	--	0.0080	0.016 - 0.025	0.0080 - 0.029	0.058 - 0.069	0.020 - 0.024	0.018 - 0.025
	Silicon	mg/L	34 - 39	29 - 36	33 - 39	--	--	--	--	--	--	--
	Silver	µg/L	9.9 - 20	4.1 - 20	4.1 - 20	--	4.1	4.1	4.1	4.1	4.1	4.1
	Sodium	mg/L	610 - 800	1100 - 1600	730 - 920	--	220 - 240	850	410 - 820	950	630 - 910	1100
	Strontium	mg/L	15 - 19	11 - 15	10 - 12	--	5.4 - 5.6	11 - 14	11 - 12	14 - 17	9.9 - 14	12 - 13
	Sulfur	mg/L	870 - 1000	1200 - 1300	890 - 960	--	--	--	--	--	--	--
	Thallium	µg/L	5.5 - 11	2.8 - 5.5	2.8 - 11	--	2.8	2.8	2.8	2.8	2.8	2.8
	Tin	µg/L	50 - 100	5.4 - 100	5.4 - 100	--	5.4	5.4	5.4	5.4	5.4	5.4
	Titanium	mg/L	0.013 - 0.025	0.025 - 0.055	0.013 - 0.025	--	0.025 - 0.035	0.019 - 0.025	0.025 - 0.51	0.65 - 0.66	0.25 - 0.35	0.21 - 1.0
	Tungsten	µg/L	--	10	10	--	10	10	10	10	10	10
	Uranium (total)	µg/L	8.0 - 11	7.9 - 10	16 - 22	--	7.0 - 7.1	11 - 25	32 - 41	17 - 27	5.2 - 15	11 - 23
	Vanadium	µg/L	44 - 88	53 - 88	42 - 88	--	31 - 32	12 - 13	15 - 48	45 - 76	29 - 50	36 - 81
	Zinc	µg/L	83 - 170	41 - 170	41 - 170	--	41 - 47	41 - 47	47 - 130	63 - 140	41 - 47	47 - 88
	Zirconium	µg/L	5.0 - 26	26	5.0 - 26	--	--	--	--	--	--	--

