Treatability Study Work Plan Permeable Reactive Barrier Pilot, Revision 1

Nevada Environmental Response Trust Site, Henderson, Nevada

Prepared for:
Nevada Environmental Response Trust

Prepared by:
ENVIRON International Corporation
Chicago, Illinois

Date:
December 27, 2013

Project Number:
2132100I (I06)

ENVIRON

Treatability Study Work Plan, Permeable Reactive Barrier Pilot, Revision 1

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

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

Title: Solely as President and not individually

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

Date: 12/24/13

Treatability Study Work Plan, Permeable Reactive Barrier Pilot, Revision 1

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

Responsible Certified Environmental Manager (CEM) for this project

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 provided 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.

______________________________ __________December 27, 2013__________

John M. Pekala, PG Date
Senior Manager

Certified Environmental Manager
ENVIRON International Corporation
CEM Certificate Number: 2347
CEM Expiration Date: September 20, 2014

The following individuals provided input to this document:
John M. Pekala, PG, CEM
Allan J. DeLorme, PE
Bruce S. Kennington
Scott D. Warner, PG, CHG, CEG
Laurie LaPat-Palasko, PhD, QEP
Kevin Kyrias-Gann, PE
Beth Richter
Chris Stubbs, PhD
Kim Kuwabara, CEM
Ruben So

Contents

List of Tables

List of Figures

List of Appendices

Acronyms and Abbreviations

AMPAC	American Pacific Corporation
AWF	Athens Road Well Field
bgs	below ground surface
BMI	Black Mountain Industrial
COC	contaminant of concern
COPCs	chemicals of potential concern
DO	dissolved oxygen
ENVIRON	ENVIRON International Corporation
FBR	fluidized bed reactor
ESTCP	U.S. Department of Defense, Environmental Security Technology Certification Program
FRTR	Federal Remediation Technologies Roundtable
ft	feet
ft/ft	feet per foot
GEO	geochemistry sampler
GC-FID	gas chromatograph – flame ionization
gpm	gallon per minute
GWETS	Groundwater Extraction and Treatment System
IC-MS/MS	Ion chromatography-mass spectroscopy-mass spectroscopy
ISM	in-situ microcosm
ITRC	Interstate Technology & Regulatory Council
IWF	Interceptor Well Field
MI	Microbial Insights, Inc.
MICRO	Bio-Trap® sampler
mg/L	milligrams per liter
mL	milliliter
NDWR	Nevada Division of Water Resources
NAC	Nevada Administrative Code
NDEP	Nevada Division of Environmental Protection
NERT	Nevada Environmental Response Trust
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System

Northgate	Northgate Environmental Management, Inc.
ORP	oxidation-reduction potential
PID	photoionization detector
PPE	Personal Protective Equipment
PRB	Permeable Reactive Barrier
PVC	polyvinyl chloride
Qal	quaternary alluvium
QA/QC	control assurance/quality control
qPCR	quantitative polymerase chain reaction
RAOs	Remedial Action Objectives
SERDP	Strategic Environmental Research & Development Program
Shaw	Shaw Environmental Inc.
Site	NERT Site
SOPs	Standard Operating Procedures
SWF	Seep Area Well Field
Tronox	Tronox LLC
µg/L	micrograms per liter
UIC	Underground Injection Control
UMCf	Upper Muddy Creek Formation
µSm/cm	microSiemens per centimeter
USA	Underground Service Alert
USDW	Underground Source of Drinking Water
USEPA	United States Environmental Protection Agency
VFAs	volatile fatty acids
WBZs	water-bearing zones

1 Introduction

ENVIRON International Corporation (ENVIRON) on behalf of the Nevada Environmental Response Trust (NERT) has prepared this Treatability Study Work Plan for a Permeable Reactive Barrier Pilot for the Nevada Division of Environmental Protection (NDEP). This Treatability Study Work Plan provides a scope of work, including in-situ microcosm (ISM) testing, bench-scale column testing, and pre-design activities to enable design of a permeable reactive barrier (PRB) pilot system to be developed to treat perchlorate-impacted groundwater at the NERT Site in Clark County, Nevada (the "Site"). ENVIRON is currently investigating potentially feasible technologies to be used in conjunction with the existing Groundwater Extraction and Treatment System (GWETS) at the Site. Various in-situ and ex-situ technologies are under consideration to mitigate the migration of perchlorate in groundwater. Of the technologies currently under consideration, in-situ treatment through the use of PRB technology appears to represent a particularly promising method to reduce current and future costs of the GWETS while providing an effective means to mitigate perchlorate migration from the Site. If effective, the PRB-emplaced treatment could help to reduce the need for downgradient extraction of groundwater and treatment in the GWETS as is currently performed at both the Athens Road Well Field (AWF) and the Seep Well Field (SWF), and thereby, significantly reduce the cost for remediation of the perchlorate groundwater plume at the Site.

This Treatability Study Work Plan provides details on the initial proposed studies, including ISM studies and bench-scale column studies, to provide information to aid the design of a PRB pilot system at the Site. Although a discussion is included as to what a PRB pilot system may entail, the information presented is preliminary and is based on the current knowledge of the Site. The design and monitoring of such a PRB pilot system will be refined as more information is collected in the ISM and column studies.

This Work Plan has been prepared and is being submitted as part of the Remedial Investigation (RI) and Feasibility Study (FS) for the Site, pursuant to the Interim Consent Agreement entered into by the Trust effective February 14, 2011. A RI/FS Work Plan to address soil and groundwater contamination at the Site was submitted to NDEP on December 27, 2012. The RI/FS Work Plan was reviewed by NDEP and various stakeholders during 2013 and a revised work plan, addressing and incorporating comments from NDEP and stakeholders, will be submitted to NDEP in January 2014. The RI/FS Work Plan and this Treatability Study Work Plan are anticipated to be reviewed by NDEP in the first quarter of 2014. Implementation of this work plan is dependent on NDEP approval of the work plan and associated budgetary approval.

1.1 Background and Regulatory Status

1.1.1 Groundwater Contamination

The Site has been undergoing active remediation to manage hexavalent chromium groundwater contamination (since 1986) and perchlorate contamination of groundwater (since 1998), under consent orders issued by NDEP to the Kerr McGee Chemical Corporation and since February 14, 2011, pursuant to an Interim Consent Agreement between NERT and NDEP. Both constituents are treated by means of a groundwater extraction system and on-site treatment facilities, collectively referred to as the GWETS. Groundwater is collected at three well fields: the on-site Interceptor Well Field (IWF), the off-site AWF, and the off-site SWF. Groundwater collected from the IWF is first treated to reduce hexavalent chromium to trivalent chromium through a ferrous sulfate treatment system. After the ferrous sulfate treatment process, perchlorate is treated using perchlorate-reducing bacteria in a series of fluidized bed reactors (FBRs). Groundwater extracted from the AWF and SWF is discharged directly to the FBR process for perchlorate removal. Following treatment, groundwater is discharged to the Las Vegas Wash under a National Pollutant Discharge Elimination System (NPDES) permit (NV0023060).

The on-site IWF also includes a bentonite-slurry barrier wall, which was constructed in 2001 as a physical barrier across the higher concentration portion of the on-site perchlorate groundwater plume. The barrier is approximately 1,600 feet (ft) in length and 60 ft deep, constructed to tie into approximately 30 ft of the underlying Upper Muddy Creek Formation (UMCf).

Although the current GWETS has effectively removed substantial amounts of perchlorate (and hexavalent chromium) from groundwater, elevated concentrations persist in groundwater at the Site.

1.2 Work Plan Organization

This Work Plan document relates to the proposed in-situ microcosm testing, column testing, and pre-design activities necessary for design and installation of a PRB pilot system and is organized as follows:

- Section 2 presents the purpose and objectives of the proposed PRB pilot;
- Section 3 presents the Site conditions in the candidate location of the proposed PRB pilot;
- Section 4 presents an overview of PRB technology and the rationale for the proposed PRB pilot;
- Section 5 presents the proposed approach for design of the PRB pilot, including up-front soil boring, well installation, in-situ and bench-scale studies, establishment of design parameters, and reporting;
- Section 6 presents a preliminary monitoring scheme to be undertaken for the PRB pilot treatability study;
- Section 7 presents the proposed schedule for the studies; and
- Section 8 details the references used in compiling this Work Plan.

Tables and Figures are presented at the back of the report text, followed by the Appendices.

2 Purpose and Objectives

2.1 Purpose

As described in Section 1.1, the GWETS is currently in operation at the Site. The GWETS extracts and treats groundwater containing perchlorate and hexavalent chromium to control the migration of these chemicals of potential concern (COPCs) in groundwater and to limit the discharge of COPCs to the Las Vegas Wash. The purpose of this Work Plan is to evaluate the technical feasibility and overall effectiveness of an in-situ PRB in treating perchlorate to levels that will achieve the remedial action objectives (RAOs) for perchlorate in groundwater at the Site. To properly evaluate this technology ENVIRON proposes to conduct ISM testing and column studies, followed by installation and operation of a PRB pilot system at the Site. The specific objectives for these studies including a summary of work done to date (by others) are provided below.

2.2 Objectives

The objective of the ISM studies, bench-scale column tests, and pilot test is to evaluate the effectiveness of using PRB technology as a component of the overall remediation of the Site. The ISM testing will provide valuable information to assess the performance of various amendments under actual in-situ conditions. The bench-scale column testing will provide supplemental information regarding the degradation of perchlorate under laboratory-controlled conditions. The ISM and bench-scale studies collectively will develop necessary information required for the design and implementation of a full-scale PRB at the Site, which could be used for sustained in-situ treatment of perchlorate in groundwater to meet RAOs. This will be achieved by the specific objectives presented below.

2.2.1 Bio-Trap® ISM Testing Objectives

Laboratory bench-scale studies have traditionally been employed to screen potential in-situ bioremediation strategies. However, duplication of in-situ conditions in the laboratory is difficult and the results may not correlate directly to the field. For this reason, ENVIRON proposes to supplement the bench-scale study described below with a method known as Bio-Trap® ISMs, to asses and screen bioremediation strategies directly in the field. ISMs are a cost-effective method to supplement laboratory studies to provide the chemical, geochemical, and microbiological lines of evidence required for screening remediation options and validating selected remediation technologies. ISM studies consist of an assembly of physically isolated units, each corresponding to a specific option, such as monitored natural attenuation, biostimulation and/or bioaugmentation. Each ISM unit contains multiple passive diffusion samplers to examine COPC concentrations, redox conditions, and microbial populations. The assembly of ISM units can be deployed in existing monitoring wells and is recovered for subsequent analysis to simultaneously screen multiple treatment options. Evaluation of remediation alternatives is based on comparisons of multiple lines of chemical, geochemical, and microbiological evidence between the ISM units.

ISMs allow the evaluation of various bioremediation approaches under actual in-situ conditions in a single-field study by simultaneously deploying multiple ISM units in a single-test well. The below illustration and photograph show the components and a picture of an ISM unit, respectively. To evaluate the effect of various treatment approaches, the ISM would be equipped with three types of passive samplers: a contaminant of concern (COC) sampler, a geochemistry (GEO) sampler, and a Bio-Trap® (MICRO) sampler. The COC sampler results are used to compare concentrations of parent compounds (perchlorate) and daughter product formation (chlorate, chlorite, and chloride) between ISM units undergoing different treatments. Quantification of geochemical parameters including competing electron acceptors (nitrate, sulfate, etc.) and volatile fatty acids (VFAs) are used to compare redox states and provide the geochemical footprint of subsurface microbial activity in each ISM unit.

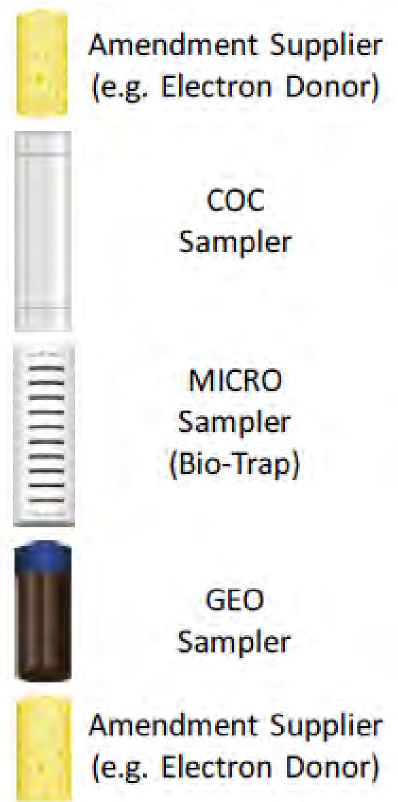


Illustration of an ISM sampler including COC sampler, GEO sampler and MICRO sampler.

Photograph of a MICRO sampler assembly.

The MICRO samplers contain a proprietary sampling matrix, Bio-Sep® beads, which are readily colonized by subsurface bacteria. Following ISM deployment, MICRO samplers are recovered from each ISM unit for quantitative polymerase chain reaction (qPCR) enumeration of key microbial populations (e.g., perchlorate reducers). Therefore, comparison of qPCR results for the MICRO samplers in each ISM provides a quantitative assessment on the efficacy of each treatment tested to stimulate growth of organisms responsible for contaminant biodegradation. The qPCR approach has been developed and used in field applications for more than a decade (Higuchi, Dollinger, Walsh, and Griffith, 1992).

The purpose of the ISM evaluation is to obtain information concerning the particular amendment that would be most successful at enhancing the indigenous microbial population to biodegrade perchlorate under native hydrogeologic groundwater conditions. The results of this testing program will identify which microbial populations predominate in the presence of various carbon donors, and how the donor amendment affects the geochemical conditions of the groundwater.

The objectives of the ISM study are as follows:

- Conduct an initial screen to evaluate a variety of electron donors to determine which amendment(s) show the most promising results for biodegradation of perchlorate in Site groundwater;
- Based on the results of the initial screen, use the most promising amendment to establish in situ biodegradation rates for perchlorate in groundwater; and

- Develop the necessary parameters from the observed reaction kinetics to enable the selection of the configuration (e.g., trench PRB, injected PRB) and sizing for design of the PRB pilot system.

2.2.2 Bench-Scale Column Study Objectives

Bench-scale testing using site-specific groundwater and soil cuttings in flow-through columns is proposed to supplement the information obtained in the ISM study for the evaluation of candidate amendments tailored to the Site conditions. The purpose of the column tests is to obtain perchlorate biodegradation rates with the selected carbon donor source and evaluate the potential for fouling or clogging of the aquifer materials with the amendment. The flow-through columns will be monitored throughout the study for influent and effluent perchlorate concentrations, electron acceptor (e.g., oxygen, nitrate, iron, and sulfate), and metals concentrations along with oxidation-reduction potential (ORP) and pH. Since a known amount of perchlorate will be injected into the columns and the amount of perchlorate and perchlorate daughter products will be monitored in the effluent at various locations throughout the column, a mass balance can be performed on the change in perchlorate concentration over time and distance within the column. These results along with the data obtained from the ISM evaluation will be used to guide the design of the PRB pilot system.

The objectives of operation of the bench-scale study are as follows:

- Develop the parameters from the observed degradation rates for design of the PRB pilot;
- Evaluate the performance of the columns under various flow rates; and
- Evaluate conditions that may result in fouling/clogging.

2.2.3 PRB Pilot Objectives

The objectives of the PRB pilot are as follows:

- Evaluate the effectiveness, implementability, and operational limitations (e.g., biofouling) of the design configuration and amendment selected from the ISM Study under actual field conditions at the Site;
- Determine the appropriate dose rates for the selected amendment;
- Evaluate the potential geochemical impact from operation of the PRB pilot system on the solubility and mobilization of metals within the aquifer; and
- Evaluate the hydraulic performance of the PRB pilot system and develop the geotechnical parameters necessary for the design and installation of a full-scale system at the Site.

2.3 Work Performed By Others

Between 2000 and 2010, a series of studies were undertaken and plans were prepared relevant to the application of PRB technology, including the following:

Date	Type of Study or Plan	Performed by
12/19/2000	Hydrogeologic	Errol L. Montgomery and Associates Inc.
1/18/2001	Seep Groundwater Characterization	Kerr-McGee Chemical, LLC
2/14/2010	Work Plan for PRB Pilot Testing	Shaw Environmental, Inc. (Shaw)
10/25/2010	Emulsion Retention Testing and Bench-Scale Jar Testing	Northgate Environmental Management, Inc. (Northgate)

A detailed summary of the work performed to date by others related to the proposed PRB pilot is provided in Table 1. In February 2011, the Trust assumed ownership of the Site, following which the Trust and NDEP discussed the implementation of a RI/FS at the Site. As a result, the Northgate and Shaw plans were not implemented and it was agreed that any treatability studies would be evaluated and proposed as part of the RI/FS. ENVIRON has reviewed the prior work plans along with associated NDEP comments and has incorporated relevant details into this Work Plan. The proposed pilot testing herein continues and builds on the preliminary evaluation of PRB technology and proposed pilot testing previously presented by others.

3 Site Conditions

3.1 Geology

From review of available borehole logs (Northgate, 2011) and as is described in the following, the geology of the area of the proposed PRB is comprised of the following three units: general fill, quaternary alluvium (Qal) and a Tertiary UMCf.

- **Fill Material** is not generally present in the area of the proposed PRB, the exceptions being in borehole MW-K5 (northeastern corner of the proposed PRB area) and PC-103 (adjacent to the southwestern corner of the proposed PRB). In these areas, fill is described as a silty sand (3.5 ft thick) overlying a clayey, sandy gravel to 8 ft below ground surface (bgs) (MW-K5); and as "construction material" (taken to refer to demolition rubble) extending to 6 ft bgs (PC-103).
- **Quaternary Alluvium** is present in each of the seven locations drilled to date in the area of the proposed PRB and generally comprises a reddish-brown heterogeneous mixture of well-graded sand and gravel with lesser amounts of silt and clay. The gravel comprises the aforementioned Tertiary volcanic rocks with rare cobbles encountered (PC-98R at 29–30 ft bgs). Caliches (hardened deposits of calcium carbonate) are also known to be present in the area and were recorded as a band of gravel from 16–20 ft bgs in PC-98R. The alluvial deposits extend to between 29 and 40.5 ft bgs with thicknesses ranging between 23 and 40.5 ft. These alluvial deposits are further described as being loose and coarse (Errol L. Montgomery & Associates, 2000).
- A major feature of the alluvial deposits is the stream-deposited sands and gravels that were laid down within paleochannels that were eroded into the surface of the UMCf during infrequent flood runoff periods. These deposits vary in thickness and are narrow and linear. These generally uniform sand and gravel deposits exhibit higher permeability than the adjacent, well-graded deposits. In general, these paleochannels trend northeastward (ENSR, 2006).
- **Tertiary UMCf** underlies the alluvial deposits and is comprised generally of gray/green sandy and silty clay to clayey sand with gypsum crystals. This formation was encountered in all but one of the boreholes drilled in the proposed PRB area (borehole I-2 drilled by Northgate as a PRB test bore in 2011, which terminated in the alluvial deposits). Referencing the available borehole logs for the proposed PRB area (Northgate, 2011), the UMCf was encountered between 29 and 40.5 ft bgs. The full thickness of the UMCf was not determined as all the boreholes drilled into it terminated within the first few feet.

Soil boring logs and well construction diagrams for wells in the vicinity of the candidate PRB location are included in Appendix A. A table of well construction details is provided in Table 2. Cross sections showing the detailed geology in the area of the proposed PRB pilot are presented on Figures 3 to 5.

3.2 Hydrology

Depth to groundwater in the candidate PRB pilot area ranges from about 21 to 24 ft bgs. The groundwater gradient averages 0.02 feet per foot (ft/ft) south of the AWF, flattening to 0.007 ft/ft just south of the SWF (ENVIRON, 2011b, 2012). The groundwater flow direction at the Site is generally north to north-northwesterly. This generally uniform flow pattern may be modified locally by subsurface alluvial channels cut into the underlying UMCf, the on-site bentonite-slurry groundwater barrier wall, off-site artificial groundwater highs or “mounds” created by the infiltration of City of Henderson wastewater effluent discharged to ponds in the Henderson Bird Viewing Preserve, and by depressions created by the groundwater extraction wells at the three groundwater recovery well fields (Northgate, 2010).

The rate of groundwater movement in the general area of the candidate PRB location has been estimated by others to be in the range of 30 to 45 ft/day (Errol L. Montgomery & Associates, 2000). Recent groundwater modeling performed by ENVIRON has resulted in estimates of groundwater velocity in the immediate vicinity of the candidate location for the Quaternary Alluvium in the range of 2 to 3 ft/day.

NDEP has defined three water-bearing zones (WBZs) that are of interest at the Black Mountain Industrial (BMI) complex: the Shallow Zone, which extends to approximately 90 ft bgs, is unconfined to partially confined, and is considered the “water table aquifer”; the Middle Zone, from approximately 90 to 300 ft bgs; and the Deep Zone, which is defined as the contiguous water-bearing zone that is generally encountered between 300 to 400 ft bgs (NDEP, 2009a). The Shallow Zone will be the focus of the PRB pilot test.

3.3 Groundwater Quality

Within the candidate PRB pilot area, perchlorate concentrations in groundwater samples range from 3 to 18 milligrams per liter (mg/L) (ENVIRON, 2011b, 2012). During the pump test of PC-98R, the following conditions were observed with respect to general groundwater quality parameters (Errol L. Montgomery & Associates, 2000).

- Temperature ranged from 23^{o} to 24^{o} C
- Specific Conductivity ranged from 12,300 to 13,500 microSiemens per centimeter (µSm/cm); and
- pH ranged from 6.90 to 7.70.

Water quality analyses performed by Northgate in 2010 included dissolved metals and anionic species. The results showed a high concentration (1,400 mg/L) of sulfate is present in shallow groundwater. A summary of groundwater indicator parameters and water quality conditions in the candidate location for the PRB pilot is presented in Table 3 and Table 4.

To further establish groundwater quality in the vicinity of the proposed PRB pilot location and as is discussed further in Section 5 below, baseline groundwater sampling and analysis is proposed as part of design activities for the PRB pilot.

4 Technology Overview and Rationale

PRB technology for the removal of perchlorate involves the creation of conditions in the subsurface environment, which are conducive to the growth of biological communities that are able to use perchlorate as an electron acceptor. The conditions required for such a reaction to occur include the presence of a suitable electron donor (or carbon source), appropriate redox potential, and the presence of other agents necessary for biological growth (e.g., trace nutrients). The specific area of the subsurface environment where these conditions are created are referred to as the reactive or treatment zone and constitute the active portion of the PRB. The treatment zones are created in the path of groundwater flow such that perchlorate in groundwater is removed biologically as it moves through the zone. Remediation of perchlorate in groundwater at the Site using an in-situ technology, such as a PRB includes the following challenges:

- Potentially high groundwater velocities;
- Natural competition in the aquifer for electron donor (i.e., electron donor demand);
- Controlling conditions (e.g., redox potential, concentration of electron donor) to limit biofouling; and
- Sustained long-term operation.

The design of the PRB will depend upon various parameters including the characteristics of the formation, the type of amendment (i.e., election donor) to be deployed, and the resulting time necessary to degrade perchlorate to the desired concentration in groundwater (Federal Remediation Technologies Roundtable ([FRTR], 2005). In addition to consideration of the stoichiometry and rate of degradation of perchlorate, dosing of the selected electron donor needs to account for other, abiotic processes that would consume the donor and reduce their bioavailability to degrade perchlorate (Strategic Environmental Research & Development Program (SERDP), 2009).

System design typically requires an estimate of groundwater flow, solute transport, and biodegradation processes that are involved in the application of a bioremediation system. Specifically, these estimates are used to ensure that the treatment system will: 1) biologically degrade perchlorate within the treatment zone, and 2) avoid excess delivery of electron donor. Using electron donor biological decay rates established based on the data obtained in the ISM study and the bench-scale column testing, the projected fate and transport of injected electron donor can be estimated. Thus, electron donor delivery can be optimized to limit downgradient migration (and subsequent secondary impacts such as metals mobilization) while still providing a sufficiently large biological treatment zone, and reducing the potential for biofouling.

4.1 PRB Functional Description

A PRB is an engineered in-situ treatment system and can include active pumping or passive flow through a reactive zone. A PRB is an in-situ, permeable treatment zone designed to intercept and remediate a contaminant plume. The term “barrier” is intended to convey the idea that contaminant migration is impeded; however, the PRB is designed to be more permeable than the surrounding aquifer media so that groundwater can easily flow through the structure without significantly altering groundwater hydrology (Interstate Technology & Regulatory Council [ITRC], 2011).

4.2 PRB Case Study Review

A literature review was performed, to obtain currently available information on the efficacy of pilot tests and full-scale installations of PRBs for treatment of perchlorate and other similar contaminants in groundwater. A summary of the selected PRB case studies reviewed is presented in Table 5. Perchlorate reductions were reported in the range of 86% to 97%. Passive PRBs (i.e., PRBs that utilized a solid substrate placed in situ) were successful in treating perchlorate concentrations from 170,000 micrograms per liter (µg/L) to non-detect levels. PRBs that utilized injection wells for delivery of amendments have been shown to be as effective as passive systems, although performance data for full-scale, long-term operation of such PRBs is limited. Proximal to the candidate PRB location at the Site, an active PRB, which employed groundwater extraction, amendment and re-injection, was operated at the neighboring American Pacific Corporation (AMPAC) site for treatment of perchlorate in groundwater. This system extracted groundwater, mixed in electron donor (sodium benzoate) ex-situ, and reinjected the groundwater downgradient. The active PRB at the AMPAC site successfully reduced perchlorate from influent levels as high as 31,000 µg/L to non-detect levels (AMPAC, 2009). The system operated for approximately six years before it was shut down after the discovery of additional perchlorate source areas. The AMPAC system did not have the capacity to treat the additional perchlorate loading anticipated and was deemed to not be cost effective in treating the additional load associated with the additional sources areas. Subsequently, AMPAC installed a higher-capacity FBR system (AMPAC, 2012).

Although the AMPAC PRB system was successful at reducing perchlorate, the system experienced problems with biofouling. Early on and to improve the infiltration capacity, AMPAC modified the system from a gallery of shallow injection wells to a deep reinjection trench due to biofouling downgradient of the injection site. Biofouling control was also attempted through the injection of several biocides, including peroxide and hypochlorite, at the injection site with varying and inconsistent results. The most effective control measure reported was the addition of an oxygen scavenger, sodium metabisulfite, in amended groundwater prior to re-injection. It was reported that this resulted in lowering of the dissolved oxygen of the injected groundwater from 6 mg/L to less than 1 mg/L (AMPAC, 2011). At the time the PRB system was shut down at the AMPAC site, the flow rate had been reduced to 130 gallon per minute (gpm) from its design flow of 225 gpm due to bio-fouling at the injection location. Operational considerations, such as introduction of oxygen during extraction and reinjection, and potential overdosing of electron donor suggested by the observed reduction of sulfate downgradient of the reinjection wells, likely contributed to the observed biofouling.

The potential for bio-fouling and mobilization of other constituents will be a key consideration during design and operation of the proposed PRB at the NERT Site. In addition to the potential for bio-fouling, the reduction of perchlorate can also result in mobilization of otherwise stable metals (e.g., manganese and iron). Mobilization of iron and manganese was noted in one of the larger pilot studies performed in Rancho Cordova, California. It is noted that manganese was also mobilized during operation of the active PRB at the AMPAC site (AMPAC, 2009, 2011).

5 PRB Pilot Design

As described above, ENVIRON proposes treatability studies at both the bench-scale and pilot-scale to gather the necessary information to evaluate the technical feasibility and overall effectiveness of using PRB technology for the sustained treatment of perchlorate in groundwater at the Site. Specifically, ENVIRON intends to:

1. Install soil borings and monitoring wells in an area designated for the PRB pilot while also collecting the necessary groundwater and soil cuttings to enable bench-scale testing;
2. Conduct in-situ studies and a bench-scale test program to test the efficiency of various electron donors, establish optimal dosing rates, and to develop parameters to enable pilot system design; and
3. Complete a final design of the PRB pilot installation at the candidate installation location at the Site.

5.1 Candidate Installation Location

ENVIRON is proposing to locate the PRB pilot in the location previously identified by Shaw and Northgate; approximately 2,000 ft downgradient of the AWF, approximately mid-way between the AWF and SWF. A groundwater potentiometric surface map and a map of perchlorate isoconcentration contours for the proposed location for the PRB pilot are shown in Figure 2a and Figure 2b, respectively. The in-situ PRB pilot will be located to intersect the flow of groundwater in the saturated alluvium overlying the UMCf. The property in the proposed installation location is owned by the City of Henderson. Arrangements for access for installation and monitoring of the PRB pilot will be required prior to installation.

This candidate location has been proposed based on the following:

- The area is far enough from the extraction well fields, such that the injected substrate will not be affected by pumping gradients;
- The area is located within the paleochannels in the UMCf, which appear to influence the direction of groundwater flow from the Site and transport of perchlorate from the Site to the Las Vegas Wash (refer to cross sections on Figures 3 to 5, and Section 3);
- Perchlorate concentrations are elevated (>10 mg/L), making observation of concentration reductions easier and (if successful) effecting a significant mass removal of perchlorate, while not being so high as to prevent effective treatment via the PRB;
- There is sufficient distance downgradient of the test area prior to the Las Vegas Wash to monitor for degradation by-products, dissolution/release of compounds that may adversely affect water quality, and unconsumed substrate; and
- The area is not occupied by existing structures or in close proximity to drainage features/other factors which might influence surface or groundwater flow or access/transportation routes.

5.2 Preliminary Activities

A soil boring, which will be converted to a new permanent monitoring well, will be installed in the area proposed for the PRB pilot. This newly installed monitoring well will be used to collect information necessary to assess local groundwater flow, and to assess the geologic conditions and soil chemistry. The newly installed monitoring well will also provide a location for ISM testing. Prior to drilling activities, land access to the area for installation will be obtained from the City of Henderson. No less than 48 hours prior to the planned drilling activities, Underground Service Alert (USA) will be notified to identify any possible subsurface utilities or piping that may be in the area of the planned installation. Following installation, the newly installed monitoring well will be developed, purged, and sampled. Both the groundwater sampled and the soil cuttings from the well installation will be shipped to the laboratory for analytical and microbial testing. To provide an in-situ measurement of horizontal groundwater flow at the candidate PRB pilot location, single borehole dilution testing will be performed at the newly installed well to measure groundwater flow. These activities are discussed in further detail below.

5.2.1 Soil Boring and Well Installation

A single monitoring well will be drilled in accordance with Nevada Division of Water Resources (NDWR) requirements outlined in Nevada Administrative Code (NAC) Chapter 534, and notices of intent to drill will be submitted to the Division for the new well.

The soil boring for well installation will be conducted using a Mini Sonic drilling rig within the candidate PRB pilot area. Soil cores will be described in the field by an experienced field geologist. Soil borings will be advanced through the alluvium and will be terminated at the contact of the alluvium and Muddy Creek formation. Samples of soil from the saturated zone within the soil boring will be collected for microbial testing to establish a baseline for perchlorate reducing microorganisms and for use in bench-scale column testing.

Upon reaching the target depth at the top of the UMCf, the soil boring will be converted to a permanent monitoring well. The monitoring well will be constructed using 2-inch diameter slotted polyvinyl chloride (PVC) screen from the top of the water table to the top of the UMCf (a length of approximately 25 ft) and 2-inch diameter schedule 40 PVC riser to the ground surface. A filter pack of washed sand will be placed around the well screen to approximately 2 to 3 ft above the top of the screen. A seal consisting of approximately 2 to 3 ft of hydrated bentonite chips will be placed above the filter pack followed by bentonite/cement grout to the surface.

Following installation, the monitoring well will be developed using a submersible pump. Well development will consist of removal of approximately 10 well volumes of groundwater from the monitoring well. Standard Operating Procedures (SOPs) for photoionization detector (PID) screening for environmental sampling, soil sampling, and monitoring well installation and development are provided in Appendix C.

5.2.2 Groundwater Sampling and Analysis

Prior to groundwater sampling, water level measurements will be collected prior to the purging and sampling of the new monitoring well. The depth to water and the total well depth will be measured using an electronic water level meter. The water levels will be determined to the nearest 0.01 of a foot with an accuracy of ±0.02 ft and the total well depth will be determined to the nearest 0.1 of a foot with an accuracy of ±0.2 ft.

5.2.3 Single Borehole Dilution Testing

A single borehole dilution test is a relatively simple hydrogeological technique used to determine the volumetric flow rate of groundwater through a borehole. The technique potentially provides a means to obtain hydrogeological properties, without the need to undertake a pumping test, avoiding the logistical difficulties of such testing. This testing method provides a measurement of ambient groundwater velocity and the capability to reveal zones of preferential flow and zones of negligible flow within a single borehole (Pitrak, M., Mares S., and Kobr, M., 2007).

Borehole dilution testing will be performed at the newly installed well in the candidate PRB location. To perform the test, a tracer solution (e.g., bromide, fluoride) of known concentration will be circulated/mixed within the screened interval of the monitoring well. The decline of tracer concentration (i.e., "dilution") with time within the well screen will be monitored directly using a vertical array of tracer specific-ion electrode probes located at known depth intervals. Based on the dilution characteristics observed, the vertical distribution (i.e., heterogeneity) of hydraulic properties and/or flow velocity can be estimated for the formation within the well screen section. The presence of vertical flow within the well screen can also be identified from the probe/depth dilution response pattern. The rate of groundwater flow measured in the borehole dilution test will be used to help establish the duration for placement of ISM Bio-Trap®s, to establish the flow rates used in the bench-scale columns, and as a parameter used in the design of the PRB pilot.

5.2.4 Management of Investigation-Derived Wastes

In obtaining soil and groundwater for the bench-scale tests, investigation-derived wastes, including leftover soil cuttings (from drilling of boreholes), groundwater (from purging/development of monitoring wells), and spent personal protective equipment (PPE) will be generated.

Consistent with current management practices and pending waste characterization, waste soil, and spent PPE will be stored in 55-gallon drums, transported to the NERT Site, and staged in a temporary holding area on the Site located away from surface water features and storm drains. The drums will be labeled with a drum identification number, the description of the contents, the date generated, and the point of contact to be reached regarding questions. Based on the results of waste characterization samples, arrangements will be made for disposal.

Purged groundwater will be temporarily stored in suitable containers prior to being transferred to the on-site GWETS for treatment.

5.3 ISM Testing

ISM testing results will be used to generate information useful in the design of the PRB pilot system. The ISM testing will provide information to enable selection of electron donors and dosing rates and to identify the geometry and sizing of the PRB for pilot testing.

The biostimulation ISM units will contain a section of sponge-like cellulosic material saturated with the commercial electron donor solution or solid electron donor material. In addition to the electron donor and nutrient amendments if needed, the ISM units will contain COC, MICRO, and GEO samplers for evaluation of perchlorate and perchlorate byproducts, electron acceptors, nutrients and microbial populations.

The specific objectives of the proposed ISM testing are:

1. Identification of suitable electron donors and supplemental amendments (e.g., nutrients) required for perchlorate reduction.
2. Evaluation of the perchlorate degradation rates achievable at the candidate PRB pilot location at the Site.
3. Establish degradation and hydraulic parameters required to design a PRB pilot.

The ISM testing will be performed in two stages at the candidate PRB location. The first stage (Stage 1 ISM study) will evaluate a variety of potential electron donors. Based on the results of the Stage 1 ISM study, the most effective electron donor will be evaluated in the subsequent second stage (Stage 2 ISM study) by means of retrieval of ISM Bio-Trap®s over time, which will provide an indication of the rate of perchlorate biodegradation in situ. A more detailed description of the proposed two-stage ISM study is provided below.

5.3.1 Stage 1 ISM Testing

The Stage 1 ISM study will include the deployment of Bio-Trap®s, to establish the most promising candidate amendment(s) for perchlorate reduction. The traps to be deployed in the Stage 1 study will include one unamended trap allowing for the analysis of monitored natural attenuation parameters. Three additional traps, each amended with a different electron donor substrate will be installed in wells PC-98R, MW-K5 and the newly installed well. The ISMs will be provided by a specialized vendor, Microbial Insights, Inc. (MI), and will be constructed at the PRB location. The following is a list of potential electron donor substrates identified for testing. At least one substrate will be evaluated from each of the three groups described below:

1. Soluble electron donors (e.g., lactate, acetate);
2. Solid carbon electron donors (e.g., compost and peat, mulch mixed with sand or pea gravel); and
3. Proprietary, slow-release electron donor (e.g., Regenesis HRC®, FMC EHC®, Duramend®, EOS Remediation EOS®).

The above electron donors were selected based on their ability to be applied to a variety of potential PRB designs (e.g., via direct injection, passive diffusion wells, or within a trenched wall). Each has demonstrated success in similar environments based on review of case studies and published research, and cost-effectiveness in full-scale application (Batelle, 2000, FRTR, 2005, ITRC, 2011).

With respect to soluble donors, acetate was selected as a candidate electron donor to be evaluated because it can be readily metabolized by a variety of microflora and requires relatively low energy to be utilized. Lactate ferments directly to acetate, and has been used in

PRBs at other sites such as the Naval Surface Warfare Center in Indian Head, Maryland (Table 5).

Proprietary electron donors, Regenesis HRC®, EOS Remediation EOS®, FMC EHC® and Duramend®, have also been identified for testing as these products are designed to provide a slow release that can extend the longevity of the PRB between dosings and can avoid some of the problems with bio-fouling associated with other substrates. Each of these proprietary products has been specifically formulated for use in in-situ anaerobic degradation of halogenated organic compounds, and would be effective at reducing perchlorate. Following approval of this Work Plan, a vendor will be selected to supply one of these proprietary electron donors for testing.

Solid carbon electron donors, hard wood mulch, peat, and compost, have been selected based on their common availability and extended release properties. Each of these solid substrates has advantages and disadvantages. For example, the lignins in mulch are not as readily bioavailable compared to other substrates (compost and peat). However, compost and peat may be less commercially available than mulch and therefore could be more costly. The addition of gravel or sand to these substrates will provide the necessary structure to achieve the desired hydraulic characteristics for flow of groundwater through the PRB. As summarized in Table 5, the use of mulch, compost, and peat as electron donors in PRBs has been demonstrated at sites such as the Naval Weapons Industrial Reserve Plant in McGregor, Texas and Whiteman Air Force Base near Kansas City, Missouri.

Once the amendments and samplers have been added to each ISM unit, the assembled units can be connected to form a single line for in well deployment. A nylon rope or cable is attached to the uppermost ISM unit. A stainless steel weight is added to the bottom-most ISM unit and the assembly is lowered into the monitoring well. The cable is typically attached to an eye bolt in the gripper plug or top of casing. The cable must be long enough to suspend the assembly of ISM units within the screened interval of the saturated zone.

Prior to installation of the ISM units, each well will be purged and the following parameters will be collected approximately every five minutes during the purging process and will be recorded in a field notebook and/or groundwater sampling log forms along with the pumping rate, depth to water, and other observations: pH, conductivity, ORP, and dissolved oxygen (DO). Purging will continue until pH, conductivity and turbidity readings have stabilized over three consecutive readings. The in-line water quality meter will be disconnected prior to sampling. After the wells have been purged and sampled for baseline parameters listed in the below table “Stage 1 ISM Study - Summary of Testing Parameters”, following the sampling SOPs of Appendix C, a series of ISM units will be deployed in each monitoring well.

After the desired minimum incubation period, the Stage 1 ISM units will be retrieved and the samplers removed, appropriately labeled, placed in zippered bags, and shipped overnight on ice to MI under standard chain-of-custody. The samplers will be analyzed for the following parameters.

Stage 1 ISM Study - Summary of Testing Parameters and Frequency

Parameter (Analytical Method)	Frequency
Perchlorate by ion chromatography-mass spectroscopy-mass spectroscopy (IC-MS/MS)[1] Nitrate/nitrate (United States Environmental Protection Agency (USEPA) Method 300.0) Conductivity (microelectrode) Total Kjeldahl Nitrogen (USEPA Method 351.2) Orthophosphate (USEPA Method 300.0 or USEPA 365.3) Microbial population: perchlorate reducers (qPCR method) and general microbial groups via Phospholipid fatty acid analysis	Baseline groundwater samples and after a minimum of 4 weeks of incubation[3] in-situ.
Redox indicators plus Chloride - Dissolved oxygen (microelectrode); - Chloride and sulfate (USEPA Method 300.0); - Chlorate (USEPA Method 300.1); - Sulfide (HACH Method 8131 (USEPA Methylene Blue Method)); - Ferric and ferrous iron (HACH Method 8008 and 8147); and - Methane in headspace (Gas chromatograph – flame ionization (GC-FID)[2])	Baseline groundwater samples and after a minimum of 4 weeks of incubation[3] in-situ.
Dissolved Metals (Ag, As, B, Ba, Be, Ca, Cd, Cr, Co, Cu, Fe, Hg, K, Mo, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, Zn), and U) (USEPA Methods 6010/6020/7400/200.8)	Baseline groundwater samples and after a minimum of 4 weeks of incubation[3] in situ.
Quality Assurance/Quality Control (QA/QC)	Duplicates will be run on 5% of the groundwater samples. Typical runs will consist of blanks, daily calibration check samples, and runs of standard reference materials, when available.

