Las Vegas Wash Bioremediation Pilot 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
bgs	below ground surface
BOD	biological oxygen demand
BOR	United States Bureau of Reclamation
CE	categorical exclusion
COH	City of Henderson
DO	dissolved oxygen
EA	environmental assessment
EC	electrical conductivity
EVO	emulsified vegetable oil
FS	Feasibility Study
IPaC	Information Planning and Conservation
ITRC	Interstate Technology & Regulatory Council
lbs/day	pounds per day
µg/L	micrograms per liter
mg/L	milligrams per liter
mV	milliVolts
NAC	Nevada Administrative Code
NDEP	Nevada Division of Environmental Protection
NDWR	Nevada Division of Water Resources
NEPA	National Environmental Policy Act
NERT or Trust	Nevada Environmental Response Trust
NFG	National Functional Guidelines
ORP	oxidation reduction potential
PLFA	phospholipid fatty acids
PVC	polyvinyl chloride
RAO	Remedial action objective
RI	Remedial Investigation
RIBs	Rapid Infiltration Basins
qPCR	quantitative polymerase chain reaction
Site	Nevada Environmental Response Trust site
SWF	Seep Well Field

Acronyms/Abbreviations	Definition
TDS	total dissolved solids
Tetra Tech	Tetra Tech, Inc.
TOC	total organic compound
UIC	Underground Injection Control
UMCf	Upper Muddy Creek formation
UNLV	University of Nevada at Las Vegas
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VFAs	volatile fatty acids
ZOI	zone of influence

Las Vegas Wash Bioremediation Pilot 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 system(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, Inc., not individually, but solely in its representative capacity as the Nevada Environmental Response Trust Trustee

Signature: _____, 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

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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: Las Vegas Wash Bioremediation Pilot Study Work Plan, Nevada Environmental Response Trust Site, Henderson, Nevada

09/22/2017

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

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 Las Vegas Wash Bioremediation Pilot Study Work Plan (Work Plan) for implementation of an in-situ bioremediation pilot study where perchlorate continues to migrate into the Las Vegas Wash, which is downgradient 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 in-situ bioremediation pilot study based on the currently available data and provides details on pre-design activities to be conducted prior to the final pilot study design.

1.1 PROJECT OBJECTIVES

The overall objective of this pilot study is to demonstrate and evaluate the effectiveness of implementing in-situ bioremediation to reduce the perchlorate mass flux that is migrating into the Las Vegas Wash. Based on data from July 2015 through June 2016, an estimated 38.5 pounds per day (lbs/day) of perchlorate discharges to the Las Vegas Wash between the Pabco Rd and Northshore Rd weirs (Ramboll Environ, 2016). Additionally, a primary remedial action objective (RAO) for the Site is to mitigate the discharge of chemicals of potential concern in groundwater to the Las Vegas Wash (ENVIRON, 2014a).

This pilot study will build on the results of the previous in-situ bioremediation treatability study performed downgradient of the Athens Road Well Field (AWF) near the City of Henderson (COH) Bird Viewing Ponds and on-going Seep Well Field (SWF) Area Bioremediation Treatability Study. Although the previous and on-going treatability studies focus on the alluvium, this pilot study will also include implementation of in-situ bioremediation in the Upper Muddy Creek formation (UMCf), which has not been evaluated to date. The pilot study will be executed on a larger scale than previous bioremediation treatability studies conducted for NERT and provide key information needed for the future Feasibility Study (FS) to evaluate design, optimization/scale-up, and cost effectiveness of this technology and its effectiveness on the RAO of mitigation of the perchlorate mass flux discharge to the Las Vegas Wash.

1.2 WORK PLAN ORGANIZATION

This Work Plan is organized as follows:

- **Introduction (Section 1.0):** Provides the primary objectives of the pilot 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 in-situ bioremediation 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 implementation of the pilot study to optimize and finalize the pilot study design.
- **Pilot Study Conceptual Design (Section 4.0):** Describes the conceptual design of the pilot 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 pilot study, including the field, analytical, and microbial groundwater monitoring and data validation requirements.

- **Access Agreement and Permitting (Section 6.0):** Summarizes access agreement and permitting requirements for pilot study implementation.
- **Ecological Review and Protection Measures (Section 7.0):** Presents a summary of federally listed species with the potential to occur within the pilot study area and a summary of protective measures, if required.
- **Reporting (Section 8.0):** Summarizes reporting related to design and execution of the pre-design field activities and pilot study.
- **Schedule (Section 9.0):** Summarizes the schedule for conducting the pre-design activities, pilot study, and associated reporting.
- **References (Section 10.0):** Lists the documents referenced in this Work Plan.

1.3 BACKGROUND

1.3.1 General

The Site has been used for industrial purposes since 1942, when it was initially developed by the United States government as a magnesium plant to support World War II operations. Since that time, the Site and the surrounding properties have been used for chemical manufacturing, including the production of various chlorate and perchlorate compounds. Entities that operated at the Site include Western Electrochemical Company, American Potash and Chemical Company, Kerr-McGee Chemical Corporation, and Tronox. On February 14, 2011, NERT took title to the Site as part of the settlement of the Tronox Chapter 11 bankruptcy proceedings. As part of a long-term lease, Tronox operates a manufacturing facility on 114 acres of the Site to produce manganese and boron products. Historical industrial production and related waste management activities conducted at the Site and on adjacent properties have resulted in the contamination of various environmental media, including soil, groundwater, and surface water. The most notable site-related contaminants of potential concern are chromium and perchlorate (ENVIRON, 2014a).

The pilot study location is northeast of the Site along the Las Vegas Wash, which is located 13 miles southeast of Las Vegas in an unincorporated section of Clark County, Nevada (Figure 1). It is surrounded by the incorporated area of the COH. Approximately 230 acres in the northeastern and central portions of the NERT RI Study Area are owned by United States Bureau of Reclamation. Other landowners along the Las Vegas Wash include Clark County and the COH.

1.3.2 Regional Geology

The Site is located near the southeast end of the Las Vegas Valley, a structural basin that also includes the metropolitan areas of North Las Vegas, Las Vegas, and Henderson. Las Vegas Valley is bounded on the west by the Spring Mountains, on the north by the southern ends of the Sheep and Las Vegas Ranges, on the east by Frenchman and Sunrise Mountains, and on the south by the River Mountains and McCullough Range. The northwest-southeast trending structural basin that underlies Las Vegas Valley is composed of Precambrian crystalline rocks; Precambrian and Paleozoic carbonate rocks; Permian, Triassic, and Jurassic clastic rocks; and Miocene igneous rocks. Gravity data indicate that the deeper parts of the basin are filled with 3,000-5,000 feet of clastic sedimentary deposits that range in age from Miocene through Holocene (Plume, 1989).

The clastic sedimentary valley-fill deposits of Las Vegas Valley are generally believed to consist of Muddy Creek Formation and younger deposits. The Muddy Creek Formation also includes thick beds of gypsum and salt and basalt flows, though these are not exposed in the Las Vegas Valley. The thickness of the valley fill deposits in the vicinity of the Site is approximately 4,000 feet. Extraction of groundwater from the valley fill since the early 1900s has resulted in significant subsidence centered on the areas with the heaviest groundwater pumping, such as downtown Las Vegas (Plume, 1989).

1.3.3 Local Geology and Hydrogeology

At and near the Site, as well as the area near the Las Vegas Wash, soil borings have encountered valley fill deposits including Quaternary alluvium, transitional Muddy Creek Formation, and the Pleistocene Upper Muddy Creek Formation (UMCf). The alluvium is generally described as reddish-brown discontinuous layers of sand and gravel with minor amounts of silt, clay, and caliche. The thickness of these alluvial deposits ranges from less than one foot to more than 50 feet beneath the Site (ENVIRON, 2014a). Thick deposits of alluvium that are structurally narrow and linear have been interpreted as stream-deposited sands and gravels that were deposited within paleochannels during flooding events. The paleochannel sand and gravel deposits often exhibit significantly greater permeability than the alluvium outside the paleochannels. At the base of the alluvium, the transitional Muddy Creek Formation is sometimes encountered below the Site. The transitional Muddy Creek Formation consists of reworked sediments derived from the Muddy Creek Formation. The UMCf underlies the transitional Muddy Creek Formation (if present) or alluvium, and consists of interbedded coarse-grained and fine-grained sediments that become progressively finer-grained to the north towards the central portion of the valley.

The UMCf subcrops beneath a thin veneer of Quaternary alluvium near the Site. In that area, the contact between the alluvium and the Muddy Creek Formation is typically marked by the appearance of a well-compacted, moderate brown silt-to-sandy silt or stiff clay-to-sandy clay (ENVIRON, 2014a). However, in the vicinity of the Las Vegas Wash and COH Bird Viewing Preserve, the contact is marked by light grey-green to yellow-green clays and silts. Recent information obtained from the on-going SWF Area Treatability Study area indicates that coarser-grained lenses also exist within the UMCf below the initial silty to clayey contact. Borehole log information in the areas east of Pabco Road indicates that the UMCf contact in that area similarly tends to be marked by silts and clays.

Locally, the ground surface slopes north toward the Las Vegas Wash. Thus, surface water north of the Site generally flows south to north toward the Las Vegas Wash (surface water on-Site does not leave the site). Surface water infiltrating into groundwater below the ponds of the COH Bird Preserve Viewing Preserve creates a groundwater high that diverts groundwater flowing north from the Site around the Bird Preserve. Subsurface paleochannels just south and east of the Bird Viewing Preserve also serve to direct impacted water from the Site toward the Las Vegas Wash.

The depth to water in wells near the proposed pilot study locations (i.e., wells AA-22, AA-23R, and WMW4.9S) tends to range between 26 and 30 feet based on recent measurements (AECOM, 2016). The horizontal groundwater gradient in the vicinity of the NERT Downgradient Study Area on unincorporated COH property is approximately 0.026 feet/foot based on recent groundwater level measurements in wells AA-22 and AA-23R (AECOM, 2016). Closer to the Las Vegas Wash, the horizontal groundwater gradient is distinctly lower, approximately 0.004 feet/foot, based on recent water level measurements in wells MW-13 and WMW4.9S (AECOM, 2016). The vertical gradient near the Las Vegas Wash is generally upward, with groundwater discharging into the Las Vegas Wash and underlying alluvium (ENVIRON, 2014a).