TABLE A2: ADDITIONAL DATA SUMMARY, 2014-2016

Nevada Environmental Response Trust Site

Henderson, Nevada

Chemical Group	Chemical	Unit	MCF-18A	HM-2	DBMW-4	BEC-9	MCF-20A	DBMW-5	AA-22	POD8	MCF-06A-R	MCF-06B
Physical	Depth to Groundwater	ft bgs	20	23 - 26	24	--	70	25	32	70 - 71	--	55
	Depth to UMCf	ft bgs	21	N/A	25	37	17	12	31	74	43	43
	Screen Interval	ft bgs	360 - 400	N/A	10 - 30	44 - 59	340 - 380	15 - 35	11 - 31	43 - 73	350 - 370	67 - 82
Field	Conductivity	µS/cm	--	--	7100 - 7700	6400 - 7200	--	6900 - 7600	--	5600 - 6300	--	35000 - 47000
	Dissolved Oxygen	mg/L	0.56	0.83	4.5	--	0.63	5.2	5.1	2.0	1.2	1.9
	Field Conductivity	µS/cm	240000	7100	7400	--	160000	7000	7100	--	160000	38000
	Field pH	SU	7.0	7.6 - 7.9	7.3	--	6.9	7.3	7.3	--	8.6	8.2
	Iron, Ferrous	mg/L	--	--	--	--	--	--	--	0	--	--
	Oxidation Reduction Potential	mV	170	150	150	--	14	170	43	48	-21	230
	Temperature	deg c	26	17	25	--	25	24	23	22	22	23
	Turbidity	NTU	61	22	0.37	--	26	31	180	3.4	2.9	0.41
	pH	SU	--	--	4.8 - 7.4	5.7 - 7.4	--	6.1 - 7.4	--	6.3 - 7.3	--	6.8 - 8.2
General Chemistry	Alkalinity	mg/L	--	--	84 - 92	120 - 130	--	82	--	170 - 180	--	66
	Alkalinity, Bicarbonate [As CaCO3]	mg/L	--	--	84 - 92	120 - 130	--	82	--	170 - 180	--	66
	Alkalinity, Carbonate [As CaCO3]	mg/L	--	--	0.54	0.54	--	0.54	--	0.54	--	0.54
	Anion Cation Balance Difference	percent	--	--	-3.8 - -3.5	-21 - 3.0	--	-8.1 - -2.8	--	-6.3 - 4.9	--	-11 - 2.6
	Bromide	mg/L	25 - 94	2.5	0.32 - 5.0	0.32 - 1.4	25	0.32 - 2.9	2.5	0.73 - 1.3	120	0.25 - 13
	Bromine	mg/L	--	--	0.64 - 3.0	0.64 - 2.8	--	0.64 - 3.2	--	1.5 - 2.6	--	0.050
	Chlorate	mg/L	1.0 - 2.0	33 - 36	73 - 77	2.6 - 3.7	0.50 - 2.0	95 - 97	100	1.1 - 1.4	1.7	1.3 - 2.8
	Chloride	mg/L	100000	910 - 1000	1100 - 1300	970 - 1000	49000 - 50000	1200 - 1300	1300	530	56000	7000 - 7200
	Chlorine	mg/L	--	--	2200 - 2600	1900 - 2000	--	2600 - 2800	--	1100	--	14000 - 16000
	Dissolved Solids (total)	mg/L	170000 - 190000	4700 - 5900	5200 - 5900	4600 - 5200	150000 - 160000	5400 - 5500	3600	4600 - 4800	180000	39000 - 46000
	Fluoride	mg/L	--	--	0.23 - 0.40	0.30 - 0.45	--	0.19	--	0.65 - 0.71	--	0.10
	Hydroxide alkalinity	mg/L	--	--	0.54	0.54	--	0.54	--	0.54	--	0.54
	Nitrate	mg/L	--	17 - 18	17 - 22	35	--	21	--	18 - 20	--	1.8
	Nitrite	mg/L	--	0.70	1.5	1.5	--	1.5	--	0.15 - 1.5	--	3.0 - 30
	Orthophosphate	mg/L	--	--	0.39 - 0.75	0.39 - 1.0	--	0.39	--	0.39 - 0.53	--	0.78 - 5.2
	Perchlorate	mg/L	0.095	3.4 - 6.1	5.6 - 50	--	0.095	2.2 - 6.9	7.1	0.30 - 0.48	0.095	2.7 - 32
	Sulfate	mg/L	--	2400	2400 - 2800	2200 - 2300	--	2500	--	2300	--	19000
Metals	Aluminum	mg/L	--	0.050	0.51 - 1.1	0.31 - 0.38	--	0.33 - 0.37	--	0.22 - 1.1	--	0.087 - 0.65
	Antimony	µg/L	--	0.50	8.4	8.4	--	1.7 - 8.4	--	8.4 - 75	--	8.4 - 84
	Arsenic	mg/L	--	0.098	0.13	0.11 - 0.13	--	0.12 - 0.15	--	0.070 - 0.10	--	0.0059 - 0.059
	Barium	µg/L	--	9.4	27 - 37	18 - 20	--	12 - 13	--	18 - 42	--	30 - 33
	Beryllium	µg/L	--	--	1.8	1.8	--	0.35 - 1.8	--	1.8 - 8.0	--	1.8 - 18
	Boron	mg/L	--	--	2.6 - 2.8	1.1 - 1.9	--	2.0 - 2.5	--	2.4 - 3.1	--	4.1 - 6.8
	Cadmium	µg/L	--	2.0	0.50	0.50	--	0.10 - 0.50	--	0.50 - 8.0	--	0.50 - 5.0
	Calcium	mg/L	--	670	620 - 670	510 - 710	--	730	--	390 - 500	--	540