Notes:

1. ClO4- concentrations will be measured by sequential ion chromatography-mass spectroscopy-mass spectroscopy (IC-MS/MS). ClO4- will be quantified using a Dionex LC 20 ion chromatography system consisting of GP50 pump, CD25 conductivity detector, AS40 automated sampler and Dionex IonPac AS16 (250 X 2 mm) analytical column. A hydroxide (NaOH) eluent at 0.3 milliliters per minute (mL min-1) is followed by 90% acetonitrile (0.3 mL min-1) as a post-column solvent. To overcome matrix effects, all samples are spiked with Cl18O3 or Cl18O4 internal standards.
2. Kampell, D.H. and S.A. Vandegrift. 1998. Analysis of Dissolved Methane, Ethane, and Ethylene in Ground Water by a Standard Gas Chromatographic Technique. J. of Chromatographic Sci. 36:253-256.
3. A minimum incubation period of 4 weeks is anticipated, but may be adjusted based on estimated of ground water velocity from the single borehole dilution testing and the results of initial baseline groundwater sampling.

Based on the results of the initial ISM testing, selection of the amendments for follow-on testing in the Stage 2 ISM study will be determined. It is anticipated that at least two amendments will be selected for the Stage 2 study.

5.3.2 Stage 2 ISM Testing

The Stage 2 study will consist of the deployment of four to five Bio-Trap®s, each amended with the selected substrate(s), for deployment in the single new monitoring well. Approximately every 2 to 3 weeks (based on the results of the Stage 1 testing), one of the Bio-Trap®s containing each of the candidate amendments will be removed for lab analysis for the parameters listed in the table below. ENVIRON estimates the Stage 2 ISM test to require a total duration of approximately 3 to 5 months. The results of this testing will provide a general rate of degradation under actual in-situ conditions in the field.

ISM Phase 2 Testing - Summary of Testing Parameters and Frequency

Location	Parameter (Analytical Method)	Frequency
MICRO Sample	Microbial Analyses: perchlorate reducers (Microbial Insights, Inc. or similar company/university)	Every 2 to 3 weeks
COC Sampler	Perchlorate by IC-MS/MS[1] Nitrate/nitrate (USEPA Method 300.0) Conductivity (microelectrode)	Every 2 to 3 weeks
GEO or pumped groundwater sample	Redox indicators plus Chloride • Dissolved oxygen (microelectrode), • Chloride, nitrite, nitrate, ferrous, ferric iron, sulfate, sulfide (USEPA Method 300.0), • Sulfide (HACH Method 8131 (USEPA Methylene Blue Method)) • Ferric and ferrous iron (HACH Method 8008 and 8147 • Methane in pore water (GC-FID[2])	Every 2 to 3 weeks

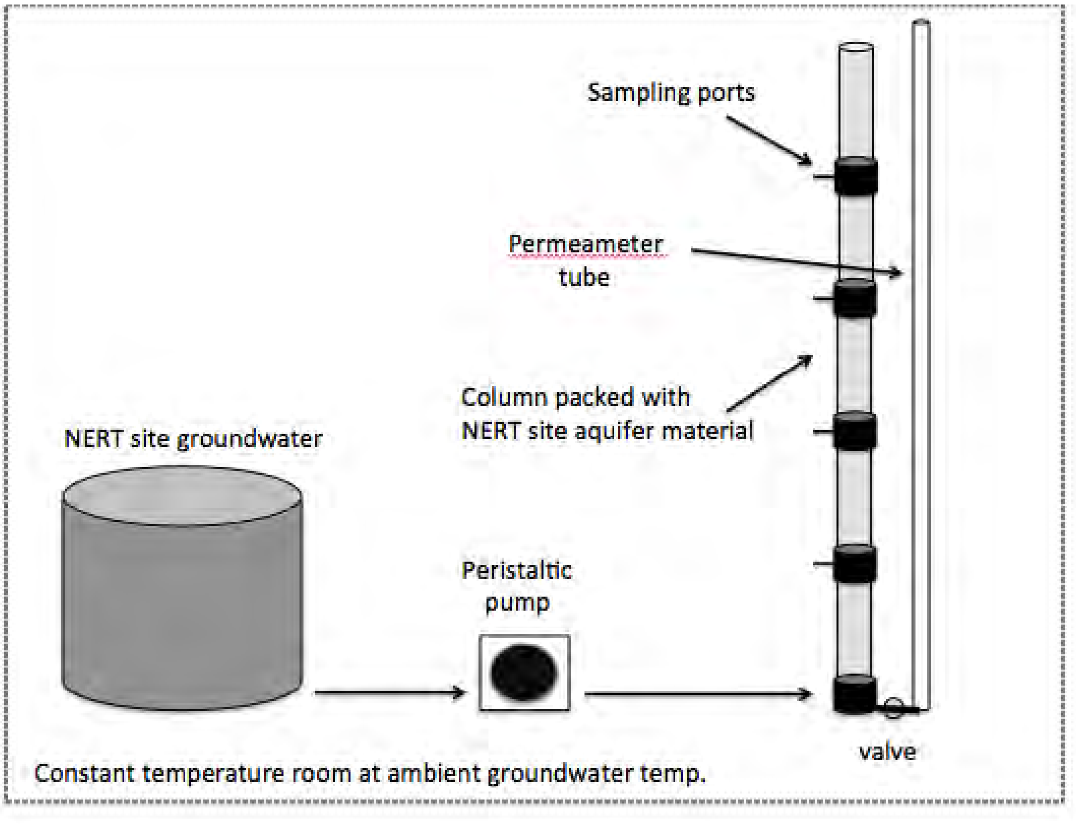
Notes:

1 ClO4- concentrations will be measured by sequential ion chromatography-mass spectroscopy-mass spectroscopy (IC-MS/MS). ClO4- will be quantified using a Dionex LC 20 ion chromatography system consisting of GP50 pump, CD25 conductivity detector, AS40 automated sampler and Dionex IonPac AS16 (250 X 2 mm) analytical column. A hydroxide (NaOH) eluent at 0.3 milliliters per minute (mL min-1) is followed by 90% acetonitrile (0.3 mL min-1) as a post-column solvent. To overcome matrix effects, all samples are spiked with Cl18O3 or Cl18O4 internal standards.

2 Kampell, D.H. and S.A. Vandegrift. 1998. Analysis of Dissolved Methane, Ethane, and Ethylene in Ground Water by a Standard Gas Chromatographic Technique. J. of Chromatographic Sci. 36:253-256.

5.3.3 Bench-Scale Column Testing

Column studies will be performed using the electron donors selected from the results of the Stage 1 ISM study and will be run in parallel with the Stage 2 ISM study activities. The column study will be used to test the effectiveness of donors in a flow-through mode simulating field conditions of the Site, providing additional information useful in the design of the PRB pilot. Specifically, the column testing will be used to refine the list of potential amendments targeted for the pilot testing. The amendment(s) chosen for the pilot testing will be those that reduce perchlorate but also maintain the hydraulic properties of the formation (minimize biofouling). A schematic diagram of the 1-D column system is shown in the laboratory column setup illustration below.



One column for each candidate amendment selected from the results of the Stage 1 ISM testing, plus one unamended control column will be constructed. Column experiments will be performed in 5-foot long, 2-inch diameter columns with five equally spaced sampling ports located along their lengths. A sample of soil cuttings from within the saturated zone of the soil boring will be submitted to a lab for microbial testing for perchlorate reducing bacteria to establish a baseline for this population. Additionally and at the conclusion of the column testing, a sample of soil from the bottom of each column will be submitted to the lab for microbial testing for perchlorate reducing bacteria to establish the change in the microbial population.

The columns will be packed with aquifer matrix material from the newly installed monitoring well at the candidate PRB location. A 5-centimeter layer of fine gravel will be placed at the bottom of each column to equalize the distribution of flow through the column. Glass wool will be inserted in the inner side of sampling ports to avoid dead zones and clogging of sampling ports. Immediately after establishment of the columns, the hydraulic conductivity of the test columns will be assessed by connecting a falling head permeameter to the column. Hydraulic conductivity will be measured using the falling head method and compared to existing data for the Site.

Laboratory Column Set-up

Groundwater collected from the candidate PRB location at the Site will be shipped to the off-site laboratory and introduced through 2 millimeter (mL) stainless steel tubing in up-flow mode. A peristaltic pump with Viton tubing will used to convey water through the column at groundwater velocities representative of conditions at the candidate location for the PRB pilot. The experiment will be set-up in a constant temperature room so that groundwater and the test columns will be maintained at ambient temperatures similar to those present at the candidate PRB location.

The influent concentrations will be monitored three times per week to track changes in perchlorate concentration. Influent samples for all column experiments will be collected at the sampling ports on the delivery side of the pump. Samples from each sample port will be collected every three to four days with a 5 mL pre-rinsed airtight glass syringe fitted with luer-lock and injected into 2-mL glass vials. Samples collected will be analyzed for perchlorate, nitrate/nitrite and conductivity. On a weekly basis, additional redox indicators will be measured including dissolved oxygen, ferrous iron, ferric iron, sulfate and sulfide, and methane. Oxidation-reduction characteristics of each sampled zone will be determined from the water chemistry parameter results. Additional samples will be collected from the columns for metals analysis at an external certified laboratory. Column studies will be run for a period of approximately 8 to 12 weeks, with flows through the columns adjusted based on the observed groundwater velocity observed from the single borehole dilution testing, subject to extension if additional information is desired. Following the termination of the studies, the falling head permeameter study will be repeated and the hydraulic conductivity measured again to assess the effect on aquifer hydraulic properties. Declines in conductivity over the duration of testing will provide evidence of conditions that may be conducive to biofouling. If conductivity declines significantly (e.g., greater than 5 to 10 times the initially measured hydraulic conductivity), column materials will be removed and total carbon measured on the aquifer material to determine the amount of biomass accumulated along the flow path.

Analytical Procedures

Major anions (Cl^-, NO^{3-}, and SO_4^{2-}) will be analyzed by ion chromatography following USEPA Method 300.0. Perchlorate concentrations will be separately measured by sequential ion chromatography-mass spectroscopy-mass spectroscopy (IC-MS/MS). Redox parameters will be measured using standard methods for DO (by microelectrode), nitrite, nitrate, ferrous and ferric iron, sulfate, sulfide (by ion chromatograph), and methane in pore water (by GC-FID). To assess the liberation of metals from the aquifer matrix, samples will also be collected for metals analysis over the course of the column testing. Below is a summary of the testing parameters, analytical methods and frequency for the column testing.

Column Testing - Summary of Testing Parameters and Frequency

Location	Parameter (Analytical Method)	Frequency
Column influent	Perchlorate by IC-MS/MS[1]	3 times/week for 12 weeks
Sample ports	Perchlorate by IC-MS/MS[1], Nitrate/nitrite (USEPA Method 300.0), Conductivity (microelectrode)	Every 3 to 4 days
All Sample Ports	Redox indicators plus Chloride • Dissolved oxygen (microelectrode), • Chloride, ferrous and ferric iron, sulfate, sulfide (USEPA Method 300.0), • Sulfide (HACH Method 8131 (USEPA Methylene Blue Method)) • Ferric and ferrous iron (HACH Method 8008 and 8147) • Methane in pore water (GC-FID[2])	Weekly
Column Effluent	Dissolved Metals (Ag, As, B, Ba, Be, Ca, Cd, Cr, Co, Cu, Fe, Hg, K, Mo, Mg, Mn, Na, Ni, Pb, Sb, Se, Ti, Zn, and U) (USEPA Methods 6010/6020/7400/200.8)	Every two weeks
Each Column	Hydraulic conductivity (Falling Head Permeability Test (ASTM D5084-10))	At beginning and after termination of study

Notes:

1 ClO4- concentrations will be measured by sequential ion chromatography-mass spectroscopy-mass spectroscopy (IC-MS/MS). ClO4- will be quantified using a Dionex LC 20 ion chromatography system consisting of GP50 pump, CD25 conductivity detector, AS40 automated sampler and Dionex IonPac AS16 (250 X 2 mm) analytical column. A hydroxide (NaOH) eluent at 0.3 milliliters per minute (mL min-1) is followed by 90% acetonitrile (0.3 mL min-1) as a post-column solvent. To overcome matrix effects, all samples are spiked with Cl18O3 or Cl18O4 internal standards.

2 Kampell, D.H. and S.A. Vandegrift. 1998. Analysis of Dissolved Methane, Ethane, and Ethylene in Ground Water by a Standard Gas Chromatographic Technique. J. of Chromatographic Sci. 36:253-256.

QA/QC

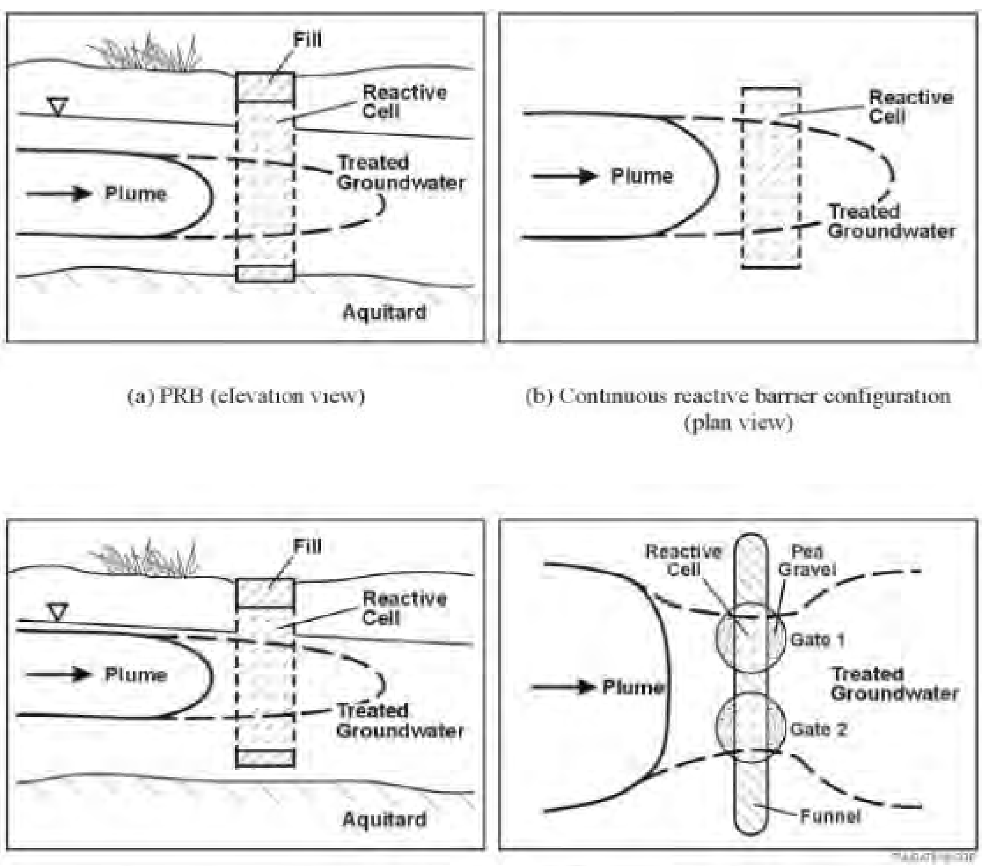
Duplicates will be run on 5% of the samples. Typical runs will consist of blanks, daily calibration check samples, and runs of standard reference materials, when available. Split samples can be provided for analysis upon request.

5.3.4 Establishment of Parameters for PRB Pilot Design

The results of the borehole dilution testing for groundwater flow measurement, the Stage 2 ISM study and the bench-scale column testing will be used to establish rate perchlorate reduction and will be applied to reactive-transport models as described below.

PRB as a treatment technology is a method of mass flux reduction. For the PRB pilot design, it will be necessary to reasonably estimate the mass of reactant that will be needed to treat the mass flux of contaminants. The geologic characteristics in the planned footprint of the area to be treated will also be important in this design. Accordingly, the dosing of amendments, the associated degradation rate and the velocity of groundwater flow through the PRB will be necessary to define for design of the PRB pilot.

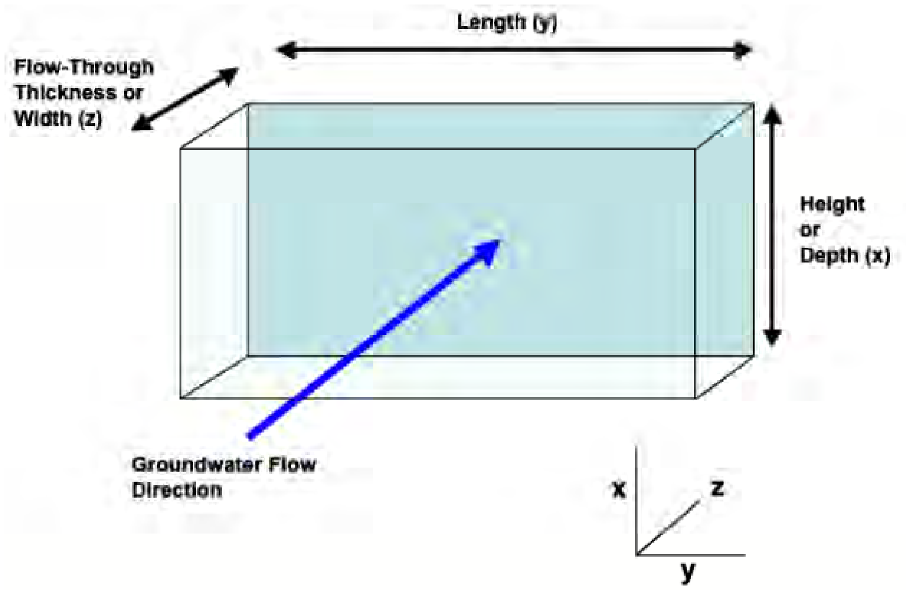
The PRB must be able to intercept the contaminant plume without unacceptable contaminant bypass either below or around the barrier. Additionally, effective remediation using a PRB will depend on the availability of appropriate quantities of reactive media and the geochemical and redox conditions to allow for sufficient constituent degradation. The reactive zone must be large (i.e., in thickness and width) enough to allow the degradation. The thickness of the PRB is designed based on the required residence time of the contaminants and the groundwater flow velocity. The residence time must be sufficient to allow for degradation of the target contaminant(s) to reduce the contaminant flux (ITRC, 2011). A schematic of various PRB configurations and flow through a PRB with the associated PRB dimensions are provided in the below illustrations.



(c) Hanging barrier configuration for shallow plumes (elevation view)

(d) Funnel-and-gate system with two gates (plan view)

Schematic Illustration of Some PRB Configurations (Batelle, 2000).



Schematic of dimensions of a PRB (ITRC, 2011).

5.3.5 Reporting

At the conclusion of the Stage 1 ISM study, a letter report summarizing the results of baseline groundwater sampling, the borehole dilution testing and the Stage 1 study along with a recommendation for candidate amendment(s) for follow-on study will be provided to the NDEP. At the conclusion of the bench-scale column testing, a letter report with the results of the Stage 2 ISM study and the bench-scale column testing will be prepared and submitted to the NDEP.

5.3.6 Final Design and Permitting

Utilizing the results of the Stage 2 ISM study and the bench-scale column testing, a Design Report for the Final PRB Pilot will be prepared and submitted to the NDEP. The Design Report will include the detailed plans and specifications for the pilot construction, along with operation and monitoring plans.

Installation of the PRB pilot will require obtaining a General Permit as a Class V Underground Injection Control (UIC) well, if an injectable amendment is selected. Class V UIC wells are non-hazardous wells that inject fluids above the underground source of drinking water (USDW). The injected PRB would qualify for a general permit under the Nevada regulation NAC 445A.891.

In addition to the Class V UIC permit, the PRB pilot will require an application for a UIC General Permit for Short-Term Remediation. UIC General Permits for Short-Term Remediation only allow for a one-time injection of electron donor amendments, and are valid for a period of less than six months. Longer term operation of the PRB pilot may ultimately be required to fully complete the study objectives. In such a case, application for a UIC General Permit for Long-Term Remediation may be necessary at that time.

The permitting process for either Long-Term or Short-Term Remediation Permits requires the submission of the project work plan, a letter of concurrence, UIC Form 200, Notice of Intent (NOI) Form U210, and the respective fees for each permit. General UIC permits are typically issued within 60 days of submission.

Additional permits may be required for construction and will be identified as part of the final design for the PRB pilot.

6 Monitoring

6.1 Preliminary Groundwater Monitoring Plan for PRB Pilot

Groundwater sampling frequency during the PRB pilot test will be established based on the reaction rates observed in the ISM studies and the bench-scale column testing. From the case study review, a potential sampling frequency could be every 2 weeks for the first 60 days, with the frequency decreasing to a monthly sampling rate after the 60-day mark. This sampling frequency was utilized at the Aerojet General Corporation's site in Rancho Cordova, California and was effective in evaluation of perchlorate removal efficiencies in this application. A monthly sampling frequency, as implemented in the Charleston Naval Weapons Station PRB installation, has been shown to provide sufficient data to demonstrate efficacy of the PRB treatment.

A suite of groundwater sampling parameters envisioned in monitoring the performance of the PRB pilot is provided in Table 6. Baseline sampling would be performed for all of the newly installed monitoring wells, existing monitoring wells, and piezometers identified prior to the installation of the PRB pilot system, and would be sampled quarterly thereafter during operation of the PRB. Based on the results observed, it may be possible to reduce or eliminate certain parameters from the monitoring program. Performance monitoring would be performed based on results obtained and Site conditions. It is currently anticipated to be performed after the installation and commencement of operation of the PRB and monthly thereafter during PRB operations.

6.2 Monitoring Well Locations

A conceptual layout of the monitoring wells and piezometers for the PRB pilot system installation is illustrated on Figure 6. A staggered well layout was selected to provide for monitoring of the groundwater conditions both laterally and downgradient of the PRB pilot system. The illustrated spacing of the monitoring wells was based on an assumed hydraulic conductivity of approximately 35 ft/day and the results of the Northgate bench-scale study that indicated successful perchlorate reductions within 14 days. Existing wells (PC-98R and MW-K5) will also be used to provide information on upgradient groundwater quality and elevations. A monitoring well located within the PRB itself is included to provide information on the geochemistry within the wall and to provide a means to observe signs of potential biofouling. Piezometers are included to monitor for changes in groundwater elevations as impacts to groundwater flow, or reductions in hydraulic conductivity that could signal biofouling of the PRB pilot system.

7 Schedule

A preliminary schedule for implementing the activities presented in this Work Plan is provided on Figure 7. The duration of the ISM studies is based on experience and the time necessary for acclimation of the microflora and for adjustments in dosing rates. Based on the results of the ISM studies and the bench-scale column tests, the design for the PRB pilot would be finalized, along with a schedule for installation and associated plans (e.g., final operations and monitoring plans). A preliminary schedule for construction and operation of the PRB pilot is included in the time schedule of Figure 7; however, the time frame presented may need to be adjusted based on the PRB pilot design.

8 References

AMPAC. 2009. July – September, 2009 Quarterly Performance, UIC, Perchlorate In Situ Bioremediation System, American Pacific Corporation, Henderson, Nevada. October 29.

AMPAC. 2011. Semi-Annual Performance Report: July 1 - December 31, 2010, Perchlorate In Situ Bioremediation System, American Pacific Corporation, Henderson, Nevada. March 22.

Battelle. 2000. Design Guidance for Application of Permeable Reactive Barriers for Groundwater Remediation. Air Force Research Laboratory Tyndall Air Force Base, Florida. Contract No. F08637-95-D-6004. March 31.

CH2MHill. 2010. The Evolution of a Field Application of Nano Scale Zero Valent Iron (nZVI) in a Deep Low Permeability Aquifer. February.

ENVIRON. 2011a. Phase I Environmental Site Assessment of Tronox LLC, Clark County, Nevada. January.

ENVIRON. 2011b. Annual Remedial Performance Report for Chromium and Perchlorate, NERT Site, Henderson, Nevada July 2010 – June 2011. August 26.

ENVIRON. 2012. Semi-Annual Remedial Performance Report for Chromium and Perchlorate, NERT Site, Henderson, Nevada, July 2011 – December 2011. February 29.

Errol L Montgomery & Associates Inc. 2000. Analysis of Rate of Groundwater Movement Based on Results of Tracer and Hydraulic Tests Conducted Between Pittman Lateral and Seep Area Henderson, Nevada. December 19.

ESTCP (U.S. Department of Defense, Environmental Security Technology Certification Program). 2010. Cost and Performance Report (ER-0221), Edible Oil Barriers for Treatment of Chlorinated Solvent and Perchlorate-Contaminated Groundwater. February.

FRTR (Federal Remediation Technologies Roundtable). 2005. Federal Remediation Technologies Reference Guide and Screening Manual, Version 4.0. February 1. Available at: http://www.frtr.gov/matrix2/top_page.html

Higuchi, R., Dollinger, G., Walsh, P.S. and Griffith, R. 1992. Simultaneous amplification and detection of specific DNA sequences. Biotechnology 10:413-417.

ITRC (Interstate Technology & Regulatory Council). 2008. Remediation Technologies for Perchlorate Contamination in Water and Soil. PERC-2. Washington, D.C.: Interstate Technology & Regulatory Council, Perchlorate Team. March. Available at: www.itrcweb.org.

ITRC. 2011. Permeable Reactive Barrier: Technology Update. PRB-5. The Interstate Technology & Regulatory Council, PRB: Technology Update Team. June. Available at: www.itrcweb.org.

Jackson, W. Andrew, M. Jeon, J. H. Pardue, and T. Anderson. 2004. Enhanced Natural Attenuation of Perchlorate in Soils Using Electrokinetic Injection. Bioremediation Journal. 8(1-2):65-79.

Kampell, D.H. and S.A. Vandegrift. 1998. Analysis of Dissolved Methane, Ethane, and Ethylene in Ground Water by a Standard Gas Chromatographic Technique. J. of Chromatographic Sci. 36:253-256.

Kerr-McGee Chemical LLC (KMCC). 2001. Seep Area Groundwater Characterization Report, Henderson Nevada Facility January 18.

NDEP (Nevada Division of Environmental Protection). 2010. Letter to Tronox LLC, Response to Shaw's proposal for demonstration of perchlorate treatment within groundwater using an injected PRB. April 15.

Northgate (Northgate Environmental Management, Inc.). 2010. Work Plan to Conduct In-Situ Permeable Reactive Barrier Pilot Test for Perchlorate-Impacted Groundwater, Tronox LLC, Henderson, Nevada October 25.

Northgate. 2011. Bench-Scale Experiments in Support of an In Situ Permeable Reactive Barrier Pilot Test: Effective Oil Retention, Biological Reduction of Perchlorate, and Metals Mobilization Using Site-Specific Soils and Groundwater, Nevada Environmental Response Trust Site, Henderson, Nevada. March 28.

Pitrak, M., Mares S., and Kobr, M. 2007. A Simple Borehole Dilution Technique in Measuring Horizontal Ground Water Flow. Ground Water. Vol. 45, No. 1, pp 89–92) January–February.

SERDP (U.S. Department of Defense Strategic Environmental Research & Development Program). 2009. "In-Situ Bioremediation of Perchlorate in Groundwater". Springer Science+Business Media, LLC.

Shaw (Shaw Environmental Inc.) 2010. Proposal for Demonstration of Perchlorate Treatment within Groundwater Using an Injected Permeable Reactive Barrier. February 14.

Solutions-IES, Inc. 2008. Final Report, Edible Oil Barriers for Treatment of Chlorinated Solvent and Perchlorate-Contaminated Groundwater, ESTCP Project ER-0221. February.

Tan, K., T.A. Anderson and W.A. Jackson. 2004. Degradation Kinetics of Perchlorate in Sediments and Soils. Water, Air, and Soil Pollution. 151:245-259.

USEPA (United States Environmental Protection Agency). 2006. Contaminated Site Clean-up Information, Technology News and Trends Newsletter, November 2006 Issue. (http://cluin.org/products/newsltrs/tnandt/view.cfm?issue=1106.cfm last accessed August 25, 2012). November.

Tables

TABLE 1
Summary of Work Performed by Others

Date of Study	Type of Study	Performed by	Details of Testing/Observations	Conclusions/Results
12/19/2000	Hydrogeologic	Errol L. Montgomery and Associates Inc.	In 2000, Errol L. Montgomery and Associates Inc. performed an assessment on the siteSite titled ñAnalysis of Rate of Groundwater Movement Based on Results of Tracer and Hydraulic Tests Conducted between Pittman Lateral and Seep Area, Henderson, Nevada (Errol L. Montgomery & Associates, 2000). This assessment was undertaken prior to establishment of the existing GWETS system, therefore the conclusions of the study may not be entirely representative of current hydrogeological conditions. The assessment was undertaken in order to determine the rate of groundwater flow across the Site area which in turn could be used to estimate the rate of perchlorate transport within groundwater across the Site. The assessment comprised three study areas one of which, Area B (near monitoring well MW-K5) being in the area of the proposed PRB field scale trial. . The assessment comprised tracer testing using bromide and deionized water and hydraulic tests.	The assessment determined the following with respect to Area B: ÅRate of groundwater movement was in the range of 30 to 45 ft(ft)/day; and ÅAquifer thickness was 25 ft, transmissivity was 55,000 gallons per day (gpd)/ft and hydraulic conductivity was 2,200 gpd/ft2. The report also noted that the lower parts of the aquifer (i.e.i.e., the alluvium) comprise coarser grained sediments which appear to facilitate more rapid groundwater movement. Specifically, the results of a pump test, performed at monitoring well PC-98R and within the candidate PRB pilot area, wereas reported. The pump test ran for 29.9 hours and the average pumping rate was circa 52 gallons per minute. The results of the pump test were: ÅTransmissivity was circa 60,000 gpd/ft; ÅHydraulic conductivity was estimated at 2,400 gpd/ft2; and ÅStorativity was approximately 0.08 (Errol L. Montgomery & Associates, 2000).
1/18/2001	Seep Groundwater Characterization	Kerr-McGee Chemical, LLC	Work was undertaken to provide supplementary information in the design of the GWETS system. The specific objectives of the assessment were to: ÅDetermine the hydrogeologic regime in the area between the Pittman lateral and the Seep; ÅDetermine the representative perchlorate concentration in the saturated thickness of the alluvial aquifer near the Seep; ÅDetermine if any additional pathways exist along the Las Vegas Wash for other significant perchlorate contribution; ÅDetermine the rate of movement and the residence time for perchlorate and groundwater between the Pittman lateral and the Seep; and ÅDetermine potential groundwater pumping strategies.	The results of the investigation indicated: ÅThe BMI Lower Ponds area (encompassing the Seep) was the only identified groundwater discharge containing significant perchlorate concentrations entering the Las Vegas Wash; ÅIn the Lower Ponds area, the main north/northeast trending alluvial paleochannel coalesces with a second poorly defined paleochannel entering the area from the southwest; ÅIn the Lower Ponds area, where the two paleochannels coalesce, the entire saturated interval of the alluvial aquifer contained perchlorate >10 milligrams per liter (mg/L) over a width of approximately 2,200 feetft; ÅThe COH-RIB facility contributed significant amounts of treated wastewater at random times for random periods of time and directly contributed to daylighting of groundwater in the Lower Ponds area and to wide fluctuations in both the flow volume and perchlorate content of the Seep; and ÅThe rate of movement for groundwater and perchlorate between the Pittman Lateral and the Seep averaged 35 ft/day and the residence time was approximately six months.
2/14/2010	Work Plan for PRB Pilot Testing	Shaw Environmental, Inc.	A Work Plan was prepared to undertake a field-scale trial of a PRB comprising the injection of slow release, edible oil organic substrate (EOSÈ598) into the saturated alluvium overlying the Muddy Creek Formation. . The PRB would be formed using a series of fixed point injection locations installed to a depth of 40 ft bgs.	In an NDEP letter to Shaw dated April 15, 2010), the Department commented that other, pertinent assessments had been carried out in the proposed PRB area employing aquifer tests, natural gradient tracer tests and injected/pump-back tracer tests (Kerr-McGee, 2001 and Errol Montgomery and Associates, 2000) and that these should be considered in justifying the proposed location of the PRB. Shaw did not progress to actually undertaking the field scale trial.
10/25/2010	Emulsion Retention Testing and Bench-Scale Jar Testing	Northgate Environmental Management, Inc.	Northgate produced a Work Plan to conduct an in-situ PRB pilot test for perchlorate impacted groundwater at the Site. The scope of the Work Plan was to perform both laboratory bench-scale testing and a field-scale pilot test. The overall objective of the proposed pilot test was to examine the feasibility of the use of emulsified oil substrate injected into the subsurface as a PRB to degrade perchlorate in the groundwater; the rationale being that PRBs using edible oil-based electron donor substrates have been shown to be effective in remediation of perchlorate contaminated groundwater. Northgate referenced the Provisional Standard for perchlorate set by NDEP of 18 Õg/L as a target for groundwater perchlorate concentrations following treatment by the proposed PRB, the distance from the PRB at which this would be achieved would be dependent upon the results of the field-scale pilot testing. The tests were conducted with the following specific objectives: ÅTo determine the effective retention of EOSÈ 598B42 and lecithin-modified EOSÈ 598B42 emulsified oil onto Site-specific soils; ÅTo chemically analyze the Site soil and groundwater to determine concentrations of metals and competing electron acceptors; ÅTo perform leachability tests on the Site derived soil using deionized water to determine a baseline for adsorbed metals stability; ÅTo establish the change in oxidation-reduction potential by adding EOSÈ 598B42 electron donor substrate to the Site derived soil and groundwater in the presence of indigenous bacteria, perchlorate and competing electron acceptors; ÅTo determine the rate of perchlorate reduction in the test reactors; and ÅTo determine the effect of oxidation-reduction potential on metals stability.	Northgate drilled one borehole in the location of the proposed PBR (I-2) to a depth of 40 ft bgs and recovered both soil cuttings and groundwater from the open borehole for use in the bench scale tests. The untreated groundwater was analyzed for metals and perchlorate concentrations and found to contain 25.7 mg/L perchlorate. Northgate concluded that a maximum effective oil retention ratio of 0.02 g/g for EOSÈ 598B42 and 0.06 g/g for lecithin ï modified EOSÈ 598B42, which exceeded the minimum retention of 0.001 g/g, was required to achieve the pilot test objectives. Batch tests were then undertaken to assess the behavior of metals when the soil, saturated with groundwater was exposed to EOSÈ 598B42 in the presence of perchlorate and competing electron acceptors. Northgate concluded that the addition of EOSÈ 598B42 stimulated indigenous bacteria to anaerobically biodegrade perchlorate without significant mobilization of arsenic. The additon of 2 to 4 milliliter (mL) of EOSÈ 598B42 per liter of groundwater led to removal of perchlorate to below the laboratory reporting limit within 14 days. Northgate asserted that the evolution of dissolved arsenic would not be expected to occur in the field due to a constant flux of dissolved oxygen, nitrate, chlorate and perchlorate entering the PRB, a condition that was not possible to be created in the jar testing that was performed. Northgate did not progress to a field-scale trial of a PRB.

TABLE 2
Well Construction Details for Existing Wells

Monitoring Well ID	Well Diameter (inches)	Drilling Method	Well Material	Screened Zone	Date Completed	Total Depth (feet bgs)	Screen Depth (feet bgs)
MW-K5	2	Unknown	Unknown	28.5-43.5	4/2/1998	43.5	28.5
PC-100	2	Hollow Stem Auger	PVC	8.5-38.5	5/18/2000	39	8.5
PC-100R	2	Unknown	PVC	15-40	8/16/2000	40.5	15
PC-103	2	Unknown	PVC	9-29	2/3/2001	29.5	9
PC-2	2	Hollow Stem Auger	PVC	16.7-31.7	3/13/1998	32	16.7
PC-53	2	Hollow Stem Auger	PVC	13-32.5	5/4/1998	33	13
PC-98	4	Hollow Stem Auger	PVC	13.5-33	5/17/2000	33.5	13.5
PC-98R	4	Unknown	PVC	20-35	8/8/2000	40.5	20
PC-1	2	Hollow Stem Auger	PVC	14.7-29.7	3/24/1998	32	29.7
PC-4	2	Hollow Stem Auger	PVC	17.7-42.7	3/24/1998	45	42.7

TABLE 3
Summary of Ground Water Indicator Parameters
Vicinity of Candidate PRB Pilot Test Location

	Well	Water Level (ft msl)	Chlorate (mg/L)	Nitrate (mg/L)	Sulfate (mg/L)	DO (mg/L)	ORP (mV)	pH (s.u.)	TOC (ug/L)	Alkalinity (ug/L as $CaCO_3$)	Perchlorate (mg/L)	TDS (mg/L)	Cr Total (mg/L)
NORTH OF BARRIER WALL	M-98	184	25	9.4	0.3418	2.6 as N	1100		7.4 to 8	474	2473		
	M-100	79.6 to 92.9	85 to 108	94	.3418 to 3.4	12.85 as N	3520		7.1 to 8	474	2473		
	M-155		1.94	86.1	8.07								
	Regional Values**		<100 to 500	<25 to 50		0.1 ï 1	-100 to 100				100 to 250	5000	.1 to 1
NEAR PRB LOCATION	MW-K5	1567.11	23	13							22	7400	0.053
	PC-103	1575.62	2.3	5.8							18	5200	<0.01
	PC-98R	1570.46									26	7200	0.054
	PC-53	1568.43									3.3	4900	0.046
	PC-2	1572.47	18	13				7.4			3.35	5100	0.0075
	Regional Values**		10 to 50	5 to ~10							1 to 20	5000	.02 to .05
SOUTH OF PRB LOCATION	ARP-4A	1587.04									27	4600	0.013
	ARP-5A	1583.73									22	6600	0.068
	ARP-6B	1583.62									31	9500	0.18
	ARP-7	1583.26									4.9	6700	0.038
NORTH OF PRB LOCATION	PC-56	1554.52									16	5200	0.1
	PC-58	1554.01									6.9	6100	0.085
	PC-59	1554.92									7.3	4000	0.034
	PC-60	1554.86									7.3	3400	0.032
	PC-62	1555.38									2.6	3400	0.0083
	PC-68	1555.87									0.58	2500	0.045

Notes:

Chlorate & nitrate data is taken from ENVIRONõs 2011 Annual performance Report

Cr and TDS values are from the ENVIRON 2012 annual report

Highest concentrations over sampling period are presented

**Interpreted from map isoconcentration lines

ENVIRON

TABLE 4
Summary of Ground Water Quality Results
(Northgate, December 2010)

Parameter	Units	Results
Dissolved Metals		
Antimony	mg/L	< 0.005
Arsenic (tot)	mg/L	0.034
Arsenc (recoverable)	mg/L	0.0378
Arsenic (III)	mg/L	< 0.000074
Arsenic (V)	mg/L	0.0319
Beryllium	mg/L	< 0.004
Cadmium	mg/L	< 0.005
Chromium (total)	mg/L	< 0.005
Chromium (VI)	mg/L	< 0.001
Copper	mg/L	< 0.01
Iron (tot)	mg/L	1.6
Iron (II)	mg/L	0.11
Lead	mg/L	< 0.005
Mercury	mg/L	< 0.001
Nickel	mg/L	0.014
Selenium	mg/L	0.01
Silver	mg/L	< 0.005
Thallium	mg/L	< 0.002
Zinc	mg/L	< 0.1
Anionic Species and Other Parameters		
Chloride	mg/L	2200
Chlorate	mg/L	28
Perchlorate	mg/L	25.7
Nitrate	mg/L	8.1
Sulfate	mg/L	1400
Sulfide	mg/L	< 0.1
DO	mg/L	8.5
DOC	mg/L	4.4
ORP	mg/L	146
pH	mg/L	7.42

ENVIRON

TABLE 5
Summary of Selected PRB Case Studies

Site Name	Technology	Hydraulic Details	Location	Contaminants	Pilot/Full Scale	Cost	Performance	Longevity
Unidynamics Phoenix Inc	Nano Scale Zero Valent Iron injection	Deep injection	Goodyear, AZ	TCE, perchlorate	In field pilot test	N/A	Experienced TCE rebound; hydrogen concentrations increased	N/A
Aerojet General Corporation	In situ horizontal flow treatment barrier wells using citric acid for electron donor to stimulate bioremediation	Used recirculation of water from Deep Aquifer Region to shallower aquifer region back to Deep. Hydraulic conductivity of 15 ft/day Injections occurred from 46-61 ft bls for upper section, and 80-100 ft bls for lower section	Rancho Cordova, CA	Perchlorate impacted groundwater (co-contaminants include nitrate and TCE). There were concerns about mobilizing Mn and Fe.	In field pilot / demonstration scale test	Capital: $403,205 O&M for 30 yrs: $784,944 Long term monitoring: $271, 342	Perchlorate concentrations decreased an average 95% from start to Day 275. Shallow well perchlorate concentrations went from 2230 µg/L to 90 µg/L. Deep well perchlorate concentrations decreased from 3722 µg/L to 1780 µg/L. Mn and Fe were not mobilized. Showed rebound of perchlorate between phased operations.	Long term operation is feasible
Alliant Techsystems, Inc	Emulsified Oil Substrate (EOS) Biobarrier	Shallow injections (15 bgs). 50 feet wide GW flow velocity = 100 ft/year, Ground permeability = 29 ft/day	Elkton, MD	Perchlorate and chlorinated solvents	In field pilot study	A 200 ft PRB estimated at $38,000 or $19/ft.	Perchlorate concentrations reduced from 9,000 µg/L to <4 µg/L. No rebound of perchlorate noted after initial injection 2.5 years later. Hydraulic conductivity reduced potentially due to biomass growth.	Effectiveness of barrier lasted 2.5 to 3.5 years
Naval Weapons Industrial Reserve Plant	Biobarrier (mushroom compost, pine wood chips, soybean oil, and 1" crushed limestone) with injected emulsified oil substrate (EOS) solution	Shallow	McGregor, TX	Perchlorate contaminated ground water	Full scale	$200/ft^2 per linear foot, or less than $15 per linear foot	Reduced perchlorate concentration from 1,000 µg/L to <2 µg/L	N/A

TABLE 5
Summary of Selected PRB Case Studies

Site Name	Technology	Hydraulic Details	Location	Contaminants	Pilot/Full Scale	Cost	Performance	Longevity
Whiteman AFB	Biobarrier (organic mulch and clean sand)	Shallow (10 to 20 ft deep)	Near Kansas City, MO	CVOCs, primarily TCE (groundwater contaminants)	Full Scale	Total $74,000 or $275/linear foot, less than $20 per vertical foot	Monitoring shows CVOC degradation within the biobarrier, CVOC concentrations in downgradient wells are 88% lower than in upgradient wells	Continued to show effective treatment after 2 years of operation
Confidential Industrial Site research funded by ESTCP	Emulsified oil (EOS) injected to form a Permeable Reactive Barrier (PRB)	Shallow (10 ft deep, 10 ft wide, 50 ft long). Shallow hydraulic gradient of 0.003 ft/ft, hydraulic conductivity averaged between 22 to 40 ft/day. Assuming 30% porosity, ground water velocity was approximately 80 ft/year. Average GW velocity in specific test area calculated to be 400 ft/year.	Eastern Maryland	Perchlorate and TCE plume	Pilot	$226/cu yd of $8.39 cu ft Full scale PRB at the site estimated at $38,000, or $0.02/gal treated 30 yr life cycle cost estimated at $161,400	Dissolved iron increased from non-detect to a maximum of 78 mg/L, manganese also increased. Perchlorate rebound experienced 4 months after injection, but concentrations continued to decrease for 7 more months. Average removal efficiency of perchlorate was 97% (reduced from 10,000 µg/L to <4 µg/L) 10' downgradient of injection wells.	At least 3.5 years (monitoring ended after 3.5 years)
Charleston Naval Weapons Station	EOS injection, plus Vitamin B-12. 28 months after initial injection, a buffered EOS was injected.	Shallow (10 ft deep), used a small grid configuration Aquifer between 0.5 ft and 6 ft bgs Hydraulic conductivity of surficial aquifer 1 to 10 ft/day	Goose Creek, S.C.	TCE	Pilot	$325/ cu yd for direct injection; $428/ cu yd for a recirculation design	Ground water was oxidative, determined this is not optimal for biodegradation. TCE was reduced by 76 to 86% lower through test cell groundwater than in background groundwater. TCE reduced by up to 96% to 99% after buffered EOS injection.	Initial injection treatment continued to work for at least 28 months, second injection treatment prolonged treatment out to 3.5 years (end of monitoring)
Naval Surface Warfare Center	Recirculation treatment using sodium lactate as electron donor, with a sodium bicarbonate buffer	Average hydraulic conductivity of 5.2 ft/day and 2.7 ft/day in Mainland an dLittoral zones	Indian Head, MD	Perchlorate	Pilot	30 year total cost $2,243,853 including monitoring. First year cost $311,837	Reduced from 170,000 µg/L to below detection (5 µg/L)	Biobarrier can be continually replenished by sodium lactate injection; study lasted 20 weeks

TABLE 5
Summary of Selected PRB Case Studies

Site Name	Technology	Hydraulic Details	Location	Contaminants	Pilot/Full Scale	Cost	Performance	Longevity
Confidential Industrial Site	Hardwood mulch biowall with pea gravel to reduce compaction (a 50/50 mix) (in situ passive permeable reactive barrier)	PRB installed to a depth of 25 ft bgs to target the permeable gravel zone at that depth. Ground water flow velocity of 25 to 51 ft/year.		Perchlorate (impacted soil and groundwater)	Full scale	Used one pass trenching, cost $185/linear foot	Perchlorate reduction seen at least 15 ft downgradient of the PRB. Ferrous Iron measurements increasing since install; reducing conditions have developed. Perchlorate concentrations immediately downgradient or PRBT reduced to non-detect (<4 µg/L) from a range of 8,000 to 13,000 µg/L	Documented operation of 2.5 years, anticipated to work as an effective barrier for “at least the next 3 – 4 years”
Grain Silo Facility Kansas	EHC injection from Adventus	Ground water table encountered at 23 ft bgs Ground water velocity averages 1.8 ft/day	Kansas	Carbon tetrachloride and its catabolites	Pilot	$37/ft^2	Carbon tetrachloride was reduced by up to 99.5%; initial concentration was 1,000 ppb, final concentration measured was 5 ppb	Documented operation of over 4 years with continuous removal of carbon tetrachloride at or over 94%

References:

- Environmental Protection Agency November 2006, Technology News and Trends.
- Environmental Alliance December 2006, Application of Mulch Biowall for Anaerobic Treatment of Perchlorate in Shallow Groundwater.
- Shaw Environmental July 2009, In Situ Bioremediation of Perchlorate in Groundwater.
- CH2MHill February 2010, The Evolution of a Field Application of nano Scale Zero Valent Iron (nZVI) in a Deep Low Permeability Aquifer.
- Solutions-IES February 2010, Edible Oil Barriers for Treatment of Chlorinated Solvent and Perchlorate-Contaminated Groundwater.
- Solutions-IES July 2010, Evaluation of Potential for Monitored Natural Attenuation of Perchlorate in Groundwater (Indian Head).