Unlike the areas west of Pabco Road, in the areas east of Pabco Road, the alluvial wells are not typically evaluated separately from the alluvial/UMCf transition and uppermost UMCf. Rather, the entire upper saturated interval down to 90 feet below ground surface (bgs) is contoured as the Shallow Zone [Daniel B. Stephens & Associates, Inc. (DBSA), 2010; AECOM, 2016]. This is in accordance with NDEP's definition of the water-bearing zones (NDEP, 2009). In the areas east of Pabco Road, the water table commonly occurs below the UMCf contact or just above it such that the layer of saturated alluvium is quite thin. Furthermore, hydraulic heads in the uppermost UMCf wells tend to be quite similar to those in nearby alluvial wells, as do perchlorate concentrations (AECOM, 2016). The underlying Middle Zone consists of thin, generally isolated sand lenses in the UMCf between 90 and 279 feet bgs, and the Deep Zone consists of UMCf between 270 and 400 feet bgs (DBSA, 2010).

1.3.4 Nature and Extent of Contamination

Recent alluvial groundwater sampling results, presented in data summaries from the Groundwater Sampling Technical Memorandum for the Downgradient Study Area (AECOM, 2016) activities, indicate that perchlorate concentrations in the area north of the Former COH Northern Rapid Infiltration Basins (RIBs) are higher than the concentrations near the Las Vegas Wash (Figure 2). Perchlorate concentrations ranged from 5,600 micrograms per liter (µg/L) (well AA-23R) to 7,100 µg/L (well AA-22) in the area to the north of the northern RIBs (Figure 2), while samples from wells closer to the Las Vegas Wash (Figure 3), exhibited lower concentrations ranging from 270 µg/L (well WMW4.9S) to 3,800 µg/L (well MW-13). In the same sampling event, hexavalent chromium concentrations north of the northern RIBs ranged from 30 µg/L (well AA-23R) to 99 µg/L (well AA-22). Samples from wells closer to the Las Vegas Wash exhibited generally lower concentrations ranging from 2.0 µg/L (well WMW4.9S) to 39 µg/L (well MW-13).

A number of shallow UMCf and alluvium/UMCf transition wells exist within the vicinity of the proposed pilot study location. These wells are typically contoured together with the alluvial wells as part of the Shallow Zone, and both sets of wells tend to have similar concentrations. Based on review of available data, perchlorate contamination is present in the shallow water-bearing zone, with elevated perchlorate concentrations potentially at depths of up to 90 feet bgs.

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 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 alteration 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 (mVs) and generally in the 0 to -100 mVs 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 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 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 site hydrogeologic characteristics of hydraulic permeability and groundwater velocity;
(ii) Bench batch microcosm and column testing at University of Nevada at Las Vegas (UNLV);
(iii) Installation of field pilot 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 this 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 site and has strong potential to be a significant component of the overall remedy. The results, findings, and lessons learned from this study can 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 pilot 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 sustained 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 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 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 the bioremediation technology 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.
- Improved definition of preferential flow pathways and paleochannel morphology may be implemented in future studies to better define the baseline perchlorate mass and mass removal rates during bioremediation.

2.3 ON-GOING SEEP WELL FIELD AREA TREATABILITY STUDY

A second treatability study is currently being undertaken 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 in-situ bioremediation to reduce the flux of perchlorate mass that is

migrating towards the Las Vegas Wash within the alluvium and is not currently being captured by the existing SWF. The subject study of this work plan, the Las Vegas Wash Bioremediation Pilot Study, builds on the results and findings of the previous COH treatability study summarized in Section 2.2 and also incorporates some of the findings and recommendations of the SWF Area Treatability Study, including the use of geophysical surveys, evaluation 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 and the first injection event for the SWF Area Treatability Study have been completed. As part of the pre-design, geophysical surveys, installation of soil borings and groundwater monitoring wells, groundwater sampling, aquifer testing, and basic bench-scale 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, i.e., EVO, results in rapid bioremediation of nitrate and perchlorate in batch microcosms of site-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 site soils, is currently being performed at UNLV. The first field carbon substrate injection event was completed in September 2017.

To achieve cost efficiencies, final results from the UNLV bench-scale testing, pre-design field activities, and effectiveness monitoring associated with the SWF Treatability Study will be evaluated and applied to the design of the Las Vegas Wash bioremediation pilot study as appropriate. These include:

- Laboratory sorption/desorption test results from bench-scale studies;
- Application of geophysics;
- Zone of influence (ZOI) of the carbon substrate injection(s) and longevity of the carbon substrate;
- Conclusions on the advantages 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.

Additional data collected from the on-going NERT Remedial Investigation (RI) and the Downgradient RI will be reviewed and evaluated as data becomes available to incorporate any additional knowledge and significant findings into this pilot study.

3.0 PRE-DESIGN FIELD AND LABORATORY ACTIVITIES

This section describes the various preliminary activities to be completed prior to the field pilot study implementation of the Las Vegas Wash Bioremediation Pilot Study. The results will provide detailed information to optimize the final pilot study locations and design. Specifically, the objectives of the pre-design activities include:

- Characterization of the lithology in sufficient detail to refine conceptual injection well spacing.
- Identification of preferential flow pathways (such as paleochannels and transmissive zones) in order to better target injections.
- Assessment of localized vertical and horizontal distribution of perchlorate to target remediation zones.
- Accurate identification of groundwater flow directions and rates to design injection wells and perform injections to best address perchlorate migration into the Las Vegas Wash.

Various field activities will be conducted to gather the appropriate data to meet the objectives of the work, including soil boring and monitoring well installation, soil and groundwater sampling, single borehole dilution and slug tests, nuclear magnetic resonance (NMR) logging, surface water evaluations, transducer data collection, and laboratory bench tests. Each of these activities and their purpose are presented in this section.

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 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 pre-design field activities and field pilot study (further described in Section 4.0), the Trust will acquire access agreements for all field activities (including injections and monitoring) from the COH and Clark County. 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 geophysical locator and utility locator service to avoid existing utilities, structures, or other site features. Prior to drilling, each location will also be cleared to a depth of 5 feet bgs either by hand augering or air knife operations.

3.1.3 Installation of Soil Borings and Monitoring Wells

Soil borings will be installed in strategic locations throughout the field study area to provide better characterization and allow for selection of the best locations for the bioremediation field pilot study. Twenty-five locations have been identified for installation of soil borings/monitoring wells (Figures 2 and 3). The purpose of the soil borings will be to obtain area-specific lithological information, physical parameters, and contaminant concentrations. 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). Some of the borings at the eastern end of Transect 1b are anticipated to encounter bedrock. These borings will be advanced into the bedrock approximately 15 feet to evaluate its characteristics.

Tetra Tech will retain a licensed drilling contractor to advance the soil borings using rotosonic drilling methods with 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. Soil borings will be advanced through the alluvium and UMCf to a depth of 120 feet to evaluate soil conditions and perchlorate concentrations within the alluvium and UMCf. The continuous soil cores will be logged by the field geologist from ground surface to total depth using the Unified Soil Classification System. To the extent borings encounter bedrock, cores will be obtained to evaluate its characteristics.

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. Selected soil samples will be analyzed for soil grain size distribution. Upon reaching groundwater, undisturbed soil samples will be collected using a Shelby tube, or similar collection device, from a select number of boreholes, for analysis of physical parameters including moisture content, porosity, soil density, and specific gravity. Soil samples will also be analyzed for a variety of chemical and biochemical parameters (***Table 1***). Depth-discrete groundwater samples will 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
Laboratory Parameters		
Perchlorate	E314.0	Estimate mass of perchlorate 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
Hexavalent Chromium	SW 846 7199	Assess potential secondary impacts of treatment such as mobilization potential of chromium into the groundwater under reducing conditions
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[4]	Examine native/natural microbial characteristics
Perchlorate Reductase Gene	Quantitative polymerase chain reaction (qPCR)	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.
4. White, D. C., H. C. Pinkart, and A. B. Ringelberg. (1995). Biomass measurements: Biochemical approaches, p. 91-101. In C. J. Hurst, G. R. Knudsen, M. J. McInerney, L. D. Stetzenbach, and M. V. Walter (ed.), Manual of Environmental Microbiology. ASM Press, Washington.

Monitoring wells will be installed to evaluate the extent of perchlorate in the pilot study area and monitor key parameters to help optimize the design and effectiveness of the field pilot study. All 25 soil boring locations will be converted to permanent monitoring wells, and up to 15 of those locations may be installed as paired or clustered wells with screened intervals in the alluvium and UMCf. In locations where bedrock is encountered near the eastern end of Transect 1b, up to two of the borings will be completed as monitoring wells screened in bedrock to evaluate its hydraulic characteristics. In cases where a well is screened in bedrock, a paired shallower well in the overlying material (i.e., alluvium or UMCf) will also be installed next to the bedrock well to evaluate vertical gradients. Decisions regarding which and how many locations will be installed as paired wells will be based on review of the soil cores and lithology encountered during the soil boring installation. If borehole log information indicates multiple highly permeable productive zones in the UMCf at significantly different depths, up to 5 additional wells may be installed and screened in the deeper zones. The purpose of the additional deeper wells would be to evaluate the perchlorate concentration and hydraulic gradient changes with depth.

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 six 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 in the alluvium and UMCf. A 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 complete, 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 generally 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 5.1, to establish baseline conditions of the soil and groundwater to be used in the laboratory bench studies. 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. If nearby existing wells have not been recently surveyed as part of the on-going Downgradient Study Area investigation, then they may be resurveyed to ensure that a consistent datum is in use.

3.1.4 Single-Borehole Dilution Test

A single-borehole dilution test will be performed in the six newly installed 4-inch diameter monitoring wells to evaluate volumetric flow in the alluvium and UMCf within the field pilot 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 (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. Based on the proximity of the pilot study area to the Las Vegas Wash, the use of fluorescent dye tracers is not recommended. Furthermore, recent water quality results indicate that groundwater near the proposed field pilot study location has a specific conductance of 3,000 to 7,000 microsiemens per centimeter (AECOM, 2016). 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 for use in the field pilot study design. All results will be provided in a final report which is further described in Section 8.0.

3.1.5 Slug Tests

Slug tests will be performed in all newly installed wells to estimate location-specific aquifer hydraulic conductivity within the field pilot study 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.