TABLE A2: ADDITIONAL DATA SUMMARY, 2014-2016

Nevada Environmental Response Trust Site

Henderson, Nevada

Chemical Group	Chemical	Unit	MCF-18A	HM-2	DBMW-4	BEC-9	MCF-20A	DBMW-5	AA-22	POD8	MCF-06A-R	MCF-06B
Metals	Chromium (total)	µg/L	20 - 100	38 - 52	87 - 120	26 - 31	2.5 - 5.0	90 - 140	80	14 - 67	5.0	5.0 - 50
	Chromium VI	µg/L	1.0	42 - 46	89 - 100	19 - 20	1.0	110 - 140	99	10 - 20	1.0	1.0 - 23
	Cobalt	µg/L	--	2.5	1.2 - 1.4	1.1	--	0.60 - 1.1	--	1.1 - 54	--	1.1 - 11
	Copper	µg/L	--	5.0	3.4 - 4.2	2.3 - 3.4	--	2.3 - 3.4	--	2.3 - 44	--	4.5 - 170
	Hardness (total)	mg/L	--	--	2500 - 2700	1900 - 2800	--	2800	--	1700 - 2100	--	13000 - 18000
	Iron	mg/L	--	0.014	0.51 - 1.1	0.32 - 0.37	--	0.44 - 0.46	--	0.13 - 0.31	--	0.16 - 1.5
	Lead	µg/L	--	2.5	2.0 - 6.1	0.87 - 1.4	--	0.85 - 0.87	--	0.87 - 40	--	3.9 - 8.7
	Lithium	mg/L	--	--	0.33 - 0.35	0.25 - 0.39	--	0.36 - 0.38	--	0.30 - 0.40	--	4.6 - 6.5
	Magnesium	mg/L	--	250	230 - 250	150 - 250	--	240	--	190 - 250	--	3800
	Manganese	µg/L	--	10	26 - 42	8.7 - 14	--	5.8 - 8.4	--	7.6 - 26	--	12 - 21
	Mercury	µg/L	--	0.10	--	--	--	--	--	0.027 - 0.14	--	--
	Molybdenum	mg/L	--	--	0.11 - 0.12	0.073 - 0.076	--	0.042 - 0.066	--	0.044 - 0.050	--	2.0 - 2.8
	Nickel	µg/L	--	5.9	4.0 - 5.3	6.0 - 6.9	--	2.7 - 3.2	--	3.5 - 51	--	4.0 - 710
	Phosphorus (total)	mg/L	--	--	--	--	--	--	--	0.14 - 0.28	--	--
	Potassium	mg/L	--	170	75 - 85	42 - 66	--	61	--	26 - 36	--	3900
	Selenium	mg/L	--	--	0.0080 - 0.034	0.0080 - 0.039	--	0.013 - 0.034	--	0.021 - 0.046	--	0.080 - 0.11
	Silicon	mg/L	--	--	--	--	--	--	--	42 - 45	--	--
	Silver	µg/L	--	--	4.1	4.1	--	0.82 - 4.1	--	4.1 - 20	--	4.1 - 41
	Sodium	mg/L	--	590	620 - 730	290 - 510	--	600	--	540 - 730	--	4400
	Strontium	mg/L	--	--	11 - 13	8.4 - 14	--	13 - 14	--	4.4 - 12	--	7.4 - 10
	Sulfur	mg/L	--	--	--	--	--	--	--	810 - 850	--	--
	Thallium	µg/L	--	--	2.8	2.8	--	0.64 - 2.8	--	2.8 - 11	--	6.3 - 28
	Tin	µg/L	--	--	5.4	5.4	--	1.1 - 5.4	--	5.4 - 100	--	5.4 - 54
	Titanium	mg/L	--	--	0.025 - 0.066	0.015 - 0.025	--	0.032	--	0.013 - 0.026	--	0.013 - 0.025
	Tungsten	µg/L	--	--	10	10	--	2.0 - 10	--	10	--	10 - 100
	Uranium (total)	µg/L	--	--	27 - 28	56 - 62	--	21 - 32	--	38 - 50	--	1.3 - 12
	Vanadium	µg/L	--	33	61 - 64	33 - 37	--	17 - 22	--	25 - 88	--	12 - 120
	Zinc	µg/L	--	10	41 - 47	41 - 47	--	9.3 - 41	--	41 - 170	--	47 - 410
	Zirconium	µg/L	--	--	--	--	--	--	--	5.0 - 26	--	--