TABLE 6
Analytical Parameters PRB Monitoring - PRB Pilot

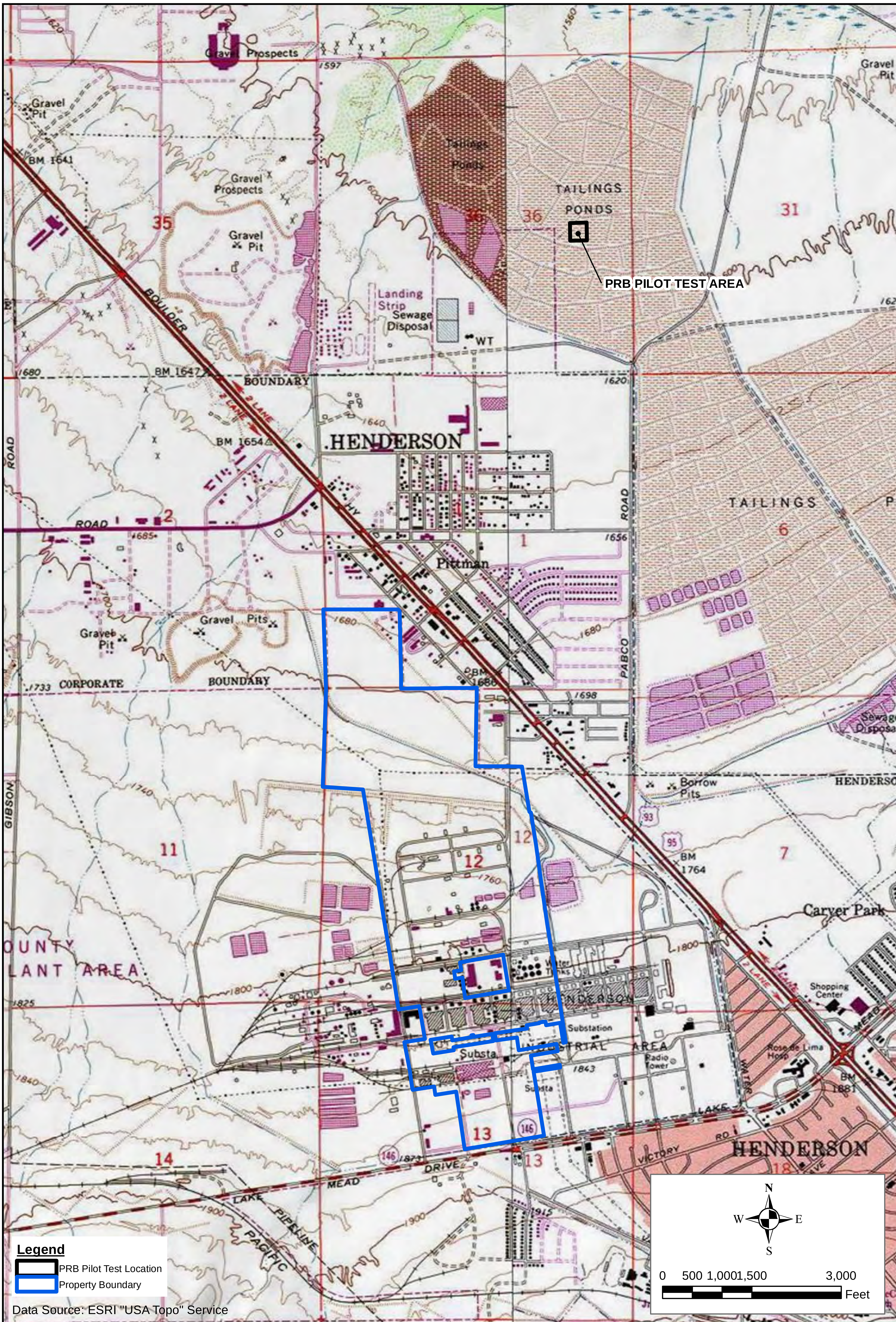
Baseline and Quarterly Sampling Parameters

Parameter	Method
Temperature, pH, Conductivity, DO and ORP	Portable field instrument
Groundwater elevation	Portable field instrument
Turbidity	USEPA Method 180.1
Total Organic Carbon (TOC)	USEPA Method 415.1
Dissolved Organic Carbon (DOC)	USEPA Method 415.1
Total Nitrogen	USEPA Method 351.1
Total Phosphorous	USEPA Method 365.1
Alkalinity	USEPA Method 310.2
Hardness	USEPA Method 130.1
Total Dissolved Solids (TDS)	USEPA Method 160.1
Perchlorate	USEPA Method 314
Chlorate / Chlorite	USEPA Method 300.1
Chloride	USEPA Method 300.0
Dissolved Metals (Ag, As, B, Ba, Be,Ca, Cd, Cr, Co, Cu, Fe, Hg, K, Mo, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, Zn), and U)	USEPA Methods 6010/6020/7400/200.8
Ferrous and Ferric Iron	HACH Method 8008 and 8147
Nitrate / Nitrite	USEPA Method 300.0
Sulfate	USEPA Method 300.0
Sulfide	HACH Method 8131 (USEPA Methylene Blue Method
Methane	

Parameters for Performance Monitoring

Parameter	Method
Temperature, pH, Conductivity, DO and ORP	Portable field instrument
Groundwater elevation	Portable field instrument
Perchlorate	USEPA Method 314
Chlorate / Chlorite	USEPA Method 300.1
Chloride	USEPA Method 300.0
Arsenic	USEPA Method 200.8
Iron	USEPA Method 236.1/236.2
Total Organic Carbon (TOC)	USEPA Method 415.1
Nitrite / Nitrate	USEPA Method 300.0
Sulfate	USEPA Method 300.0
Sulfide	HACH Method 8131 (USEPA Methylene Blue Method
Volatile Fatty Acids	Method SW8015 Modified
Hexavalent chromium	USEPA Method 7199

Figures



L:\Loop Project Files\00_CAD FILES\21\Lepet XXVII NERT Remediation 21-29100H\GIS\MXDs\PRB_Work_Plan\Figure1_Site_Basemap.mxd

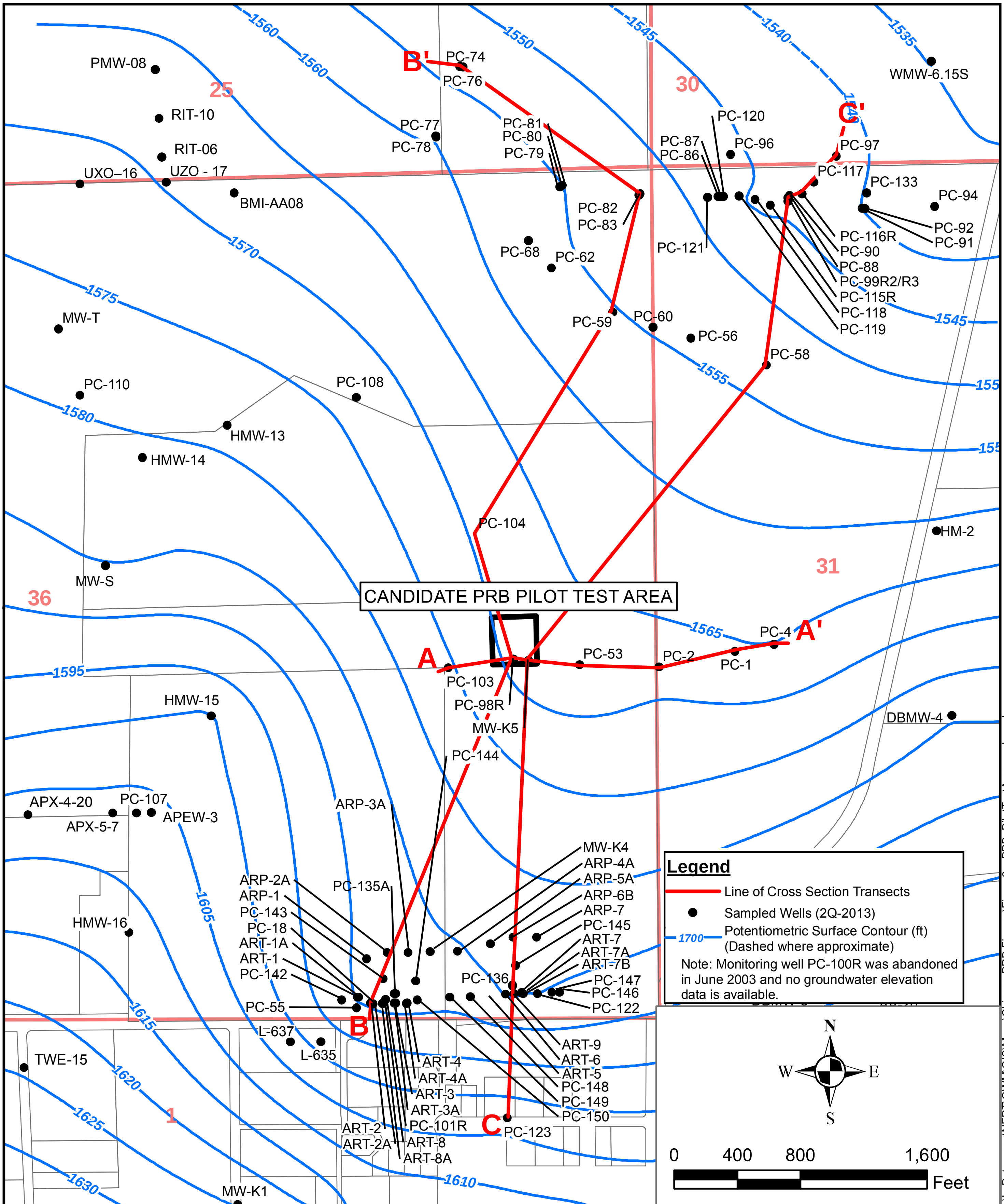
ENVIRON

SITE LOCATION MAP

Nevada Environmental Response Trust Site, Henderson, Nevada

Figure **1**

Drafter: CCS	Date: 8/9/2012	Contract Number: 21-29100H	Approved by:	Revised:



C:\LePetomane\NERT\GWM\GIS\Maps\Chicago PRB Figures\Figure2a_PRB_PilotTestArea_mpk.mxd

ENVIRON

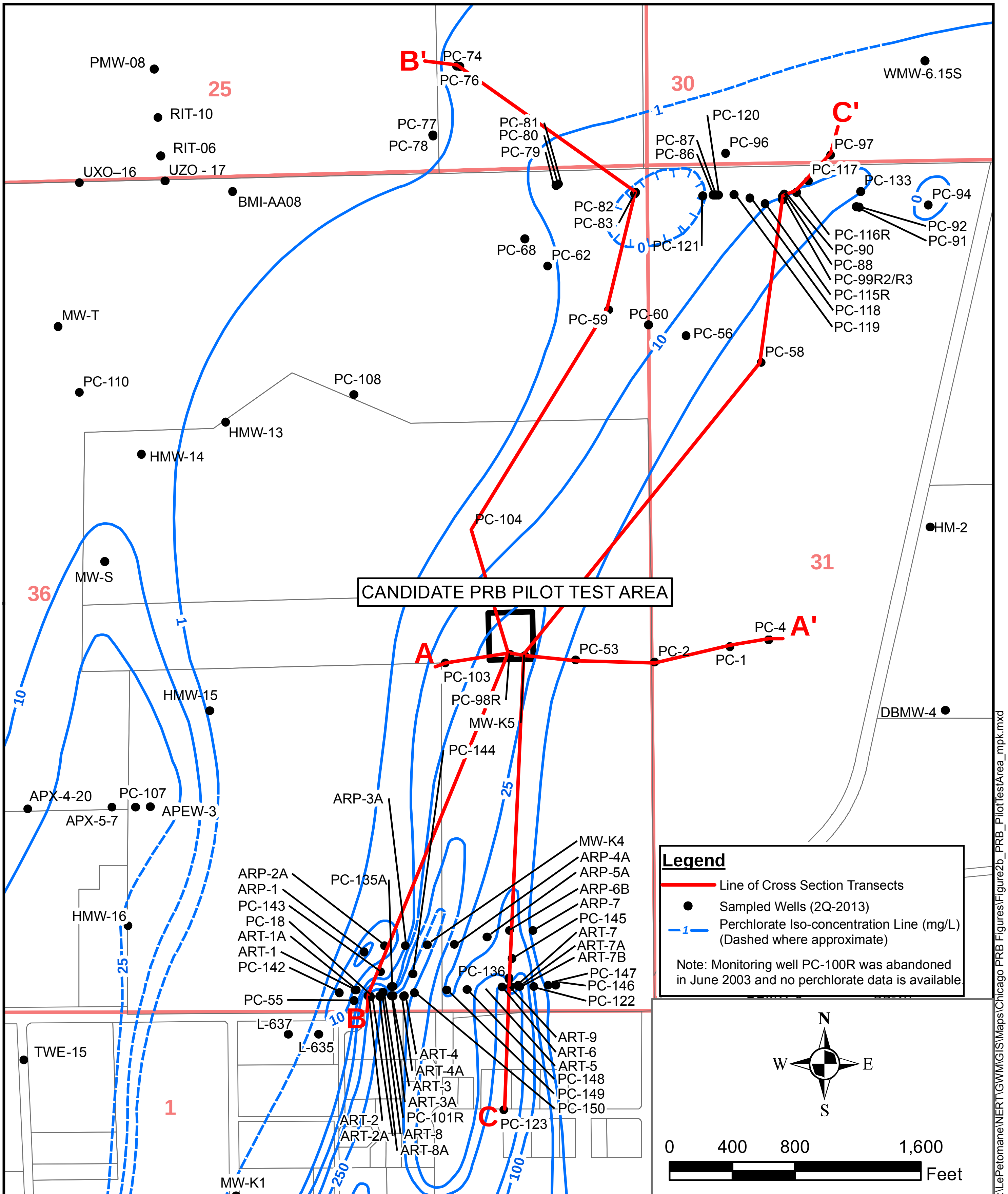
PROPOSED PRB PILOT TEST LOCATION

Potentiometric Surface Map

Nevada Environmental Response Trust Site, Henderson, Nevada

Figure **2a**

Drafter: EA | Date: 11/15/2013 | Contract Number: 21-29100H | Approved by: BSK | Revised:

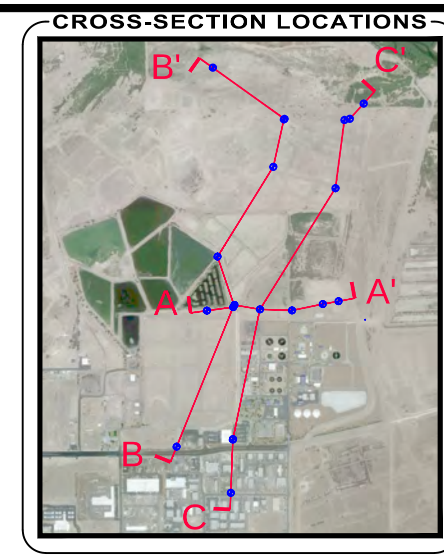


ENVIRON

PROPOSED PRB PILOT TEST LOCATION
Groundwater Perchlorate Iso-concentrations
Nevada Environmental Response Trust Site, Henderson, Nevada

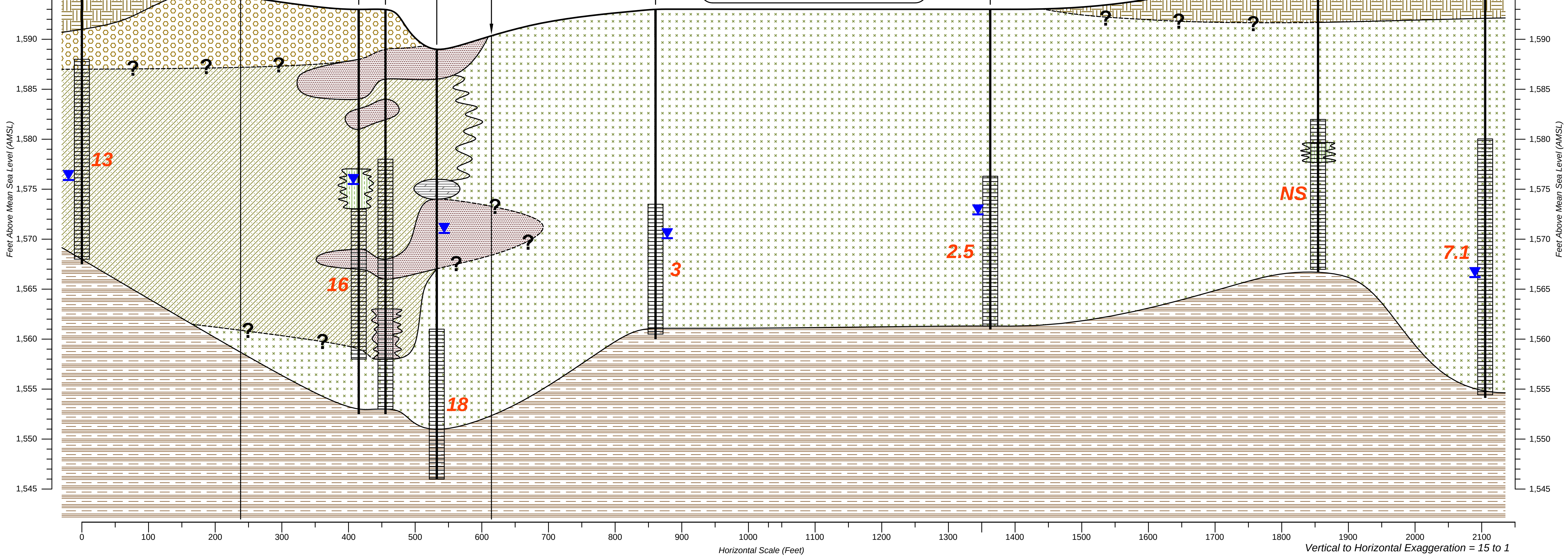
Figure
2b

Drafter: EA | Date: 11/15/2013 | Contract Number: 21-29100H | Approved by: BSK | Revised:



Notes:

1. Perclorate concentration in mg/L.
2. Groundwater levels and perchlorate concentrations for PC-1, PC-2, and PC-4 were collected on May 3, 2011.
3. Groundwater levels and perchlorate concentrations for PC-103, PC-98R, MW-K5, and PC-53 were collected on December 13, 2011.
4. PC-1 was dry and no sample was collected.
5. PC-100R was abandoned in June 2003, and, thus, groundwater levels and perchlorate concentrations are not available.
6. Groundwater levels and perchlorate concentrations are from Appendix A in the *Semi-Annual Remedial Performance Report for Chromium & Perchlorate*, February 2012.
7. Lithology and well construction details from site boring logs and are included in Appendix A.



LEGEND

- MONITORING WELL
- WATER LEVEL
- WELL SCREEN
- 2.5 — PERCHLORATE SAMPLE (mg/L)

FILL | GRAVELLY SAND | SAND | SILTY SAND / GRAVEL | GRAVEL / SANDY GRAVEL | SANDY CLAY | CALICHE | SILTY CLAY

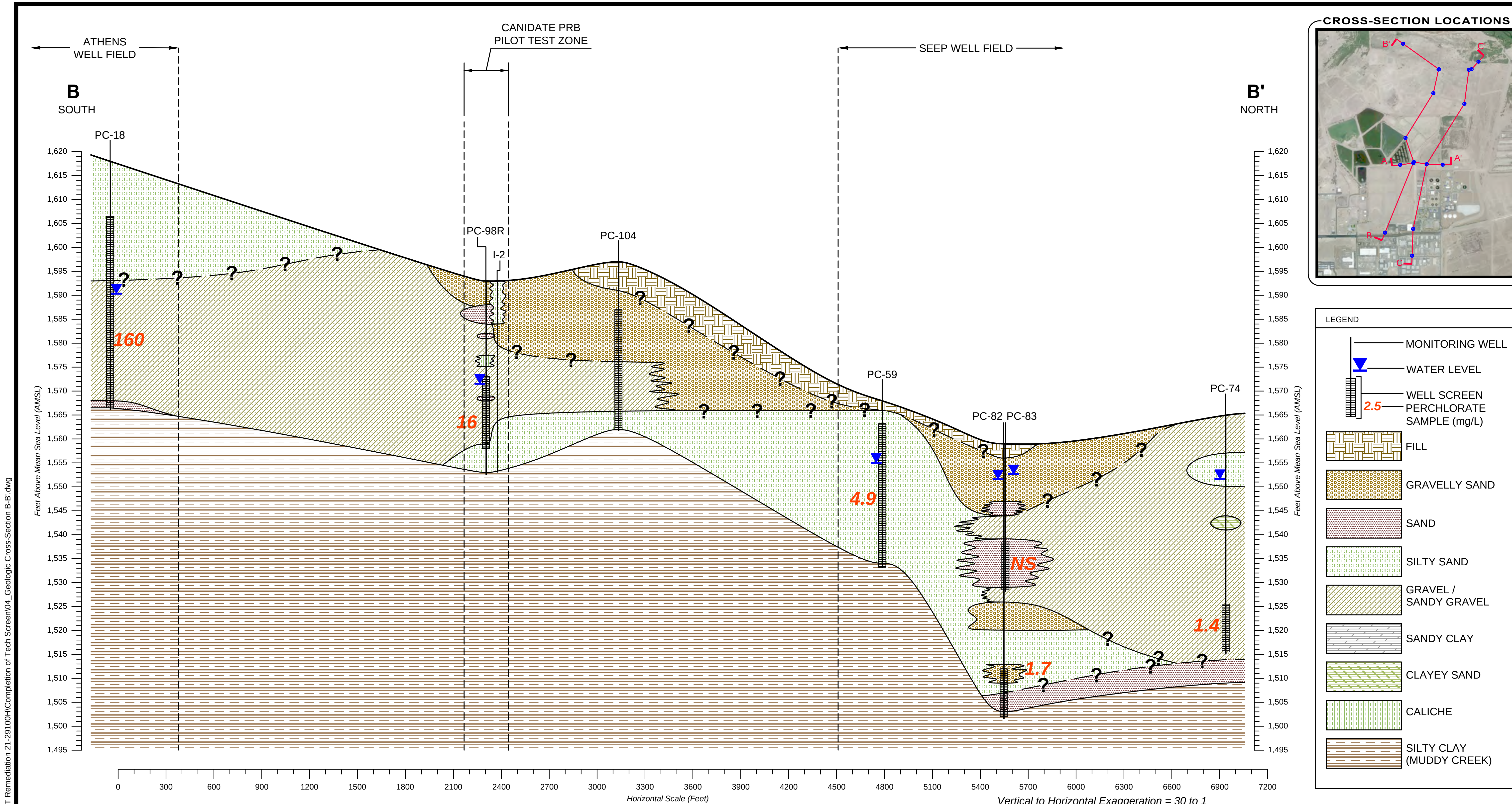
CROSS-SECTION A - A'
NEVADA ENVIRONMENTAL RESPONSE TRUST
HENDERSON, NEVADA

ENVIRON

FIGURE 3

DRAFTED BY: ELS | DATE: 11/15/13 | 21-9100I

L:\Loop Project Files\00_CAD FILES\21\LePet XXVII NERT Remediation Investigation 21-32100\03_Cross-Section A-A'.dwg



Notes:

1. Perclorate concentration in mg/L.
2. Groundwater levels and perchlorate concentrations for PC-74, PC-82, and PC-83 were collected on May 2-3, 2011.
3. Groundwater levels and perchlorate concentrations for PC-18, PC-59, and PC-98R were collected on December 12-13, 2011.
4. No sample was collected at PC-83.
5. Groundwater level perchlorate concentration not available for PC-104.
6. Groundwater levels and perchlorate concentrations are from Appendix A in the *Semi-Annual Remedial Performance Report for Chromium & Perchlorate*, February 2012.
7. Lithology and well construction details from site boring logs and are included in Appendix A.

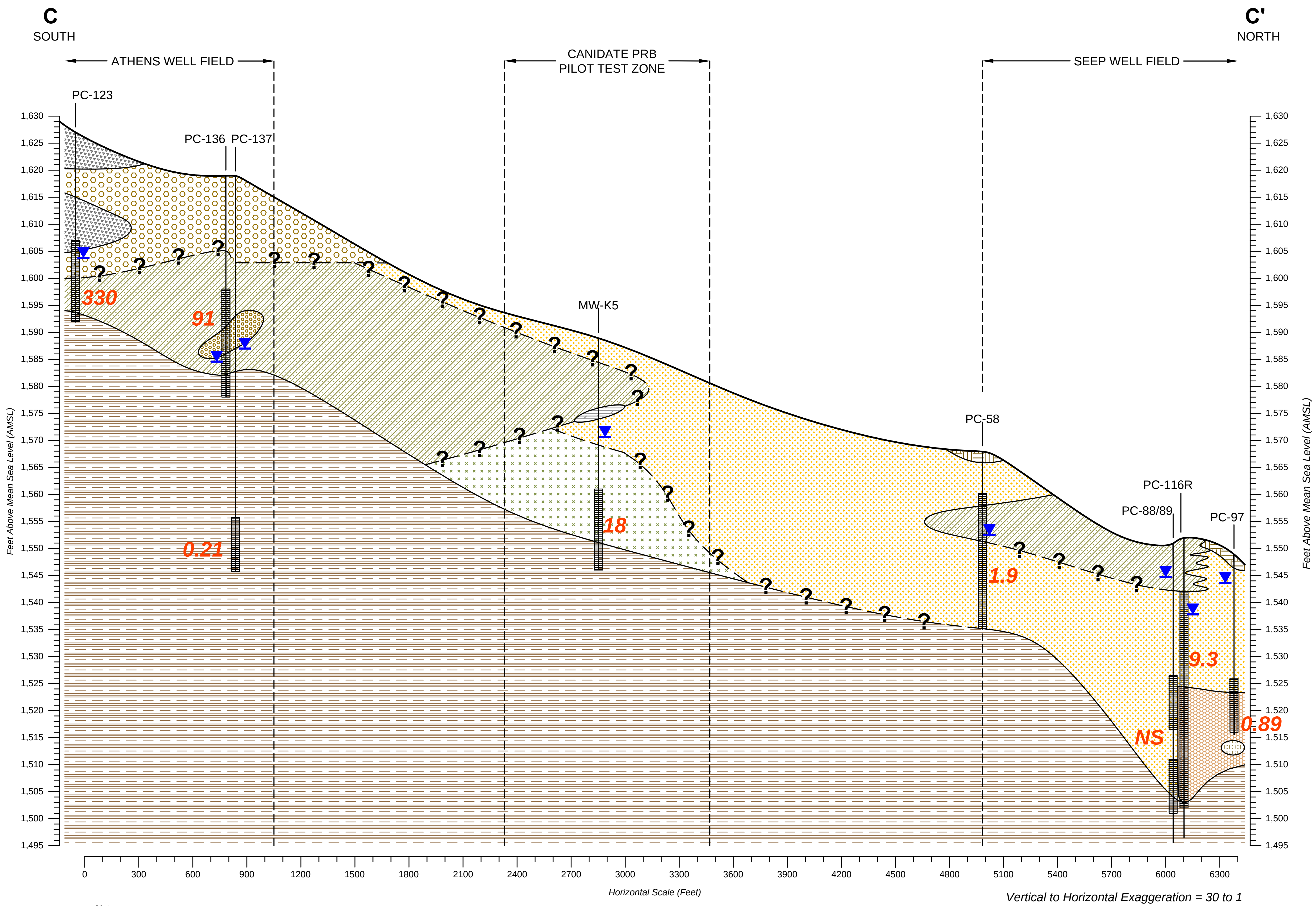
L:\Loop Project Files\00_CAD FILES\21\Lepet XXVII NERT Remediation 21-29100H\Completion of Tech Screen\04_Geologic Cross-Section B-B'.dwg

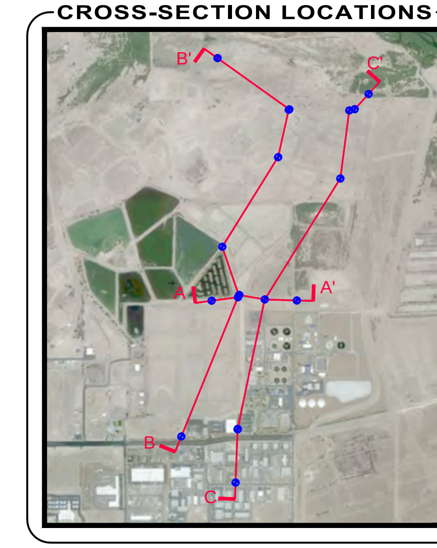
GEOLOGIC CROSS-SECTION B - B'
NEVADA ENVIRONMENTAL RESPONSE TRUST
HENDERSON, NEVADA

ENVIRON

FIGURE 4

DRAFTED BY: ELS | DATE: 12/4/13 | 21-9100H





Notes:

1. Perclorate concentration in mg/L.
2. Groundwater levels and perchlorate concentrations for PC-88 were collected on May 2, 2011.
3. Groundwater levels and perchlorate concentrations for PC-123, PC-136, and PC-137 were collected October 31-November 1, 2011.
4. Groundwater levels and perchlorate concentrations for MW-K5, PC-97, and PC-116R were collected December 5-31, 2011.
5. No sample was collected at PC-88.
6. Groundwater levels and perchlorate concentration not available for PC-89.
7. Groundwater level perchlorate concentrations are from Appendix A in the *Semi-Annual Remedial Performance Report for Chromium & Perchlorate*, February 2012.
8. Lithology and well construction details from site boring logs are included in Appendix A.