3.1.6 Nuclear Magnetic Resonance Logging

As discussed in Section 2.2, one of the lessons learned during the previous treatability study was that improved definition of preferential flow pathways and paleochannel morphology was needed to better define the baseline perchlorate mass and mass removal rates during bioremediation. As a result, down-hole geophysics using NMR logging will be performed on all newly installed monitoring wells and select existing monitoring wells. This method was used successfully at the SWF Area Treatability Study area to identify higher-transmissivity zones within each well. NMR will be used in newly installed and select existing monitoring wells to delineate localized preferential flow pathways. This technology can be used in open or PVC-cased wells to provide high-resolution downhole estimates of hydraulic conductivity, total water content, 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 pathways.

3.1.7 Las Vegas Wash Surface Water Evaluation

Groundwater from the pilot study area footprint generally discharges into the Las Vegas Wash. The Las Vegas Wash greatly influences groundwater flow directions in its vicinity and the engineered weirs that have been/will be installed in the Las Vegas Wash result in complex groundwater flow patterns adjacent to the Las Vegas Wash. Theoretically, groundwater should discharge from within the footprint of this pilot study to the Las Vegas Wash downstream of weirs and be recharged by the Las Vegas Wash upstream of weirs. However, determining exactly where the areas transition from recharge to discharge (and vice versa) is problematic and would require a level of effort beyond the scope of this pilot study.

Hence, a simplified approach is proposed to identify the general groundwater flow direction in the vicinity of the Las Vegas Wash so that the injection transects and monitoring wells can be properly located. The surface water elevation will be measured from the following existing nearby gauges each time groundwater elevations are measured in the existing and new wells in the Las Vegas Wash study area:

- Las Vegas Wash at Pabco Rd Nr Henderson, NV [United States Geological Survey (USGS) #09419700]
- Las Vegas Wash 05 Middle Way (USGS #360517114585301)
- Las Vegas Wash Abv Bostick Weir Nr Henderson, NV (USSG #09419747)
- Las Vegas Wash 07 Lower Narrows Abv Lower Narrows Weir (USGS #360535114574001)
- Las Vegas Wash Abv Homestead Weir Nr Henderson, NV (USGS #09419749)

The gauges will be re-surveyed at the same time as the pre-design monitoring wells to ensure that all points are on a consistent datum and accurately located with measuring points surveyed to 0.01 foot vertically. The water levels will be compared to nearby groundwater elevations to help assess the groundwater flow directions.

Surface water samples are currently collected on a monthly basis to monitor the mass flux of perchlorate migrating into the Las Vegas Wash, pursuant to the RI Phase 2 Investigation Modification No. 3 (Ramboll Environ, 2017). These data will be used during the pre-design phase to refine the quantity of the mass flux of perchlorate migrating into the Las Vegas Wash. The current surface water sampling program includes sample collection from Pabco, Bostick, Homestead, Three Kids, Sunrise Mountain, and Duck Creek weirs and includes analysis for perchlorate, chlorate, and TDS. As part of the pre-design, surface water samples will also be collected from the Historic Lateral, Calico Ridge, and Lower Narrows weirs. In addition to perchlorate, chlorate, and TDS, surface water samples will also be analyzed for organic content in terms of TOC and/or biological oxygen demand (BOD), as well as dissolved metals.

3.1.8 Transducer Data Collection

Data will be obtained from transducers installed in nearby existing monitoring wells by AECOM as part of their Downgradient Study Area RI field work that is currently on-going. This data will be compared to available USGS gauging station data to assist in assessing localized groundwater/surface water interactions over time. In addition, transducers will be installed in up to 10 of the newly installed pre-design monitoring wells to assess vertical and horizontal gradients in the alluvium and UMCf.

3.1.9 Management of Investigation-Derived Wastes

Investigation-derived waste generated during pre-design field activities 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.

3.1.10 Health and Safety

Fieldwork will be conducted in accordance with an Activity Hazard Analysis and other elements of Tetra Tech's internal Site-wide Health and Safety Plan (Tetra Tech, Inc., 2015), which addresses potential chemical and physical hazards associated with the field pilot 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 for the alluvium. However, because the Las Vegas Wash Bioremediation Pilot Study will incorporate in-situ bioremediation not only in the alluvium but also the UMCf, additional bench-scale studies are warranted to gather information on site-specific soil and groundwater from the UMCf within the pilot study footprint. As a result, for purposes of this pilot study, 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 be encountered in the vicinity of the Las Vegas Wash and provide an estimate of the acclimation time and perchlorate biodegradation rates. In addition to EVO, soluble substrate(s) (such as glycerin, acetate, and lactate) 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) **Column studies** will be performed to simulate the upward migration of perchlorate from the UMCf into the alluvium and help establish the hydraulic, physical, and chemical relationship between these two lithological zones. These tests will be designed in order to understand the potential for upflux or transport of the perchlorate from the UMCf into the alluvium and better target these zones with carbon substrate during the pilot study and future remediation activities. While much is known about diffusion of ionic contaminants through low conductivity formations or clay liners, very little is known about back-diffusion of contaminants under the same conditions (Liu and Ball, 2002). It may be hypothesized that once the perchlorate in the alluvium groundwater is remediated, perchlorate in the UMCf may move via molecular diffusion into the alluvial portions of the formation. Such transport behavior is important and could be advantageous to addressing the perchlorate that could be residing in the upper portions of the UMCf, by focusing remediation activity and operations in the alluvium, which continually receives perchlorate via back diffusion.

Laboratory experiments are proposed to determine back-diffusion coefficients between the alluvium and the UMCf formations for perchlorate and co-contaminants. This will be accomplished by using Thorough Diffusion Cells and assuming Fickian diffusion (Shackelford, 2013). Several levels of TDS

will be used to simulate the various concentrations of TDS found in the UMCf and the alluvium. The set-up is likely to involve two chambers that will be filled with TDS-laden water and compacted cylinders of soils (i.e. alluvium and UMCF) placed between the cylinders. Once the soil column is placed among the two chambers, ions will start to diffuse through the soil column to the chambers and the TDS concentration and specific ion concentration in each will indicate the preferential path of the contaminants. The results will indicate whether back-diffusion is likely to occur to what extent it is expected to occur in the field in a given period of time.

(iii) 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 pilot study will examine the UMCf.

To achieve cost efficiencies and because the Galleria Road Bioremediation Treatability Study will be performed during a similar timeframe, only one set of laboratory studies will be performed for both the Las Vegas Wash Bioremediation Pilot Study and Galleria Road Bioremediation Treatability Study, presuming soil lithological and geochemical characteristics are similar for both areas.

4.0 PILOT STUDY CONCEPTUAL DESIGN

This section describes the conceptual design for the field pilot study, which includes specific objectives, pilot study location details, conceptual well layout, and preliminary substrate design. The field pilot study design, as well as the effectiveness monitoring program (described in Section 5.0), may be modified or refined based on the results of pre-design field and laboratory activities described in Section 3.0. The final design will be presented in a pilot study work plan addendum prior to implementation of the pilot study (described in Section 8.0).

4.1 OBJECTIVES

The objectives of the pilot study are to accomplish the following:

- Evaluate the feasibility and effectiveness of implementing in-situ bioremediation to reduce the flux of perchlorate mass migrating toward the Las Vegas Wash;
- Evaluate critical hydraulic (flow, migration, gradients) and chemical (perchlorate and other electron acceptors) relationships between the alluvium and UMCf that govern the flux to the Las Vegas Wash;
- Estimate the ZOI for substrate and biodegradation achievable in the alluvium and UMCf during the pilot study;
- Estimate or extrapolate the longevity of the carbon substrate and frequency of carbon substrate replenishment required to prevent perchlorate breakthrough immediately downgradient of the injection transect; and
- Examine the approach and feasibility for full-scale transect treatment including equipment, injection, and monitoring well layout, substrate addition and replenishment, and analytical sampling evaluation criteria to provide critical information applicable to the remedial alternatives evaluation in the forthcoming FS.

4.2 PILOT STUDY LOCATION

As shown in Figures 2 and 3, the proposed area for the pilot study is at two locations, noted as Transect 1a and Transect 1b. Transect 1a is located directly east of Pabco Road (also referred to as Aguila Road) on COH-owned property. This location was selected to intercept perchlorate contamination generally greater than 5,000 μg/L, which represents one of two higher perchlorate concentration locations within the Downgradient Study Area that are contributing to the total mass flux migrating into the Las Vegas Wash, and proposed work in this area will provide valuable information on the potential mass flux pathways, mechanisms, and rates, which will be critical for developing a remedy evaluation for the feasibility study. Transect 1b is located upgradient of the Las Vegas Wash on Clark County-owned property and was selected to treat contamination potentially migrating into the Las Vegas Wash from a second area that generally has perchlorate contamination at concentrations greater than 5,000 μg/L. Transect 1b is designed to connect with the bedrock outcrop at its eastern end. It is anticipated that the bedrock outcrop is an important feature influencing groundwater flow and perchlorate mass flux in this area.

4.3 CONCEPTUAL LAYOUT

This section describes the injection and monitoring wells that will be installed to evaluate the effectiveness of the in-situ bioremediation pilot study. Access agreements (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

Although the final number, location, spacing and orientation of the injection wells will be determined after completion of the pre-design field and laboratory activities described in Section 3.0, the injection wells within Transects 1a and 1b will be configured to best meet project objectives. Based on results from the previous and on-going treatability studies, there could be considerable heterogeneity in the lithology within relatively short distances. The soil grain type, thickness of sand/gravel lenses, and paleochannels vary in all three dimensions in the saturated subsurface. Therefore, flow pathways and transport of organic carbon during injections will likely be non-uniform. 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 in the final design of injection well transects and possible implementation of a staggered well network, if beneficial. Figures 4 and 5 depict the general injection well transect location. The final number of injection wells and configuration of the injection well transect line(s) will be determined in the pilot study work plan addendum.

The layout of the injection wells will also consider the orientation of the transects with respect to groundwater flow directions. It is anticipated that Transect 1a will be installed close to perpendicular to groundwater flow. Transect 1b will include portions that might be close to perpendicular to groundwater flow toward its eastern end while other portions near its center and western end might be more parallel to groundwater flow.

The injection well layout will potentially target both perchlorate-contaminated groundwater in the alluvium and UMCf in order to evaluate layouts that appropriately address the RAO of mitigation of perchlorate mass flux discharge to the Las Vegas Wash. Due to their difference in characteristics, the alluvium and UMCf will be addressed separately, as far as the injection well system is concerned. This includes the spacing, configuration, number of wells, and well design. Results of the pre-design activities, proposed UNLV bench-scale tests, and results of the on-going SWF Area Treatability Study will be used to finalize the injection system network.