TABLE A2: ADDITIONAL DATA SUMMARY, 2014-2016

Nevada Environmental Response Trust Site

Henderson, Nevada

Chemical Group	Chemical	Unit	MCF-06C	DBMW-7	DBMW-8	BEC-6	MCF-16C	MW-1	MW-2	AA-UW6	MCF-12B
Physical	Depth to Groundwater	ft bgs	55	56	55 - 56	59	64 - 65	6.3	26	51 - 56	62 - 64
	Depth to UMCf	ft bgs	43	41	41	55	70	N/A	N/A	33	52
	Screen Interval	ft bgs	44 - 59	50 - 70	48 - 68	65 - 80	53 - 73	N/A	N/A	37 - 57	64 - 84
Field	Conductivity	µS/cm	9200 - 12000	--	8100 - 11000	5400	7100 - 12000	--	--	4300 - 5600	4100 - 5400
	Dissolved Oxygen	mg/L	4.8	6.1	6.2	--	--	3.3	3.3	--	--
	Field Conductivity	µS/cm	9300	8200	8600	--	--	8200	7100	--	--
	Field pH	SU	7.1	7.3	7.2	--	--	7.6	7.6	--	--
	Iron, Ferrous	mg/L	--	--	--	--	--	--	--	--	--
	Oxidation Reduction Potential	mV	37	190	47	--	--	200	180	--	--
	Temperature	deg c	24	25	27	--	--	18	18	--	--
	Turbidity	NTU	50	0.11	1.4	--	--	160	1.7	--	--
	pH	SU	5.6 - 7.2	--	5.8 - 7.4	7.6	5.6 - 7.7	--	--	5.2 - 6.1	5.5 - 7.6
General Chemistry	Alkalinity	mg/L	90 - 98	--	60	63	76 - 82	--	--	120 - 160	50 - 58
	Alkalinity, Bicarbonate [As CaCO3]	mg/L	90 - 98	--	60	63	76 - 82	--	--	120 - 160	50 - 58
	Alkalinity, Carbonate [As CaCO3]	mg/L	0.54	--	0.54	0.54	0.54	--	--	0.54	0.54
	Anion Cation Balance Difference	percent	-18 - 3.4	--	-20 - 5.1	-1.2	-21 - -1.4	--	--	-2.0 - 6.6	-6.4 - 4.4
	Bromide	mg/L	0.13 - 5.0	5.0	0.13 - 5.0	0.23	0.35 - 1.3	2.5	2.5	0.44 - 1.0	0.44 - 0.65
	Bromine	mg/L	0.050 - 0.32	--	0.050	0.46	0.70 - 2.6	--	--	0.88 - 2.0	0.88 - 1.3
	Chlorate	mg/L	6.5 - 9.9	7.6 - 8.0	6.1 - 10	0.10	13 - 17	16	11	0.10	3.3 - 5.3
	Chloride	mg/L	1700 - 2000	1400 - 1500	1400 - 1600	290	960 - 1000	1100	870	220 - 260	370 - 410
	Chlorine	mg/L	3400 - 4000	--	3200 - 3800	580	1900 - 2000	--	--	440 - 560	740 - 820
	Dissolved Solids (total)	mg/L	7000 - 7400	6300	5800 - 6300	4600	4700 - 12000	6300	5600	4000 - 4200	3300 - 3800
	Fluoride	mg/L	0.20 - 0.31	--	0.17	0.19	0.37 - 0.60	--	--	0.28 - 0.37	0.29 - 0.50
	Hydroxide alkalinity	mg/L	0.54	--	0.54	0.54	0.54	--	--	0.54	0.54
	Nitrate	mg/L	49	--	46	0.043	16 - 23	--	--	8.6 - 12	5.8 - 7.4
	Nitrite	mg/L	1.5	--	1.5	0.060	0.15 - 1.5	--	--	0.060 - 0.60	0.60
	Orthophosphate	mg/L	0.39	--	0.39	0.44	0.80 - 0.92	--	--	0.11 - 0.35	0.16 - 0.43
	Perchlorate	mg/L	5.6	4.4 - 4.6	7.0	0.0018	8.4 - 9.4	8.8	7.4	0.045 - 0.054	4.2 - 5.1
	Sulfate	mg/L	2700 - 3000	--	2100	2800	2200 - 7000	--	--	2200 - 2500	1700 - 2100
Metals	Aluminum	mg/L	2.3 - 4.2	--	0.16 - 0.67	0.087	0.065 - 0.087	--	--	0.71 - 9.7	0.087 - 0.12
	Antimony	µg/L	8.4	--	8.4	8.4	8.4	--	--	8.4	8.4
	Arsenic	mg/L	0.039 - 0.055	--	0.038 - 0.042	0.068	0.017 - 0.034	--	--	0.072 - 0.12	0.036 - 0.076
	Barium	µg/L	60 - 100	--	8.8 - 14	25	16 - 17	--	--	15 - 200	11 - 30
	Beryllium	µg/L	1.8	--	1.8	1.8	1.8	--	--	1.8	1.8
	Boron	mg/L	1.7 - 2.3	--	1.1 - 1.7	2.8	0.96 - 6.4	--	--	1.9 - 2.8	1.8 - 1.9
	Cadmium	µg/L	0.50	--	0.50	0.50	0.50	--	--	0.50	0.50
	Calcium	mg/L	610 - 720	--	820	520	480 - 490	--	--	490 - 500	390 - 420