GEOLOGIC CROSS-SECTION C - C'

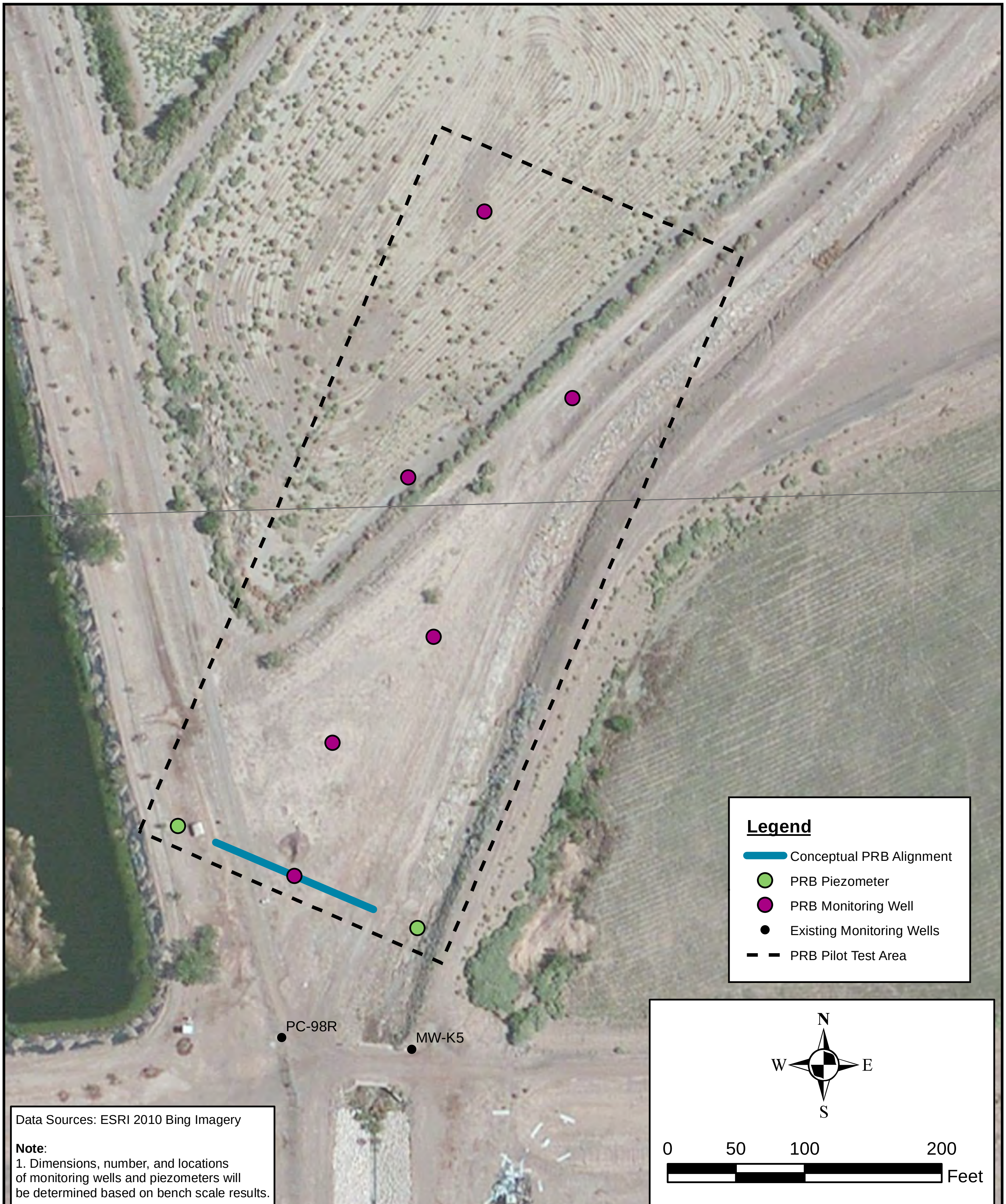
NEVADA ENVIRONMENTAL RESPONSE TRUST
HENDERSON, NEVADA

ENVIRON

FIGURE 5

DRAFTED BY: ELS | DATE: 12/4/13 | 21-29100H

L:\Loop Project Files\00_CAD FILES\21\Lepet XXVII NERT Remediation 21-29100H\Completion of Tech Screen\05_Geologic Cross-Section C-C'.dwg



L:\Loop Project Files\00_CAD FILES\21\Lepet XXVII NERT Remediation 21-29100H\GIS\MXDs\PRB_Work_Plan\Figure4_ConceptualLayoutPilotScalePRB_r3.mxd

ENVIRON

CONCEPTUAL LAYOUT OF PILOT SCALE PRB

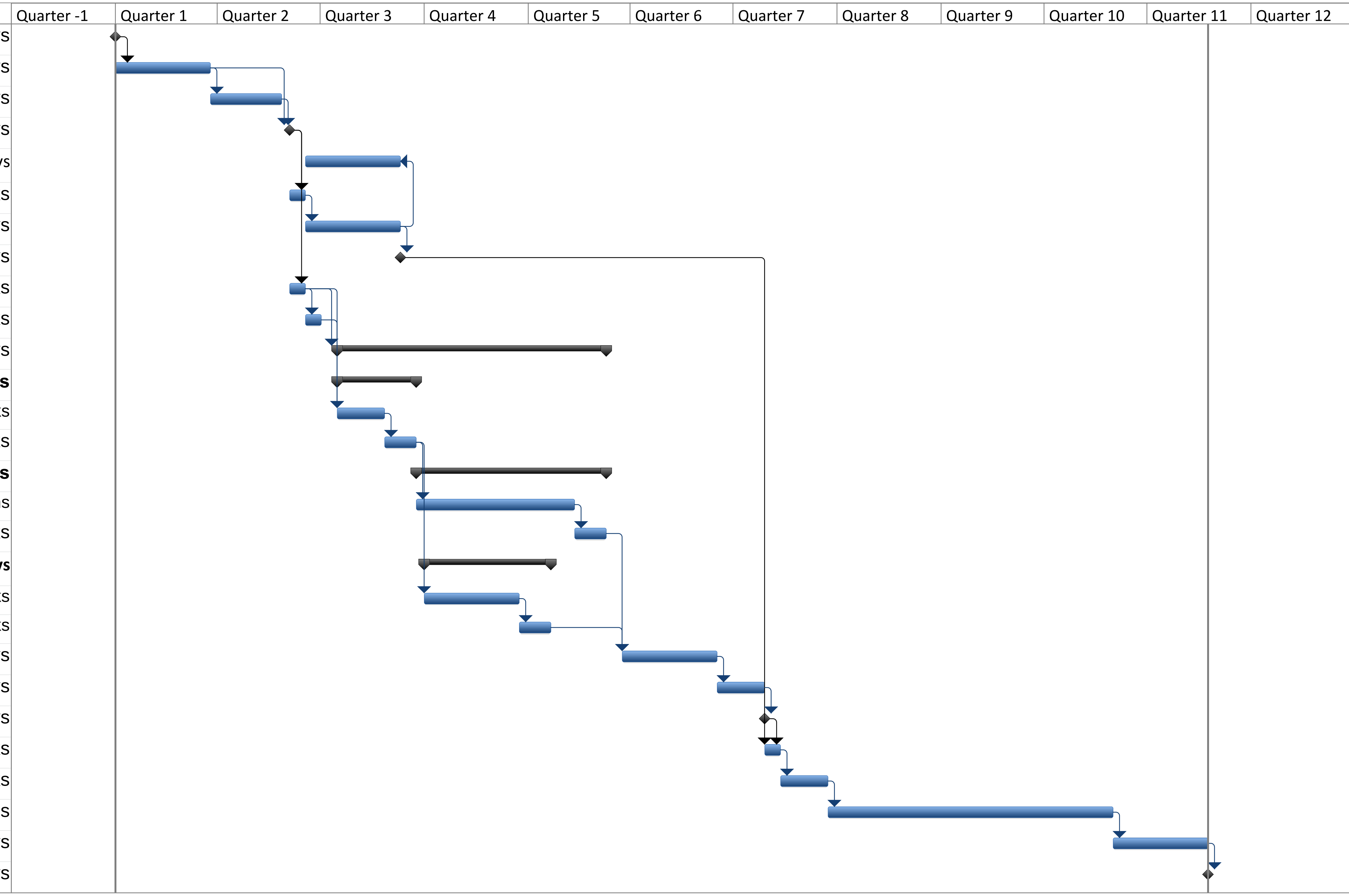
Nevada Environmental Response Trust Site, Henderson, Nevada

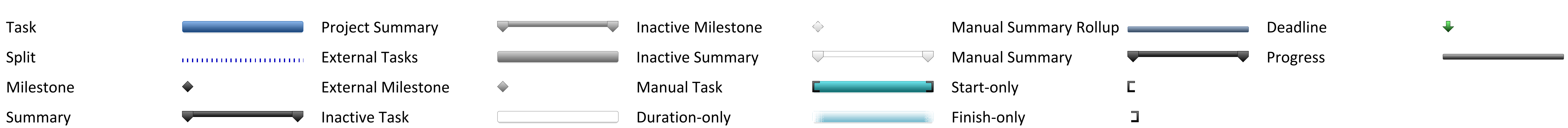
Figure **6**

Drafter: CCS | Date: 9/4/2012 | Contract Number: 21-29100H | Approved by: | Revised:

Figure 7. Preliminary Time Schedule for PRB Treatability Study

ID	Task Name	Duration
1	Work Plan Submittal to NDEP	0 days
2	NDEP Review	60 days
3	Respond to NDEP Comments/Finalize Work Plan	45 days
4	NDEP Approval of Work Plan	0 days
5	Coordination for Access with City of Henderson	60 days
6	Prepare and Submit UIC General Permit Application	2 wks
7	NDEP Review UIC General Permit Application	60 days
8	NDEP Issuance of UIC General Permit	0 days
9	Preliminary Field Activities	2 wks
10	Single Well Dilution Testing	2 wks
11	In-Situ Microcosm (ISM) Studies	170 days
12	ISM Stage 1	**50 days**
13	ISM Stage 1 Study (minimum incubation of 4 weeks)	6 wks
14	ISM Stage 1 Analysis and Reporting	4 wks
15	ISM Stage 2	**120 days**
16	ISM Stage 2 Study (estimated at 3 to 5 months)	5 mons
17	ISM Stage 2 Analysis and Reporting	4 wks
18	Bench-Scale Study	**80 days**
19	Laboratory Column Testing (estimated at 8 to 12 weeks)	12 wks
20	Data analysis and Reporting	4 wks
21	Finalize Field-Scale Pilot Design	60 days
22	NDEP Review Final Field-Scale Pilot Design	30 days
23	NDEP Approve Final Field-Scale Pilot Design	0 days
24	Mobilization for Construction of Field-Scale Pilot	2 wks
25	Construction of Field-Scale Pilot	6 wks
26	Field-Scale Pilot Operations	9 mons
27	Prepare Treatability Study Report of Field-Scale Pilot	60 days
28	Submit Treatability Study Report to NDEP	0 days





Appendix A

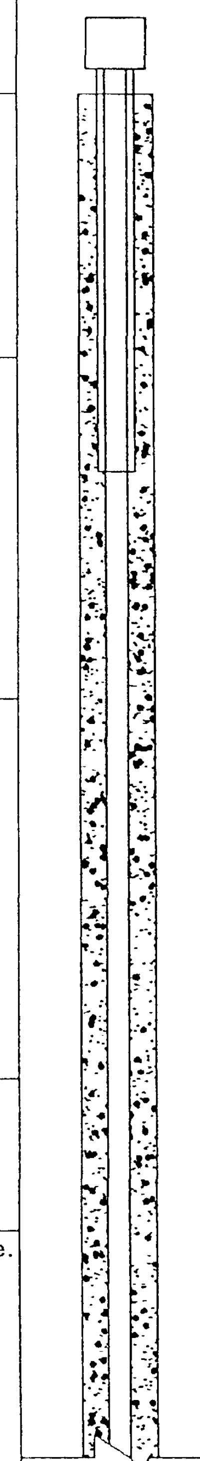
Boring Logs and Well Construction Diagrams

EXPLORATION LOG
MW-K5

CONFIDENTIAL

OJECT: FORMER PEPCON FACILITY
PROJECT NO.: 97664V1
LE LOCATION: SEE SITE PLAN
EXPLORATION DATE: 4-2-98
EXPLORATION SIZE (diameter): 2" MONITORING WELL
EQUIPMENT: MOBILE B-61-HDX
G.S. ELEVATION: 1592.49
LOGGED BY: S. JOHNSON

INITIAL DEPTH TO WATER: 24
DATE MEASURED: 4-2-98
FINAL DEPTH TO WATER: 18.7
DATE MEASURED: 4-3-98

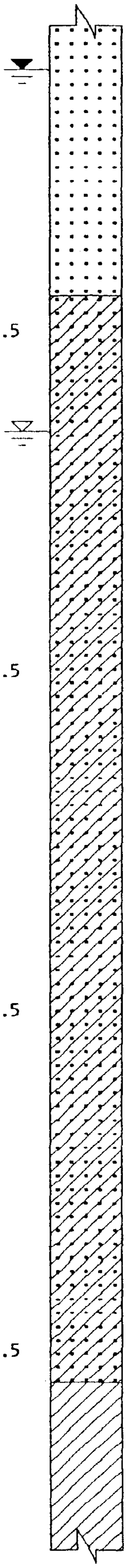
LEVATION/ DEPTH	SOIL & SAMPLE SYMBOLS	USCS	DESCRIPTION	WELL CONSTRUCTION
1592.5 — 0 1590 — 2.5		F	Dark brown poorly graded sand with silt, moist and dense.	
587.5 — 5 1585 — 7.5		F	Dark brown poorly graded gravel with clay and sand, moist and dense. ...black with organic material to 8.0	
582.5 — 10 1580 — 12.5		GP-GC	Dark brown poorly graded gravel with clay and sand, moist and dense.	
		CL	Dark brown sandy lean clay, moist and very stiff.	
577.5 — 15 1575 — 17.5		SP	Dark brown poorly graded sand, moist to very moist and very dense. ...groundwater encountered, medium dense to 22.0	

EXPLORATION LOG
MW-K5

CONFIDENTIAL

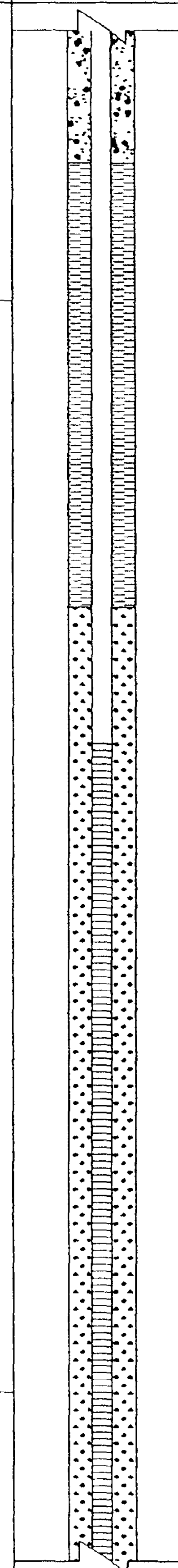
ELEVATION/ DEPTH	
1572.5	20
1570	22.5
1567.5	25
1565	27.5
1562.5	30
1560	32.5
1557.5	35
1555	37.5
1552.5	40

SOIL & SAMPLE SYMBOLS



USCS	DESCRIPTION
	...gravel lense to 22.0
SP-SC	Dark reddish brown clayey sand, wet and medium dense to dense.
	...gravel lense to 27.5
	... dense to 32.5
	...gravel lense to 32.5
	...dense to very dense to 35.0
	...medium dense to 38.0
CL	White and green mottled sandy lean clay, moist to very moist and stiff.

WELL CONSTRUCTION



EXPLORATION LOG
MW-K5

CONFIDENTIAL

ELEVATION/ DEPTH	SOIL & SAMPLE SYMBOLS	USCS	DESCRIPTION	WELL CONSTRUCTION
1550 — 42.5				
			END OF BORING AT 43.5 FEET	
1547.5 — 45				
1545 — 47.5				
1542.5 — 50				
1540 — 52.5				
1537.5 — 55				
1535 — 57.5				
1532.5 — 60				
1530 — 62.5				

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC LLC	LOCATION: HENDERSON, NV	BORING NUMBER: PC 100

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–18	0-18 gravelly SAND, mod yell brn (10YR5/4). 10% silt, 25% volc granules & sm pebbles up to 1"		SW							damp @ 16'
18–29	18-29 slty sdy GRAVEL lt brn (5YR5/4). 20-25% silt, 20-25% poorly sorted, SA-SR, vf-vc sd 50% volc granules and pebbles to 3" Locally hard thin calichified zones		SW							▽ @ 25'
29–36	29-36 slty SAND, lt. yell brn (10YR 6/4). vf-fg w/com m-cg, SR-SA, 25-30% silt. Very calcareous. Minor m-vc size caliche nodules		SM							
36–	36-45 slty grav SAND, mod yell brn (10YR 5/4) 25% silt, 25% volc granules		SW							

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED	5-18-00
PAGE	1 of 2
DRILLING METHOD	HSA
DRILLED BY	Compliance
LOGGED BY	ED KRISH
EXISTING GRADE ELEVATION (FT AMSL)	
LOCATION OR GRID COORDINATES	

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC LLC	LOCATION: HENDERSON, NV	BORING NUMBER: PC 100

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
	and sm pebbles; vf-vc sd									
	42-45 silty gravelly SAND, gry oran pink		SW							
45	(5YR 6/2) 10% clay, 20% silt, 20% volc + ls granules to 1/8"-1/2" dissem throughout Very calcareous w/ minor sm. caliche nodules									MC not reached
	TD 45'									

EXPLANATION

- Water Table (24 Hour)
- Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE
- THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

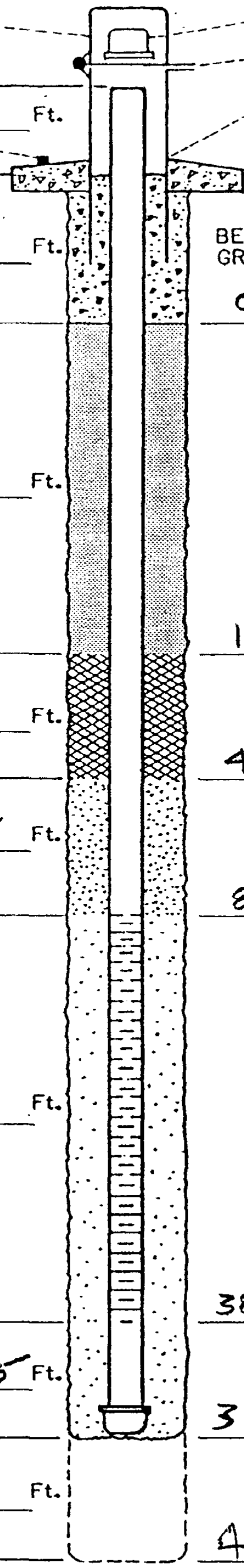
GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED: 5-18-00	PAGE: 2 of 2
DRILLING METHOD: HSA	
DRILLED BY: Compliance	
LOGGED BY: ED KRISH	
EXISTING GRADE ELEVATION (FT AMSL):	
LOCATION OR GRID COORDINATES:	

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM

FLUSH MOUNT



Protective Pipe — Yes ☐ No ☐ — Steel ☐ PVC ☐

Surveying Pin ? Yes ☐ No ☐ ______ Ft.

Casing Cap Vent ? Yes ☐ No ☐

Lock ? Yes ☐ No ☐

Weep Hole ? Yes ☐ No ☐

Concrete Pad ______ Ft. x ______ Ft. x ______ Inches

		DEPTH BELOW GRADE	DEPTH FROM TOP OF CASING
Concrete	______ Ft.	0	
Cement/Bentonite Grout Mix — Yes ☒ No ☐ — 5.5 Gallons Water to 94Lb. Bag Cement & 3–5 Lb. Bentonite Powder — Other: ______	1 Ft.	1	
Bentonite Seal — Pellets ☒ Slurry ☐	3 Ft.	4	
Filter Pack Above Screen	4.5 Ft.	8.5	
FILTER PACK MATERIAL — Silica Sand ☐ Washed Sand ☒ Pea Gravel ☐ Other: ______ Sand Size 2-12 MESH	30 Ft.	38.5	
Dense Phase Sampling Cup Bottom Plug Yes ☒ No ☐	0.5 Ft.	39	
Overdrilled Material Backfill — Grout ☐ Sand ☒ Caved Material ☒ Other: ______	1.0 Ft.	40	

DRILLING INFORMATION:

1. Borehole Diameter= 8 Inches.
2. Were Drilling Additives Used ? Yes ☐ No ☒
   Revert ☐ Bentonite ☐ Water ☐
   Solid Auger ☐ Hollow Stem Auger ☒
3. Was Outer Steel Casing Used ? Yes ☐ No ☒
   Depth= ______ to ______ Feet.
4. Borehole Diameter for Outer Casing ______ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC ☒ Galvanized ☐ Teflon ☐
   Stainless ☐ Other ______
2. Type of Casing Joints: Screw–Couple ☒ Glue–Couple ☐ Other ______
3. Type of Well Screen: PVC ☒ Galvanized ☐
   Stainless ☐ Teflon ☐ Other ______
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: 0.020
6. Type of Screen Perforation: Factory Slotted ☒
   Hacksaw ☐ Drilled ☐ Other ______
7. Installed Protector Pipe w/Lock: Yes ☐ No ☒

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing ☐ Pumping ☒
   Air Surging (Air or Nitrogen) ☐ Other ______
2. Time Spent on Well Development ?
   ______ / 60 (Minutes)/Hours
3. Approximate Water Volume Removed ? ______ Gallons
4. Water Clarity Before Development ? Clear ☐
   Turbid ☒ Opaque ☐
5. Water Clarity After Development ? Clear ☒
   Turbid ☐ Opaque ☐
6. Did Water have Odor ? Yes ☐ No ☒
   If Yes, Describe ______
7. Did Water have any Color ? Yes ☐ No ☒
   If Yes, Describe ______

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 25 Ft. Date 5-18-00

Before Development 14.03 Ft. Date 5-19-00

After Development ______ Ft. Date ______

Driller/Firm COMPLIANCE

Drill Rig Type Mobile B-59

Date Installed 5-18-00

Drill Crew LOYA

Well No. PC 100

Kerr–McGee Hydrologist ED KRISH

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC LLC	LOCATION: Henderson, NV	BORING NUMBER: PC 100 R

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–4	0-4 gravelly SAND, gry brn w/ 10-15% silt. 20-30% volc granules to pea gravel. vf-vc SA sd		SW		—					start drilling @ 8:30 am finish @ 9:00
4–7	4-7 SAND, gry brn w/ 10% silt and 5-10% v. sm granules to 1/10". f-vc, SA-SR sand.		SW		—					
7–9	7-9 sdy GRAVEL, brn, A-SA to 1". 30-35% vf-vc sand		GW		—					
9–11	9-11 SAND, brn, w/ 10% silt + 5-10% v. sm gran. f-vc, SA sand		SW		—					
11–25	11-25 sdy GRAVEL brn w/ 5-10% silt + 25-30% vf-vc, SR-SA sd. Grav. up to 2" (ave 1/10"-3/4") volc w/ minor caliche coatings		GW		—					damp @ 12'; ∇ @ 18'
25–27	25-27 SAND brn, mod slty (15-20%). Calcareous. w/ 10-15% sm volc granules vf-vc, SA-SR		SW		—					
27–30	27-30 sdy GRAVEL, brn, volc up to 2" (ave 3/4") clean, vf-vc sd		GW		—					
30–35	30-35 SAND, brn, vf-c w/ minor vc, SA-SR. 10-15% silt, calcareous		SW		—					
35–38	35-38 slty SAND/sdy SILT var amts of silt in vf-fg SA-SR sd		SM		—					
38–			GM/SM		—					

EXPLANATION

- ▼ Water Table (24 Hour)
- ∇ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method

SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED	8-16-00
PAGE	1 of 2
DRILLING METHOD	PERCUSSION
DRILLED BY	LAYNE
LOGGED BY	ED KRISH
EXISTING GRADE ELEVATION (FT. AMSL)	
LOCATION OR GRID COORDINATES	

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC LLC	LOCATION: HENDERSON, NV	BORING NUMBER: PC100R

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
40.5	38-40.5 gravelly slty SAND, brn. 20-25% silt and 10-20% vclc sm granules. SA-SR vf-vc sd.		CL							MC @ 40.5'
45	40.5-41.5 lt grn slty CLAY w/ gyp xtals									
	TD 41.5'									

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method

SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

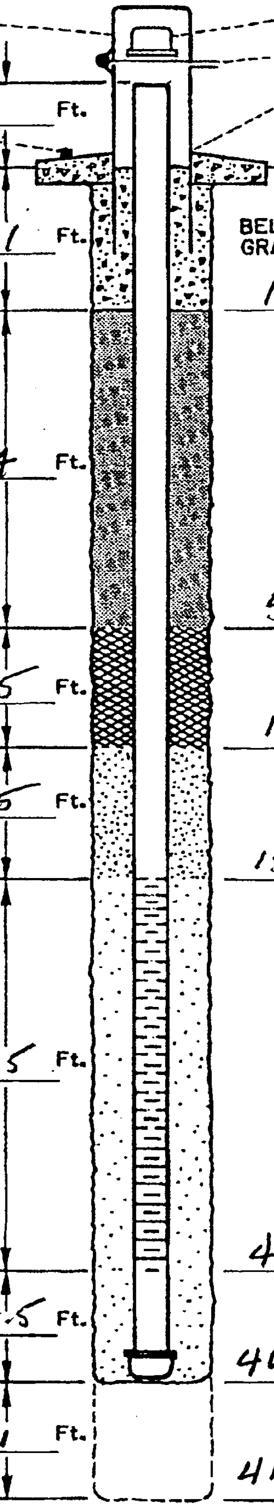
GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED	8-16-00
PAGE	2 of 2
DRILLING METHOD	PERCUSSION
DRILLED BY	LAYNE
LOGGED BY	ED KRISH
EXISTING GRADE ELEVATION (FT. AMSL)	
LOCATION OR GRID COORDINATES	

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM

FLUSH MOUNT



Protective Pipe — Yes ☐ No ☐ — Steel ☐ PVC ☐ — ____ Ft.

Surveying Pin ? Yes ☐ No ☐

Casing Cap Vent ? Yes ☐ No ☐

Lock ? Yes ☐ No ☐

Weep Hole ? Yes ☐ No ☐

Concrete Pad ____ Ft. x ____ Ft. x ____ Inches

		DEPTH BELOW GRADE	DEPTH FROM TOP OF CASING
Concrete	1 Ft.	1	
Cement/Bentonite Grout Mix — Yes ☒ No ☐ — 5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder — Other:	4 Ft.	5	
Bentonite Seal — Pellets ☒ Slurry ☐	5 Ft.	10	
Filter Pack Above Screen	5 Ft.	15	
FILTER PACK MATERIAL — Silica Sand ☒ Washed Sand ☐ Pea Gravel ☐ Others: — Sand Size 8-12	15 Ft.	40	
Dense Phase Sampling Cup — Bottom Plug Yes ☒ No ☐	0.5 Ft.	40.5	
Overdrilled Material Backfill — Grout ☐ Sand ☒ Caved Material ☐ Other:	1 Ft.	41.5	

DRILLING INFORMATION:

1. Borehole Diameter= 9 Inches.
2. Were Drilling Additives Used ? Yes ☐ No ☒
   Revert ☐ Bentonite ☐ Water ☐
   Solid Auger ☐ Hollow Stem Auger ☐
3. Was Outer Steel Casing Used ? Yes ☐ No ☒
   Depth= ____ to ____ Feet.
4. Borehole Diameter for Outer Casing ____ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC ☒ Galvanized ☐ Teflon ☐ Stainless ☐ Other ____
2. Type of Casing Joints: Screw-Couple ☒ Glue-Couple ☐ Other ____
3. Type of Well Screen: PVC ☒ Galvanized ☐ Stainless ☐ Teflon ☐ Other ____
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: 0.040
6. Type of Screen Perforation: Factory Slotted ☒ Hacksaw ☐ Drilled ☐ Other ____
7. Installed Protector Pipe w/Lock: Yes ☐ No ☐

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing ☐ Pumping ☐ Air Surging (Air or Nitrogen) ☒ Other ____
2. Time Spent on Well Development ?
   2 / ____ ~~Minutes~~/Hours
3. Approximate Water Volume Removed ? ____ Gallons
4. Water Clarity Before Development ? Clear ☐ Turbid ☒ Opaque ☐
5. Water Clarity After Development ? Clear ☐ Turbid ☒ Opaque ☐
6. Did Water have Odor ? Yes ☒ No ☐
   If Yes, Describe Pesticide
7. Did Water have any Color ? Yes ☒ No ☒
   If Yes, Describe ____

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 18' Ft. Date 8-16-00

Before Development ____ Ft. Date ____

After Development 13.64 Ft. Date 8-17-00

Driller/Firm HORMANN / LAYNE — Drill Rig Type AP-1000 — Date Installed 8-16-00

Drill Crew ____ — Well No. PC 100R — Kerr-McGee Hydrologist Ed Krish

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY KMC LLC	LOCATION Henderson NV	BORING NUMBER PC 103

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–6	0-6 BERM. Com construction material									
6–10	6-10 SAND, gravelly, brn (5YR5/4), 10-20% volc pea grav to 1/4" in vf-vc, A-SR sd		SW							
10–17	10-17' GRAVEL, sdy, silty, brn, 10-20% silt & 20-30% vf-vc, SA-SR sd in volc gravel to 1". Sl. calcareous. [Prob. series of fining-up. alluvial beds] 16'-17' Gravel to 4"		GM							damp @ 14'
17–29	17-29 Gravel, sl. sdy tr silt. 10-15% vf-vc sd, A-SR, volc SA-SR pea gravel to 1/2" w/ local thin beds up to 4" 25'-28' com lg volc gravel to 4" 28-29' gravel w/ 20-30% silt in matrix		GP							▽ WTR @ 17'
29–30	29'-30' CLAY, silty & CLAY, lt grn gry (5GY8/1), 10-20% silt in matrix, non-calcareous, tr-sp gypsum TD 30'		CL							MC @ 29'

EXPLANATION

▼ Water Table (24 Hour)
▽ Water Table (Time of Boring)
PID Photoionization Detection (ppm)
NO. Identifies Sample by Number
TYPE Sample Collection Method

SPLIT-BARREL | AUGER | ROCK CORE
THIN-WALLED TUBE | CONTINUOUS SAMPLER | NO RECOVERY

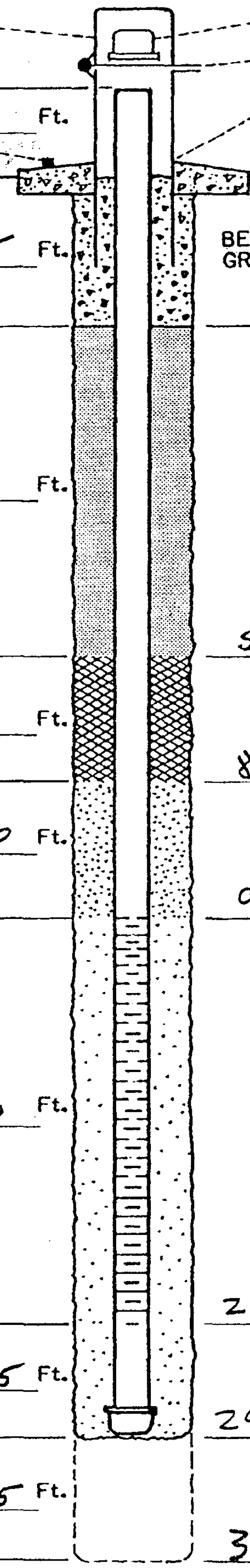
DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY | DEBRIS FILL
SILT | HIGHLY ORGANIC (PEAT)
SAND | SANDY CLAY
GRAVEL | CLAYEY SAND
SILTY CLAY |
CLAYEY SILT |

DATE DRILLED: 2-3-01	PAGE 1 of 1
DRILLING METHOD: PERCUSSION	
DRILLED BY: LAYNE	
LOGGED BY: Ed Krish	
EXISTING GRADE ELEVATION (FT. AMSL):	
LOCATION OR GRID COORDINATES:	

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM



Protective Pipe — Yes [X] No [ ] — Steel [X] PVC [ ] — 3 Ft.

Casing Cap Vent ? Yes [X] No [ ]

Lock ? Yes [ ] No [X]

Weep Hole ? Yes [ ] No [X]

Surveying Pin ? Yes [ ] No [X]

Concrete Pad ______ Ft. x ______ Ft. x ______ Inches

Section	Thickness	Depth Below Grade	Depth From Top of Casing
Concrete	5 Ft.		
Cement/Bentonite Grout Mix — Yes [ ] No [X] — 5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder — Other: ______	0 Ft.	5	
Bentonite Seal — Pellets [X] Slurry [ ]	3 Ft.	8	
Filter Pack Above Screen	1.0 Ft.	9	
FILTER PACK MATERIAL — Silica Sand [ ] Washed Sand [X] Pea Gravel [ ] Other: ______ Sand Size 3-12	20 Ft.	29	
Dense Phase Sampling Cup — Bottom Plug Yes [X] No [ ]	0.5 Ft.	29.5	
Overdrilled Material Backfill — Grout [ ] Sand [ ] Caved Material [X] Other: ______	0.5 Ft.	30	

DRILLING INFORMATION:

1. Borehole Diameter= 9 Inches.
2. Were Drilling Additives Used ? Yes [ ] No [X]
   Revert [ ] Bentonite [ ] Water [ ]
   Solid Auger [ ] Hollow Stem Auger [ ]
3. Was Outer Steel Casing Used ? Yes [ ] No [X]
   Depth= ______ to ______ Feet.
4. Borehole Diameter for Outer Casing ______ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC [X] Galvanized [ ] Teflon [ ]
   Stainless [ ] Other ______
2. Type of Casing Joints: Screw-Couple [X] Glue-Couple [ ] Other ______
3. Type of Well Screen: PVC [X] Galvanized [ ]
   Stainless [ ] Teflon [ ] Other ______
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: 0.020
6. Type of Screen Perforation: Factory Slotted [X]
   Hacksaw [ ] Drilled [ ] Other ______
7. Installed Protector Pipe w/Lock: Yes [X] No [ ]

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing [ ] Pumping [X]
   Air Surging (Air or Nitrogen) [ ] Other ______
2. Time Spent on Well Development ?
   ______ / ______ Minutes/Hours
3. Approximate Water Volume Removed ? ______ Gallons
4. Water Clarity Before Development ? Clear [ ]
   Turbid [ ] Opaque [ ]
5. Water Clarity After Development ? Clear [ ]
   Turbid [ ] Opaque [ ]
6. Did Water have Odor ? Yes [ ] No [ ]
   If Yes, Describe ______
7. Did Water have any Color ? Yes [ ] No [ ]
   If Yes , Describe ______

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 17 Ft. Date 2-3-01

Before Development ______ Ft. Date ______

After Development ______ Ft. Date ______

Driller/Firm LAYNE — Drill Rig Type AP-1000 — Date Installed 2-3-01

Drill Crew Perry — Well No. PC-103 — Kerr-McGee Hydrologist Ed Krish

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMCLLC	LOCATION: HENDERSON, NV.	BORING NUMBER: PC-2

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–5	SAND/SILTY SAND w/ ABD GRAVEL; LT. TAN-BROWN; WELL-GRADED; DRY					Auger			
5	GRAVEL @ 6-7'								
10	SAND AS ABOVE	SM-GM							
	GRAVEL @ 14-15'								
18'	SAND AS ABOVE; SATURATED	∇							
25									GROUNDWATER SAMPLE TAKEN @ 30'
30–31			3, 12, 27		1	Split-barrel	30–31.5	1.4'	
31–35	SILTY CLAY; REDDISH-BROWN GRADING INTO LT. GRAY-GREEN <u>MUDDY CREEK</u>	CL							
35	TD 35'								

EXPLANATION

- ▼ Water Table (24 Hour)
- ∇ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method

SPLIT-BARREL · AUGER · ROCK CORE · THIN-WALLED TUBE · CONTINUOUS SAMPLER · NO RECOVERY

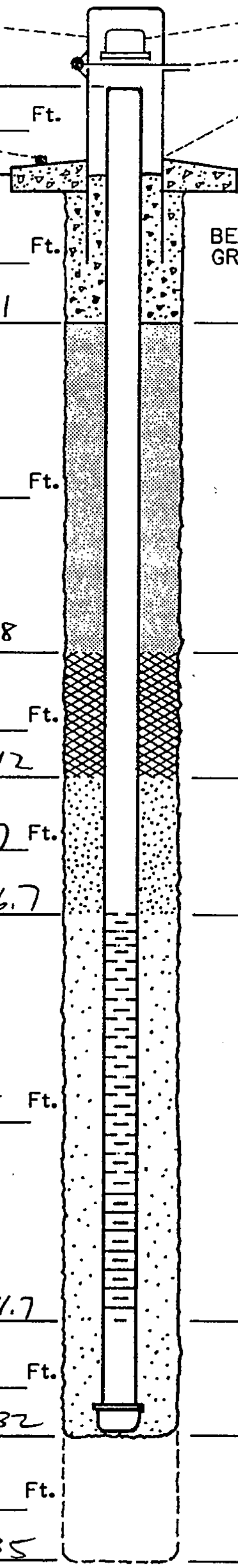
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY · DEBRIS FILL · SILT · HIGHLY ORGANIC (PEAT) · SAND · SANDY CLAY · GRAVEL · CLAYEY SAND · SILTY CLAY · CLAYEY SILT

DATE DRILLED	3/23/98
PAGE	1 of 1
DRILLING METHOD	HSA
DRILLED BY	WEBER DRILLING
LOGGED BY	T. REED
EXISTING GRADE ELEVATION (FT AMSL)	
LOCATION OR GRID COORDINATES	

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM



Protective Pipe: Yes [x] No [ ]
Steel [x] PVC [ ]
____ Ft.
Surveying Pin ? Yes [ ] No [ ]

Casing Cap Vent ? Yes [ ] No [ ]
Lock ? Yes [x] No [ ]
Weep Hole ? Yes [ ] No [ ]
Concrete Pad ____ Ft. x ____ Ft. x ____ Inches

DEPTH: BELOW GRADE / FROM TOP OF CASING

Concrete: 1 Ft. — 1

Cement/Bentonite Grout Mix: Yes [x] No [ ]
5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder
Other: ____
7 Ft. — 8

Bentonite Seal: Pellets [x] Slurry [ ]
4 Ft. — 12

Filter Pack Above Screen: 4.7 Ft. — 16.7

FILTER PACK MATERIAL
Silica Sand [x]
Washed Sand [ ]
Pea Gravel [ ]
Other: ____
Sand Size 8-12
15 Ft. — 31.7

Dense Phase Sampling Cup Bottom Plug: Yes [x] No [ ]
.3 Ft. — 32

Overdrilled Material Backfill: Grout [ ] Sand [ ]
Caved Material [x]
Other: ____
____ Ft. — 35

DRILLING INFORMATION:

1. Borehole Diameter= 8 Inches.
2. Were Drilling Additives Used ? Yes [ ] No [x]
   Revert [ ] Bentonite [ ] Water [ ]
   Solid Auger [ ] Hollow Stem Auger [x]
3. Was Outer Steel Casing Used ? Yes [ ] No [x]
   Depth= ____ to ____ Feet.
4. Borehole Diameter for Outer Casing ____ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC [x] Galvanized [ ] Teflon [ ]
   Stainless [ ] Other ____
2. Type of Casing Joints: Screw-Couple [x] Glue-Couple [ ] Other ____
3. Type of Well Screen: PVC [x] Galvanized [ ]
   Stainless [ ] Teflon [ ] Other ____
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: .020
6. Type of Screen Perforation: Factory Slotted [x]
   Hacksaw [ ] Drilled [ ] Other ____
7. Installed Protector Pipe w/Lock: Yes [x] No [ ]

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing [ ] Pumping [x]
   Air Surging (Air or Nitrogen) [ ] Other ____
2. Time Spent on Well Development ?
   10 / 1 Minutes/Hours
3. Approximate Water Volume Removed ? 75 Gallons
4. Water Clarity Before Development ? Clear [ ]
   Turbid [ ] Opaque [x]
5. Water Clarity After Development ? Clear [x]
   Turbid [ ] Opaque [ ]
6. Did Water have Odor ? Yes [ ] No [x]
   If Yes, Describe ____
7. Did Water have any Color ? Yes [ ] No [x]
   If Yes, Describe ____

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 18' Ft. Date 3/23/98
Before Development ____ Ft. Date ____
After Development 20.01' Ft. Date 3/25/98 (From TOC)

Driller/Firm LEE ROBERTSON / WEBER DRLG. Drill Rig Type B-61 Date Installed 3/23/98

Drill Crew L. ROBERTSON / B. JOHNSON Well No. PC-2 Kerr-McGee Hydrologist T. REED

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY KMC-LLC	LOCATION HENDERSON NV	BORING NUMBER PC-52

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–17	SILTY SAND W/ GRAVEL LT TAN - RED BRN WELL GRADED DRY		SM/GM							
17	▽ (water table, time of boring)									
17–33	SAND/GRAVEL DARK BRN CLAYEY MOIST BCMG WET									GROUND WATER SAMPLE COLLECTED AT 20'
	SAND CRS-VCRS DK BRN TR GRAVEL		SM							
33	SILTY CLAY LT GRAY TO OFF WHITE LAM SOFT TO FIRM		CL							33' T/ MUDDY CREEK
34										TD 34'

EXPLANATION

▼ Water Table (24 Hour)
▽ Water Table (Time of Boring)
PID Photoionization Detection (ppm)
NO. Identifies Sample by Number
TYPE Sample Collection Method

SPLIT-BARREL · AUGER · ROCK CORE · THIN-WALLED TUBE · CONTINUOUS SAMPLER · NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY · DEBRIS FILL · SILT · HIGHLY ORGANIC (PEAT) · SAND · SANDY CLAY · GRAVEL · CLAYEY SAND · SILTY CLAY · CLAYEY SILT

DATE DRILLED	5/4/98
PAGE	1 of 1
DRILLING METHOD	HSA
DRILLED BY	WEBER
LOGGED BY	J. CRAWFORD
EXISTING GRADE ELEVATION (FT. AMSL)	
LOCATION OR GRID COORDINATES	

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY KMC-LLC	LOCATION HENDERSON NV	BORING NUMBER PC-53

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–5	SILTY SAND RD BRN TO TAN GRAVELS WELL GRADED DRY									
5, 10										
15	SILTY SAND W/ GRAVEL BCMG CLAYEY MOIST DARK BROWN	▽								
20										
25	SAND SILTY BRN-DK BRN SL CLAYEY TR GRAVELS CRS-V CRS GR SAT									
30										32' T/MUDDY CREEK
	SILTY CLAY GRN GY TO OFF WH LAM FIRM									
										TD 35'

EXPLANATION

▼ Water Table (24 Hour)
▽ Water Table (Time of Boring)
PID Photoionization Detection (ppm)
NO. Identifies Sample by Number
TYPE Sample Collection Method

SPLIT-BARREL — AUGER — ROCK CORE — THIN-WALLED TUBE — CONTINUOUS SAMPLER — NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

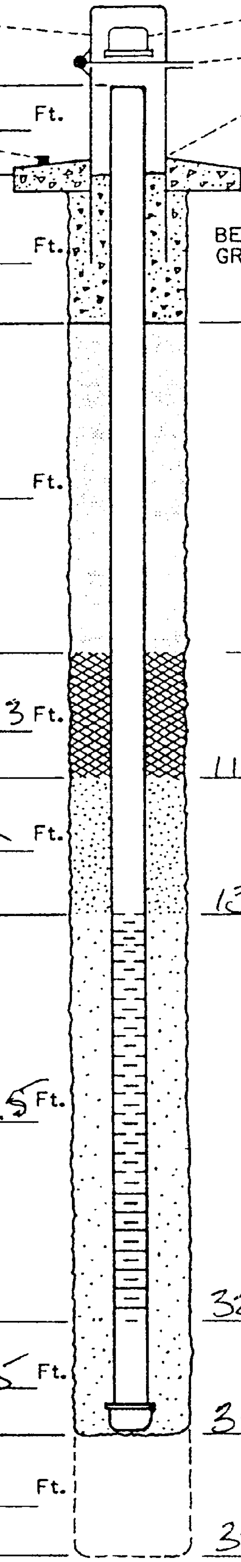
GRAPHIC LOG LEGEND

CLAY — DEBRIS FILL — SILT — HIGHLY ORGANIC (PEAT) — SAND — SANDY CLAY — GRAVEL — CLAYEY SAND — SILTY CLAY — CLAYEY SILT

DATE DRILLED	5/4/98
PAGE	1 of 1
DRILLING METHOD	HSA
DRILLED BY	WEBER
LOGGED BY	J. CRAWFORD
EXISTING GRADE ELEVATION (FT AMSL)	
LOCATION OR GRID COORDINATES	

[CASING PROTECTOR]
FLUSH MOUNT

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM



Protective Pipe — Yes ☒ No ☐ (crossed out)
Steel ☒ PVC ☐
Surveying Pin ? Yes ☐ No ☒
______ Ft.