Injection 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 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. Paired wells may be used to separate screened intervals within the alluvium and UMCf to maximize subsurface distribution during substrate injections as needed. 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 complete, Tetra Tech will develop each of the newly installed wells.

4.3.2 Effectiveness Monitoring Wells

A monitoring well network, consisting of upgradient and downgradient monitoring wells, will be required to evaluate pilot study effectiveness. Upgradient monitoring wells will be used to determine the perchlorate concentrations in groundwater that are migrating into the injection well transect(s) and thereby, ultimately migrating into the Las Vegas Wash, if untreated. Downgradient monitoring wells will be installed at strategic locations downgradient of the injection well transects, directly in-line and offset from the injection wells, to monitor for treatment effectiveness. To the extent possible, monitoring wells that have been or will be installed by others in the vicinity of the pilot test will be incorporated in the monitoring well network. Periodic sampling of the Las Vegas Wash water will also be performed to provide additional information regarding bioremediation effectiveness on the RAO of mitigation of the perchlorate mass flux discharge to the Las Vegas Wash (Section 5.3).

Monitoring wells installed as part of the pre-design phase will be incorporated into the effectiveness monitoring program. Based on pre-design results and final pilot study layout, additional monitoring wells may be required. The exact number and location of monitoring wells will be finalized following the pre-design activities and presented in a pilot study work plan addendum (described in Section 8.0).

In general, new monitoring wells will be constructed of 2-inch schedule 40 PVC casing and screened with 2-inch diameter slotted PVC well screen and #3/16 filter pack, 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 depth to groundwater. Dual-nested or paired monitoring wells may be used to separate screened intervals, if conditions warrant. 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 complete, 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. Results of the previous treatability studies 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 in the conceptual injection design for both carbon substrate injections and follow-up distribution water. As the results from the on-going SWF Area Treatability Study are evaluated, the findings will be utilized for the final design of the pilot study and will be presented in a pilot study work plan addendum (described in Section 8.0).

4.4.1 Carbon Substrate Injections

Findings from the previous treatability study (described in Section 2.2) indicated that the effects of the first carbon injection lasted between two and three months in relatively high groundwater flow conditions (32 ft/day). That study incorporated a second injection event utilizing half of the quantity of carbon substrate used in the first event. The reason for adding only half the quantity was to examine the lower threshold of the substrate that would be required for bioremediation. In addition, the UNLV bench-scale column study indicated that temporary reductions in aquifer transmissivity could be an issue if excess carbon substrate was added. The second carbon substrate addition appeared to be sufficient for approximately two months, despite the observation that perchlorate continued to degrade and very little DO was present. The on-going SWF Area Treatability Study will provide additional data and information on the effectiveness and durability of the initial carbon substrate injection and frequency and need for subsequent injections.

In addition to the results from the previous and ongoing treatability studies, factors to be considered when determining the quantity of carbon substrate used for the Las Vegas Wash Bioremediation Pilot Study include the results and findings of the pre-design activities, known chemistry and geochemistry of the groundwater, and stoichiometric requirements for the carbon substrate based on the mass of perchlorate and other electron acceptors that will migrate through the transects. These estimates of carbon substrate quantities and projected frequency of the injections for the pilot study will be performed for the alluvium and UMCf, into which injections are expected to occur via two separate injection well network systems. The final substrate type and quantity for the injections into the UMCf (EVO, soluble substrate, or a combination of the two) will be evaluated and finalized in the pilot study work plan addendum based on the results and findings of the pre-design activities and UNLV bench-scale studies.

Prior to actual carbon substrate injections, slug tests will be performed on as many as half of the injection wells and monitoring wells to determine pre-injection hydraulic conditions. Step-rate injection tests will also 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 pilot 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. 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. Prior to each injection, water will be used for dilution of the carbon substrate (generally diluted at a ratio of 1:4 parts of carbon substrate to water).

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 barrier. 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 well either with or following injections.

Based on results observed regarding the impact of distribution water during the two injection events in the previous treatability study (Section 2.2), it appears that fairly large amounts of distribution water will likely be required to enhance distribution of the carbon substrate in the vicinity of the injection wells. It appears that up to two-thirds of a single pore volume of distribution water could be required for each well. Preliminary findings also indicated that injecting distribution water into alternate wells within the transect provided better distribution of the carbon substrate that was injected. Results and lessons learned from the injections associated with the SWF Area Treatability Study will also be incorporated into the final distribution water protocol for the Las Vegas Wash Bioremediation Pilot Study, which will be presented in a pilot study work plan addendum following completion of the pre-design activities (described in Section 8.0).

Based on a review of the available water sources, there are three choices for distribution water. Specifically, these include COH water obtained from a nearby hydrant, extraction of groundwater from nearby monitoring wells, and water from the Las Vegas Wash itself. A detailed evaluation of each water source, their advantages and disadvantages, and final selection will be provided in a forthcoming pilot study work plan addendum that will present the final pilot study design. 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. However, the SWF Area Treatability Study used extracted groundwater 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 submittal of the Las Vegas Wash Bioremediation Pilot Study technical memorandum (described in Section 8.0) and lessons learned from these injections will be incorporated in the evaluation of distribution water sources.

5.0 EFFECTIVENESS MONITORING PLAN

This section describes the conceptual groundwater and surface water monitoring programs to determine treatment effectiveness during the pilot study. This section also describes the methodology to evaluate the pilot study's impact on perchlorate mass flux. Based on the results of the pre-design investigation, the monitoring plan may be modified in the final pilot study design presented in the pilot study work plan addendum (described in Section 8.0).

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.

5.1.1 Effectiveness Monitoring

Groundwater samples will be collected from all injection and monitoring wells in the vicinity of the pilot study areas 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, purpose, and frequency after injections. 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 pre-design phase. The actual frequency of sampling, selected wells, and specific parameters to be sampled during each individual event will be presented as part of the final design and adjusted based on the results from pilot 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 field pilot study to examine any changes in hydraulic conductivity as a result of carbon injections and geochemical processes.

Table 2 Example Groundwater Effectiveness Monitoring Sampling Protocol

Parameter	Analytical Method	Purpose	Potential Frequency
Field Parameters			
EC	Field Meter	Assess geochemical conditions	Baseline, Weekly (Month 1), Biweekly (Month 2), Monthly thereafter
pH	Field Meter		
DO	Field Meter		
ORP	Field Meter		
Temperature	Field Meter		
Turbidity	Field Meter		

Parameter	Analytical Method	Purpose	Potential Frequency
Laboratory Parameters			
Perchlorate	E314	Assess treatment effectiveness	Baseline, Weekly (Month 1), Biweekly (Month 2), Monthly (Months 3 – 12), Quarterly thereafter
TOC	SM5310B	Assess carbon substrate distribution in the aquifer	
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	
Chlorate/Chlorite	E300.1	Assess treatment effectiveness and examination as intermediate by-product of perchlorate biodegradation	
TDS	SM2540C	Assess impact of salts on delayed or slower perchlorate biodegradation in the flow-through mode	Baseline, Monthly (Months 1 – 6), Quarterly thereafter
Alkalinity	SM2320B	Assess geochemical conditions	
Hexavalent Chromium	SW846 7199	Assess secondary impacts of treatment	
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	
Chloride	E300.0	Potential estimation of conservative end-product of biodegradation	
PLFA	Microbial Insights Method[2]	Examine microbial response to carbon substrate addition, evaluate impact of carbon substrate on total live biomass over time	Baseline, Quarterly (through Month 6), Semi-annually
Perchlorate Reductase Gene	qPCR	Examine microbial response to carbon substrate addition	

Acronyms and Abbreviations:
BL: Baseline
EC: Electrical conductivity
DO: Dissolved Oxygen
ORP: Oxidation-reduction potential
PLFA: Phospholipid Fatty Acids
qPCR: quantitative polymerase chain reaction
TOC: Total organic carbon
TDS: Total dissolved solids
VFAs: Volatile Fatty Acids

Notes:
(1) Metals include arsenic, chromium, iron, and manganese.
(2) White, D. C., H. C. Pinkart, and D. B. Ringelberg. (1997). Biomass measurements: Biochemical approaches, p. 91-101. *In* C. J. Hurst, G. R. Knudsen, M. J. McInerney, L. D. Stetzenbach, and M. V. Walter (ed.), Manual of Environmental Microbiology. ASM Press, Washington.

5.2 MASS FLUX EVALUATION

In conjunction with groundwater monitoring, a groundwater model will be developed to assess the effectiveness of the pilot 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 within the footprint of the pilot study after the 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 by Tetra Tech to focus on the pilot study areas and Las Vegas Wash by using grid refinement and site-specific material properties measured by field techniques and laboratory analyses, such as 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 pilot study.

5.3 SURFACE WATER SAMPLING

Surface water samples are currently collected on a monthly basis to monitor the mass flux of perchlorate migrating into the Las Vegas Wash, pursuant to the RI Phase 2 Investigation Modification No. 3 at NERT (Ramboll Environ, 2017). This data will be used during the pre-design and pilot study phases to monitor for potential decreases in the mass flux of perchlorate migrating into the Las Vegas Wash resulting from this pilot study. The current surface water sampling program includes sample collection from six weir locations along the Las Vegas Wash, including Pabco, Bostick, Homestead, Three Kids, Sunrise Mountain, and Duck Creek weirs. Samples are analyzed for perchlorate, chlorate, and TDS. As part of the pilot study effectiveness monitoring program, surface water samples will also be periodically collected from three additional weir locations, including the Historic Lateral, Calico Ridge, and Lower Narrows weirs. In addition to surface water sampling, surface water elevations will also be periodically measured from nearby gauges and results will be compared to nearby groundwater elevations to help assess groundwater flow directions (locations presented in Section 3.1.8).

Surface water samples will be collected using similar techniques as used during collection of surface water samples required under RI Phase 2 Investigation Modification No. 3. Field parameters (temperature, pH, turbidity, electrical conductivity, DO, and ORP) will be monitored and recorded on field sampling forms prior to sample collection. In addition to the current monthly surface water sample analysis of perchlorate, chlorate, and TDS, organic content in terms of TOC and/or BOD as well as dissolved metals will be analyzed to obtain a baseline prior to in-situ bioremediation activities and to monitor for progress and secondary effects.