TABLE A2: ADDITIONAL DATA SUMMARY, 2014-2016

Nevada Environmental Response Trust Site

Henderson, Nevada

Chemical Group	Chemical	Unit	MCF-06C	DBMW-7	DBMW-8	BEC-6	MCF-16C	MW-1	MW-2	AA-UW6	MCF-12B
Metals	Chromium (total)	µg/L	64 - 78	63 - 66	63 - 72	5.0	99 - 120	41	22	8.5 - 19	16 - 22
	Chromium VI	µg/L	72 - 140	79 - 81	70 - 81	0.015	80 - 120	49	24	3.3 - 3.9	14 - 22
	Cobalt	µg/L	1.2 - 1.7	--	1.1	1.1	1.1	--	--	1.1 - 2.9	1.1
	Copper	µg/L	2.9 - 3.4	--	2.3 - 3.4	3.4	2.3 - 3.4	--	--	2.6 - 9.7	2.3 - 3.4
	Hardness (total)	mg/L	2800 - 3500	--	2500 - 3300	2000	1800 - 5700	--	--	2000 - 2600	1600
	Iron	mg/L	2.5 - 3.9	--	0.23 - 0.69	0.44	0.10 - 0.16	--	--	1.0 - 8.8	0.11 - 0.16
	Lead	µg/L	2.3 - 3.5	--	0.87 - 0.92	1.9	0.87 - 2.2	--	--	1.3 - 6.8	0.87
	Lithium	mg/L	0.46 - 0.61	--	0.27 - 0.35	0.92	0.30 - 1.8	--	--	0.29 - 0.33	0.22 - 0.23
	Magnesium	mg/L	310 - 410	--	320	150	150 - 1200	--	--	190 - 200	150 - 160
	Manganese	µg/L	85 - 120	--	4.4 - 11	120	4.4 - 10	--	--	58 - 230	7.5 - 12
	Mercury	µg/L	--	--	--	--	--	--	--	--	--
	Molybdenum	mg/L	0.23 - 0.30	--	0.074 - 0.087	0.23	0.22 - 0.32	--	--	0.061 - 0.095	0.031 - 0.064
	Nickel	µg/L	7.0 - 8.9	--	2.6 - 4.0	4.0	2.0 - 4.0	--	--	2.0 - 9.1	2.0 - 4.0
	Phosphorus (total)	mg/L	--	--	--	--	--	--	--	--	--
	Potassium	mg/L	210 - 290	--	80	140	38 - 700	--	--	69 - 85	72 - 84
	Selenium	mg/L	0.0080 - 0.048	--	0.0080 - 0.014	0.0080	0.037 - 0.051	--	--	0.012	0.017 - 0.022
	Silicon	mg/L	--	--	--	--	--	--	--	--	--
	Silver	µg/L	4.1	--	4.1	4.1	4.1	--	--	4.1	4.1
	Sodium	mg/L	590 - 790	--	670	530	300 - 630	--	--	360 - 400	340 - 350
	Strontium	mg/L	11 - 14	--	11 - 15	10	7.9 - 8.0	--	--	9.8 - 10	8.5
	Sulfur	mg/L	--	--	--	--	--	--	--	--	--
	Thallium	µg/L	2.8	--	2.8	2.8	2.8	--	--	2.8	2.8
	Tin	µg/L	5.4	--	5.4	5.4	5.4	--	--	5.4	5.4 - 10
	Titanium	mg/L	0.098 - 0.12	--	0.026 - 0.028	0.025	0.013 - 0.025	--	--	0.023 - 0.26	0.025
	Tungsten	µg/L	10	--	10	10	10	--	--	10	10
	Uranium (total)	µg/L	19 - 32	--	16 - 22	1.2	9.9 - 16	--	--	5.0 - 11	5.6 - 5.7
	Vanadium	µg/L	17 - 19	--	12	12	12 - 42	--	--	19 - 37	12 - 17
	Zinc	µg/L	41 - 47	--	41 - 47	47	41 - 47	--	--	41 - 47	41 - 47
	Zirconium	µg/L	--	--	--	--	--	--	--	--	--