Casing Cap Vent ? Yes ☒ No ☐
Lock ? Yes ☒ No ☐
Weep Hole ? Yes ☐ No ☐
Concrete Pad 1 Ft. x 1 Ft. x 2 Inches

	Ft.	DEPTH BELOW GRADE	DEPTH FROM TOP OF CASING
Concrete			
Cement/Bentonite Grout Mix: Yes ☐ No ☐; 5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder; Other: ______		8	
Bentonite Seal: Pellets ☒ Slurry ☐	3	11	
Filter Pack Above Screen	2	13	
FILTER PACK MATERIAL: Silica Sand ☐ Washed Sand ☒ Pea Gravel ☐ Other: ______ Sand Size 8-12	19.5	32.5	
Dense Phase Sampling Cup Bottom Plug: Yes ☒ No ☐	0.5	33	
Overdrilled Material Backfill: Grout ☐ Sand ☐ Caved Material ☐ Other: ______		35	

DRILLING INFORMATION:

1. Borehole Diameter= ______ Inches.
2. Were Drilling Additives Used ? Yes ☐ No ☒
   Revert ☐ Bentonite ☐ Water ☐
   Solid Auger ☐ Hollow Stem Auger ☒
3. Was Outer Steel Casing Used ? Yes ☐ No ☐
   Depth= ______ to ______ Feet.
4. Borehole Diameter for Outer Casing ______ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC ☒ Galvanized ☐ Teflon ☐
   Stainless ☐ Other ______
2. Type of Casing Joints: Screw–Couple ☒ Glue–Couple ☐ Other ______
3. Type of Well Screen: PVC ☒ Galvanized ☐
   Stainless ☐ Teflon ☐ Other ______
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: .020
6. Type of Screen Perforation: Factory Slotted ☒
   Hacksaw ☐ Drilled ☐ Other ______
7. Installed Protector Pipe w/Lock: Yes ☐ No ☐

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing ☐ Pumping ☒
   Air Surging (Air or Nitrogen) ☐ Other ______
2. Time Spent on Well Development ?
   ______/ 1 Minutes/Hours
3. Approximate Water Volume Removed ? 100 Gallons
4. Water Clarity Before Development ? Clear ☐
   Turbid ☐ Opaque ☒
5. Water Clarity After Development ? Clear ☒
   Turbid ☐ Opaque ☐
6. Did Water have Odor ? Yes ☐ No ☒
   If Yes, Describe ______
7. Did Water have any Color ? Yes ☐ No ☒
   If Yes, Describe ______

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling ______ Ft. Date ______
Before Development 18 Ft. Date 5/4/98
After Development 19.54 Ft. Date 5/12/98

Driller/Firm WEBER Drill Rig Type MOBILE B 61 Date Installed 5/4/98
Drill Crew LEE ROBERTSON Well No. PC-53 Kerr-McGee Hydrologist J. CRAWFORD

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC LLC	LOCATION: HENDERSON NV	BORING NUMBER: PC 98

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
5, 10	0-12 gravelly SAND, mod yell brn (10YR 5/4), 20-25% granules & sm. pebbles to 1" diam (volc) sp-mod silt in matrix (10-20%). Sand vf-vc, SR-SA	SP							
16, 20	12-16 slty sdy GRAVEL lt brn (5YR 5/4), 20% silt 25% vf-vc A-SR sand. 50% volc granules to cobbles up to 6" diam Mod com caliche throughout 13-16 v. hard, dense calcification	GW							damp @ 15 ▽ @ 22'
25, 30, 34	16-34 slty gravelly SAND, mod brn (5YR 4/4) 20-25% silt, 20-25% granules and sm pebbles to 3/4". 50% vf-vc A-SR sand	SW							
37	34-37 slty SAND. lt yell brn (10YR 6/4). vf-fg w/ minor mg, SR-SA. 25-30% silt. Mod com m-vc caliche nodules. Very calcareous	SM							
		GC-ML							

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method

SPLIT-BARREL · AUGER · ROCK CORE · THIN-WALLED TUBE · CONTINUOUS SAMPLER · NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY · DEBRIS FILL · SILT · HIGHLY ORGANIC (PEAT) · SAND · SANDY CLAY · GRAVEL · CLAYEY SAND · SILTY CLAY · CLAYEY SILT

DATE DRILLED	5-16-00
PAGE	1 of 2
DRILLING METHOD	HSA
DRILLED BY	COMPLIANCE
LOGGED BY	ED KRISH
EXISTING GRADE ELEVATION (FT AMSL)	
LOCATION OR GRID COORDINATES	

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC LLC	LOCATION: HENDERSON, NV	BORING NUMBER: PC 98

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
41	37-41 sdy grav SILT/slty grav SAND w/ 15% dissem granules to 1/8-1/4", mod gry orange pink (5YR 6/2). Contains 25-50% vf-f sd in silt/clay matrix. 10-20% vc +ls granules to 1/8-1/4". Very calcareous w/ mod c-vc caliche nodules.		CL							MC @ 41'
45	41-45 slty CLAY, lt grn gry (5GY 8/1) and yell gry (5G 8/1). 25% silt, v. calcareous w/ minor m-vc sized caliche nodules dissem.									
	45' TD									

EXPLANATION

- Water Table (24 Hour)
- Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

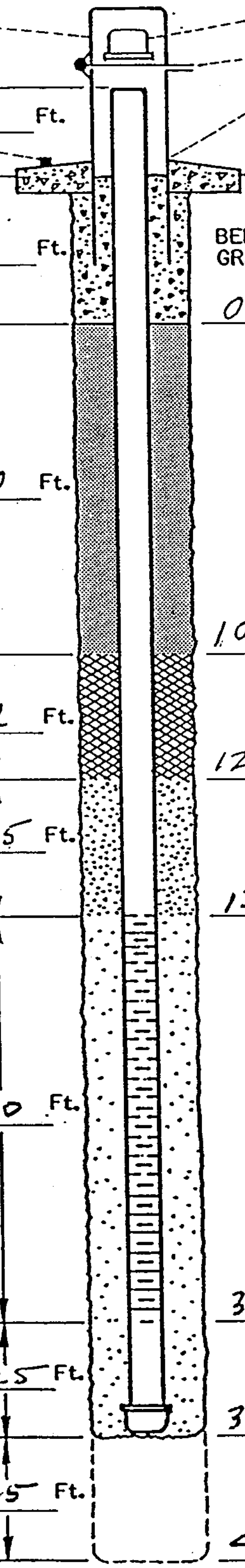
GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED	5-16-00
PAGE	2 of 2
DRILLING METHOD	HSA
DRILLED BY	COMPLIANCE
LOGGED BY	ED KRISH
EXISTING GRADE ELEVATION (FT AMSL)	
LOCATION OR GRID COORDINATES	

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM

FLUSH MOUNT



Protective Pipe — Yes ☐ No ☐ — Steel ☐ PVC ☐ — ______ Ft.

Casing Cap Vent ? Yes ☐ No ☐

Lock ? Yes ☐ No ☐

Weep Hole ? Yes ☐ No ☐

Surveying Pin ? Yes ☐ No ☐

Concrete Pad ______ Ft. x ______ Ft. x ______ Inches

Concrete ______ Ft.

DEPTH	BELOW GRADE	FROM TOP OF CASING
Top of grout	0	
Top of bentonite seal	10	
Top of filter pack	12	
Top of screen	13.5	
Bottom of screen	33	
Bottom plug	33.5	
Total depth	45	

Cement/Bentonite Grout Mix — Yes ☒ No ☐ — 10 Ft.
5.5 Gallons Water to 94Lb. Bag Cement & 3–5 Lb. Bentonite Powder
Other: ______

Bentonite Seal — 2 Ft.
Pellets ☒ Slurry ☐

Filter Pack Above Screen — 1.5 Ft.

FILTER PACK MATERIAL — 20 Ft.
Silica Sand ☐
Washed Sand ☒
Pea Gravel ☐
Other: ______
Sand Size 2-12 mesh

Dense Phase Sampling Cup — 0.5 Ft.
Bottom Plug Yes ☒ No ☐

Overdrilled Material Backfill — 11.5 Ft.
Grout ☐ Sand ☒
Caved Material ☒
Other: ______

DRILLING INFORMATION:

1. Borehole Diameter= 10.5 Inches.
2. Were Drilling Additives Used ? Yes ☐ No ☒
   Revert ☐ Bentonite ☐ Water ☐
   Solid Auger ☐ Hollow Stem Auger ☒
3. Was Outer Steel Casing Used ? Yes ☐ No ☒
   Depth= ______ to ______ Feet.
4. Borehole Diameter for Outer Casing ______ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC ☒ Galvanized ☐ Teflon ☐
   Stainless ☐ Other ______
2. Type of Casing Joints: Screw–Couple ☒ Glue–Couple ☐ Other ______
3. Type of Well Screen: PVC ☒ Galvanized ☐
   Stainless ☐ Teflon ☐ Other ______
4. Diameter of Casing and Well Screen:
   Casing 4 Inches, Screen 4 Inc
5. Slot Size of Screen:
6. Type of Screen Perforation: Factory Slotted ☒
   Hacksaw ☐ Drilled ☐ Other ______
7. Installed Protector Pipe w/Lock: Yes ☐ No ☒

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing ☐ Pumping ☒
   Air Surging (Air or Nitrogen) ☐ Other ______
2. Time Spent on Well Development ?
   1 / 60 (Minutes)/Hours
3. Approximate Water Volume Removed ? ______ Gallons
4. Water Clarity Before Development ? Clear ☐
   Turbid ☒ Opaque ☐
5. Water Clarity After Development ? Clear ☒
   Turbid ☐ Opaque ☐
6. Did Water have Odor ? Yes ☐ No ☒
   If Yes, Describe ______
7. Did Water have any Color ? Yes ☐ No ☒
   If Yes, Describe ______

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 22 Ft. Date 5-16-00
Before Development 14.01 Ft. Date 5-17-00
After Development ______ Ft. Date ______

Driller/Firm COMPLIANCE
Drill Rig Type Mobile B-59
Date Installed 5-17-00
Drill Crew Loya
Well No. PC 98
Kerr–McGee Hydrologist ED KRIVH

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY	LOCATION	BORING NUMBER
	KMCC	Henderson NV	PC98R

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
5	0-5 gravelly SAND grysh brn w/10% silt, 20-30% granules - pea gravel to 3/4". vf-vc SA sd		SP							
9	5-9 SAND, gry brn w/10% silt and 5-10% volc granules to 1/4". f-vc SA sand		SW							
	9-10 sdy GRAVEL (to 1") 25-35% vf-vc sd		GW							
12			SW							damp @ 12'
15	10-12 SAND, brn, 10% silt, 5% granules. f-vc volc, SA sand									
20	12-24 sdy GRAVEL brn. w/ 5-10% silt, 25% vf-vc, SA-A sand. Granules to pea gravel, A-SA. 1/2"-3/4" w/ minor 3/4"-2" Locally caliche cemented. 16'-20' hard. Com caliche cement		GW	6 30 15			X	20'-21.5'	50%	∇ @ 18'
24										
26	24-26 SAND. gry brn, SR, clean, f-mg w/ c-vcg		SP	25 50			X	25-26	75%	
30	26-34 sdy GRAVEL gry brn, 10-15% silt, 25-30% vf-vc, SA sand in granule - pea gravel to 1/2"-3/4'. 29-30 - cobbles up to 7"		GW	22 29 30			X	30'-31.5'	80%	
34	34-40.5 gravelly silty SAND 20-30% silt and 10-15% volc granules to 1/4", brn. Com. dissem sd-size		GM/SM	12 13 31			X	35'-36.5'	100%	

EXPLANATION

- ▼ Water Table (24 Hour)
- ∇ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED	8-8-00
PAGE	1 of 2
DRILLING METHOD	PERCUSSION
DRILLED BY	LAYNE
LOGGED BY	Ed KRISH
EXISTING GRADE ELEVATION (FT AMSL)	
LOCATION OR GRID COORDINATES	

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMCC	LOCATION: HENDERSON NV	BORING NUMBER: PC 98R

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
40.5	caliche nodules. Very calcareous. Sand is vf-f w/minor mg, SA-SR		CL							
	40.5-41.5 silty CLAY lt grn, w/ dissem sm gypsum xtals									
	TD 41.5'									

EXPLANATION

- Water Table (24 Hour)
- Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method

SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

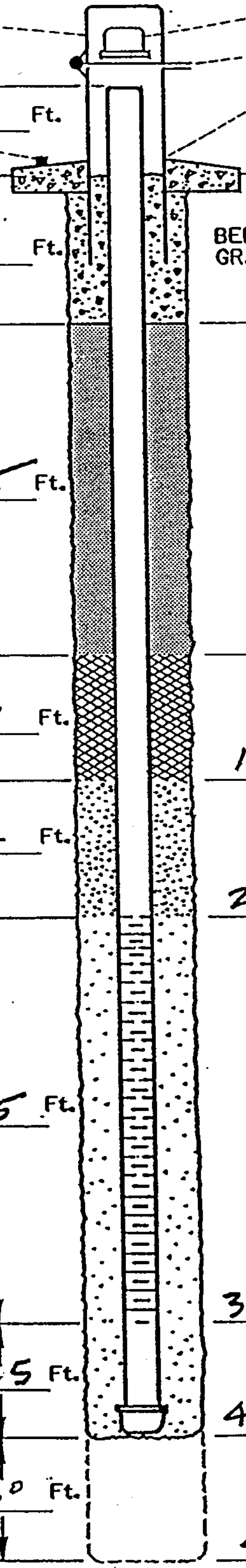
GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED	8-8-00
PAGE	2 of 2
DRILLING METHOD	Percussion
DRILLED BY	LAYNE
LOGGED BY	ED KRISH
EXISTING GRADE ELEVATION (FT AMSL)	
LOCATION OR GRID COORDINATES	

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM

FLUSH MOUNT



Protective Pipe: Yes ☐ No ☒
Steel ☐ PVC ☐
_____ Ft.
Surveying Pin ? Yes ☐ No ☒

Concrete _____ Ft.

Cement/Bentonite Grout Mix: Yes ☒ No ☐
5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder — 5 Ft.
Other: ____________

Bentonite Seal — 11 Ft.
Pellets ☐ Slurry ☐

Filter Pack Above Screen — 4 Ft.

FILTER PACK MATERIAL — 15 Ft.
Silica Sand ☒
Washed Sand ☐
Pea Gravel ☐
Other: ____________
Sand Size 8-12 mesh

Dense Phase Sampling Cup — 5.5 Ft.
Bottom Plug: Yes ☒ No ☐

Overdrilled Material Backfill — 1.0 Ft.
Grout ☐ Sand ☒
Caved Material ☐
Other: ____________

DEPTH BELOW GRADE	DEPTH FROM TOP OF CASING
5	
16	
20	
35	
40.5	
41.5	

Casing Cap Vent ? Yes ☐ No ☒
Lock ? Yes ☐ No ☒
Weep Hole ? Yes ☐ No ☒
Concrete Pad _____ Ft. x _____ Ft. x _____ Inches

DRILLING INFORMATION:

1. Borehole Diameter= 9 Inches.
2. Were Drilling Additives Used ? Yes ☐ No ☒
   Revert ☐ Bentonite ☐ Water ☐
   Solid Auger ☐ Hollow Stem Auger ☐
3. Was Outer Steel Casing Used ? Yes ☐ No ☒
   Depth= _____ to _____ Feet.
4. Borehole Diameter for Outer Casing _____ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC ☒ Galvanized ☐ Teflon ☐
   Stainless ☐ Other _____
2. Type of Casing Joints: Screw-Couple ☒ Glue-Couple ☐ Other _____
3. Type of Well Screen: PVC ☒ Galvanized ☐
   Stainless ☐ Teflon ☐ Other _____
4. Diameter of Casing and Well Screen:
   Casing 4 Inches, Screen 4 Inches.
5. Slot Size of Screen: 0.040
6. Type of Screen Perforation: Factory Slotted ☒
   Hacksaw ☐ Drilled ☐ Other _____
7. Installed Protector Pipe w/Lock: Yes ☐ No ☒

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing ☐ Pumping ☐
   Air Surging (Air or Nitrogen) ☒ Other _____
2. Time Spent on Well Development ?
   / 120 Minutes/~~Hours~~
3. Approximate Water Volume Removed ? _____ Gallons
4. Water Clarity Before Development ? Clear ☐
   Turbid ☒ Opaque ☐
5. Water Clarity After Development ? Clear ☒
   Turbid ☐ Opaque ☐
6. Did Water have Odor ? Yes ☒ No ☐
   If Yes, Describe faint pesticide
7. Did Water have any Color ? Yes ☐ No ☒
   If Yes, Describe _____

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 18 Ft. Date 8-8-00
Before Development _____ Ft. Date _____
After Development _____ Ft. Date _____

Driller/Firm _____ Drill Rig Type AP-1000 Date Installed 8-8-00

Drill Crew _____ Well No. PC 98R Kerr-McGee Hydrologist ED KRISH

northgate environmental management, inc.

Northgate Environmental Management
24411 Ridge Route Drive
Laguna Hills, CA 92653
main (949) 716-0050; fax (949) 716-0055

Boring Log

Project Number: 2027.11.10		**Boring ID:** PRB-Beach test boring (I-2)	
Project Name: Tronox PRB beach Test		**Location:** COH / WRF Henderson, NV	
Drilling Contractor: Eagle		**Logged By:** Patrick Ferringer	
Drilling Method: HSA B-51	**Date Started:** 12/6/10	**Total Depth:** 40' BGS	**Depth to Water:**
Borehole Dia. (in):	**Completed:**	**Surface Elev.:**	**TOC Elev.:**

Surface Seal Type:
Interval (ft bgs) From: **To:**

Remarks:
- Collect (3) 5 gal. buckets of soil in saturated zone ~20'-40'
- Collect 10 gal of water w/ bailer from borehole

Depth (ft)	Sample ID	Sample Time	Recovery %	Blow Count	Graphic Log	USCS Code	Material Description	Water Level	PID (ppm)
0–5						SP-SM	Brown (7.5YR 5/4) poorly graded sand w/ silt, trace fine SR-SA gravel, <10% med + coarse sand, 75% v.fine-fine sand, 15% silt, dry and med dense, non plastic, strong HCl rxn.		
5							5': brown (7.5YR 4/3), trace fine - med gravel, ≤15% med-coarse sand, 75% v.fine-fine sand, 10% silt.		
7							7': trace fine gravel		
9						SP	9': Brown (7.5YR 4/3) poorly graded sand, trace fine gravel SR-SA, ~5% coarse sand, ~20% med sand, ~70% v.fine-fine sand, 5% silt, dry and med dense, strong HCl rxn. non-plastic		
16.25							16.25': ~5% fine gravel		
18							18': 5% fine gravel, 5-10% coarse sand, 20-25% med sand, 60-70% v.fine-fine sand, 5% silt		
24.5							24.5': moist		
27						SP-SM	27': brown (7.5YR 5/3) poorly graded sand w/ silt, ~10% med sand, 70% v.fine-fine sand, 15% silt, ≤5% clay. wet med dense, low plasticity strong HCl rxn.	27' ▽	

northgate
environmental management, inc.

Boring Log

Northgate Environmental Management
24411 Ridge Route Drive
Laguna Hills, CA 92653
main (949) 716-0050; fax (949) 716-0055

Project Number: 2027.11.10	**Boring ID:** PRB Bench test boring (I-2)
Project Name: Tronox PRB bench test	**Location:** COH / WRF Henderson, NV
Drilling Contractor: Eagle	**Logged By:** Patrick Ferringer

Remarks:

Depth (ft)	Sample ID	Sample Time	Recovery %	Blow Count	Graphic Log	USCS Code	Material Description	Water Level	PID (ppm)
31									
32									
33							-33': trace fine - coarse R-SA gravel		
34									
35									
36									
37									
38									
39									
40									
41									
42									
43									
44									
45							TD @ 40' BGS		
46									
47									
48									
49									
50									
51									
52									
53									
54									
55									
56									
57									
58									
59									
60									
61									
62									
63									
64									
65									

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC-LLC	LOCATION: HENDERSON NV	BORING NUMBER: PC-18

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–5	SILTY SAND RD BRN DRY WELL GRADED GRAVELS		SM							
5										
10										
15			GM							
20										COLLECT GROUNDWATER SAMPLE AT 22'
25	Sand/gravel brn lt? moist well graded									
~27	- - - - - - - -		∇							
30										
~33	SAND/GRAVEL GRAYISH BROWN WELL GRADED SAT SILTY		GM							

EXPLANATION

▼ Water Table (24 Hour)
∇ Water Table (Time of Boring)
PID Photoionization Detection (ppm)
NO. Identifies Sample by Number
TYPE Sample Collection Method

SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED: 4/2/98
PAGE: 1 of 2
DRILLING METHOD: HSA
DRILLED BY: WEBER
LOGGED BY: J. CRAWFORD
EXISTING GRADE ELEVATION (FT. AMSL):
LOCATION OR GRID COORDINATES:

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC - LLC	LOCATION: HENDERSON NV	BORING NUMBER: PC-18

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
	Sand/Gravel BRN WELL GRADED		GM							SPLIT SPOON AT 42'
55										POOR RETURNS
50	SAND BRN F-CRS gr Sm 1/4" GRAVEL WELL GRADED SAT LOOSE SLI SILTY		SW							T/MUDDY CREEK 52'
T/MC	SILTY CLAY RD BRN W/ Sm FINE SAND + SMALL GRAVELS		CL							
	SILTY CLAY GREENISH GRAY W/ TAN to BROWN VARIG. BLOCKY									DRILL TD 53'

EXPLANATION

- Water Table (24 Hour)
- Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL
- AUGER
- ROCK CORE
- THIN-WALLED TUBE
- CONTINUOUS SAMPLER
- NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

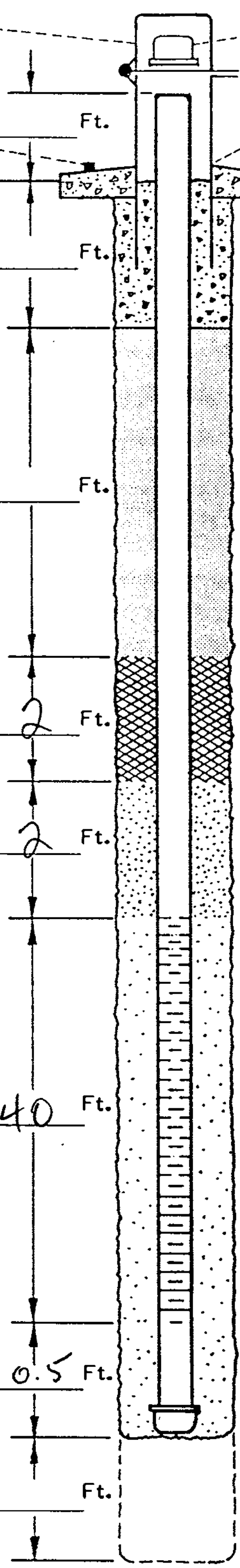
GRAPHIC LOG LEGEND

CLAY, DEBRIS FILL, SILT, HIGHLY ORGANIC (PEAT), SAND, SANDY CLAY, GRAVEL, CLAYEY SAND, SILTY CLAY, CLAYEY SILT

DATE DRILLED	4/2/98
PAGE	2 of 2
DRILLING METHOD	HSA
DRILLED BY	WEBER
LOGGED BY	J. CRAWFORD
EXISTING GRADE ELEVATION (FT. AMSL)	
LOCATION OR GRID COORDINATES	

FLUSH MOUNT

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM



Protective Pipe — Yes ☐ No ☐ — Steel ☐ PVC ☐ (crossed out)

Surveying Pin ? Yes ☐ No ☐ (crossed out)

Casing Cap Vent ? Yes ☐ No ☐

Lock ? Yes ☑ No ☐

Weep Hole ? Yes ☐ No ☐

Concrete Pad ______ Ft. x ______ Ft. x ______ Inches

______ Ft.

Concrete ______ Ft.

DEPTH: BELOW GRADE / FROM TOP OF CASING

Interval	Ft.	Depth Below Grade	Depth From Top of Casing
Concrete			
Cement/Bentonite Grout Mix Yes ☑ No ☐ — 5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder; Other: ______		7.5	
Bentonite Seal — Pellets ☑ Slurry ☐	2	9.5	
Filter Pack Above Screen	2	11.5	
FILTER PACK MATERIAL — Silica Sand ☒ Washed Sand ☐ Pea Gravel ☐ Other: ______ Sand Size 8-12	40	51.5	
Dense Phase Sampling Cup — Bottom Plug Yes ☑ No ☐	0.5	52	
Overdrilled Material Backfill — Grout ☐ Sand ☐ Caved Material ☑ Other: ______		53	

DRILLING INFORMATION:

1. Borehole Diameter= 8 Inches.
2. Were Drilling Additives Used ? Yes ☑ No ☐
   Revert ☐ Bentonite ☐ Water ☑
   Solid Auger ☐ Hollow Stem Auger ☑
3. Was Outer Steel Casing Used ? Yes ☐ No ☑
   Depth= ______ to ______ Feet.
4. Borehole Diameter for Outer Casing ______ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC ☑ Galvanized ☐ Teflon ☐
   Stainless ☐ Other ______
2. Type of Casing Joints: Screw-Couple ☑ Glue-Couple ☐ Other ______
3. Type of Well Screen: PVC ☑ Galvanized ☐
   Stainless ☐ Teflon ☐ Other ______
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: 10
6. Type of Screen Perforation: Factory Slotted ☑
   Hacksaw ☐ Drilled ☐ Other ______
7. Installed Protector Pipe w/Lock: Yes ☐ No ☐

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing ☐ Pumping ☑
   Air Surging (Air or Nitrogen) ☐ Other ______
2. Time Spent on Well Development ?
   ______ / 1 Minutes/Hours
3. Approximate Water Volume Removed ? 110 Gallons
4. Water Clarity Before Development ? Clear ☐
   Turbid ☐ Opaque ☑
5. Water Clarity After Development ? Clear ☑
   Turbid ☐ Opaque ☐
6. Did Water have Odor ? Yes ☐ No ☑
   If Yes, Describe ______
7. Did Water have any Color ? Yes ☐ No ☑
   If Yes, Describe ______

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 22 Ft. Date 4/8/98

Before Development 19.80' Ft. Date 4/17/98

After Development 19.90' Ft. Date 4/17/98

Driller/Firm WEBER — Drill Rig Type MOBILE B-61 XD — Date Installed 4/8/98

Drill Crew LEE ROBERTSON — Well No. PC-18 — Kerr-McGee Hydrologist J. CRAWFORD

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY KMCLLC	LOCATION HENDERSON, NV	BORING NUMBER PC - 58

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–2.5	BERM : SAND w/ GRAVEL									
2.5	SAND w/ SILT ; MED. BROWN; SLI. MOIST ; OCC. GRAVEL		SM							
10	GRAVEL ZONE @ 10-14'		GM							
13			▽							
15			SM							
25	GRAVEL ZONE @ 26-28'		GM							
34	SILTY CLAY - CLAYEY SILT; GREENISH-WHITE V. SLI. PLASTIC ; MUDDY CREEK		CL-ML			1		35 36.5	1.5'	
36	TD 36'									

EXPLANATION

▼ Water Table (24 Hour)
▽ Water Table (Time of Boring)
PID Photoionization Detection (ppm)
NO. Identifies Sample by Number
TYPE Sample Collection Method

SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

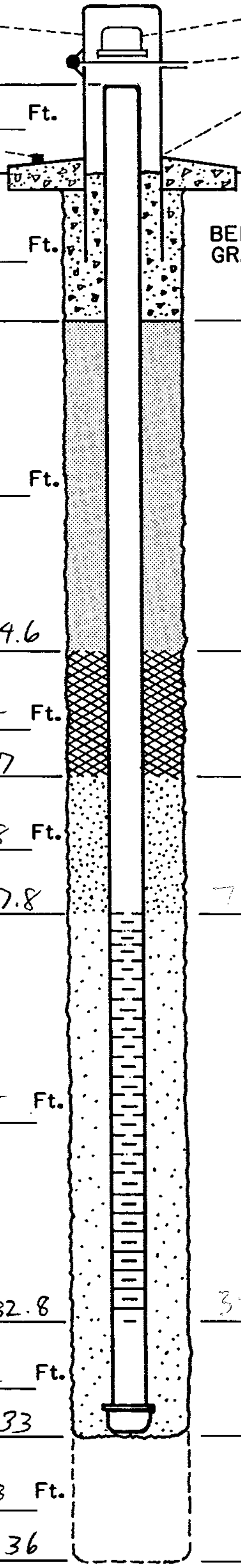
GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED	5/21/98
PAGE	1 of 1
DRILLING METHOD	HSA
DRILLED BY	WEBER DRLG.
LOGGED BY	T. REED
EXISTING GRADE ELEVATION (FT. AMSL)	
LOCATION OR GRID COORDINATES	~ 500' EAST OF PC-56

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM

FLUSH MOUNT



Protective Pipe (crossed out) — Yes ☐ No ☐ — Steel ☐ PVC ☐

Surveying Pin ? Yes ☐ No ☒ — ______ Ft.

Casing Cap Vent ? Yes ☐ No ☐

Lock ? Yes ☐ No ☐

Weep Hole ? Yes ☐ No ☐

Concrete Pad ______ Ft. x ______ Ft. x ______ Inches

Concrete ______ Ft.

DEPTH — BELOW GRADE / FROM TOP OF CASING

Cement/Bentonite Grout Mix
Yes ☑ No ☐
5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder
Other: ______

______ Ft. — 4.6

Bentonite Seal
Pellets ☑ Slurry ☐
2.4 Ft. — 7

Filter Pack Above Screen
0.8 Ft. — 7.8 (below grade: 7.8)

FILTER PACK MATERIAL
Silica Sand ☐
Washed Sand ☑
Pea Gravel ☐
Other: ______
Sand Size 8-12

25 Ft. — 32.8 (below grade: 32.8)

Dense Phase Sampling Cup
Bottom Plug
Yes ☐ No ☑
.2 Ft. — 33

Overdrilled Material Backfill
Grout ☐ Sand ☐
Caved Material ☑
Other: ______
3 Ft. — 36

DRILLING INFORMATION:

1. Borehole Diameter= 8 Inches.
2. Were Drilling Additives Used ? Yes ☐ No ☑
   Revert ☐ Bentonite ☐ Water ☐
   Solid Auger ☐ Hollow Stem Auger ☑
3. Was Outer Steel Casing Used ? Yes ☐ No ☑
   Depth= ______ to ______ Feet.
4. Borehole Diameter for Outer Casing ______ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC ☑ Galvanized ☐ Teflon ☐
   Stainless ☐ Other ______
2. Type of Casing Joints: Screw-Couple ☑ Glue-Couple ☐ Other ______
3. Type of Well Screen: PVC ☑ Galvanized ☐
   Stainless ☐ Teflon ☐ Other ______
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: .020
6. Type of Screen Perforation: Factory Slotted ☑
   Hacksaw ☐ Drilled ☐ Other ______
7. Installed Protector Pipe w/Lock: Yes ☐ No ☑

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing ☐ Pumping ☑
   Air Surging (Air or Nitrogen) ☐ Other ______
2. Time Spent on Well Development ?
   45 / 0 Minutes/Hours
3. Approximate Water Volume Removed ? 80 Gallons
4. Water Clarity Before Development ? Clear ☐
   Turbid ☐ Opaque ☑
5. Water Clarity After Development ? Clear ☑
   Turbid ☐ Opaque ☐
6. Did Water have Odor ? Yes ☐ No ☑
   If Yes, Describe ______
7. Did Water have any Color ? Yes ☐ No ☑
   If Yes , Describe ______

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 13 Ft. Date 5/21/98

Before Development ______ Ft. Date ______

After Development 8.00 Ft. Date 6/15/98

Driller/Firm ROBERTSON / WEBER DRLG. Drill Rig Type B-61 HDX Date Installed 5/21/98

Drill Crew L. ROBERTSON / M. ROBESON Well No. PC-58 Kerr-McGee Hydrologist T. REED

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMCLLC	LOCATION: HENDERSON, NV	BORING NUMBER: PC-59

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–2	BERM: SAND W/GRAVEL									
2	SAND W/ SILT; OCC. GRAVEL; MED. BROWN; WELL-GRADED; SLI. MOIST GRAVEL @ 3-4'		SM							
~8	(water table, time of boring)		▽							
19	SAND AS ABOVE; SATURATED; OCC. GRAVEL		SM							
30	SANDY SILT; LT. BEIGE; SATURATED; OCC FINE-MED. SAND		ML							
34	SILTY CLAY; CLAYEY-SILT; MED-GREEN-BEIGE; V. SLI. PLASTIC MUDDY CREEK		CL-ML							
38	TD 38'					1		38 39.5	1.4'	

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method

SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY

- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

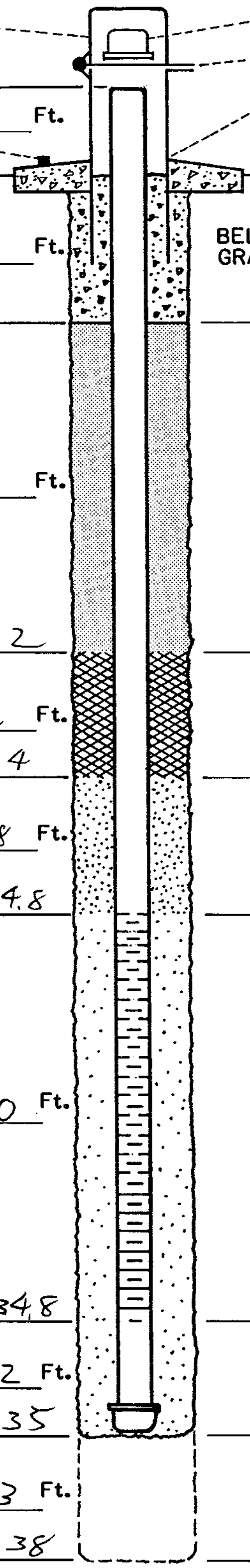
DATE DRILLED	5/22/93
PAGE	1 of 1
DRILLING METHOD	HSA
DRILLED BY	WEBER DRLG.
LOGGED BY	T. REED
EXISTING GRADE ELEVATION (FT. AMSL)	
LOCATION OR GRID COORDINATES	~500' WEST OF PC-56

FLUSH MOUNT

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM

Protective Pipe (crossed out)
Yes ☐ No ☐
Steel ☐ PVC ☐
Surveying Pin ? ______ Ft.
Yes ☐ No ☐

Casing Cap Vent ? Yes ☐ No ☐
Lock ? Yes ☐ No ☐
Weep Hole ? Yes ☐ No ☐
Concrete Pad ______ Ft. x ______ Ft. x ______ Inches



DEPTH: BELOW GRADE / FROM TOP OF CASING

Concrete ______ Ft.

Cement/Bentonite Grout Mix
Yes ☑ No ☐
5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder ______ Ft.
Other: ______

Depth: 2

Bentonite Seal 2 Ft.
Pellets ☑ Slurry ☐

Depth: 4

Filter Pack Above Screen .8 Ft.

Depth: 4.8

FILTER PACK MATERIAL 30 Ft.
Silica Sand ☐
Washed Sand ☑
Pea Gravel ☐
Other: ______
Sand Size 8-12

Depth: 34.8

Dense Phase Sampling Cup 2 Ft.
Bottom Plug
Yes ☐ No ☑

Depth: 35

Overdrilled Material Backfill 3 Ft.
Grout ☐ Sand ☐
Caved Material ☑
Other: ______

Depth: 38

DRILLING INFORMATION:

1. Borehole Diameter= 8 Inches.
2. Were Drilling Additives Used ? Yes ☐ No ☑
   Revert ☐ Bentonite ☐ Water ☐
   Solid Auger ☐ Hollow Stem Auger ☑
3. Was Outer Steel Casing Used ? Yes ☐ No ☑
   Depth= ______ to ______ Feet.
4. Borehole Diameter for Outer Casing ______ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC ☑ Galvanized ☐ Teflon ☐
   Stainless ☐ Other ______
2. Type of Casing Joints: Screw-Couple ☑ Glue-Couple ☐ Other ______
3. Type of Well Screen: PVC ☑ Galvanized ☐
   Stainless ☐ Teflon ☐ Other ______
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: .020
6. Type of Screen Perforation: Factory Slotted ☑
   Hacksaw ☐ Drilled ☐ Other ______
7. Installed Protector Pipe w/Lock: Yes ☐ No ☑

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing ☐ Pumping ☑
   Air Surging (Air or Nitrogen) ☐ Other ______
2. Time Spent on Well Development ?
   15 / 1 Minutes/Hours
3. Approximate Water Volume Removed ? 110 Gallons
4. Water Clarity Before Development ? Clear ☐
   Turbid ☐ Opaque ☑
5. Water Clarity After Development ? Clear ☑
   Turbid ☐ Opaque ☐
6. Did Water have Odor ? Yes ☐ No ☑
   If Yes, Describe ______
7. Did Water have any Color ? Yes ☐ No ☑
   If Yes , Describe ______

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 8 Ft. Date 5/22/98
Before Development ______ Ft. Date ______
After Development 9.14' Ft. Date 6/15/98

Driller/Firm ROBERTSON / WEBER DRLG. Drill Rig Type B-61 HDX Date Installed 5/22/98
Drill Crew ______ Well No. PC-59 Kerr-McGee Hydrologist T. REED

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC LLC	LOCATION: Henderson NV	BORING NUMBER: PC 74

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–8 (5)	0-8 GRAVEL w/ slty sd, yell orange. 30% gravel + boulders to 2' diam. volcanics 60% vc-vf SA sd 10% silt		GW							
8–15 (10, 15)	8-15 slty SAND w/minor gravel. Inc in silt to 25%. gry brn. sd is vf-vc, SA-A. Gravel up to 2"		SM							damp @ 7' @ 12.45' ▼ 4-29-00
15–21 (20)	15-21 sdy GRAVEL w/minor silt. gry brn volc grav. to 2" w/ sd vc-f SA-A matrix. 10-15% silt		GW-GM							▽ WTR @ 16' (Perched) 4-26-00 only damp @ 21'
21–24	21-24 cly SAND, gry grn, sd f-vc w/ com (40%) clay		SC							▽ WTR @ 24' 4-26-00
24–51 (25, 30, 35)	24-51 Pea Gravel w/ vc-f sd matrix. grn gry. st. slty 25% sd 70% pea gravel 27-28.5 w/ com cobbles/ boulders 37-48 boulder zones (thin) scattered throughout		GW							

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED: 4-26-00

PAGE 1 of 2

DRILLING METHOD: HSA

DRILLED BY: Compliance

LOGGED BY: E KRISH

EXISTING GRADE ELEVATION (FT AMSL):

LOCATION OR GRID COORDINATES:

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY KMC LLC	LOCATION Henderson NV	BORING NUMBER PC74

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
45			GW							SCREENED 40'-50' WTR SMPL 4-28-00 pH 7.3 TDS 7100
51	51-56 SAND, m-vc, SA-SR, grn gry, hard. Sl. slty (10%). w/ 10% granules		SW							
56, 60, 65	56-70 slty sdy CLAY, grn gry & red brn, mottled. Calcareous, sticky, drills slow. w/ 5-15% vf-mg sand in matrix. Contains 10% c-vc-gran sized caliche nodules dissem. throughout		CL-ML							Muddy Creek @ 56'
70	TD 70'									

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL
- AUGER
- ROCK CORE
- THIN-WALLED TUBE
- CONTINUOUS SAMPLER
- NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

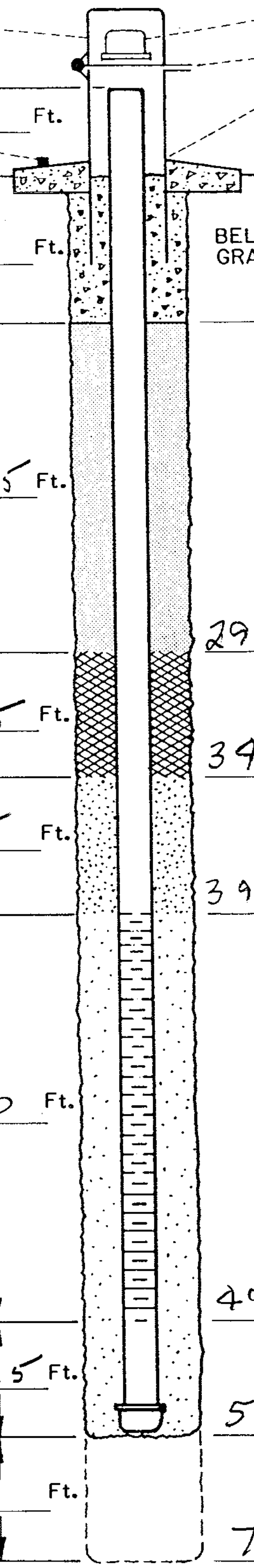
GRAPHIC LOG LEGEND

CLAY, DEBRIS FILL, SILT, HIGHLY ORGANIC (PEAT), SAND, SANDY CLAY, GRAVEL, CLAYEY SAND, SILTY CLAY, CLAYEY SILT

DATE DRILLED	4-26-00
PAGE	2 of 2
DRILLING METHOD	HSA
DRILLED BY	Compliance
LOGGED BY	E KRISH
EXISTING GRADE ELEVATION (FT AMSL)	
LOCATION OR GRID COORDINATES	

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM

FLUSH MOUNT



Protective Pipe: Yes [X] No [ ]
Steel [X] PVC [ ]
Surveying Pin ? Yes [ ] No [ ]
Casing Cap Vent ? Yes [X] No [ ]
Lock ? Yes [ ] No [ ]
Weep Hole ? Yes [ ] No [ ]
Concrete Pad ______ Ft. x ______ Ft. x ______ Inches

______ Ft.

Concrete ______ Ft.

	DEPTH BELOW GRADE	DEPTH FROM TOP OF CASING
Concrete		
Cement/Bentonite Grout Mix	29.5	
Bentonite Seal	34.5	
Filter Pack Above Screen	39.5	
Screen	49.5	
Dense Phase Sampling Cup	50'	
Overdrilled Material	70'	

Cement/Bentonite Grout Mix
Yes [X] No [ ]
5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder — 29.5 Ft.
Other: ______

Bentonite Seal — 5 Ft.
Pellets [X] Slurry [ ]

Filter Pack Above Screen — 5 Ft.