5.4 DATA VALIDATION

All pilot 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 pilot 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 access agreements and permits will be required prior to performing pre-design and/or injection activities associated with this pilot study. This section presents a summary of the access and permit requirements that will likely be required for the implementation of this pilot study.

6.1 ACCESS NEGOTATIONS

Due to the off-site location of the pilot study, the Trust will acquire land use authorizations for all field activities. As described in Section 4.2, the proposed areas for the pre-design and pilot study consist of two locations that are public parcels of land under the jurisdiction of COH and Clark County, respectively. As a result, Tetra Tech, on behalf of NERT, will prepare and submit all required applications for access to these parcels, in coordination with the Trust. Any adjustments made to the plot study resulting from this process will be presented in the pilot study work plan addendum (described in Section 8.0).

6.2 PERMITTING

There will be a series of permits required for the various activities that are being proposed as part of the pilot study. In addition to the permits described herein, a review of other potential permitting requirements was conducted and based on project design, several regulatory requirements likely will not apply. These include an entry permit issued by the BOR because no new wells are proposed to be installed on Federal land for the pre-design or pilot study activities. No new entry permit is anticipated as the only activity anticipated on Federal lands is limited to collecting data from existing wells, for which entry permits have already been established. 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 Land Use Authorization

As described above, land use authorization for well installation and operation will be required from COH and Clark County. The authorizations will consist of an application by Tetra Tech, on behalf of NERT, and demonstration that the land use meets applicable zoning requirements. This process may take several months and require Planning Commission review and approval, which could be expedited under an administrative review if the agencies consider the project a “governmental” facility or utility. Coordination also would be required with Clark County Parks & Recreation for facilities located in the Wetlands Park.

6.2.2 Well Installation Permitting

Both pre-design and field pilot 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 injection wells and monitoring wells. The Monitoring Well Drilling Waiver also requires a completed, signed, and notarized Affidavit of Intent to Abandon a Well as an attachment. As required, the 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 pilot 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. It is currently anticipated that most, if not all, of the injection and monitoring wells to be installed as part of this pilot study will remain in place at the end of the pilot study.

6.2.3 County Permitting

Per the Clark County Department of Air Quality, a dust control permit is required for activities that result in soil disturbance greater than 0.25 acres. A review of installation activities associated with pre-design and pilot study phases will be conducted to determine whether the soil disturbance will be greater than 0.25 acres. If required, Tetra Tech, on behalf of NERT, will prepare and submit the required dust control permitting application. No air permitting other than dust control is anticipated because there will be no air emissions associated with the wells or equipment needed for their installation and operation that would trigger minor source permitting.

6.2.4 NDEP – Underground Injection Control Program

The pilot 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.

6.2.5 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 to be presented in the forthcoming pilot study work plan addendum that will present the final pilot study design.

7.0 ECOLOGICAL REVIEW AND PROTECTION MEASURES

As previously explained, the pilot study is located within the downgradient study area on private land that is owned by COH and on land that is under the jurisdiction of Clark County Wetlands Park. The most common vegetation community is desert shrubland, dominated by fourwing saltbush (*Atriplex canescens*), quailbush (*Atriplex lentiformis*), screw-bean mesquite (*Prosopis pubescens*), honey mesquite (*Prosopis glandulous* var. *torreyana*), salt cedar (*Tamarix chinensis*), and creosote (*Larrea tridentata*). Soils are loamy and gravelly. To the north of the pilot study areas is the riparian corridor of the Las Vegas Wash. Riparian vegetation communities are comprised of cottonwood (*Populus angustifolia*), willow (*Salix gooddingii*), and salt cedar, with inclusions of cattail (*Typha sp*.) wetlands.

Much of the pilot study area has been heavily disturbed for erosion control along the Las Vegas Wash, development of park infrastructure, and to support multiple wastewater outfalls for facilities discharging to the Las Vegas Wash. General disturbances near the Las Vegas Wash include roadways and a parking lot; picnic shelters and bathroom facilities; a paved bike path; unpaved trails; electric transmission structures; concrete weirs for treated wastewater outfalls to the wash; erosion control structures; and areas of active revegetation projects.

A desktop data review for federally listed species with the potential to occur was completed for the project area [Tetra Tech, 2017; United States Department of Interior – Bureau of Reclamation (USDOI – BOR), 2017]. Species for consideration were identified in a United States Fish and Wildlife Service (USFWS) Information Planning and Conservation (IPaC) report (USFWS, 2016). Surveys for federally protected species with the potential to occur were completed as recently as 2017 (Tetra Tech, 2017; USDOI-BOR, 2017). Documentation of past threatened and endangered species surveys in the Clark County Wetlands Park area is also provided in the Las Vegas Wash Wildlife Management Plan prepared by Southern Nevada Water Authority (SNWA) (SNWA, 2008) and the USFWS Biological Opinion prepared for other phases of SNWA weir construction (USFWS, 2009a). There is no federally-designated critical habitat for threatened or endangered species within 0.5 mile of the proposed pilot study locations, as documented in critical habitat rulemaking for individual species (USFWS, 2016; USFWS, 1994, 2013, 2014a). Findings of the desktop data review and surveys are summarized as follows:

- Southwest willow flycatcher (*Empidonax traillii extimus*) inhabits dense riparian tree and shrub habitat, especially where willows and/or tamarisk are present, as well as standing water or saturated soils. It is typically found below 8,500 feet in elevation. Breeding and nesting occurs from early May through July (USFWS, 2014b). Individuals have been recorded in the Las Vegas Wash during migration, but no nesting has been documented. It was not documented as a breeding species in the Las Vegas Wash during an extensive avian population survey conducted between 2005 and 2015 (Great Basin Bird Observatory, 2016). The 2017 surveys did not document individuals of this species (Tetra Tech, 2017; USDOI-BOR, 2017). Nesting is considered unlikely due to the lack of suitable habitat and of historic use records.
- Yuma clapper rail (*Rallus longirostris yumanensis*) is a marsh bird found in dense cattail or cattail-bulrush marshes along the lower Colorado River in Mexico north to the lower Muddy River and Virgin River in Utah – above those rivers' confluence with Lake Mead. In Nevada, this subspecies can be found along the Virgin River and lower Muddy River, along the Colorado River around Lake Mohave, and along the Las Vegas Wash (USFWS, 1983). Nesting is typically March through May (USFWS, 2010). Individuals were detected along the wash during multiple surveys conducted since 1998, but no nesting was documented (SNWA 2008). It was not documented as a breeding species in the Las Vegas Wash during an extensive avian population survey conducted between 2005 and 2015 (Great Basin Bird Observatory, 2016). The 2017 surveys did not document individuals of this species (Tetra Tech, 2017; USDOI-BOR, 2017).
- The yellow-billed cuckoo (*Coccyzus americanus*) is a riparian obligate that nests almost exclusively in large tracts of riparian woodlands, most commonly in cottonwood-willow-dominated woodlands

(Halterman, et al. 2015). Suitable breeding habitat is in multi-layered riparian woodlands (with a tree overstory and shrubby understory) and at least 12 acres in size. The species is typically found below 8,500 feet (USFWS, 2015). The nesting season for this species is considered June 1 through September 15. No migrant or resident yellow-billed cuckoo (*Coccyzus americanus*) were detected during systematic surveys along the wash during each year from 2000 to 2004 (SNWA, 2008). No individuals were found in the Las Vegas Wash during an extensive avian population survey conducted between 2005 and 2015 (Great Basin Bird Observatory, 2016). The 2017 surveys did not document individuals of this species (Tetra Tech, 2017; USDOI-BOR, 2017).

- Desert tortoise (*Gopherus agassizii*) were observed on the north side of Las Vegas Wash in 2003 (SNWA 2008). In 2005, tortoise burrows were found within portions of Clark County Wetlands Park, and additional burrows, a carcass, and scat evidence were found outside of the park (SNWA, 2008; USFWS, 2009a). Two separate desert tortoise survey events conducted according to USFWS protocol were completed in 2017. Surveys did not detect desert tortoises or tortoise signs. However, an incidental observation of a live desert tortoise in the Downgradient Study Area was reported by a SNWA subcontractor on March 28, 2017 (personal communication from Carlton Parker, NDEP).

Riparian habitat lies outside of the pre-design and pilot study areas. Federally listed avian species are not anticipated to nest in the portion of the Las Vegas Wash located near the pre-design and pilot study areas. Effects to avian species from the work proposed as part of the pre-design and pilot study are not anticipated. Therefore, additional protection measures are not required.

The majority of the project area is disturbed as the remaining suitable habitat is fragmented by urban development. However, it is possible for the desert tortoise to occur based on historic documentation. Effects to the desert tortoise may occur from the work proposed as part of the pre-design and pilot study. Direct effects may include mortality caused by crushing or impact from vehicle and equipment operation. Potential indirect effects considered include habitat degradation, fragmentation, and loss; and behavioral alterations caused by noise disturbance, creation of dust hazards from heavy equipment and vegetation removal, and human and vehicle presence.

Protection measures, which may be implemented, if warranted, include the following, which are identified in the 2009 USFWS Biological Opinion (USFWS, 2009a) and in the Desert Tortoise (Mojave Population) Field Manual (USFWS, 2009b):

- An authorized desert tortoise biologist would serve as a biological monitor during activities that required the use of heavy equipment or that resulted in ground disturbance. The monitor would have authority to cease activities if a desert tortoise appeared in the proposed pilot study areas.
- Desert tortoises will be treated in a manner to ensure that they do not overheat, exhibit signs of overheating (e.g., gaping, foaming at the mouth, etc.), or be placed in a situation where they cannot maintain surface and core temperatures necessary to their well-being. Unless the tortoise is in imminent danger, no desert tortoise shall be captured, moved, transported, released or purposefully caused to leave its burrow for whatever reason when the ambient air temperature is above 95 degrees, or if the ambient air temperature is anticipated to exceed 95 degrees before handling can be completed.
- Desert tortoise education would be presented to field personnel prior to initiating activities.
- A maximum speed of 15 miles per hour would be enforced.
- Litter would be controlled to avoid opportunistic predators, such as desert kit fox, coyotes, and common ravens.

8.0 REPORTING

Monthly status updates will be provided to the Trust and NDEP summarizing the progress and results of the pre-design field activities, laboratory, and pilot 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 pre-design 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; and
- Schedule of pilot study activities, including implementation, anticipated injection intervals, monitoring, and reporting.

Following completion of the pilot study, a final Las Vegas Wash Bioremediation Pilot Study Report will be prepared and submitted for NDEP and US EPA review. This report will summarize the pilot study activities and will include:

- Results of soil borings, single borehole dilution tests, slug tests, and NMR logging conducted both during and following installation of the injection well network;
- Analytical results summary of soil and groundwater samples collected during injection and monitoring well installation as part of pilot study implementation;
- Summary of bench testing results;
- Evaluation of effectiveness in reducing perchlorate-contaminated groundwater that is migrating towards the Las Vegas Wash, including an estimate of the perchlorate mass reduction during the pilot 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, including:
    - Potential layout and plan for full-scale implementation;
    - Preliminary estimates of capital and operating costs for full-scale implementation;
    - Possible insights gathered from the predesign and pilot testing on where the mass flux is passing through the two transects and entering the Las Vegas Wash; and
    - Management of possible temporary reductions in aquifer transmissivity and any release of secondary constituents (e.g.: arsenic).

9.0 SCHEDULE

A general schedule for the primary deliverables and activities associated with implementing the pre-design and pilot 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.

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	July 2018
Pilot Study Work Plan Addendum (presents pre-design results and final pilot study design)	July 2018	September 2018
Pilot Study Installation	October 2018	March 2019
Pilot Study Injections, Monitoring, and Reporting	April 2019	December 2020

10.0 REFERENCES

AECOM. (2016). *Groundwater Sampling Technical Memorandum.* October 2016.

ASTM International. (2008). *Standard Test Method for (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers.*

Daniel B. Stephens & Associates, Inc. (2010). *2009 Groundwater Monitoring Report, BMI Common Areas (Eastside)*. Prepared for Basic Remediation Company. May 12, 2010.

Dong, Weiquan. (2017). "Re: DVSR/EDD for the data from NERT treatability studies." Email received by Nevada Environmental Response Trust from NDEP. January 11, 2017

Duffield, G. M. (2014). *AQTESOLV for Windows Version 4.5 Users Guide.*

ENVIRON. (2014a). R*emedial Investigation and Feasibility Study Work Plan, Revision 1*, *Nevada Environmental Response Trust, Henderson, Nevada.* January 10, 2014.

ENVIRON. (2014b). *Field Sampling Plan, Revision 1, Nevada Environmental Response Trust Site, Henderson, Nevada.*

Great Basin Bird Observatory. (2016). *Bird Population and Vegetation Trends at the Las Vegas Wash*, *2005-2015*.

Halterman, M., et al. (2015). *A Natural History Summary and Survey Protocol for the Western Distinct Population Segment of the Yellow-billed Cuckoo*. April 22, 2015.

ITRC. (2008). *Technical/Regulatory Guidance. Remediation Technologies for Perchlorate Contamination for Water and Soil.*

LaFara, Donald. "Re: Sterile Filtration of Non-Compliance Perchlorate Samples". Letter received by Nevada Environmental Response Trust from NDEP. June 27, 2016.

Liu, C. and Ball, W.P. (2002). Back diffusion of chlorinated solvent contaminants from a natural aquitard to a remediated aquifer under well-controlled field conditions: Predictions and measurements. *Groundwater*, *40*(2), pp.175-184.

NDEP. (2009). *Hydrogeologic and Lithologic Nomenclature Unification*. January 2009.

Parker, Carlton, P.G. (2017). Personal communication regarding desert tortoise sighting in Downgradient Study Area, Supervisor, Bureau of Industrial Site Cleanup, Nevada Division of Environmental Protection. April.

Pitrak, M., Mares, S., and Kobr, M. (2007). *A Simple Borehole Dilution Technique in Measuring Horizontal Ground Water Flow*. Ground Water, volume 45, issue 1.

Plume, R. (1989). *Ground-Water Conditions in Las Vegas Valley, Clark County, Nevada. Part 1: Hydrologic Framework*.

Ramboll Environ. (2016). *Annual Remedial Performance Report for Chromium and Perchlorate*, *Nevada Environmental Response Trust, Henderson, Nevada.* October 31, 2016.

Ramboll Environ. (2017). *Remedial Investigation Phase 2, Investigation Modification No. 3, Nevada Environmental Response Trust, Henderson, Nevada*. May 31, 2017.

Shackelford, C.D. and Moore, S.M., (2013). Fickian diffusion of radionuclides for engineered containment barriers: Diffusion coefficients, porosities, and complicating issues. *Engineering Geology*, *152*(1), pp.133-147.

SNWA. (2008). *Las Vegas Wash Wildlife Management Plan*. Prepared for the Las Vegas Wash Coordination Committee. March 2008.

Tetra Tech. (2015). *Health and Safety Plan for Site-Wide Investigations and Remedial Activities, Nevada Environmental Response Trust, Henderson, Nevada*.

Tetra Tech. (2016a). *Groundwater Bioremediation Treatability Study Results Report*, *Nevada Environmental Response Trust, Henderson, Nevada.*

Tetra Tech. (2016b). *Seep Well Field Area Bioremediation Treatability Study Work Plan, Nevada Environmental Response Trust, Henderson, Nevada*.

Tetra Tech. (2017). *Weir Dewatering Treatment Biological Survey and Assessment. Nevada Environmental Response Trust, Henderson, Nevada*. January 31, 2017.

USDOI-BOR. (2017). *Downgradient Study Area Phases I and II Groundwater Monitoring Well Installation, and Full-Scale Geophysical Investigation*. Draft Environmental Assessment. LC-2517, LND-6.00.

USFWS. (1983). *Yuma Clapper Rail Recovery Plan*. U.S. Fish and Wildlife Service, Albuquerque, NM. February 4, 1983.

USFWS. (1994). *Determination of Critical Habitat for the Mojave Population of the Desert Tortoise*. Final Rule. 59 Federal Register 5820. February 8, 1994.

USFWS. (2009a). *Biological Opinion for Weir Construction Associated Activities within the Clark County Wetlands Park*. U.S. Fish and Wildlife Service. April 23, 2009.

USFWS. (2009b). D*esert Tortoise (Mojave Population) Field Manual: (Gopherus agassizii)*. U.S. Fish and Wildlife Service. December 2009.

USFWS. (2010). *Yuma Clapper Rail Recovery Plan* (*Rallus longirostris yumaensis*). U.S. Fish and Wildlife Service. February 10, 2010.

USFWS. (2013). *Designation of Critical Habitat for Southwestern Willow Flycatcher*. Final Rule. 78 Federal Register 344. January 3, 2013.

USFWS. (2014a). *Designation of Critical Habitat for Western Distinct Population Segment of the Yellow-billed Cuckoo*. Proposed Rule. 79 Federal Register 48548. August 15, 2014.

USFWS. (2014b). *Southwestern Willow Flycatcher* (*Empidonax traillii extimus*) *5-Year Review: Summary and Evaluation*. U.S. Fish and Wildlife Service. August 15, 2014.

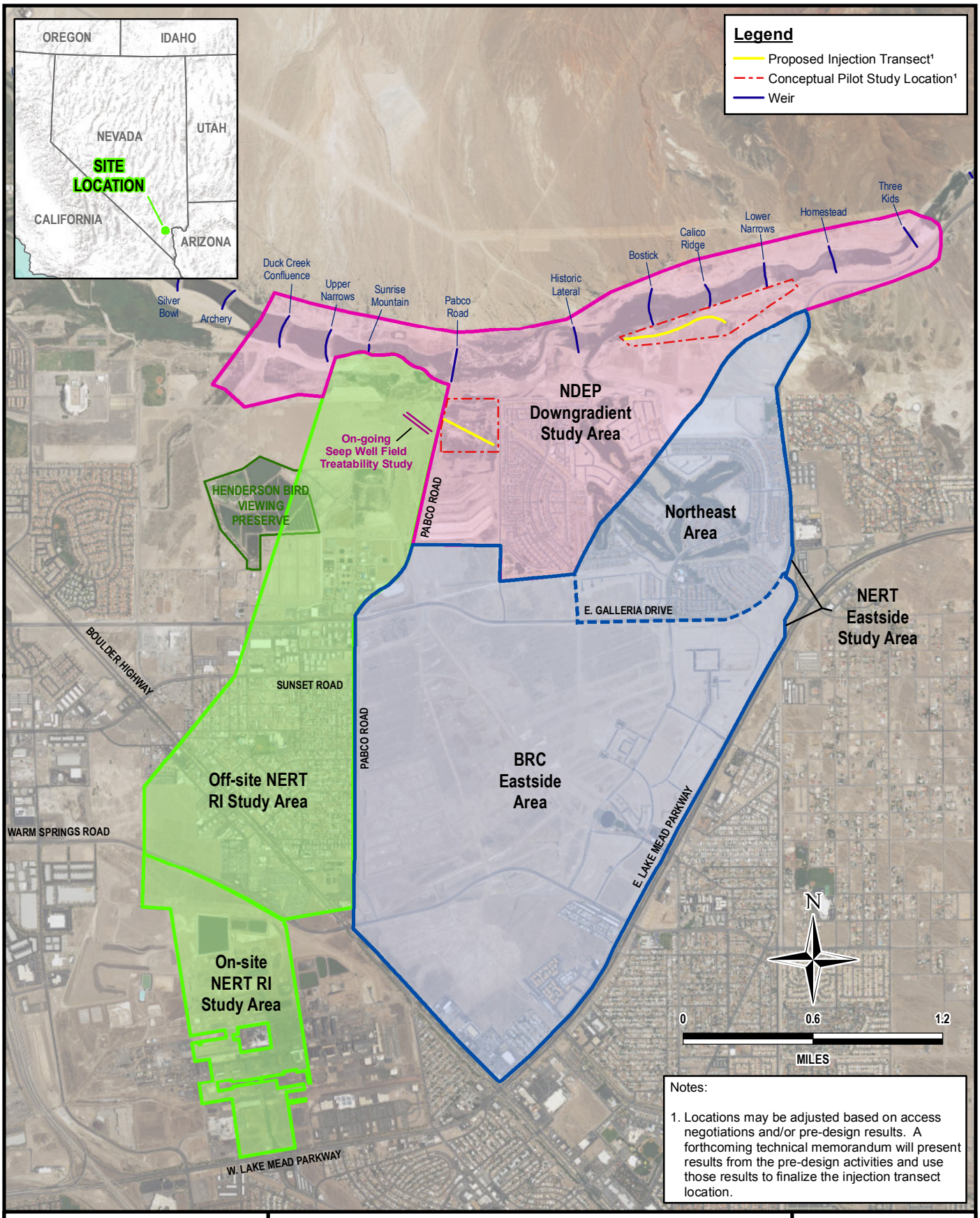
USFWS. (2015). *Guidelines for Identification of Suitable Habitat for Western Yellow-billed Cuckoo in Utah*. USFWS. June 2015.