FILTER PACK MATERIAL — 10 Ft.
Silica Sand [ ]
Washed Sand [X]
Pea Gravel [ ]
Other: ______
Sand Size #3

Dense Phase Sampling Cup — 0.5 Ft.
Bottom Plug
Yes [X] No [ ]

Overdrilled Material Backfill ______ Ft.
Grout [ ] Sand [X]
Caved Material [ ]
Other: ______

DRILLING INFORMATION:

1. Borehole Diameter= 10 1/2 Inches.
2. Were Drilling Additives Used ? Yes [ ] No [X]
   Revert [ ] Bentonite [ ] Water [ ]
   Solid Auger [ ] Hollow Stem Auger [X]
3. Was Outer Steel Casing Used ? Yes [ ] No [X]
   Depth= ______ to ______ Feet.
4. Borehole Diameter for Outer Casing ______ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC [X] Galvanized [ ] Teflon [ ]
   Stainless [ ] Other ______
2. Type of Casing Joints: Screw-Couple [X] Glue-Couple [ ] Other ______
3. Type of Well Screen: PVC [X] Galvanized [ ]
   Stainless [ ] Teflon [ ] Other ______
4. Diameter of Casing and Well Screen:
   Casing 2" Inches, Screen 2" Inches.
5. Slot Size of Screen: 0.02
6. Type of Screen Perforation: Factory Slotted [X]
   Hacksaw [ ] Drilled [ ] Other ______
7. Installed Protector Pipe w/Lock: Yes [X] No [ ]

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing [ ] Pumping [X]
   Air Surging (Air or Nitrogen) [ ] Other ______
2. Time Spent on Well Development ?
   ______ / 60 Minutes/Hours (Minutes circled)
3. Approximate Water Volume Removed ? ______ Gallons
4. Water Clarity Before Development ? Clear [ ]
   Turbid [X] Opaque [ ]
5. Water Clarity After Development ? Clear [X]
   Turbid [ ] Opaque [ ]
6. Did Water have Odor ? Yes [ ] No [X]
   If Yes, Describe ______
7. Did Water have any Color ? Yes [ ] No [X]
   If Yes , Describe ______

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 24 Ft. Date 4-26-00
Before Development 12.45 Ft. Date 4-29-00
After Development 13.41' Ft. Date 5-11-00

Driller/Firm Compliance   Drill Rig Type Mobile 53   Date Installed 4-26-00

Drill Crew Wells,   Well No. PC 74   Kerr-McGee Hydrologist Ed Krish

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC LLC	LOCATION: HENDERSON, NV	BORING NUMBER: PC 82

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0	0-3 disturbed berm material silty grav SAND	SM-GM							@2' damp
3–12 (5, 10)	3-12 silty gravelly SAND, dk brn, 20% silt, 40% granules & pea gravel (SR) of volc. 40% vf-vc sd, SA-SR	SM-GM							▽ @5'
12–15	12-15 sdy cly SILT, dk brn, 15-25% vf-m, SA-SR, sd, 20% clay, 10% sm volc granules. sticky	ML							
15–20	15-20 silty sdy GRAVEL, dk brn, SR-SA, 20% silt, 25% vf-vc sd, SA-SR	GM							
20–30 (25)	20-30 silty gravelly SAND, dk brn, 20% silt, 40% volc granules to pea gravel to 1/2", SR; vf-vc, SR-SA sd	SM-GM							
30–33	30-33 sdy silty GRAVEL, dk brn, 30% SA-SR, vf-c sd, 20% silt, 50% volc w/ minor ls gravel to 2-3", SR	GM							
33–39 (35)	33-39 silty gravelly SAND, as above. @38'-39' gravel zone, volc SR up to 3" diam	SM-GM							
39	39-46 silty SAND, brn,	SM							

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED	5-4-00
PAGE	1 of 2
DRILLING METHOD	HSA
DRILLED BY	COMPLIANCE
LOGGED BY	ED KRISH
EXISTING GRADE ELEVATION (FT. AMSL)	
LOCATION OR GRID COORDINATES	

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC LLC	LOCATION: HENDERSON, NV	BORING NUMBER: PC82

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
	SA, 30% silt in 70% vf-f sd w/ minor c-vc grains sticky. calcareous		SM							
45										
	46-50 silty gravelly SAND, dk brn, as above		SM-GM							
50	50-52 cly, silty SAND, lt. red brn + grn gry. SA-SR vf-fg sd w/ 20% clay + 30% silt. Com sm caliche nodules; calcareous		SM-SC							
52			SM-GM							
56	52-56 silty gravelly SAND, f-c SR-SA w/ 20% silt and 30% volc + ls pebbles to 2"					Muddy Ck @ 56'				
60	56-67 silty CLAY, lt grn yellow, sticky		CL							
65										
67	TD 67'									

EXPLANATION

- ▼ Water Table (24 Hour)
- ∇ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE
- THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

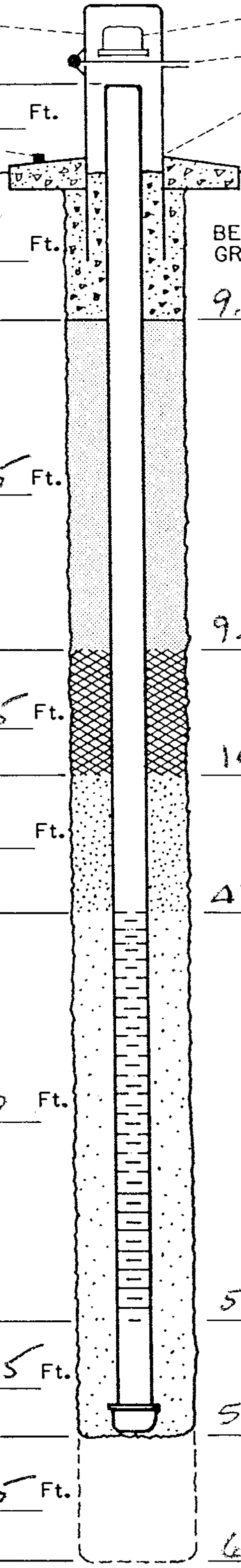
GRAPHIC LOG LEGEND

CLAY, DEBRIS FILL, SILT, HIGHLY ORGANIC (PEAT), SAND, SANDY CLAY, GRAVEL, CLAYEY SAND, SILTY CLAY, CLAYEY SILT

DATE DRILLED	5-4-00
PAGE	2 of 2
DRILLING METHOD	HSA
DRILLED BY	COMPLIANCE
LOGGED BY	ED KRISH
EXISTING GRADE ELEVATION (FT AMSL)	
LOCATION OR GRID COORDINATES	

KERR–McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM

FLUSH MOUNT



Protective Pipe — Yes ☐ No ☐ — Steel ☐ PVC ☐

____ Ft.

Surveying Pin ? Yes ☐ No ☐

Concrete ____ Ft.

Casing Cap Vent ? Yes ☐ No ☐

Lock ? Yes ☐ No ☐

Weep Hole ? Yes ☐ No ☐

Concrete Pad ____ Ft. x ____ Ft. x ____ Inches

	DEPTH BELOW GRADE	DEPTH FROM TOP OF CASING
Concrete	9.5	
Cement/Bentonite Grout Mix — Yes ☒ No ☐ — 5.5 Gallons Water to 94Lb. Bag Cement & 3–5 Lb. Bentonite Powder — Other: ____ — 9.5 Ft.	9.5	
Bentonite Seal — Pellets ☒ Slurry ☐ — 4.5 Ft.	14	
Filter Pack Above Screen — 33 Ft.	47	
Screen — 10 Ft.	57	
Dense Phase Sampling Cup — 0.5 Ft.	57.5	
Overdrilled Material Backfill — 9.5 Ft.	67	

FILTER PACK MATERIAL

Silica Sand ☐

Washed Sand ☒

Pea Gravel ☐

Other: Cave-in gravel

Sand Size ____

Bottom Plug Yes ☐ No ☐

Overdrilled Material Backfill: Grout ☐ Sand ☐ Caved Material ☒ Other: ____

DRILLING INFORMATION:

1. Borehole Diameter= 8 Inches.
2. Were Drilling Additives Used ? Yes ☐ No ☒
   Revert ☐ Bentonite ☐ Water ☐
   Solid Auger ☐ Hollow Stem Auger ☒
3. Was Outer Steel Casing Used ? Yes ☐ No ☒
   Depth= ____ to ____ Feet.
4. Borehole Diameter for Outer Casing ____ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC ☒ Galvanized ☐ Teflon ☐ Stainless ☐ Other ____
2. Type of Casing Joints: Screw–Couple ☒ Glue–Couple ☐ Other ____
3. Type of Well Screen: PVC ☒ Galvanized ☐ Stainless ☐ Teflon ☐ Other ____
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: 0.020
6. Type of Screen Perforation: Factory Slotted ☒
   Hacksaw ☐ Drilled ☐ Other ____
7. Installed Protector Pipe w/Lock: Yes ☐ No ☒

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing ☐ Pumping ☒
   Air Surging (Air or Nitrogen) ☐ Other ____
2. Time Spent on Well Development ?
   ____ / 60 (Minutes)/Hours
3. Approximate Water Volume Removed ? ____ Gallons
4. Water Clarity Before Development ? Clear ☐ Turbid ☒ Opaque ☐
5. Water Clarity After Development ? Clear ☒ Turbid ☐ Opaque ☐
6. Did Water have Odor ? Yes ☐ No ☒
   If Yes, Describe ____
7. Did Water have any Color ? Yes ☐ No ☒
   If Yes , Describe ____

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 5' Ft. Date 5-4-00

Before Development 4.91' Ft. Date 5-5-00

After Development 5.42' Ft. Date 5-11-00

Driller/Firm COMPLIANCE Drill Rig Type MOBILE B-59 Date Installed 5-4-00

Drill Crew WELLS Well No. PC 82 Kerr–McGee Hydrologist ED KROH

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY KMC LLC	LOCATION HENDERSON, NV	BORING NUMBER PC 83

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
	PC 83 is 11' NORTH of PC82. See log for PC82 for lithology									
5										▽ @5' 5-4-00
10										
15										
20										
25										
30										
35										
	37' TD									

EXPLANATION

▼ Water Table (24 Hour)
▽ Water Table (Time of Boring)
PID Photoionization Detection (ppm)
NO. Identifies Sample by Number
TYPE Sample Collection Method

SPLIT-BARREL | AUGER | ROCK CORE | THIN-WALLED TUBE | CONTINUOUS SAMPLER | NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

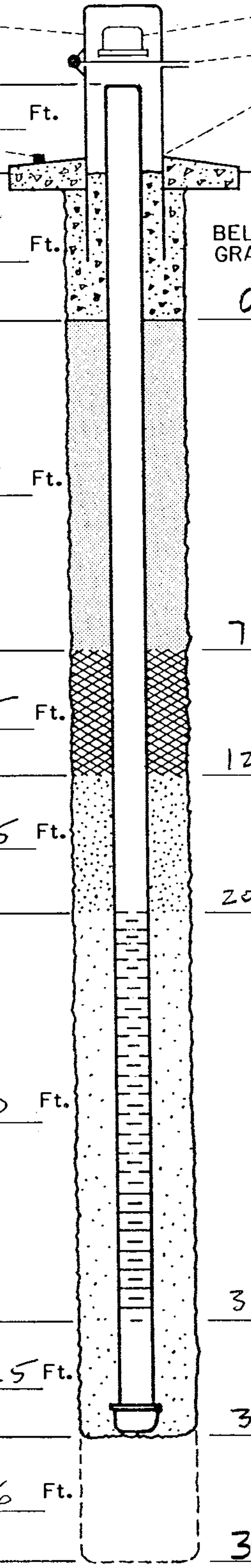
GRAPHIC LOG LEGEND

CLAY | DEBRIS FILL | SILT | HIGHLY ORGANIC (PEAT) | SAND | SANDY CLAY | GRAVEL | CLAYEY SAND | SILTY CLAY | CLAYEY SILT

DATE DRILLED: 5-4-00	PAGE 1 of 1
DRILLING METHOD: HSA	
DRILLED BY: COMPLIANCE	
LOGGED BY: ED KRISH	
EXISTING GRADE ELEVATION (FT. AMSL):	
LOCATION OR GRID COORDINATES:	

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM

FLUSH MOUNT



Protective Pipe — Yes [ ] No [ ] — Steel [ ] PVC [ ]

Casing Cap Vent ? Yes [ ] No [ ]

Lock ? Yes [ ] No [ ]

Weep Hole ? Yes [ ] No [ ]

______ Ft.

Surveying Pin ? Yes [ ] No [ ]

Concrete Pad ______ Ft. x ______ Ft. x ______ Inches

Interval	Thickness	Depth Below Grade	Depth From Top of Casing
Concrete	______ Ft.	0	______
Cement/Bentonite Grout Mix	7 Ft.	7	______
Bentonite Seal	5 Ft.	12	______
Filter Pack Above Screen	8.5 Ft.	20.5	______
Filter Pack Material	10 Ft.	30.5	______
Dense Phase Sampling Cup	0.5 Ft.	31	______
Overdrilled Material Backfill	6 Ft.	37	

Cement/Bentonite Grout Mix — Yes [X] No [ ]

5.5 Gallons Water to 94Lb. Bag Cement & 3–5 Lb. Bentonite Powder

Other: ______

Bentonite Seal — Pellets [X] Slurry [ ]

FILTER PACK MATERIAL

Silica Sand [ ]

Washed Sand [X]

Pea Gravel [ ]

Other: caved gravel

Sand Size #3

Dense Phase Sampling Cup

Bottom Plug — Yes [X] No [ ]

Overdrilled Material Backfill — Grout [ ] Sand [ ] Caved Material [X]

Other: ______

DRILLING INFORMATION:

1. Borehole Diameter= 8 Inches.
2. Were Drilling Additives Used ? Yes [ ] No [X]
   Revert [ ] Bentonite [ ] Water [ ]
   Solid Auger [ ] Hollow Stem Auger [X]
3. Was Outer Steel Casing Used ? Yes [ ] No [X]
   Depth= ______ to ______ Feet.
4. Borehole Diameter for Outer Casing ______ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC [X] Galvanized [ ] Teflon [ ]
   Stainless [ ] Other ______
2. Type of Casing Joints: Screw–Couple [X] Glue–Couple [ ] Other ______
3. Type of Well Screen: PVC [X] Galvanized [ ]
   Stainless [ ] Teflon [ ] Other ______
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: 0.020
6. Type of Screen Perforation: Factory Slotted [X]
   Hacksaw [ ] Drilled [ ] Other ______
7. Installed Protector Pipe w/Lock: Yes [ ] No [X]

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing [ ] Pumping [X]
   Air Surging (Air or Nitrogen) [ ] Other ______
2. Time Spent on Well Development ?
   ______ / 60 (Minutes) / Hours
3. Approximate Water Volume Removed ? ______ Gallons
4. Water Clarity Before Development ? Clear [ ]
   Turbid [X] Opaque [ ]
5. Water Clarity After Development ? Clear [X]
   Turbid [ ] Opaque [ ]
6. Did Water have Odor ? Yes [ ] No [X]
   If Yes, Describe ______
7. Did Water have any Color ? Yes [ ] No [X]
   If Yes , Describe ______

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 5' Ft. Date 5-4-00

Before Development 3.82' Ft. Date 5-11-00

After Development ______ Ft. Date ______

Driller/Firm COMPLIANCE — Drill Rig Type Mobile B-59 — Date Installed 5-5-00

Drill Crew WELLS — Well No. PC 83 — Kerr–McGee Hydrologist ED KRISH

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC LLC	LOCATION: HENDERSON, NV	BORING NUMBER: PC 88

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6'	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–12	0-12 sdy GRAVEL, pale brn (5YR 5/2). 10% silt, 30% sd (SA-SR, vf-vc) and 60% volc gravel (SA-SR, up to 3" diam.		GW							damp @ 0' ▽ @ 2'
12–51	12-51 slty gravelly SAND. pale yell brn (10YR 6/2). Var. silt 20-40%. 20-30% pea gravel to 3/4" (volc). Sand SA-SR vf-vc 12-21 10-20% slty matrix 21-51 com silt in matrix 30-40% 27-33 gravel zone w/ pebbles to 3". Var. caliche cement 32-33 v. hard. slow drilling abu caliche cement 37-51 Var. amts of gravel (pebbles to 2") up to 50%		SM-GM							

Depth scale: 5, 10, 15, 20, 25, 30, 35

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED	5-11-00
PAGE	1 of 2
DRILLING METHOD	HSA
DRILLED BY	COMPLIANCE
LOGGED BY	ED KRISH
EXISTING GRADE ELEVATION (FT AMSL)	
LOCATION OR GRID COORDINATES	

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC LLC	LOCATION: HENDERSON, NV	BORING NUMBER: PC 88

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
45	NOTE: Most likely this unit is a series of fluvial fining-upward sediments from gravels to silts		SM GM							
51	51-62 silty CLAY, grn gry (5GY8/2) and yell gry (5Y8/1)									MC @ 51'
55			CL							
60										
62	TD 62'									

EXPLANATION

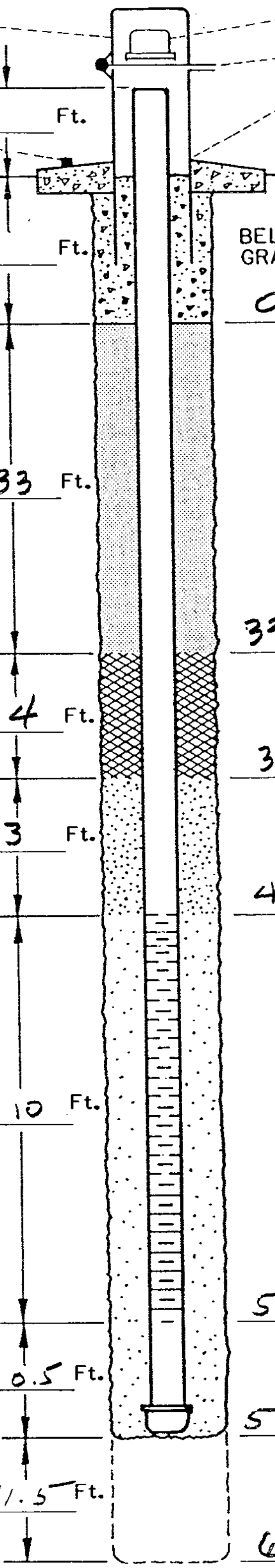
- Water Table (24 Hour)
- Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE
- THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED: 5-12-00	PAGE: 2 of 2
DRILLING METHOD: HSA	
DRILLED BY: COMPLIANCE	
LOGGED BY: ED KRISH	
EXISTING GRADE ELEVATION (FT AMSL):	
LOCATION OR GRID COORDINATES:	

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM FLUSH MOUNT



Protective Pipe — Yes ☐ No ☐
Steel ☐ PVC ☐
Surveying Pin ? Yes ☐ No ☐ ____ Ft.

Casing Cap Vent ? Yes ☐ No ☐
Lock ? Yes ☐ No ☐
Weep Hole ? Yes ☐ No ☐
Concrete Pad ____ Ft. x ____ Ft. x ____ Inches

Layer	Thickness	Depth Below Grade	Depth From Top of Casing
Concrete	____ Ft.	0	
Cement/Bentonite Grout Mix — Yes ☒ No ☐ — 5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder — Other: ____	33 Ft.	33	
Bentonite Seal — Pellets ☒ Slurry ☐	4 Ft.	37	
Filter Pack Above Screen	3 Ft.	40	
Screen (Filter Pack Material: Silica Sand ☐ Washed Sand ☒ Pea Gravel ☐ Other: ____; Sand Size 2-12 MESH)	10 Ft.	50	
Dense Phase Sampling Cup — Bottom Plug Yes ☒ No ☐	0.5 Ft.	50.5	
Overdrilled Material Backfill — Grout ☐ Sand ☐ Caved Material ☒ Other: ____	11.5 Ft.	62	

DRILLING INFORMATION:

1. Borehole Diameter= 8 Inches.
2. Were Drilling Additives Used ? Yes ☐ No ☒
   Revert ☐ Bentonite ☐ Water ☐
   Solid Auger ☐ Hollow Stem Auger ☒
3. Was Outer Steel Casing Used ? Yes ☐ No ☒
   Depth= ____ to ____ Feet.
4. Borehole Diameter for Outer Casing ____ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC ☒ Galvanized ☐ Teflon ☐ Stainless ☐ Other ____
2. Type of Casing Joints: Screw-Couple ☒ Glue-Couple ☐ Other ____
3. Type of Well Screen: PVC ☒ Galvanized ☐ Stainless ☐ Teflon ☐ Other ____
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: 0.020
6. Type of Screen Perforation: Factory Slotted ☒ Hacksaw ☐ Drilled ☐ Other ____
7. Installed Protector Pipe w/Lock: Yes ☐ No ☒

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing ☐ Pumping ☒
   Air Surging (Air or Nitrogen) ☐ Other ____
2. Time Spent on Well Development ?
   ____ / 60 (Minutes)/Hours
3. Approximate Water Volume Removed ? ____ Gallons
4. Water Clarity Before Development ? Clear ☐ Turbid ☒ Opaque ☐
5. Water Clarity After Development ? Clear ☒ Turbid ☐ Opaque ☐
6. Did Water have Odor ? Yes ☐ No ☒
   If Yes, Describe ____
7. Did Water have any Color ? Yes ☐ No ☒
   If Yes, Describe ____

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 2' Ft. Date 5-11-00
Before Development 0.21' Ft. Date 5-13-00
After Development ____ Ft. Date ____

Driller/Firm COMPLIANCE — Drill Rig Type MOBILE B.59 — Date Installed 5-11-00

Drill Crew WELLS — Well No. PC 88 — Kerr-McGee Hydrologist ED KRISH

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY KMC LLC	LOCATION HENDERSON, NV	BORING NUMBER PC89

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
										▽ @ 2'
5	PC89 located 7' east of PC88. See log of PC88 for lithology									
10										
15										
20										
25										
30										
35										
39	TD 39'									

EXPLANATION

▼ Water Table (24 Hour)
▽ Water Table (Time of Boring)
PID Photoionization Detection (ppm)
NO. Identifies Sample by Number
TYPE Sample Collection Method

SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

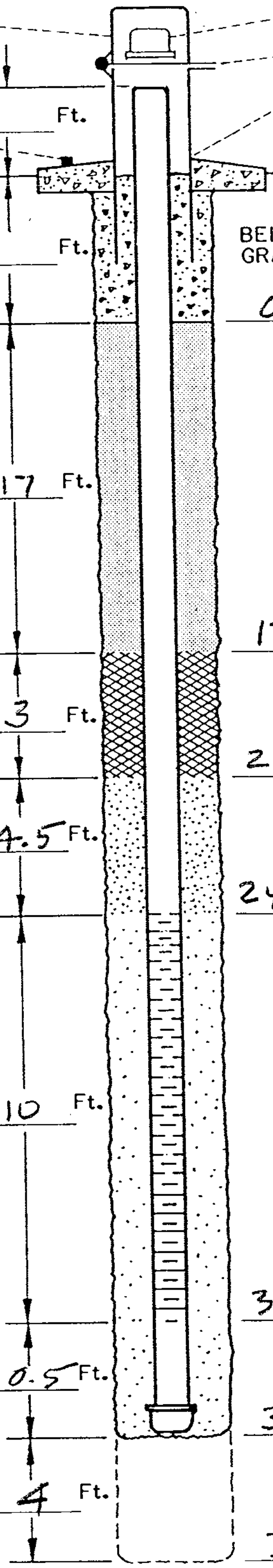
GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED: 5-12-00
PAGE: 1 of 1
DRILLING METHOD: HSA
DRILLED BY: COMPLIANCE
LOGGED BY: ED KRISH
EXISTING GRADE ELEVATION (FT AMSL):
LOCATION OR GRID COORDINATES:

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM

FLUSH MOUNT



Protective Pipe — Yes ☐ No ☐ — Steel ☐ PVC ☐ — ______ Ft.

Surveying Pin ? Yes ☐ No ☐

Casing Cap Vent ? Yes ☐ No ☐

Lock ? Yes ☐ No ☐

Weep Hole ? Yes ☐ No ☐

Concrete Pad ______ Ft. x ______ Ft. x ______ Inches

Interval	Thickness	Depth Below Grade	Depth From Top of Casing
Concrete	______ Ft.	0	
Cement/Bentonite Grout Mix — Yes ☒ No ☐ — 5.5 Gallons Water to 94Lb. Bag Cement & 3–5 Lb. Bentonite Powder — Other: ______	17 Ft.	17	
Bentonite Seal — Pellets ☒ Slurry ☐	3 Ft.	20	
Filter Pack Above Screen	4.5 Ft.	24.5	
FILTER PACK MATERIAL — Silica Sand ☐ Washed Sand ☒ Pea Gravel ☐ Other: ______ — Sand Size 3-12 MESH	10 Ft.	34.5	
Dense Phase Sampling Cup — Bottom Plug Yes ☒ No ☐	0.5 Ft.	35	
Overdrilled Material Backfill — Grout ☐ Sand ☐ Caved Material ☒ Other: ______	4 Ft.	39	

DRILLING INFORMATION:

1. Borehole Diameter= 8 Inches.
2. Were Drilling Additives Used ? Yes ☐ No ☒
   Revert ☐ Bentonite ☐ Water ☐
   Solid Auger ☐ Hollow Stem Auger ☒
3. Was Outer Steel Casing Used ? Yes ☐ No ☒
   Depth= ______ to ______ Feet.
4. Borehole Diameter for Outer Casing ______ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC ☒ Galvanized ☐ Teflon ☐ Stainless ☐ Other ______
2. Type of Casing Joints: Screw–Couple ☒ Glue–Couple ☐ Other ______
3. Type of Well Screen: PVC ☒ Galvanized ☐ Stainless ☐ Teflon ☐ Other ______
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: 0.020
6. Type of Screen Perforation: Factory Slotted ☒
   Hacksaw ☐ Drilled ☐ Other ______
7. Installed Protector Pipe w/Lock: Yes ☐ No ☒

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing ☐ Pumping ☒
   Air Surging (Air or Nitrogen) ☐ Other ______
2. Time Spent on Well Development ?
   ______ / 60 Minutes/Hours (Minutes circled)
3. Approximate Water Volume Removed ? ______ Gallons
4. Water Clarity Before Development ? Clear ☐ Turbid ☒ Opaque ☐
5. Water Clarity After Development ? Clear ☒ Turbid ☐ Opaque ☐
6. Did Water have Odor ? Yes ☐ No ☒
   If Yes, Describe ______
7. Did Water have any Color ? Yes ☐ No ☒
   If Yes , Describe ______

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 2 Ft. Date 5-12-00

Before Development +0.08' Ft. Date 5-13-00

After Development ______ Ft. Date ______

Driller/Firm COMPLIANCE — Drill Rig Type Mobile B-59 — Date Installed 5-12-00

Drill Crew WELLS — Well No. PC 89 — Kerr-McGee Hydrologist ED KRISH

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC LLC	LOCATION: HENDERSON, NV	BORING NUMBER: PC 97

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–5	0-5 Berm material brn slty gravelly SAND		SW							damp @ 3'
5–20	5-20 slty gravelly SAND, pale brn (5YR5/2) 10% silt, 25% volc granules and sm pebbles up to 1" diam Sand is vf-vc, SA-SR		SW							▽ @ 6'
20–25	20-25 slty SAND w/ minor gravel. pale yell brn (10YR 6/2). Silt up to 25%, gravel (gran. + pea size up to 20%. Sand as above... vf-vc, SR-SA.		SM							
25–36	25-36 slty sdy GRAVEL pale yell brn (10YR 6/2). 25% silt, 25% vf-vc, SA-SR Gravel 50%, SR-SA, granules and pebbles to 2" diam locally com caliche cement		GW							
36–	36-42 silty SAND pale yell brn (10YR6/2) bimodal: vf-fg w/ com.		SM							

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method

SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED	5-16-00
PAGE	1 of 2
DRILLING METHOD	HSA
DRILLED BY	COMPLIANCE
LOGGED BY	ED KRISH
EXISTING GRADE ELEVATION (FT AMSL)	
LOCATION OR GRID COORDINATES	

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC LLC	LOCATION: HENDERSON NV	BORING NUMBER: PC97

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
	c-vc, SR, sand. 25% silt in matrix. Calcareous		SM		—					
42–43	42-43 silty gravelly SAND pale yell brn. Gravels up to 3/4" diam w/ minor caliche cement, calcareous		SW							dense + dry
43–45	43-45 cly sdy SILT lt grn gry (5GY 8/1), 10-20% clay in matrix, 10-20% vf-fg sand. Calcareous, w/ minor sm. caliche nodules		ML-CL		—					MC @ 43
	TD 45'									

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

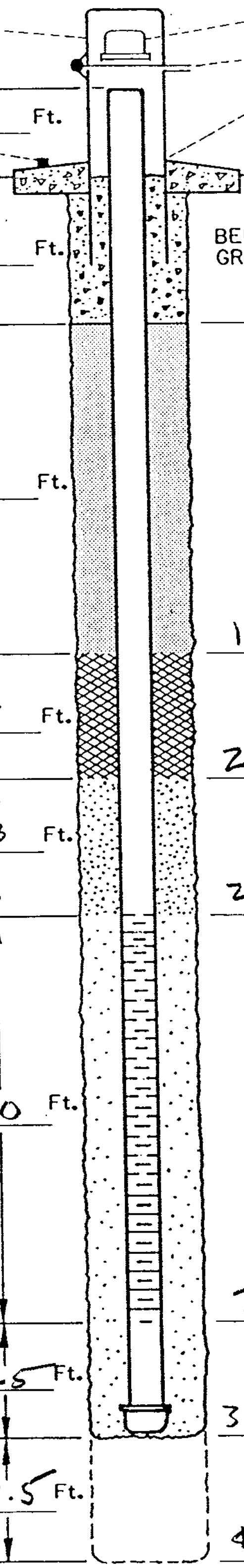
GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED	5-16-00
PAGE	2 of 2
DRILLING METHOD	HSA
DRILLED BY	COMPLIANCE
LOGGED BY	ED KRISH
EXISTING GRADE ELEVATION (FT AMSL)	
LOCATION OR GRID COORDINATES	

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM

FLUSH Mount



Protective Pipe
Yes ☐ No ☐
Steel ☐ PVC ☐
______ Ft.
Surveying Pin ?
Yes ☐ No ☐

Concrete ______ Ft.

Casing Cap Vent ? Yes ☐ No ☐
Lock ? Yes ☐ No ☐
Weep Hole ? Yes ☐ No ☐
Concrete Pad ______ Ft. x ______ Ft. x ______ Inches

	DEPTH BELOW GRADE	DEPTH FROM TOP OF CASING
Bottom of Concrete		
Cement/Bentonite Grout Mix ______ Ft.	13	
Bentonite Seal 7 Ft.	20	
Filter Pack Above Screen 3 Ft.	23	
Screen / Filter Pack 10 Ft.	33	
Dense Phase Sampling Cup 0.5 Ft.	33.5	
Overdrilled Material Backfill 11.5 Ft.	45	

Cement/Bentonite Grout Mix
Yes ☒ No ☐
5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder
Other: ______

Bentonite Seal
Pellets ☒ Slurry ☐

Filter Pack Above Screen

FILTER PACK MATERIAL
Silica Sand ☐
Washed Sand ☒
Pea Gravel ☐
Other: ______
Sand Size 2-12 mesh

Dense Phase Sampling Cup Bottom Plug
Yes ☒ No ☐

Overdrilled Material Backfill
Grout ☐ Sand ☐
Caved Material ☒
Other: ______

DRILLING INFORMATION:

1. Borehole Diameter= 8 Inches.
2. Were Drilling Additives Used ? Yes ☐ No ☒
   Revert ☐ Bentonite ☐ Water ☐
   Solid Auger ☐ Hollow Stem Auger ☒
3. Was Outer Steel Casing Used ? Yes ☐ No ☒
   Depth= ______ to ______ Feet.
4. Borehole Diameter for Outer Casing ______ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC ☒ Galvanized ☐ Teflon ☐
   Stainless ☐ Other ______
2. Type of Casing Joints: Screw-Couple ☒ Glue-Couple ☐ Other ______
3. Type of Well Screen: PVC ☒ Galvanized ☐
   Stainless ☐ Teflon ☐ Other ______
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: 0.020
6. Type of Screen Perforation: Factory Slotted ☒
   Hacksaw ☐ Drilled ☐ Other ______
7. Installed Protector Pipe w/Lock: Yes ☐ No ☒

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing ☐ Pumping ☒
   Air Surging (Air or Nitrogen) ☐ Other ______
2. Time Spent on Well Development ?
   ______ / 60 (Minutes)/Hours
3. Approximate Water Volume Removed ? ______ Gallons
4. Water Clarity Before Development ? Clear ☐
   Turbid ☒ Opaque ☐
5. Water Clarity After Development ? Clear ☒
   Turbid ☐ Opaque ☐
6. Did Water have Odor ? Yes ☐ No ☒
   If Yes, Describe ______
7. Did Water have any Color ? Yes ☐ No ☒
   If Yes , Describe ______

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 6' Ft. Date 5-16-00
Before Development 0.26' Ft. Date 5-17-00
After Development ______ Ft. Date ______

Driller/Firm COMPLIANCE | Drill Rig Type Mobile B-29 | Date Installed 5-16-00

Drill Crew WELLS | Well No. PC 97 | Kerr-McGee Hydrologist ED KRISH

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY KMC LLC	LOCATION Henderson, NV	BORING NUMBER PC 104

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–6	0-6 Berm Material sdy, gravelly mix									
6 10 15 21	6'-21' SAND, gravelly & silty. Brn (5YR 5/4). 10-20% silt in sd matrix of f-c g w/ minor vcg, SA-SR, 20-30% SA-SR, volc pea gravel to 3/4" w/ locally thin zones to 2". Non-calcareous. 6'-12' com gravel to 2"		SW							
21 25 30 35	21-35 GRAVEL & sdy GRAVEL, interbedded, brn (5YR 5/4). Volc clasts up to 1" except locally to 5", SA-SR, contains var. amts of vf-vc, SA-SR sd. tr silt 23-26' com lg gravel to 4" 29-30 slty gravelly SAND vf-vc w/ 20-30% silt 34'-35' com lg gravel to 5"		GP/GM							damp @ 21' wet @ 22'
35 36	35'-36' CLAY, slty, gry yel grn (5GY 7/2). 10-20% silt in matrix, non-calcareous. Tr-sp gypsum TD @ 36'		CL							MC @ 35'

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

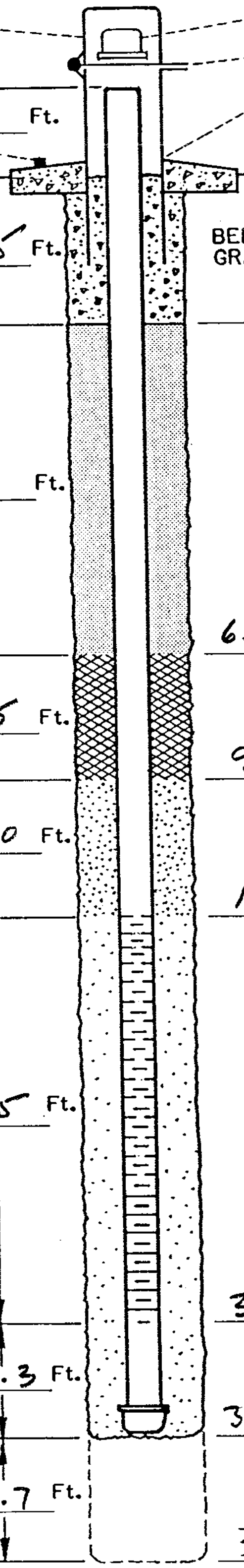
GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED	2-3-01
PAGE	1 of 1
DRILLING METHOD	PERCUSSION
DRILLED BY	LAYNE
LOGGED BY	Ed Krish
EXISTING GRADE ELEVATION (FT AMSL)	
LOCATION OR GRID COORDINATES	

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM

FLUSH MOUNT



Protective Pipe — Yes ☐ No ☒
Steel ☐ PVC ☐
____ Ft.
Surveying Pin ? Yes ☐ No ☒

Casing Cap Vent ? Yes ☒ No ☐
Lock ? Yes ☐ No ☒
Weep Hole ? Yes ☐ No ☒
Concrete Pad ____ Ft. x ____ Ft. x ____ Inches

	Thickness	DEPTH BELOW GRADE	DEPTH FROM TOP OF CASING
Concrete	6.5 Ft.		
Cement/Bentonite Grout Mix — Yes ☐ No ☒ — 5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder — Other: ____	0 Ft.	6.5	
Bentonite Seal — Pellets ☒ Slurry ☐	3.5 Ft.	9	
Filter Pack Above Screen	1.0 Ft.	10	
FILTER PACK MATERIAL — Silica Sand ☐ Washed Sand ☒ Pea Gravel ☐ Other: ____ Sand Size 3-12	25 Ft.	35	
Dense Phase Sampling Cup — Bottom Plug Yes ☒ No ☐	0.3 Ft.	35.3	
Overdrilled Material Backfill — Grout ☐ Sand ☐ Caved Material ☒ Other: ____	0.7 Ft.	36	

DRILLING INFORMATION:

1. Borehole Diameter= 9 Inches.
2. Were Drilling Additives Used ? Yes ☐ No ☒
   Revert ☐ Bentonite ☐ Water ☐
   Solid Auger ☐ Hollow Stem Auger ☐
3. Was Outer Steel Casing Used ? Yes ☐ No ☒
   Depth= ____ to ____ Feet.
4. Borehole Diameter for Outer Casing ____ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC ☒ Galvanized ☐ Teflon ☐
   Stainless ☐ Other ____
2. Type of Casing Joints: Screw—Couple ☒ Glue—Couple ☐ Other ____
3. Type of Well Screen: PVC ☒ Galvanized ☐
   Stainless ☐ Teflon ☐ Other ____
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: 0.020
6. Type of Screen Perforation: Factory Slotted ☒
   Hacksaw ☐ Drilled ☐ Other ____
7. Installed Protector Pipe w/Lock: Yes ☐ No ☒

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing ☐ Pumping ☒
   Air Surging (Air or Nitrogen) ☐ Other ____
2. Time Spent on Well Development ?
   ____/____ Minutes/Hours
3. Approximate Water Volume Removed ? ____ Gallons
4. Water Clarity Before Development ? Clear ☐
   Turbid ☐ Opaque ☐
5. Water Clarity After Development ? Clear ☐
   Turbid ☐ Opaque ☐
6. Did Water have Odor ? Yes ☐ No ☐
   If Yes, Describe ____
7. Did Water have any Color ? Yes ☐ No ☐
   If Yes, Describe ____

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 22 Ft. Date 2-3-01
Before Development ____ Ft. Date ____
After Development ____ Ft. Date ____

Driller/Firm LayNE Drill Rig Type AP-1000 Date Installed 2-3-01
Drill Crew Perry Well No. PC-104 Kerr-McGee Hydrologist Ed Krish

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY	LOCATION	BORING NUMBER
	KMC LLC	HENDERSON	PC 116 R

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–10 (5)	0-10 GRAVEL, sdy and SAND, gravelly – interbedded. Minor thin slty layers. Brn. 50-80% gran → 2" peb. 10-30% silt in sdy matrix 20-50% vf-vc, SA sd.		GW/SW							damp @ 1'; wet 2-18'
10–18 (15)	10'-18' SAND, slty brn, vf-c g, SA 10-30% silt in matrix locally com. sd-size caliche nodules		SM							
18–20	18-20 SILT, sdy, gry grn, com calche nods, 20-30% vf-f sd		ML							damp
20–27	20-27 SAND, slty, lt. brn. vf-m g w/ minor c-vc. 20-30% silt in matrix		SM							WTR @ 20'
27– (30, 35)	27-49 GRAVEL, sdy w/ minor gravelly sand and silty sand. pale brn. (Series of fining-up seq.) 70% volc + ls. granules → cobbles. 20-30% f-vc sd and thin layers w/ 20-30% silt in sdy matrix. 27-38 pea gravel		GP/GM							

EXPLANATION

- Water Table (24 Hour)
- Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED	7-25-01
PAGE	1 of 2
DRILLING METHOD	PERCUSSION
DRILLED BY	LAYNE
LOGGED BY	ED KRISH
EXISTING GRADE ELEVATION (FT. AMSL)	
LOCATION OR GRID COORDINATES	

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY: KMC LLC	LOCATION: HENDERSON, NV	BORING NUMBER: PC 116R

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
45	38'-49' com. cobbles to 6"		GP/GM							
49	49-58 CLAY & silty clay, w/ root traces & sm. gyp xtals. greenish and blue green		CL							MC @ 49' damp
58	TD 58'									

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method

SPLIT-BARREL · AUGER · ROCK CORE · THIN-WALLED TUBE · CONTINUOUS SAMPLER · NO RECOVERY

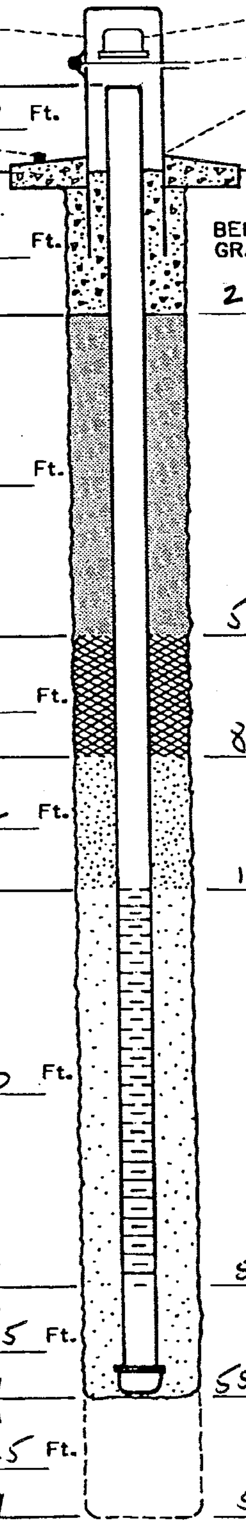
DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY · DEBRIS FILL · SILT · HIGHLY ORGANIC (PEAT) · SAND · SANDY CLAY · GRAVEL · CLAYEY SAND · SILTY CLAY · CLAYEY SILT

DATE DRILLED	7-25-01
PAGE	2 of 2
DRILLING METHOD	PERCUSSION
DRILLED BY	LAYNE
LOGGED BY	Ed Krish
EXISTING GRADE ELEVATION (FT. AMSL)	
LOCATION OR GRID COORDINATES	

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM



Protective Pipe: Yes ☐ No ☒
Steel ☐ PVC ☐
2.0 Ft.
Surveying Pin ? Yes ☐ No ☒

Casing Cap Vent ? Yes ☐ No ☒
Lock ? Yes ☐ No ☒
Weep Hole ? Yes ☐ No ☐
Concrete Pad ______ Ft. x ______ Ft. x ______ Inches

Interval	Thickness	DEPTH BELOW GRADE	DEPTH FROM TOP OF CASING
Concrete	0 Ft.	2	
Cement/Bentonite Grout Mix: Yes ☐ No ☒ (5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder) Other: CONCRETE	3 Ft.	5	
Bentonite Seal: Pellets ☒ Slurry ☐	3 Ft.	8	
Filter Pack Above Screen	2 Ft.	10	
FILTER PACK MATERIAL: Silica Sand ☐ Washed Sand ☒ Pea Gravel ☐ Other: ______ Sand Size 8X12 MESH	40 Ft.	50	
Dense Phase Sampling Cup; Bottom Plug Yes ☒ No ☐	5.5 Ft.	55.5 (5' blank)	
Overdrilled Material Backfill: Grout ☐ Sand ☒ Caved Material ☐ Other: ______	2.5 Ft.	58	

DRILLING INFORMATION:

1. Borehole Diameter= 13 1/4 Inches.
2. Were Drilling Additives Used ? Yes ☐ No ☒
   Revert ☐ Bentonite ☐ Water ☐
   Solid Auger ☐ Hollow Stem Auger ☐
3. Was Outer Steel Casing Used ? Yes ☐ No ☒
   Depth= ______ to ______ Feet.
4. Borehole Diameter for Outer Casing ______ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC ☒ Galvanized ☐ Teflon ☐ Stainless ☐ Other ______
2. Type of Casing Joints: Screw-Couple ☒ Glue-Couple ☐ Other ______
3. Type of Well Screen: PVC ☒ Galvanized ☐ Stainless ☐ Teflon ☐ Other ______
4. Diameter of Casing and Well Screen:
   Casing 8 Inches, Screen 8 Inches.
5. Slot Size of Screen: 0.040
6. Type of Screen Perforation: Factory Slotted ☒
   Hacksaw ☐ Drilled ☐ Other V-WIRE
7. Installed Protector Pipe w/Lock: Yes ☐ No ☐

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing ☐ Pumping ☒
   Air Surging (Air or Nitrogen) ☒ Other SURGE BLOCK
2. Time Spent on Well Development ?
   / 3 1/2 ~~Minutes~~/Hours
3. Approximate Water Volume Removed ? 2000 Gallons
4. Water Clarity Before Development ? Clear ☐ Turbid ☒ Opaque ☐
5. Water Clarity After Development ? Clear ☒ Turbid ☐ Opaque ☐
6. Did Water have Odor ? Yes ☐ No ☒
   If Yes, Describe ______
7. Did Water have any Color ? Yes ☐ No ☒
   If Yes, Describe ______

WATER LEVEL INFORMATION:
Water Level Summary (From Top of Casing)

	Ft.	Date
During Drilling		
Before Development		
After Development	4.20	7-27-01

Driller/Firm LAYNE
Drill Rig Type AP 1000
Date Installed 7-26-01
Drill Crew P. HORMAN
Well No. PC116R
Kerr-McGee Hydrologist ED KRISH

SOIL BORING LOG KM–5655-A

KERR-McGEE CORPORATION Hydrology Dept. Engineering Services	KM SUBSIDIARY	LOCATION	BORING NUMBER
	KMC LLC	HENDERSON, NV	PC 123

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
	0–1 Pavement [illegible]									
	1–8 GRAVEL, [illegible], brn, 65% [illegible] pebbles [illegible] w/25% vf-vc sd and 10% silt.		GW/GM							
8	8–12 SAND, gravelly, brn, 70% vf-vc, SA-SR sd w/ [illegible] gravel		SW							
12	12–22 GRAVEL, [illegible], brn 70% [illegible] pebbles, SR, to ½–1" w/20% vf-vc, SA-SR sd. AND 10% silt		GW/GM							DAMP @ 17'
22	22–27 SAND, gravelly, 70% [illegible] brn w/ 20% ½" [illegible] gravel & 10% SILT		SW/SM							WET @ 22'
27	27–33 GRAVEL, sdy, brn w/mod. hard calichified matrix. 70% gravel to [illegible]" w/30% sd. mod calichified		GW							
33	33–35 CLAY, silty, grn gry		CL							MC @ 33'
35.5	TD 35.5									

EXPLANATION

▼ Water Table (24 Hour)

▽ Water Table (Time of Boring)

PID Photoionization Detection (ppm)

NO. Identifies Sample by Number

TYPE Sample Collection Method

SPLIT-BARREL — AUGER — ROCK CORE — THIN-WALLED TUBE — CONTINUOUS SAMPLER — NO RECOVERY

DEPTH Depth Top and Bottom of Sample

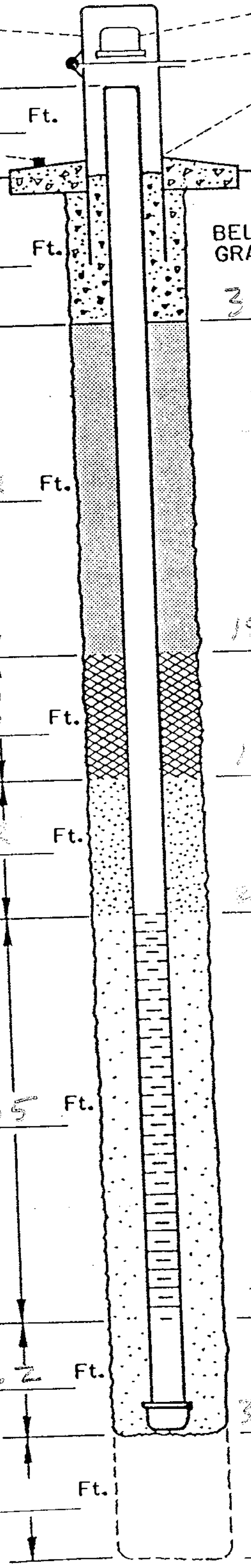
REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY — DEBRIS FILL — SILT — HIGHLY ORGANIC (PEAT) — SAND — SANDY CLAY — GRAVEL — CLAYEY SAND — SILTY CLAY — CLAYEY SILT

DATE DRILLED	3-9-04
PAGE	1 of 1
DRILLING METHOD	HSA
DRILLED BY	WDC
LOGGED BY	[illegible] KRISH
EXISTING GRADE ELEVATION (FT. AMSL)	
LOCATION OR GRID COORDINATES	

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM



Protective Pipe — Yes [ ] No [X] — Steel [X] PVC [ ]

______ Ft.

Surveying Pin ? Yes [ ] No [X]

Casing Cap Vent ? Yes [ ] No [ ]

Lock ? Yes [ ] No [X]

Weep Hole ? Yes [ ] No [X]

Concrete Pad ______ Ft. x ______ Ft. x ______ Inches

	DEPTH BELOW GRADE	DEPTH FROM TOP OF CASING
Concrete — 3 Ft.	3	
Cement/Bentonite Grout Mix — 12 Ft.	15	
Bentonite Seal — 3 Ft.	18	
Filter Pack Above Screen — 2 Ft.	20	
Filter Pack Material — 15 Ft.	35	
Dense Phase Sampling Cup — .2 Ft.	35.2	
Overdrilled Material Backfill — ______ Ft.		

Concrete 3 Ft.

Cement/Bentonite Grout Mix
Yes [X] No [ ]
5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder
Other: ______
12 Ft.

Bentonite Seal 3 Ft.
Pellets [X] Slurry [ ]

Filter Pack Above Screen 2 Ft.

FILTER PACK MATERIAL
Silica Sand [X]
Washed Sand [ ]
Pea Gravel [ ]
Other: ______
Sand Size 8 - 12
15 Ft.

Dense Phase Sampling Cup .2 Ft.
Bottom Plug
Yes [X] No [ ]

Overdrilled Material Backfill ______ Ft.
Grout [ ] Sand [ ]
Caved Material [ ]
Other: ______

DRILLING INFORMATION:

1. Borehole Diameter= [illegible] Inches.
2. Were Drilling Additives Used ? Yes [ ] No [X]
   Revert [ ] Bentonite [ ] Water [ ]
   Solid Auger [ ] Hollow Stem Auger [X]
3. Was Outer Steel Casing Used ? Yes [ ] No [ ]
   Depth= ______ to ______ Feet.
4. Borehole Diameter for Outer Casing ______ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC [X] Galvanized [ ] Teflon [ ]
   Stainless [ ] Other ______
2. Type of Casing Joints: Screw-Couple [X] Glue-Couple [ ] Other ______
3. Type of Well Screen: PVC [X] Galvanized [ ]
   Stainless [ ] Teflon [ ] Other ______
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: [illegible]
6. Type of Screen Perforation: Factory Slotted [X]
   Hacksaw [ ] Drilled [ ] Other ______
7. Installed Protector Pipe w/Lock: Yes [ ] No [X]

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing [ ] Pumping [ ]
   Air Surging (Air or Nitrogen) [ ] Other SURGE BLOCK/AIR LIFT
2. Time Spent on Well Development ?
   60 Minutes/~~Hours~~
3. Approximate Water Volume Removed ? ______ Gallons
4. Water Clarity Before Development ? Clear [ ]
   Turbid [X] Opaque [ ]
5. Water Clarity After Development ? Clear [X]
   Turbid [ ] Opaque [ ]
6. Did Water have Odor ? Yes [ ] No [X]
   If Yes, Describe ______
7. Did Water have any Color ? Yes [ ] No [X]
   If Yes, Describe ______

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling	22.3 Ft.	Date [illegible]
Before Development	22 Ft.	Date [illegible]
After Development	______ Ft.	Date [illegible]

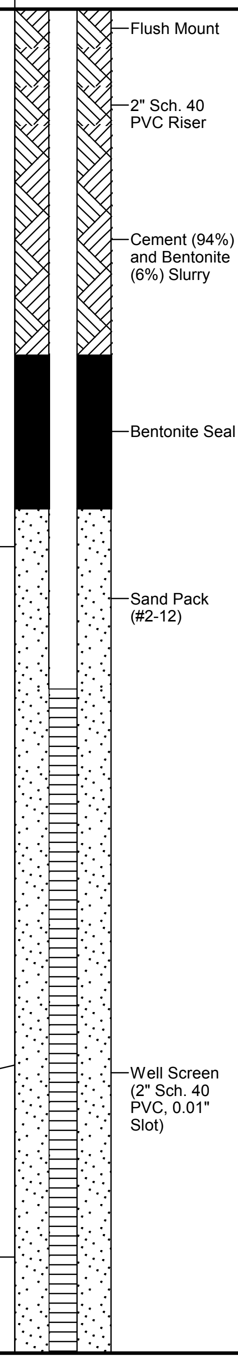
Driller/Firm [illegible] | Drill Rig Type [illegible] | Date Installed [illegible]

Drill Crew [illegible] | Well No. TC 127 | Kerr-McGee Hydrologist [illegible]

ENSR AECOM ENSR 1220 Avenida Acaso Camarillo, CA 93012 (805)388-3775	*Client:* Tronox LLC *Project Number:* 04020-023-160 *Site Description/Location:* East Side of Athens Road Well Field, Henderson, NV *Coordinates:* 26728191.37 N 829517.89 E *Elevation:* 1615.08 FT *Drilling Method:* Sonic with continuous coring *Sample Type(s):* Split Spoon and Core *Boring Diameter:* 8 In.	**Well No. PC-136** *Sheet:* 1 *of* 2 *Monitoring Well Installed:* Yes *Screened Interval:* 17.7-37.7 ft.
Weather: NA	*Logged By:* E. Krish / *Date/Time Started:* 12/18/2008 11:30	*Depth of Boring:* 38 ft.
Drilling Contractor: Boart Longyear / D. Cervantez	*Backfill:* NA / *Date/Time Finished:* 12/18/2007 15:00	*Water Level:* Not Encountered

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"	Recovery (ft)	Headspace (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay) description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.
0						SP-SM		**ALLUVIUM:** GRAVELLY SAND, light brown (5YR 5/4), 10% silt, 35% fine grained gravel to 3/4" with minor 1-3" from 6-9" , 55% very fine to very coarse grained subangular to subrounded sand, moderate calcareous coatings.
5								
10								
14						GP-GM		SANDY GRAVEL, light brown (5YR 6/4), 10% silt, 40% very fine to very coarse grained subangular to subrouned sand, 50% fine grained gravel to 3/4" with minor 1-3" ,
15								
17.5								SANDY GRAVEL, at 17.5 feet bgs cobbles to 6".
19								SANDY GRAVEL, caliche zone from 19-19.5 feet bgs.
20								
22.5								SANDY GRAVEL, caliche zone from 22.5-23 feet bgs.
25								
27							▼	SANDY GRAVEL, groundwater encountered at 32 feet bgs.
27.5						SM		SILTY GRAVELLY SAND, dark yellowish brown (10YR 4/2), locally up to 25% silt, 35% fine grained angular to subrounded volcanic pea gravel, up to 40% very fine to very coarse grained subangular to subrounded sand, alternating silty and clean sand.
30								
32.5						GP-GM		SANDY SILTY GRAVEL, brownish gray, very hard calichification, 20-30% very fine to coarse grained sand in matrix, 10-20% silt. SANDY SILTY GRAVEL, from 32.5-33 feet bgs very silty-40%.
35								

Well Diagram



Notes:

ENSR | AECOM ENSR 1220 Avenida Acaso Camarillo, CA 93012 (805)388-3775	*Client:* Tronox LLC	**Well No. PC-136**
	Project Number: 04020-023-160	
	Site Description/Location: East Side of Athens Road Well Field, Henderson, NV	
	Coordinates: 26728191.37 N 829517.89 E *Elevation:* 1615.08 FT	*Sheet:* 2 *of* 2
	Drilling Method: Sonic with continuous coring	*Monitoring Well Installed:* Yes
	Sample Type(s): Split Spoon and Core *Boring Diameter:* 8 In.	*Screened Interval:* 17.7-37.7 ft.
Weather: NA	*Logged By:* E. Krish *Date/Time Started:* 12/18/2008 11:30	*Depth of Boring:* 38 ft.
Drilling Contractor: Boart Longyear / D. Cervantez	*Backfill:* NA *Date/Time Finished:* 12/18/2007 15:00	*Water Level:* Not Encountered

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"	Recovery (ft)	Headspace (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay) description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.	Well Diagram
						GP-GM		SANDY SILTY GRAVEL, brownish gray, very hard calichification, 20-30% very fine to coarse grained sand in matrix, 10-20% silt. *(continued)*	
						CL		**MUDDY CREEK FORMATION:** CLAY, light greenish gray (10Y 7/1).	

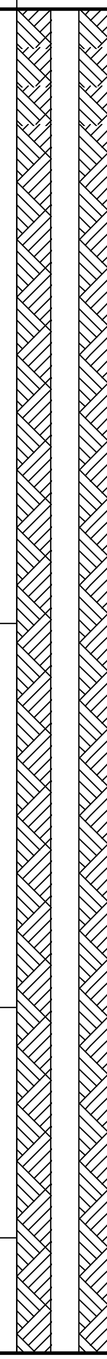
Total Depth = 38 feet.
Boring Terminated
Target depth achieved

Notes:

ENSR | AECOM ENSR 1220 Avenida Acaso Camarillo, CA 93012 (805)388-3775	*Client:* Tronox LLC *Project Number:* 04020-023-160 *Site Description/Location:* East Side of Athens Road Well Field, Henderson, NV *Coordinates:* 26728198.98 N 829517.57 E *Elevation:* 1614.83 FT *Drilling Method:* Sonic with continuous coring *Sample Type(s):* Split Spoon and Core *Boring Diameter:* 8 In.	**Well No. PC-137** *Sheet:* 1 *of* 2 *Monitoring Well Installed:* Yes *Screened Interval:* 59.7-69.7 ft.
Weather: NA *Drilling Contractor:* Boart Longyear / D. Cervantez	*Logged By:* E. Krish *Date/Time Started:* 12/17/2007 14:15 *Backfill:* NA *Date/Time Finished:* 12/17/2007 17:30	*Depth of Boring:* 70 ft. *Water Level:* 28 ft.

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"	Recovery (ft)	Headspace (ppm)	USCS	Graphic Log	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay) description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.
0–16						SP-SM		**ALLUVIUM:** GRAVELLY SAND, light brown (5YR 6/4), 10% silt, 70% very fine to very coarse grained, subangular to subrounded sand, 20% fine grained volcanic pea gravel, subangular to subrounded to 3/4" with minor 1-2", moderately soft calcareous grain coatings.
16–26						GP-GM		SANDY GRAVEL, light brown (5YR 6/4), 10% silt, 30% very fine to very coarse grained subangular to subrounded sand, 60% fine, angular to subrounded, pea gravel to 1/4", moderate calcareous coatings. -groundwater encoutered at 21 feet bgs.
26–32						SP		GRAVELLY SAND, moderate brown (5YR 4/2), 5% silt, 15% fine grained angular to subrounded , volcanic pea gravel to 3/8", 80% very fine to very coarse grained, subangular to subround sand
32–35						GM		SANDY SILTY GRAVEL, very pale orange (10YR 8/2), 20% silt, 30% very fine to very coarse grained subangular to subrounded sand, 50% fine grained angular to subangular pea gravel to 3/8" with minor 1". -hard calichified zone from 34-36 feet bgs.

Well Diagram



Notes:

ENSR | AECOM

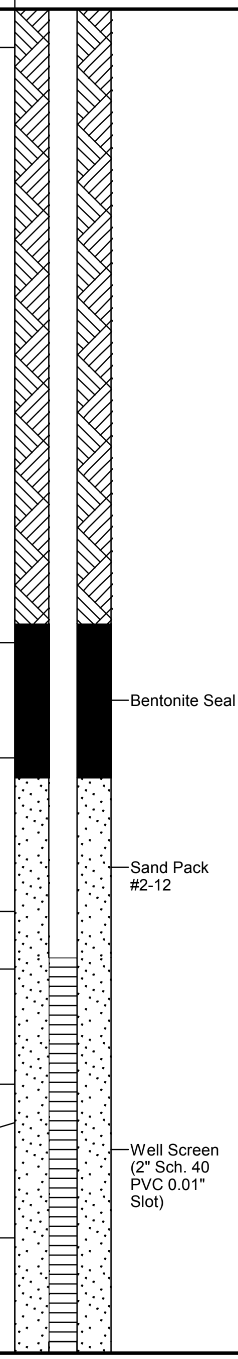
ENSR
1220 Avenida Acaso
Camarillo, CA 93012
(805)388-3775

Well No. PC-137

Client: Tronox LLC			
Project Number: 04020-023-160			
Site Description/Location: East Side of Athens Road Well Field, Henderson, NV			
Coordinates: 26728198.98 N 829517.57 E	*Elevation:* 1614.83 FT		*Sheet:* 2 of 2
Drilling Method: Sonic with continuous coring			*Monitoring Well Installed:* Yes
Sample Type(s): Split Spoon and Core	*Boring Diameter:* 8 In.		*Screened Interval:* 59.7-69.7 ft.
Weather: NA	*Logged By:* E. Krish	*Date/Time Started:* 12/17/2007 14:15	*Depth of Boring:* 70 ft.
Drilling Contractor: Boart Longyear / D. Cervantez	*Backfill:* NA	*Date/Time Finished:* 12/17/2007 17:30	*Water Level:* 28 ft.

DEPTH (ft)	Sample ID	Sample Depth (ft)	Blows per 6"	Recovery (ft)	Headspace (ppm)	USCS	MATERIAL IDENTIFICATION, color, description of fine grained material (silt and clay) description of coarse grained material (sand and gravel), structural or mineralogical features, density or stiffness, moisture content, odors or staining.
						GM	
						CL-ML	**MUDDY CREEK FORMATION:** INTERBEDDED SILTY CLAY AND SANDY CLAYEY SILT, yellow gray (5Y8/1) to medium gray (N5), predominately low plastic fines with up to 20% very fine grained sand present -light greenish gray (5GY 8/1) from 38 to 40 feet bgs.
40							-yellowish gray (5Y 7/2) from 40 to 49 feet bgs.
45							
50							-mottled dark yellowish green (5Y 6/2) to dark gray (5Y 9/1) from 49 to 50.5 feet bgs.
						CL-ML	SANDY AND SILTY CLAY, medium gray (N5) and light gray (N7) 25% silt, 15% very fine grained sand.
55						ML	SANDY SILT, dusky yellow (5Y 6/4) , 20% very fine grained sand.
						ML	SANDY SILT, pale olive (10YR 6/2)
						SM	SILTY SAND, medium blue gray (5B 5/1), 30% silt, 70% very fine grained sand.
60		X		1.5		CL	SILTY CLAY AND CLAYEY SILT, greenish gray (5G 6/1), disseminated very fine grained marcasite.
						SM	SILTY AND CLAYEY SAND, greenish gray (5G 6/1), 40% silty clay, 60% very fine grained sand, disseminated very fine grained marcasite.
65						CL	CLAY WITH GYPSUM CRYSTALS, dark yellowish brown (10YR 4/2), abundant gypsum crystals 3/8 to 11/2".
						CL	INTERBEDDED SILTY CLAY AND CLAYEY SILT, moderate brown (10YR 5/4), no crystals.
70							

Well Diagram



Notes:

Total Depth = 70 feet.
Boring Terminated
Target depth achieved

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY KMcLLC	LOCATION HENDERSON, NV	BORING NUMBER PC-1

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–5	FILL: SAND/GRAVEL IN IMPOUNDMENT BERM									
5	SAND/SILTY SAND; LT. TAN-BROWN; GRAVEL COMMON; WELL-GRADED; DRY		SM-GM							
10	SAND AS ABOVE									
15	CALICHE ZONE @ 17-19'									
20	SAND AS ABOVE; BECOMING MOIST GRAVEL ZONE @ 22'									
23.5			▽	▼ 23.79						
25										GROUNDWATER SAMPLE COLLECTED @ 28'
30										
31–32	SILTY CLAY; RED-BROWN W/ LT. GRAY-GREEN REDUCED ZONES MUDDY CREEK		CL	8/14/48		1		32–33.5'	1.2'	
	TD 32'									

EXPLANATION

▼ Water Table (24 Hour)
▽ Water Table (Time of Boring)
PID Photoionization Detection (ppm)
NO. Identifies Sample by Number
TYPE Sample Collection Method

SPLIT-BARREL — AUGER — ROCK CORE
THIN-WALLED TUBE — CONTINUOUS SAMPLER — NO RECOVERY

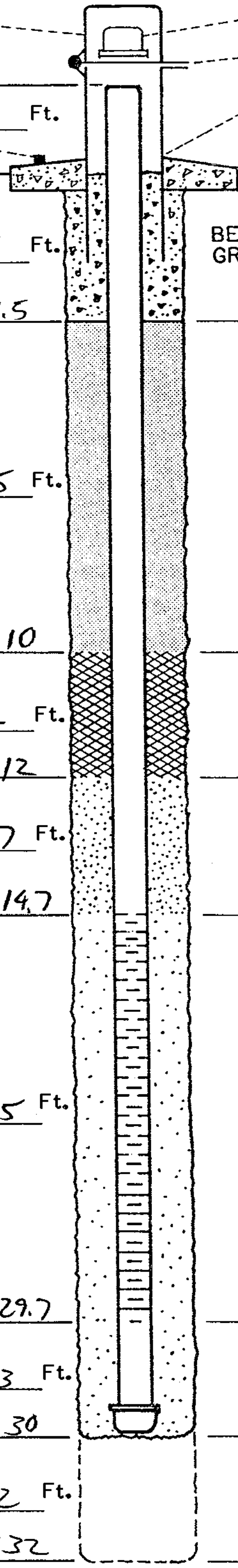
DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY — DEBRIS FILL
SILT — HIGHLY ORGANIC (PEAT)
SAND — SANDY CLAY
GRAVEL — CLAYEY SAND
SILTY CLAY — ______
CLAYEY SILT — ______

DATE DRILLED: 3/23/98	PAGE 1 of 1
DRILLING METHOD: HSA	
DRILLED BY: WEBER DRILLING	
LOGGED BY: T. REED	
EXISTING GRADE ELEVATION (FT. AMSL)	
LOCATION OR GRID COORDINATES	

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM



Protective Pipe — Yes [✓] No [ ]
Steel [✓] PVC [ ]
_____ Ft.
Surveying Pin ? Yes [ ] No [ ]

Casing Cap Vent ? Yes [ ] No [ ]
Lock ? Yes [✓] No [ ]
Weep Hole ? Yes [ ] No [ ]
Concrete Pad _____ Ft. x _____ Ft. x _____ Inches

DEPTH — BELOW GRADE / FROM TOP OF CASING

Concrete 1.5 Ft. — 1.5

Cement/Bentonite Grout Mix
Yes [✓] No [ ]
5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder — 8.5 Ft.
Other: _____
— 10

Bentonite Seal 2 Ft.
Pellets [✓] Slurry [ ]
— 12

Filter Pack Above Screen 2.7 Ft.
— 14.7

FILTER PACK MATERIAL — 15 Ft.
Silica Sand [ ]
Washed Sand [✓]
Pea Gravel [ ]
Other: _____
Sand Size 8-12
— 29.7

Dense Phase Sampling Cup .3 Ft.
Bottom Plug
Yes [✓] No [ ]
— 30

Overdrilled Material Backfill 2 Ft.
Grout [ ] Sand [ ]
Caved Material [✓]
Other: _____
— 32

DRILLING INFORMATION:

1. Borehole Diameter= 8 Inches.
2. Were Drilling Additives Used ? Yes [ ] No [✓]
   Revert [ ] Bentonite [ ] Water [ ]
   Solid Auger [ ] Hollow Stem Auger [✓]
3. Was Outer Steel Casing Used ? Yes [ ] No [✓]
   Depth= _____ to _____ Feet.
4. Borehole Diameter for Outer Casing _____ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC [✓] Galvanized [ ] Teflon [ ]
   Stainless [ ] Other _____
2. Type of Casing Joints: Screw-Couple [✓] Glue-Couple [ ] Other _____
3. Type of Well Screen: PVC [✓] Galvanized [ ]
   Stainless [ ] Teflon [ ] Other _____
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: .020
6. Type of Screen Perforation: Factory Slotted [✓]
   Hacksaw [ ] Drilled [ ] Other _____
7. Installed Protector Pipe w/Lock: Yes [✓] No [ ]

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing [ ] Pumping [✓]
   Air Surging (Air or Nitrogen) [ ] Other _____
2. Time Spent on Well Development ?
   10 / 1 Minutes/Hours
3. Approximate Water Volume Removed ? 140 Gallons
4. Water Clarity Before Development ? Clear [ ]
   Turbid [ ] Opaque [✓]
5. Water Clarity After Development ? Clear [✓]
   Turbid [ ] Opaque [ ]
6. Did Water have Odor ? Yes [ ] No [✓]
   If Yes, Describe _____
7. Did Water have any Color ? Yes [ ] No [✓]
   If Yes, Describe _____

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 23.5 Ft. Date 3/23/98
Before Development 20.3 Ft. Date 3/24/98
(FROM TOC) After Development 22.42 Ft. Date 3/25/98

Driller/Firm ROBERTSON / WEBER DRILLING Drill Rig Type MOBILE B-61 Date Installed 3/24/98

Drill Crew ROBERTSON / JOHNSON / RIVIERA Well No. PC-1 Kerr-McGee Hydrologist T. REED

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY KMCLLC	LOCATION HENDERSON, NV	BORING NUMBER PC-4

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
0–5	FILL: SAND AND GRAVEL IN IMPOUNDMENT BERM								
5	SAND / SILTY SAND; GRAVEL COMMON TO ABD; LT. TAN-BROWN; DRY TO SLI. MOIST; WELL-GRADED								
10	GRAVEL @ 11-13.5'								
15	SAND AS ABOVE	SM-GM							
20									
22	∇ (water table, time of boring)								
25	GRAVEL @ 25-27'								
30	SAND AS ABOVE; SATURATED	SM-GM							
35	GRAVEL @ 38-40'								
40									

EXPLANATION

▼ Water Table (24 Hour)
∇ Water Table (Time of Boring)
PID Photoionization Detection (ppm)
NO. Identifies Sample by Number
TYPE Sample Collection Method

SPLIT-BARREL | AUGER | ROCK CORE | THIN-WALLED TUBE | CONTINUOUS SAMPLER | NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY | DEBRIS FILL | SILT | HIGHLY ORGANIC (PEAT) | SAND | SANDY CLAY | GRAVEL | CLAYEY SAND | SILTY CLAY | ______ | CLAYEY SILT | ______

DATE DRILLED: 3/24/98
PAGE: 1 of 2
DRILLING METHOD: HSA
DRILLED BY: WEBER DRILLING
LOGGED BY: T. REED
EXISTING GRADE ELEVATION (FT. AMSL):
LOCATION OR GRID COORDINATES:

SOIL BORING LOG KM-5655-B

KERR-McGEE CORPORATION Hydrology Dept. - S&EA Division	KM SUBSIDIARY KMLLC	LOCATION HENDERSON, NV	BORING NUMBER PC-4 (CONT.)

DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER 6"	PID (ppm)	SOIL SAMPLE NO.	TYPE	DEPTH	REC.	REMARKS OR FIELD OBSERVATIONS
40	GRAVEL @ 41.5-42.5'		SM-GM				AUGER			GROUNDWATER SAMPLE TAKEN @ 42'
43.5	SILTY CLAY; LT. GRAY-GREEN; SL. PLASTIC MUDDY CREEK		CL							
45	TD 45'			17 34 52		1	SPLIT-BARREL	45 46.5	1.4'	

EXPLANATION

- ▼ Water Table (24 Hour)
- ▽ Water Table (Time of Boring)
- PID Photoionization Detection (ppm)
- NO. Identifies Sample by Number
- TYPE Sample Collection Method
- SPLIT-BARREL; AUGER; ROCK CORE; THIN-WALLED TUBE; CONTINUOUS SAMPLER; NO RECOVERY
- DEPTH Depth Top and Bottom of Sample
- REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY; DEBRIS FILL; SILT; HIGHLY ORGANIC (PEAT); SAND; SANDY CLAY; GRAVEL; CLAYEY SAND; SILTY CLAY; CLAYEY SILT

DATE DRILLED: 3/24/98

PAGE: 2 of 2

DRILLING METHOD: HSA

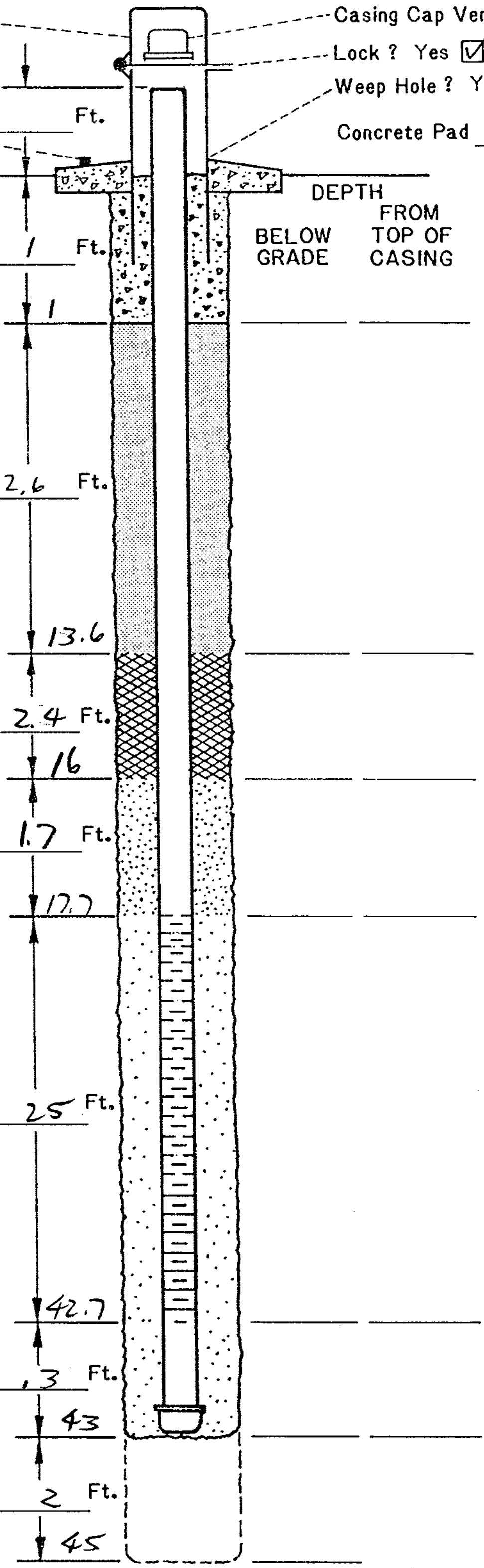
DRILLED BY: WEBER DRILLING

LOGGED BY: T. REED

EXISTING GRADE ELEVATION (FT. AMSL):

LOCATION OR GRID COORDINATES:

KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM



Protective Pipe: Yes [x] No [ ]
Steel [x] PVC [ ]
____ Ft.
Surveying Pin ? Yes [ ] No [ ]

Casing Cap Vent ? Yes [ ] No [ ]
Lock ? Yes [x] No [ ]
Weep Hole ? Yes [ ] No [ ]
Concrete Pad ____ Ft. x ____ Ft. x ____ Inches

Concrete: 1 Ft.

Cement/Bentonite Grout Mix: Yes [x] No [ ]
5.5 Gallons Water to 94Lb. Bag Cement & 3-5 Lb. Bentonite Powder — 12.6 Ft.
Other: ____

Bentonite Seal — 2.4 Ft.
Pellets [x] Slurry [ ]

Filter Pack Above Screen — 1.7 Ft.

FILTER PACK MATERIAL — 25 Ft.
Silica Sand [x]
Washed Sand [ ]
Pea Gravel [ ]
Other: ____
Sand Size 8-12

Dense Phase Sampling Cup — .3 Ft.
Bottom Plug Yes [ ] No [ ]

Overdrilled Material Backfill — 2 Ft.
Grout [ ] Sand [ ]
Caved Material [x]
Other: ____

DRILLING INFORMATION:

1. Borehole Diameter= 8 Inches.
2. Were Drilling Additives Used ? Yes [ ] No [x]
   Revert [ ] Bentonite [ ] Water [ ]
   Solid Auger [ ] Hollow Stem Auger [x]
3. Was Outer Steel Casing Used ? Yes [ ] No [x]
   Depth= ____ to ____ Feet.
4. Borehole Diameter for Outer Casing ____ Inches.

WELL CONSTRUCTION INFORMATION:

1. Type of Casing: PVC [x] Galvanized [ ] Teflon [ ]
   Stainless [ ] Other ____
2. Type of Casing Joints: Screw-Couple [x] Glue-Couple [ ] Other ____
3. Type of Well Screen: PVC [x] Galvanized [ ]
   Stainless [ ] Teflon [ ] Other ____
4. Diameter of Casing and Well Screen:
   Casing 2 Inches, Screen 2 Inches.
5. Slot Size of Screen: .020
6. Type of Screen Perforation: Factory Slotted [x]
   Hacksaw [ ] Drilled [ ] Other ____
7. Installed Protector Pipe w/Lock: Yes [ ] No [ ]

WELL DEVELOPMENT INFORMATION:

1. How was Well Developed ? Bailing [ ] Pumping [x]
   Air Surging (Air or Nitrogen) [ ] Other ____
2. Time Spent on Well Development ?
   45 / ____ Minutes/Hours
3. Approximate Water Volume Removed ? 50 Gallons
4. Water Clarity Before Development ? Clear [ ]
   Turbid [ ] Opaque [x]
5. Water Clarity After Development ? Clear [ ]
   Turbid [x] Opaque [ ]
6. Did Water have Odor ? Yes [ ] No [x]
   If Yes, Describe ____
7. Did Water have any Color ? Yes [ ] No [x]
   If Yes, Describe ____

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling 22' Ft. Date 3/24/98
Before Development ____ Ft. Date ____
(FROM TOC) After Development 23.65' Ft. Date 3/25/98

Driller/Firm L. ROBERTSON / WEBER DRLG. Drill Rig Type MOBILE B-61 Date Installed 3/24/98

Drill Crew ROBERTSON / JOHNSON / RIVERA Well No. PC-4 Kerr-McGee Hydrologist T. REED

Appendix B

Research Laboratory Bench-Scale Testing Protocols

TREATABILITY STUDIES FOR PERCHLORATE FROM AQUIFER MATERIAL AT THE NEVADA ENVIRONMENTAL TRUST SITE

John H Pardue PhD, PE and W. Andrew Jackson, PhD, PE

Creation of a permeable reactive barrier (PRB) is one strategy to reduce perchlorate to nontoxic end products in contaminated aquifers. Kinetic information on perchlorate reduction and the identity of suitable electon donors is required to effectively design PRBs for this purpose. The treatability studies proposed below are designed to identify suitable electron donors that will drive perchlorate reduction without seriously impacting the permeability of the formation or causing unaceptable downgradient water quality impacts. The site of interest is the Nevada Envrionmental Response Trust (NERT) site in Henderson, NV. Based on previous microcosm studies, perchlorate reduction is electron donor limited in the Las Vegas wash and in the contaminaed groudwater (Battista et al., 2003). Reduction will not occur in the absence of a supplemental carbon source. Required dosage is unknown and depends on the background demand from other electon acceptors and the demand from perchlorate reducers. The goal of these treatability studies is to identify the identity and dose of a suitable carbon source.

1.1 Objectives

The overall objective of these bench-scale studies is to ensure success for a pilot PRB. The specific objectives of the proposed bench-scale treatability studies are:

1. Identification of suitable electron donors for perchlorate reduction
2. Measurement of perchlroate reduction kinetics in NERT aquifer material.
3. Establish kinetic and hydraulic parameters required to design a PRB pilotTasks

1.2 Tasks

<u>Task 1. Identification of suitable organic donors</u>

Soluble, slow-release and solid electron donors will be tested to establish candidate amendments for perchlorate reduction in the PRB pilot. Example soluble donors may inlcude acetate, lactate or mixed donors (e.g., yeast extract) (Coates and Jackson, 2009). Proprietary slow-release donors will also be tested. These will be contrasted with a mixture of peat and sand to mimic constuction of a PRB out of a solid electron donor instead of amendment of the existing aquifer material. A total of 8-10 donors will be evaluated. Final selection of the amendments will be made jointly with ENVIRON. To establish effectiveness, serum bottle testing will be conducted on mixtures of site aquifer material, site groundwater and different concentrations of candidate donors. Testing will be conducted using methods described in the attached SOP. Briefly, materials will be assembled in a glove box in 160 mL serum bottles sealed with Teflon-lined septa and crimp caps (Tan et al., 2004 and Jackson et al., 2004). Bottles will be repetitvely sampled over time to establish the kinetics of perchlorate reduction. In addition to perchlorate, concentrations of relavent redox pairs will be measured as the changes in the aquifer material/groundwater systems progress. These will include oxygen, nitrate/nitrite, ferric/ferrous iron, sulfate/sulfide and methane. Studies will be run for 6-8 weeks or until the perchlorate is reduced by 80-90%. Successful electron donors will be evaluated based on kinetics of perchlorate reduction and mitigation of lag time due to presence of oxygen and nitrate. Cost and implementability will be additional strong considerations for candidate donors for further evaluation in 1-D columns.

Task 2. Assessment of perchlorate reduction kinetics in 1-D columns

Coumn studies will be used to test the effectivess of donors in a flow-through mode. Successful donors will be those that reduce perchlorate but also maintain the hysraulic properties of the formation (minimize biofouling). A schematic diagram of the 1-D column system is shown in Figure 1. Column experiments will be performed in three, 5 ft long, 2 inch diameter columns with 5 equispaced sampling ports located along their lengths. The columns will be packed with aquifer material from the NERT site. A 5 cm layer of fine gravel will placed at the bottom for even distribution of flow through the column. Glass wool will be inserted in the inner side of sampling ports to avoid dead zones and clogging of sampling ports. Immediately after establishment of the columns, the hydraulic conductivity of the test columns will be assessed by connecting a falling head permeameter to the column. Hydrualic conductivity will be measured using the falling head method and compared to existing site data.