USFWS. (2016). *Information for Planning and Conservation (IPaC) Trust Report*. U.S. Fish and Wildlife Service. July 2016. http://ecos.fws.gov/ipac/Project/ZFLQT-O3SRV-CYXKQ-7VH24-H2GCNE.

Walsh, D., Turner, P., Grunewald, E., Zhang, H., Butler Jr., J., Reboulet, E., Knobbe, S., Christy, T., Lane Jr., J., Johnson, C., Munday, T., Fitzpatrick, A. (2013). *A Small-Diameter NMR Logging Tool for Ground-water Investigations*. Ground Water, volume 51, issue 6, November 2013.

White, D. C., H. C. Pinkart, and A. B. Ringelberg. (1995). Biomass measurements: Biochemical approaches, p. 91-101. In C. J. Hurst, G. R. Knudsen, M. J. McInerney, L. D. Stetzenbach, and M. V. Walter (ed.), Manual of Environmental Microbiology. ASM Press, Washington.

Figures



Notes:

1. Locations may be adjusted based on access negotiations and/or pre-design results. A forthcoming technical memorandum will present results from the pre-design activities and use those results to finalize the injection transect location.

\\TTS100FS1\PROJECTS\NERT\GIS FIGURE DATABASE\MXD\WORK PLAN\1_SITE_LOCATION.MXD

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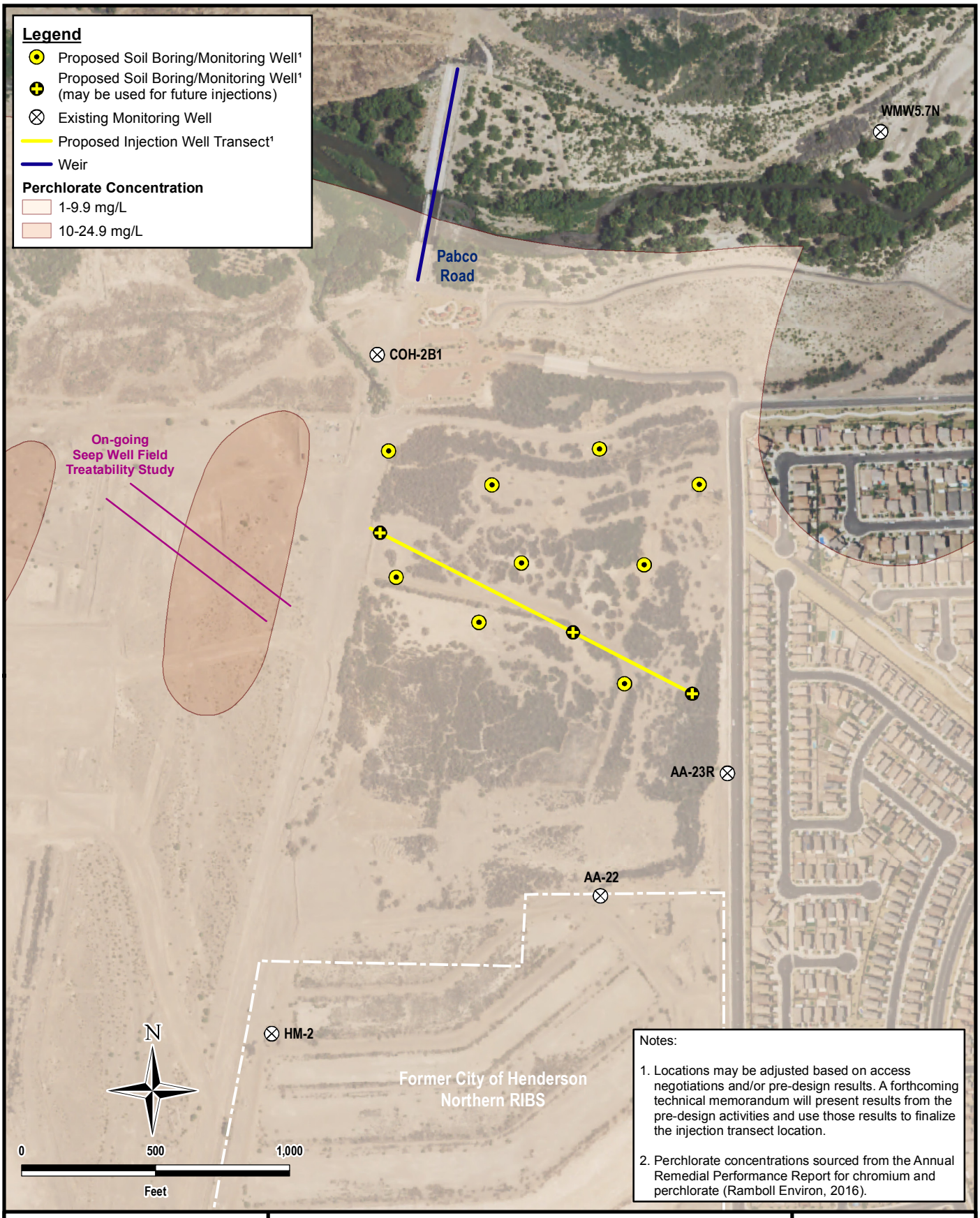
NEVADA ENVIRONMENTAL RESPONSE TRUST

LAS VEGAS WASH PILOT STUDY WORK PLAN

SITE LOCATION

Project No.:	114-520225
Date:	AUGUST 17, 2017
Designed By:	SRA
Figure No.	1



Notes:

1. Locations may be adjusted based on access negotiations and/or pre-design results. A forthcoming technical memorandum will present results from the pre-design activities and use those results to finalize the injection transect location.
2. Perchlorate concentrations sourced from the Annual Remedial Performance Report for chromium and perchlorate (Ramboll Environ, 2016).

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NEVADA ENVIRONMENTAL RESPONSE TRUST

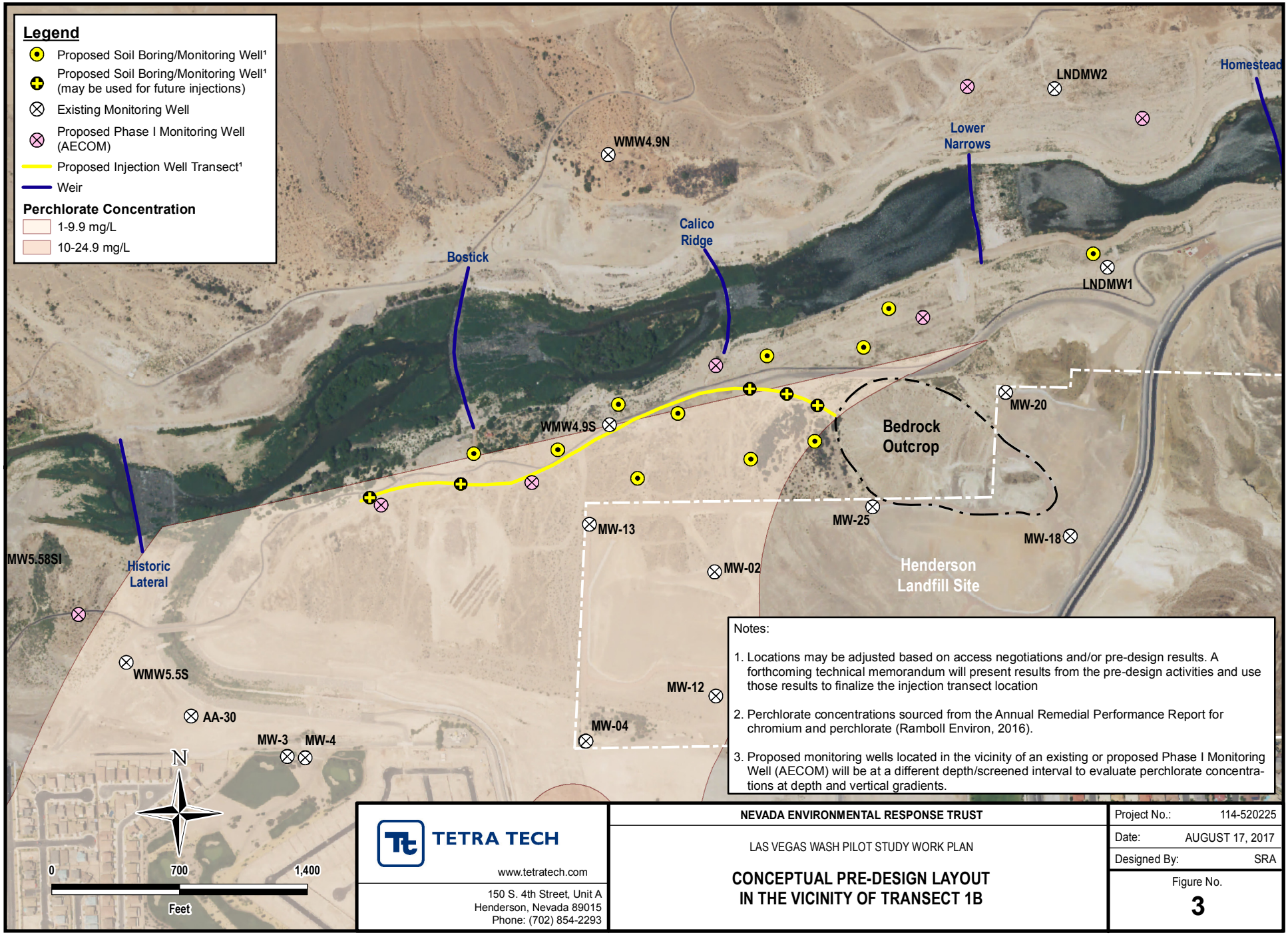
LAS VEGAS WASH PILOT STUDY WORK PLAN

CONCEPTUAL PRE-DESIGN LAYOUT IN THE VICINITY OF TRANSECT 1A

Project No.:	114-520225
Date:	AUGUST 17, 2017
Designed By:	SRA

Figure No. **2**

\\TTS100FS1\PROJECTS\NERT\GIS FIGURE DATABASE\MXD\WORK PLAN\2_CONCEPTUAL PRE-DESIGN LAYOUT - TRANSECT 1A.MXD



Notes:

1. Locations may be adjusted based on access negotiations and/or pre-design results. A forthcoming technical memorandum will present results from the pre-design activities and use those results to finalize the injection transect location
2. Perchlorate concentrations sourced from the Annual Remedial Performance Report for chromium and perchlorate (Ramboll Environ, 2016).
3. Proposed monitoring wells located in the vicinity of an existing or proposed Phase I Monitoring Well (AECOM) will be at a different depth/screened interval to evaluate perchlorate concentrations at depth and vertical gradients.

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NEVADA ENVIRONMENTAL RESPONSE TRUST

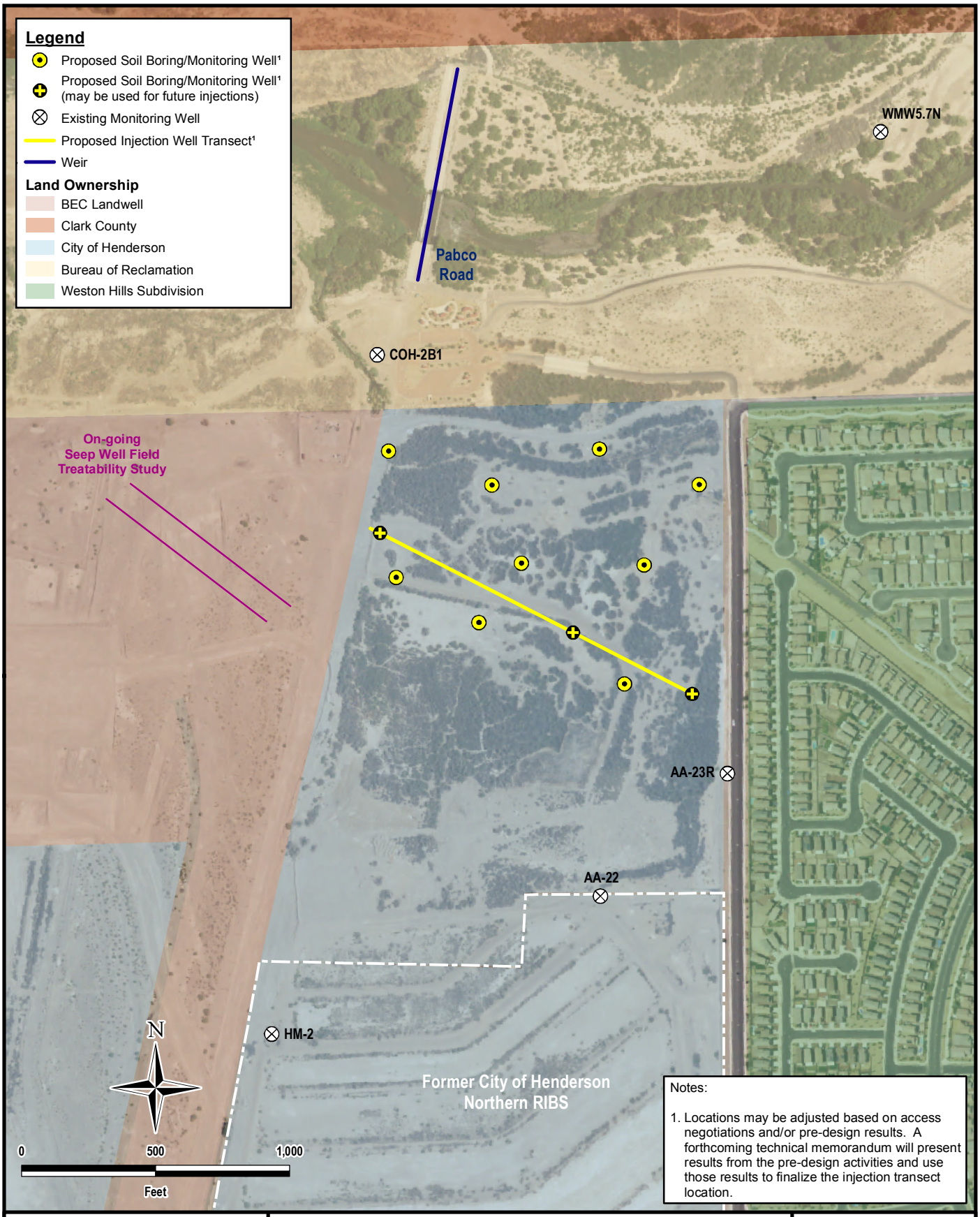
LAS VEGAS WASH PILOT STUDY WORK PLAN

CONCEPTUAL PRE-DESIGN LAYOUT IN THE VICINITY OF TRANSECT 1B

Project No.:	114-520225
Date:	AUGUST 17, 2017
Designed By:	SRA

Figure No. **3**

\\TTS100FS1\PROJECTS\NERT\GIS FIGURE DATABASE\MXD\WORK PLAN\3_CONCEPTUAL PRE-DESIGN LAYOUT - TRANSECT 1B.MXD



\\TTS100FS1\PROJECTS\NERT\GIS DATABASE\MXD\WORK PLAN\4_TRANSECT 1A - LOCATION WITH PROPERTY OWNERSHIP.MXD

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NEVADA ENVIRONMENTAL RESPONSE TRUST

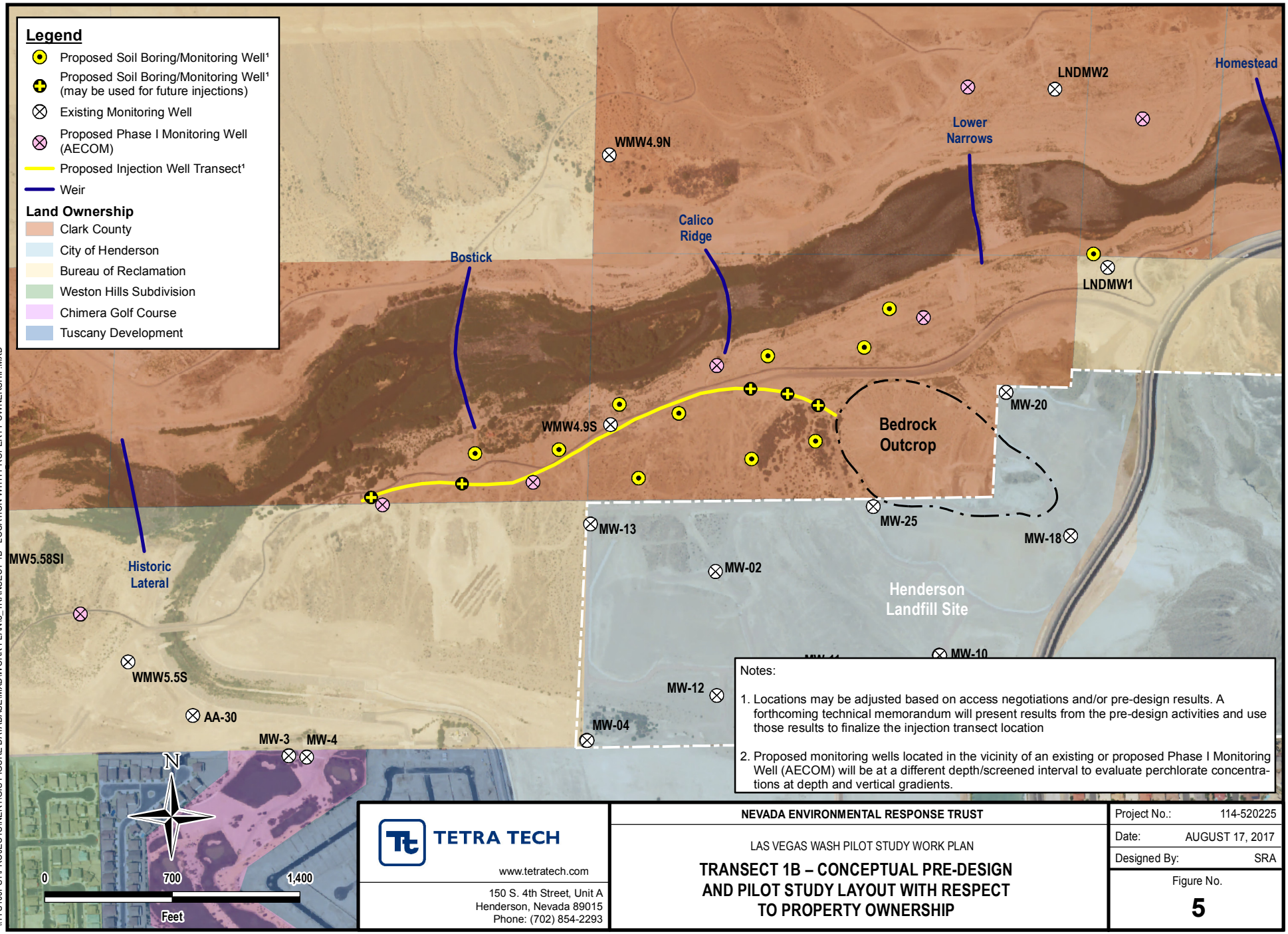
LAS VEGAS WASH PILOT STUDY WORK PLAN

TRANSECT 1A – CONCEPTUAL PRE-DESIGN AND PILOT STUDY LAYOUT WITH RESPECT TO PROPERTY OWNERSHIP

Project No.:	114-520225
Date:	AUGUST 17, 2017
Designed By:	SRA

Figure No.

4



Notes:

1. Locations may be adjusted based on access negotiations and/or pre-design results. A forthcoming technical memorandum will present results from the pre-design activities and use those results to finalize the injection transect location

2. Proposed monitoring wells located in the vicinity of an existing or proposed Phase I Monitoring Well (AECOM) will be at a different depth/screened interval to evaluate perchlorate concentrations at depth and vertical gradients.

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NEVADA ENVIRONMENTAL RESPONSE TRUST

LAS VEGAS WASH PILOT STUDY WORK PLAN

TRANSECT 1B – CONCEPTUAL PRE-DESIGN AND PILOT STUDY LAYOUT WITH RESPECT TO PROPERTY OWNERSHIP

Project No.:	114-520225
Date:	AUGUST 17, 2017
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Figure No.

5

\\TTS100FS1\PROJECTS\NERT\GIS FIGURE DATABASE\MXD\WORK PLAN\5_TRANSECT 1B - LOCATION WITH PROPERTY OWNERSHIP.MXD