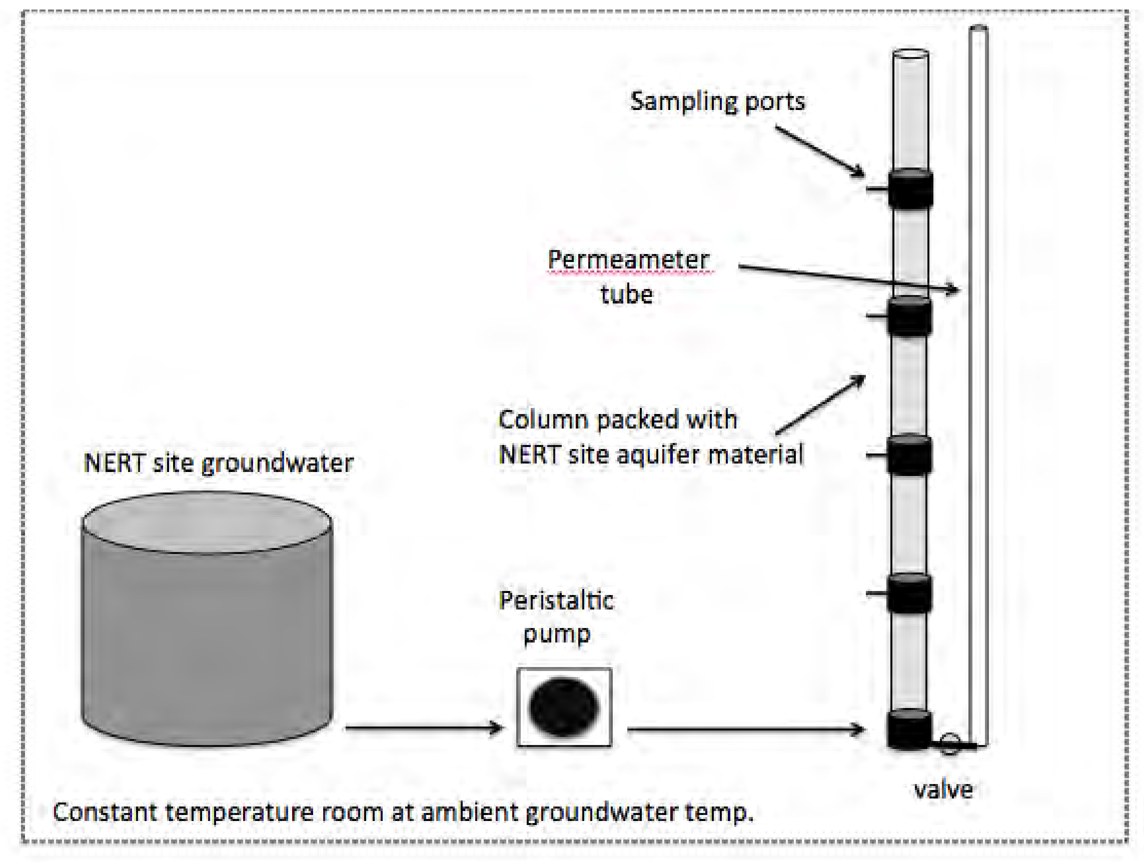


Figure 1. Column set-up

Contaminated groundwater, shipped from the site, will be introduced through 2 mm stainless steel tubing in upflox mode. A peristaltic pump (Cole Parmer Masterflex) with Viton tubing will used to convey water through the column at groudnwater velocities representative of site conditions. The experiment will be set-up in a constant temperature room so that site groundwater and the test columns will be maintained at the ambient site temperature.

The influent concentrations will be monitored three times a week to track changes in perchlorate concentration. Influent samples for all column experiments will be collected at the sampling ports on the delivery side of the pump. Samples were collected with a 5 mL prerinsed airtight glass syringe fitted with luer-lock and injected into 2 mL glass vials. Sampling was performed after every three-four days for determination of perchlroate concentration, nitrate/nitrate concentrations and conductivity. On a weekly basis, additonal redox indicators will be measured including O_2, nitrite, nitrate, ferrous iron, ferric iron, sulfate and sulfide, and methane. Redox characteristics of each sampled zone would be determined from these multiple lines of evidence from the water chemistry testing. Additional samples will be removed for metals analysis at an external certified laboratory acceptable to ENVIRON. Column studies will be run for 12 weeks, subject to extension if additional information is desired. Following the termination of the studies, the falling head permeameter study will be repeated and the hydraluc conductivity measured again. Declines in conductivity over the 12 weeks may be evidence of biofouling. If conductivity declines signfiicantly (>5-10x), column materials will be removed and total carbon measured on the aquifer material to determine the amount of biomass accumulated along the flowpath.

Task 3. Establishing kinetic and hydraulic parameters

Column data for removal of perchlorate can be assessed using 1-D reactive-transport models:

$$\frac{\partial C}{\partial t} = -\frac{u_x}{R}\frac{\partial C}{\partial x} + \frac{D_x}{R}\frac{\partial^2 C}{\partial x^2} - \frac{k}{R}C$$

Because of the uncertainty in the scale-dependent dispersion term, D_x (the dispersion term is very small over the short depth of the columns), a simpler exponential equation can also be used to assess kinetics for pechlorate treatment.

$$C = C_o e^{-kRx/v}$$

where C [M/L^3] is the concentration of the pollutant at a vertical distance, x [L], C_o [M/L^3] is the initial concentration, k [T^{-1}] is a lumped temporal degradation rate constant, R is the retardation coefficient and v [L/T] is the seepage velocity. The equation captures several important mechanisms including equilibrium partitioning, advection and first-order reduction of perchlorate. Partitioning is expected to be negligible for perchlorate (e.g., R=1). Biodegradation rate constants will be determined by fitting the equation to contaminant profiles measured in Task 2 using CXTFIT, a curve fitting program used for 1-D column studies (Toride et al., 1995) or using non-linear regression for the simpler exponential equation.

1.2.1 *Analytical Procedures*

Major anions (Cl^-, NO_3^-, and SO_4^{2-}) will analyzed by ion chromatography following EPA Method 300.0. ClO_4^- concentrations will be separately measured by sequential ion chromatography-mass spectroscopy-mass spectroscopy (IC-MS/MS). ClO_4^- will quantified using a Dionex LC 20 ion chromatography system consisting of GP50 pump, CD25 conductivity detector, AS40 automated sampler and Dionex IonPac AS16 (250 X 2 mm) analytical column. The IC system is coupled with an Applied Biosystems – MDS SCIEX API 2000™ triple quadrupole mass spectrometer equipped with a Turbo-IonSpray™ source. A hydroxide (NaOH) eluent at 0.3 mL min^{-1} is followed by 90% acetonitrile (0.3 mL min^{-1}) as a post-column solvent. To overcome matrix effects, all samples were spiked with $Cl^{18}O_3$ or $Cl^{18}O_4$ internal standards. Redox paramaters will be measured using standard methods O_2 (microelectrode), nitrite, nitrate, ferrous, ferric iron, sulfate, sulfide (ion chromatograph), methane in porewater (GC-FID), SOPs of each of these measurements are available upon request.

QA/QC

Full details of QA/QC procedures are available in the SOPs. Briefly, the QC program consists of blanks, calibration checks, matrix spikes and matrix spike duplicates. Our QA/QC for these parameters has been approved by a number of agencies including the US Army, Florida DEQ and others. Split samples will be provided for analysis at external laboratories at ENVIRON's request.

References:

Batista, Jacimaria R. , Amy, Penny S. , Chen, Yi-Tung , Papelis, Lambis , Unz, Richard. 2003. The Fate and Transport of Perchlorate in a Contaminated Site in the Las Vegas Valley. Part A: Investigation of the Influence of Biological Degradation and Sorption on the Fate of Perchlorate. Part B: Modeling of the Transport of Perchlorate in the Las Vegas Wash. Final Project Report EPA Grant Number: R827622E03

J. Coates and W.A. Jackson. 2009. Development of *In Situ* Bioremediation Technologies for Perchlorate in In Situ Bioremediation of Perchlorate in Groundwater. Hans F. Stroo and Herb Ward, (Eds.) 2009, XLVI, PP. 29-53.

Jackson, W. Andrew, M. Jeon, J. H. Pardue, and T. Anderson. 2004. Enhanced Natural Attenuation of Perchlorate in Soils Using Electrokinetic Injection. Bioremediation Journal. 8(1-2):65-79.

Tan, K., T.A. Anderson and W.A. Jackson. 2004. Degradation Kinetics of Perchlorate in Sediments and Soils. Water, Air, and Soil Pollution. 151:245-259.

Toride, N., F. J. Leij, and M. Th. van Genuchten. 1995. The CXTFIT Code for Estimating Transport Parameters from Laboratory or Field Tracer Experiments, Version 2.0. Research Report No. 137, U.S. Salinity Laboratory, USDA, ARS, Riverside, California.

Appendix C

Standard Operating Procedures

Standard Operating Procedure C-1:

Soil Sampling with Direct-Push or Hollow-Stem Auger Samplers

Standard Operating Procedure C-1: Soil Sampling with Direct-Push or Hollow-Stem Auger Samplers

This standard operating procedure (SOP) is applicable to the collection of representative soil samples using a direct-push or hollow-stem auger sampling technique. The methodologies discussed in this SOP are generic in nature and may be modified in whole or part to meet the handling and analytical requirements of the contaminants of concern, as well as the constraints presented by site conditions and equipment limitations. Modifications of sampling methodologies will be documented in the appropriate field logbook and discussed in reports summarizing field activities and analytical results. For the purposes of this procedure, soils are those mineral and organic materials not submerged in water for an extended period of time sufficient to support aquatic life.

Sample Collection

The primary means for the collection of subsurface soil samples will be a direct-push technique using a Geoprobe® or equivalent driver. Direct-push soil samples will be obtained using a closed-piston soil sampler with a liner (or equivalent sampling system). If needed, a hollow-stem auger sampler may be used to collect soil samples. The sampler will be operated in accordance with the manufacturer's recommended operating procedures for the type of equipment used.

Discrete Soil Sampling Procedures

Soil samples will be collected at predetermined intervals based on specific data needs. Each discrete sample will be described in the field notebook using the Unified Soil Classification System (USCS) as described below. Soil samples that will not become composite samples will be placed directly in the appropriate sample containers using a clean plastic or metal spatula, or by using a clean gloved hand.

Subsamples selected for laboratory analysis will be placed in appropriate sample containers provided by the analytical laboratory, labeled, placed in an iced cooler, and stored in accordance with chain-of-custody requirements specified in the QAPP (Appendix A to the Final (100%) Design Report) until shipment to the laboratory (or laboratories) is arranged. Chain-of-custody records will be completed for all samples according to the methods described in the QAPP (Appendix A to the Final (100%) Design Report).

Discrete samples that will become aliquots of a composite sample will be covered or capped as soon as possible after collection if the compositing process is not completed immediately. Each sample container will be labeled and stored on ice pending the composite process.

Composite Soil Sampling Procedures

Composite samples will be prepared from the discrete samples following collection of the required number of discrete sample specified for the sampling area. Each discrete sample will be removed from the sample container and placed on a clean sheet of aluminum foil. After removing sticks, grass, stones, and other debris, each discrete sample will be separated into quarters – cores will be cut lengthwise into 4 equal portions, while disturbed samples will be homogenized and divided. Three of the four quarters of each sample will then be placed into one of three individual foil pans. The fourth portion of the discrete sample will be placed in a plastic baggie, labeled, sealed, and stored separately for potential individual analysis.

The compositing process of quartering discrete samples will be repeated for successive discrete samples until each of the three pans contains one quarter of each discrete sample. The contents of each aluminum foil pan will then be thoroughly mixed either by hand or by using an electrical or mechanical mixer. Upon completion of the mixing process, the contents of each individual pan will then be combined into one clean pan and again thoroughly mixed, resulting in one homogeneous sample. The composite soil sample will then be placed in the appropriate sample containers, labeled, and placed on ice pending shipment to the laboratory.

VOC Sample Collection Procedures

Soil samples obtained for laboratory analysis of VOCs will be collected in compliance with SW-846 Method 5035. Each soil sample will be obtained directly from the sampling device (i.e., not homogenized) using an En Core™ sampler or field preserved using Method 5035 compatible containers. A description of each sampling procedure is as follows:

EnCore Sampler

The EnCore™ sampler is a single use, commercially available device constructed of an inert composite polymer. EnCore™ uses a coring/storage chamber to collect either a 5-gram or 25-gram sample of cohesive soils. It has a press-on cap with a hermetically vapor tight seal and a locking arm mechanism. Three EnCore™ samplers shall be filled at each sample location using the following procedures:

- Place the EnCore™ sampler into the EnCore™ T-Handle tool.
- Push the sampler into the soil sample until the small o-ring on the plunger of the EnCore™ sampler is visible in the T-Handle viewing hole.
- Wipe off any excess soil from the coring body exterior using a clean paper towel.
- Place the cap on the end of the EnCore™ sampler and twist to lock the cap into place.
- Remove the sampler from the T-Handle and lock the plunger by rotating extended plunger rod fully counterclockwise until the plunger wings rest firmly against the plunger tabs.
- Place the label on the sampler and place the sampling into a labeled EnCore™ sampler bag and zip closed.
- Place the filled EnCore™ samplers in a cooler with ice for overnight shipment to the laboratory using standard chain-of-custody procedures. The soil samples must be prepared for analysis or frozen within 48 hours of sample collection.

Field Preservation

The procedures for the field preservation method are as follows:

- Push a one-time use plastic sampling tool such as a Terra Core™ sampler into the soil to be samples to collect an approximately 5-gram sample aliquot.
- Transfer the 5-gram aliquot to laboratory provided, pre-preserved, 40-milliliter vials containing a specific amount of methanol, sodium bisulfate, and/or organic-free water. The

number of vials provided with each preservative will vary by the laboratory performing the analysis. One unpreserved container shall also be filled to allow for laboratory calculation of the sample dry weight.

- Label each sample and place in a cooler with ice for overnight shipment to the laboratory using standard chain-of-custody procedures.

Sample Description and Field Documentation

After samples for chemical and physical analysis have been prepared, a visual soil or lithologic description of each sample will be made according to the USCS, and will be recorded in a bound log notebook. Each sampling location will be photographed, and the approximate location will be placed on a site map and recorded in the field notebook.

Residual soil from the compositing process and stored individual discrete sample portions will be disposed in accordance with the Sampling and Analysis Plan.

Equipment Decontamination

Drilling and support equipment will not come in direct contact with the samples, so cross-contamination of samples is not a concern. However, this equipment will likely come in contact with impacted soil and must therefore be decontaminated prior to moving from one location to another.

The drilling equipment used for soil sampling and monitoring well installation will be cleaned with high-pressure/hot water washing equipment prior to initiating the field investigation. The same procedure will be applied to all drilling equipment between each boring location. The cleaning will occur at a decontamination pad constructed at a suitable location(s) at the site. Water used for cleaning will be obtained from a local potable water source. Equipment subject to these decontamination procedures includes, but is not limited to, the following:

- Direct-push or hollow-stem auger drill rig.
- Direct-push or hollow-stem auger sampler components.

In addition, downhole equipment that comes in direct contact with samples will be decontaminated between each sample interval. This procedure will include washing with a nonphosphate detergent and rinsing with clean potable water.

If required, a piece of sampling equipment that comes in direct contact with soil samples (e.g., split-barrel samplers) will be selected for collection of field equipment blanks. After the equipment has been cleaned, it will be rinsed with DI water. The rinse water will be collected and submitted for analysis of all constituents for which the normal samples collected with the equipment are being analyzed.

Field blanks will be collected at the frequency specified in the QAPP (Appendix A to the Final (100%) Design Report).

Standard Operating Procedure C-2:

Low-Flow Groundwater Sampling for Chemical Analysis

Standard Operating Procedure C-2: Low-Flow Groundwater Sampling for Chemical Analysis

1 Purpose and Scope

This standard operating procedure (SOP) describes the procedures to be followed by a Field Geologist/Engineer while collecting groundwater samples using low-flow purging and sampling procedures. The low-flow methodology may alternatively be referred to by names such as “micropurging”, “low-stress purging”, low-impact purging, or “minimal drawdown purging.” This SOP should be used primarily for collection of groundwater samples from permanent wells that have been designed, constructed, and developed for the purpose of monitoring groundwater. The groundwater samples that are collected using this SOP are acceptable for the analysis of environmental contaminants including, but not limited to: volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides and herbicides, polychlorinated biphenyls (PCBs), petroleum hydrocarbons, metals, and other inorganic compounds.

The procedures presented herein are intended to be of general use and may be supplemented by a Work Plan, Sampling and Analysis Plan, Quality Assurance Project Plan, and/or a Health and Safety Plan. Some of these procedures may not be required depending on the specific scope of work being conducted. As the work progresses, and if warranted, appropriate revisions may be made by the Project Manager. Procedures in this protocol may be superseded by applicable regulatory requirements.

2 General Requirements

All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e).

The laboratory must be certified by the appropriate regulating agency for the analyses to be performed. If drilling is required as part of the scope of work, permits will be acquired from the appropriate agency, and an underground utility check will be performed before drilling begins. An underground utility check will, at a minimum, consist of contracting with a local utility alert service, if available. Under certain circumstances, including at sites with deeply buried, unknown, or multiple underground utilities, as well as at high risk sites such as oil refineries and heavy industrial facilities, manual utility clearance using hand auger or air knife methods should also be performed.

The activities described in this SOP require the implementation of a site-specific Health and Safety Plan to inform personnel of the hazards associated with this work and to describe the methods that will be employed to mitigate those hazards. The Health and Safety Plan must be prepared and approved by the Project Manager and the local Health and Safety Coordinator prior to initiating field work. A Health and Safety Meeting must be held at the start of each day to reassess any potential hazards associated with that day’s field work.

3 Methods

This SOP has been prepared in accordance with the United States Environmental Protection Agency (USEPA) Standard Operating Procedure for Low-Stress (Low Flow)/Minimal Drawdown

Ground-Water Sample Collection, dated 2002. This guidance document is included as Attachment 3 of the Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers, which may be found via the following internet link:

http://www.epa.gov/swertio1/tsp/download/gw_sampling_guide.pdf

This methodology described herein is also consistent with the California Environmental Agency's (Cal-EPA), Representative Sampling of Groundwater for Hazardous Substances, Guidance Manual for Ground Water Investigations, dated June 2005. This document may be found via the following internet link:

http://www.dtsc.ca.gov/SiteCleanup/upload/SMP_Representative_Sampling_GroundWater.pdf

Unlike traditional purging methods, low-flow purging and sampling does not require the removal of an arbitrary volume of water from a well prior to sampling. Instead, low-flow purging and sampling relies on careful monitoring of water quality indicator parameters to determine when a representative groundwater sample can be collected. The low-flow methodology minimizes the effects on groundwater chemistry caused by the purging process by minimizing drawdown, reducing the amount of water removed from the well, and reducing the amount of turbidity in groundwater samples.

4 Equipment and Materials

A non-exhaustive summary of common supplies and equipment is presented below:

- Health and Safety Plan
- Site information (maps, contact numbers, previous field logs, etc.)
- Electronic water level indicator (Solinst or similar)
- Photoionization Detector (PID) of Flame ionization detector (FID) if VOCs are suspected
- Adjustable-rate sampling pump capable of rates <0.5 liters per minute (bladder pump preferred, e.g., QED Sample Pro)
- Bladders for sample pump
- Sample tubing (Teflon® or Teflon®-lined tubing preferred for sampling organic compounds)
- Multi-parameter meter (e.g. YSI 556 Multi-Parameter Meter) with flow through cell capable of measuring (at a minimum) temperature, pH, specific electrical conductance (SEC), dissolved oxygen (DO), and oxidation-reduction potential (ORP)
- Turbidity meter
- In-line filters (if required, e.g. for dissolved metals)
- Certified-clean sample containers and preservation supplies, sample labels, Ziploc™ bags

- Cooler with ice
- Decontamination supplies (e.g. phosphate-free detergent, distilled water)
- Tool kit with appropriate tools (socket wrench set, pry bar, Dolphin locks/keys)
- Drum(s) to collect purged water and decontamination water
- Drum labels
- Personal Protective Equipment (PPE), typically PPE will consist of:
  - Long-sleeved shirt and long pants
  - Steel-toed boots
  - Hardhat
  - Nitrile gloves
  - Safety glasses with side shields
  - Other as required by Health and Safety Plan
- Field Forms (If the project requires it, a project-specific Field Logbook may substitute for any of the following with the exception of the Chain of Custody)
  - *Field Investigation Daily Log*
  - *Water Level Measurement Log*
  - *Low-Flow Purging and Sampling Log*
  - *Equipment Calibration Log*
  - *Chain-of-Custody*

5 Procedures

The following sections discuss the procedures to follow during low-flow purging and sampling monitoring wells with dedicated or non-dedicated equipment (e.g., bladder pumps with adjustable rate controls). Where applicable and when possible, the purging and sampling techniques should remain consistent from one sampling event to the next.

5.1 Pre-Sampling Activities

1. Sampling should begin at the monitoring well with the least contamination, generally up-gradient or farthest from the site or suspected source. Then proceeding systematically to the monitoring wells with the higher expected groundwater concentrations.
2. All measuring devices and monitoring equipment should be calibrated according to manufacturer's recommendations. Water quality meters must be calibrated daily before use. Equipment calibration details should be recorded in the *Equipment Calibration Log*.
3. Unlock well and/or remove well cap. Record any damage or evidence of pressure (positive or negative) in the well in the Water Level Measurement Log. Monitor the headspace at the

top of the well for VOCs with a PID or FID and record findings. If VOCs are present, monitor worker breathing zones during purging and sampling in accordance with the site Health and Safety Plan.

4. Prior to sampling, the depth-to-water in all wells must be measured to obtain the current static water level. Water levels should be measured to the nearest 0.01 feet relative to a reference measuring point on the Top of Casing (TOC) which must be surveyed relative to ground elevation. If there is no marked reference point on the TOC, measure from the North side of the casing. Record depth to groundwater information in the *Water Level Measurement Log*. The same water level measuring device should be used for all wells, if possible, and must be decontaminated between each well.

5. Use existing site information for total depth (TD) of monitoring well and use the information from depth to water to calculate the volume of water in the monitoring well. The TD of wells to be sampled should not be tagged prior to sampling to avoid disturbing sediments at the bottom of the well. If possible, have this information prior to the day of sampling. The TD of wells should be verified after sampling. Record TD and water volume information in the *Low-Flow Purging and Sampling Log*.

5.2 Purging and Sampling

1. If using non-dedicated equipment, place the pump and support equipment at the well head and slowly lower the pump and tubing down into the monitoring well until the location of the pump intake is set at a predetermined location within the screen interval. Where possible, pre-measured tubing should be used to place the pump intake at the same depth as previous sampling events, or at a depth where there is known contamination within the screen interval. If there is no previous information for the well, the pump intake should be placed at the middle (or slightly above the middle) of the screen interval. Record the pump depth in the *Low-Flow Purging and Sampling Log*.

2. Measure depth to water to the nearest 0.01 feet relative to the reference measuring point on the TOC with an electronic water level indicator. Record depth to groundwater information in the *Low-Flow Purging and Sampling Log*. Leave water level indicator in the well.

3. Connect the discharge line from the pump to a flow-through cell that at a minimum measures temperature, pH, SEC, DO, and ORP. Turbidity measurements can be made using a separate turbidity meter. The discharge line from the flow-through cell must be directed to a container to hold purge water collected during purging and sampling of the well.

4. Start pumping the well at a flow rate of between 0.1 and 0.5 liters per minute (L/min) and slowly increase the flow rate. (For new wells or wells with no purging history, start at the lower end of that range.) Check the water level. Maintain a steady flow rate while maintaining a drawdown of less than 0.3 feet. (Zero drawdown is optimal, but infrequently achievable). If drawdown is greater than 0.3 feet, lower the flow rate; 0.3 feet is a goal to help guide with the flow rate adjustment. This goal will be difficult to achieve in some wells due to low hydraulic conductivities and limitations to the lowest flow rate a pump can produce while maintaining steady flow. This goal may be adjusted based on site-specific conditions and personal experience. See the Special Advisory at the end of these

procedures.

5. Measure the discharge rate of the pump with a graduated cylinder and a stopwatch.

   Also, measure the water level and record both flow rate and water level on the *Low-Flow Purging and Sampling Log*. Continue purging, monitor and record water level and pump rate every 3 to 5 minutes. Purging rates should be kept at minimal flow to ensure

   minimal drawdown in the monitoring well.

6. A minimum of one tubing volume (including the volume of the water in the pump and flow cell) must be purged prior to recording the water quality indicator parameters. After this has been accomplished, monitor and record the water quality indicator parameters every three to five minutes in the *Low-Flow Purging and Sampling Log*. Stable readings of temperature, pH, SEC, DO, turbidity and ORP indicate when a representative sample can be collected. The stabilization criterion is based on three successive readings of the water quality indicator parameters as shown in Table 1. ORP may not always be an appropriate stabilization parameter and will depend on site-specific conditions. However, readings should be recorded because of its value for double-checking oxidizing conditions. The stabilization criterion is based on three successive readings of the water quality indicator parameters as shown in Table 1.

TABLE 1: Stabilization Criteria for Water Quality Indicator Parameters

Parameter	**Stabilization Criteria**
Temperature	± 3% of reading (minimum of ±0.2° C)
pH	± 0.1 pH units
Specific Electrical Conductance (SEC)	± 3% S/cm
Dissolved Oxygen (DO)	± 0.3 milligrams per liter
Turbidity	± 10% NTUs (when turbidity is greater than 10 NTUs)
Oxidation-Reduction Potential (ORP)	± 10 millivolts

7. Maintain the same pumping rate or reduce slightly for sampling as necessary in order to minimize disturbance of the water column. Sampling should be collected directly from the discharge port of the pump tubing prior to passing through the flow-through cell. Disconnect the pump’s tubing from the flow-through cell so that the samples are collected from the pump’s discharge tubing. For samples collected for dissolved gases or VOC analyses, the pump tubing needs to be completely full of ground water to prevent the ground water from being aerated as it flows through the tubing. Generally, the sequence of the samples is immaterial unless filtered (dissolved) samples are collected. Filtered samples must be collected last (see below). All sample containers should be filled with minimal turbulence by allowing the ground water to flow from the tubing gently down the inside of the container.

When filling VOC samples using volatile organic analysis (VOA) vials, a meniscus must be formed over the mouth of the VOA vial to eliminate the formation of air bubbles and head space prior to capping. Effervescence and colorimetric reactions should be recorded in the *Low-Flow Purging and Sampling Log.*

8. If a filtered (dissolved) metal sample is to be collected, then an inline filter is fitted at the end of the discharge tubing and the sample is collected after the filter. The inline filter must first be flushed in accordance with manufacturer's recommendations and if there are no recommendations for flushing, a minimum of 0.5 to 1.0 liter of groundwater from the monitoring well must pass through the filter prior to sampling. (Note: Groundwater filter cartridges are dedicated sampling equipment. A new cartridge should be used at each sampling location. Do not attempt to clean filter cartridges. If the filter becomes clogged or groundwater flow is too slowed, remove and replace with a new filter cartridge.)

9. For non-dedicated systems, remove the pump from the monitoring well. Decontaminate the pump and dispose of the tubing. For dedicated systems, disconnect the tubing that extends from the plate at the wellhead (or cap) and discard after use.

10. Close and lock the well.

Special Advisory: If a stabilized drawdown in the well can't be maintained at 0.3 feet and the water level is approaching the top of the screened interval, reduce the flow rate or turn the pump off (for 15 minutes) and allow for recovery. It should be noted whether or not the pump has a check valve. A check valve is required if the pump is to be shut off during purging. Under no circumstances should the well be pumped dry. Begin pumping at a lower flow rate, if the water draws down to the top of the screened interval again, turn pump off and allow for recovery. If two tubing volumes (including the volume of water in the pump and flow cell) have been removed during purging, then sampling can proceed next time the pump is turned on. This information should be noted in the *Low-Flow Purging and Sampling Log.* This behavior may necessitate an alternative purging and sampling procedure for subsequent sampling events.

5.3 Equipment Decontamination

The electronic water level indicator and the water quality meters will be decontaminated by the following procedures:

1. The water level indicator will be hand washed with phosphate-free detergent and a scrubber, then thoroughly rinsed with distilled water, or steam-cleaned.
2. Water quality meter sensors and flow-through cell will be rinsed with distilled water between sampling locations. No other decontamination procedures are necessary or recommended for these meters since they are sensitive instruments. After the sampling event, the flow-through cell and sensors must be cleaned and maintained per the manufacturer's requirements.

Upon completion of the groundwater sample collection the sampling pump must be decontaminated between monitoring wells. The pump and discharge line including support cable and electrical wires which were in contact with the groundwater in the well casing must be decontaminated by the following procedure:

1. The outside of the pump, tubing, support cable and electrical wires must be pressure-sprayed with soapy water, tap water and distilled water. Spray outside of tubing and pump until water is flowing off of tubing with each rinse. Use bristle brush to help remove visible dirt and contaminants.
2. Place the sampling pump in a bucket or in a short cylinder or well casing (4-inch diameter) with one end capped. The pump placed in this device must be completely submerged in the water. A small amount of phosphate-free detergent must be added with the potable (tap) water.
3. Remove the pump from the bucket or 4-inch casing and scrub the outside of the pump housing and cable.
4. Place pump and discharge line back in the container, start pump and re-circulate soapy water for approximately 2 minutes.
5. Re-direct discharge line to a 55-gallon drum. Continue to add 5 gallons of potable (tap) water.
6. Turn pump off and place pump into a second bucket of potable (tap) water. Continue to add 5 gallons of tap water.
7. Turn off and place pump into a third bucket which contains distilled/deionized water, continue to add 3 to 5 gallons of water.
8. If hydrophobic contaminants are present (such as separate phase (i.e. LNAPL or DNAPL, high levels of PCBs, etc.) an additional decontamination step, or steps, may be required.
9. Decontamination water will be collected and stored on-site for future disposal by the client unless other arrangements have been made.

6 Quality Control Samples

All field Quality Control (QC) samples must be prepared the same as primary samples with regard to sample volume, containers, and preservation. The sample handling and chain-of-custody procedures for the QC samples will be identical to the primary samples. The following are QC samples that may be collected during groundwater sampling:

- A field duplicate is an independent sample collected as close as possible to the same time that the primary sample is collected and from the same source. Field duplicates are used to document sample precision. Field duplicates will be labeled and packaged in the same manner as primary samples so that the laboratory cannot distinguish between the primary sample and the duplicate sample. Field duplicates are analyzed for the same suite of parameters as the primary samples. The frequency of analysis of field duplicates is generally one for every 20 primary samples, but may vary depending on project requirements.
- Equipment blanks are obtained by running distilled or deionized water over or through the

sample collection equipment after it has been decontaminated, and capturing the water in the appropriate sample containers for analysis. Equipment blanks are analyzed for the same suite of parameters as the primary samples. The frequency of analysis of equipment blanks is generally one for every day that non-dedicated sampling equipment is used, but may vary depending on project requirements.

- Field blanks are used to assess the presence of contaminants arising from field sampling procedures. Field blank samples are obtained by filling a clean sampling container with reagent-grade deionized water. Field blanks are analyzed for the same suite of parameters as the primary samples. Field blanks may or may not be incorporated into a groundwater sampling plan depending on project requirements.
- Trip blanks are sample containers that are used to evaluate sample cross-contamination of VOCs during shipment. For groundwater sampling, trip blanks consist of hydrochloric acid-preserved, analyte-free, deionized water prepared by the laboratory in VOA vials that will be carried to the field, stored with the samples, and returned to the laboratory for VOC analysis. Generally, one trip blank is required to accompany each sample shipping container or cooler that contains samples for VOC analysis; however, this may vary depending on project requirements.

7 Sample Handling and Custody

Samples will be collected, handled, and stored in such a manner that they are representative of their original condition and chemical composition. Identification of samples and maintenance of custody are important elements that must also be utilized to ensure samples characterize site conditions. All samples will be properly identified and maintained under chain-of-custody protocol to protect sample integrity. The following sections discuss the sample handling and custody requirements.

7.1 Sample Identification

To maintain consistency, a sample identification convention including unique identifiers for all groundwater and QC samples must be developed and followed throughout the project. The sample identifiers will be entered onto the sample labels, field forms, chain-of-custody forms, and other records documenting sampling activities.

7.2 Sample Labels

A sample label will be affixed to all sample containers sent to the analytical laboratory. Field personnel will complete an identification label for each sample with the following information written in waterproof, permanent ink:

- Client and project number;
- Sample location and depth, if relevant;
- Unique sample identifier;
- Date and time sample collected;
- Filtering performed, if any;
- Preservative used, if any;

- Name or initials of sampler; and
- Analyses or analysis code requested.

The use of pre-printed sample labels is preferred in order to reduce sample misidentification problems due to transcription errors. Sample labels must be completed and affixed to the sample container in the field at the time of sample collection.

If errors are made on a sample label, corrections will be made by drawing a single line through the error and recording the correct information. Corrections will be dated and initialed.

7.3 Containers, Preservation, and Hold Time

Each lot of preservative and sampling containers will be certified as contaminant-free by the supplier. All preserved samples will be clearly identified on the sample label and *Chain-of-Custody* form. If samples requiring preservation are not preserved, field records will clearly specify the reason for the discrepancy.

Chemical activity continues in the sample until it is either analyzed or preserved. Once the sample has been preserved, the sample may be held for a period of time before analysis. The time from the collection of the sample to the analysis is defined as the holding time. The holding time varies depending on the media being sampled and the analyses being performed. The collection, preservation, and analysis of samples must be conducted to avoid exceeding relevant holding times.

7.4 Sample Handling and Transport

Proper sample handling techniques are used to ensure the integrity and security of the samples. Samples for field measured parameters will be analyzed immediately in the field and recorded in the appropriate field forms. Samples for laboratory analysis will be transferred immediately to appropriate laboratory supplied containers in accordance with the following sample handling protocols:

- Don clean gloves before touching any sample containers, and take care to avoid direct contact with the sample;
- Samples will be quickly observed for color, appearance, and composition and recorded as necessary;
- The sample container will be labeled before or immediately after sampling;
- Sample containers and liners will be capped with Teflon™-lined caps before being placed in Ziploc™-type plastic bags. The samples will be placed in an ice chest kept at 4 °C for transport to the laboratory;
- All sample lids will stay with the original containers, and will not be mixed;
- Sample bottles will be wrapped in bubble wrap as necessary to minimize the potential for breakage during shipment; and
- The *Chain-of-Custody* form will be placed in a separate plastic bag and taped to the cooler

lid or placed inside the cooler. A custody seal will be affixed to the cooler if the samples are to be shipped by commercial carrier. For shipped samples, U.S. Department of Transportation shipping requirements will be followed and the sample shipping receipt will be retained in the project files as part of the permanent Chain-of-Custody document.

7.5 Sample Chain-of-Custody

Sample chain-of-custody procedures will be used to maintain and document sample integrity during collection, transportation, storage, and analysis. A sample is considered to be under the control of, and in the custody of, the responsible person if the samples are in their physical possession, locked or sealed in a tamper-proof container, or stored in a secure area.

The *Chain-of-Custody* form provides an accurate written record that traces the possession of individual samples from the time of collection in the field until they are accepted at the analytical laboratory. The *Chain-of-Custody* form also documents the samples collected and the analyses requested. The sampler will record the following information on the *Chain-of-Custody* forms:

- Client and project number;
- Name or initials and signature of sampler;
- Name of destination analytical laboratory;
- Name and phone number of Project Leader in case of questions;
- Unique sample identifier for each sample;
- Data and time of collection for each sample;
- Number and type of containers included for each sample;
- Analysis or analyses requested for each sample;
- Preservatives used, if any, for each sample;
- Sample matrix for each sample;
- Any filtering performed, if applicable, for each sample;
- Signatures of all persons having custody of the samples;
- Dates and times of transfers of custody;
- Shipping company identification number, if applicable; and
- Any other pertinent notes, comments, or remarks.

Blank spaces on the *Chain-of-Custody* will be crossed out and initialed by the field sampler between the last sample listed and the signatures at the bottom of the sheet.

The field sampler will sign the *Chain-of-Custody* and will record the time and date at the time of transfer to the laboratory or an intermediate person. A set of signatures is required for each relinquished/received transfer, including internal transfer. The original imprint of the *Chain-of-Custody* will accompany the sample containers and a duplicate copy will be kept in the project file.

If the samples are to be shipped to the laboratory, the original *Chain-of-Custody* relinquishing the samples will be sealed inside a plastic bag within the ice chest, and the chest will be sealed with custody tape that has been signed and dated by the last person listed on the *Chain-of- Custody*. U.S. Department of Transportation shipping requirements will be followed and the sample shipping receipt will be retained in the project files as part of the permanent *Chain-of- Custody* document. The shipping company (e.g., Federal Express, UPS) will not sign the *Chain- of-Custody* forms as a receiver; instead the laboratory will sign as a receiver when the samples are received.

8 Field Documentation

Information collected during groundwater sampling may be recorded on individual field forms. If the project requires it, a project-specific Field Logbook may replace any of the individual field forms with the exception of the *Chain-of-Custody* form. Following review by the Project Manager, the original field records will be kept in the project file. The following forms may be used to document the field activities:

- *Field Investigation Daily Log*
- *Water Level Measurement Log*
- *Low-Flow Purging and Sampling Log*
- *Equipment Calibration Log*
- *Chain-of-Custody*

The *Field Investigation Daily Log* will be completed for each day of fieldwork containing (at a minimum) the times and descriptions of the work performed, the activities of the drillers and any other subcontractors or visitors on-site, arrival and departure times for all involved, and any other pertinent information. For larger projects, or when otherwise deemed appropriate by the Project Manager, this information may alternatively be recorded in a Field Logbook. In these cases, a separate Field Logbook must be used for each project or site.

The *Water Level Measurement Log* will be used to record water level measurements for all wells prior to commencement of groundwater sampling. The type, serial number, and calibration date for the water level measuring device will be included on this form. Additionally, this form will be used to record general observations of the conditions of the wells, wellheads, well boxes, and/or monuments.

The *Low-Flow Purging and Sampling Log* will be used to record the details of purging and sampling information for each well including the depth of the pump, purge rates, and volume purged from each well. This form will also be used to record all of the measurements of drawdown and water quality indicator parameters used for evaluating stabilization.

The *Equipment Calibration Log* will be used to document the calibration and status of any measuring instruments used in the field, e.g., PID/FID, water level measuring device, water quality meters, etc. The frequency and method of calibration will depend on the instrument. Any instruments used will be used in accordance with the factory-provided operating and/or service manuals.

Locations and unique identification of water samples collected from the monitoring wells will be recorded on the *Field Investigation Daily Log*, *Low-Flow Purging and Sampling Log*, a site map, and/or other appropriate forms.

Samples names, date/times, analyses to be performed, and other pertinent information will be recorded on the *Chain-of-Custody* form (discussed in Section 7.5) as a means of identifying and tracking the samples.

Standard Operating Procedure C-3:

Monitoring Well Installation and Development

Standard Operating Procedure C-3: Monitoring Well Installation and Development

This standard operating procedure (SOP) is applicable to the installation and development of wells for groundwater monitoring or remediation purposes. This SOP is generic in nature and may be modified in whole or part depending on constraints presented by site conditions and equipment limitations. Modifications of methodologies will be documented in the appropriate field logbook and discussed in reports summarizing field activities. The procedures herein are consistent with Title 35 Section 620E.505(a)(5)(F) of the Illinois Rules.

Well Installation

Prior to invasive activities, a subsurface utility check will be conducted. Wells will generally be constructed using 5- to 20-foot-long screen and sufficient riser to complete the well to, or slightly above, ground surface. The length of the well screen will be selected based on the planned use of each well and the observed lithology. Wells will be constructed using schedule 40 polyvinyl chloride (PVC) casing and 0.010 slot schedule 40 PVC well screen with a threaded bottom cap. Wells will generally be completed with a protective steel cover equipped with a lock to protect the well against damage and unauthorized entry.

Filter Material

Filter material will be well-graded, clean sand (generally less than 2-percent by weight passing a No. 200 sieve and less than 5 percent by weight of calcareous material).

Setting Wells

Upon completion of borehole drilling, the boring will be sounded to determine the total depth, and the PVC well materials will be assembled and lowered into the boring. PVC well materials will be measured to the nearest 0.1 foot and will be assembled such that the screened interval is positioned opposite the target formation. No PVC cement or other solvents will be used. Once the well has been positioned at the desired depth, filter sand will be slowly added to the borehole to fill the annular space to a depth approximately 1 to 2 feet above the top of the well screen. During sand placement, the driller will continually measure the depth to the sand using a weighted tape measure or other device to verify that the sand does not bridge between the auger and the well screen. Two feet of bentonite chips will be added on top of the filter sand and subsequently hydrated using clean, municipal water to form a transition seal. After the bentonite has hydrated for at least 30 minutes, the depth to the top of the bentonite will be measured and recorded. A neat cement/bentonite grout will be added from the top of the bentonite; a tremie pipe will be utilized to ensure that the grout is added from the bottom, upwards. The grout will be permitted to cure for 48 hours prior to well development.

Well Completion

All monitoring wells and monitoring points will be completed with a protective steel cover equipped with a lock to protect the well against damage and unauthorized entry. Wells will typically be completed above grade unless they are located within parking/driving areas, or are piped to a remediation system. Wells completed aboveground will be capped with a push-on well cap and completed with a steel stick-up casing. Wells completed below ground surface will be capped with an expandable locking well cap and completed with a flush mounted traffic rated steel cover set into a 2 foot by 2 foot concrete pad. All wells will be labeled with a permanent marker that includes the well ID.

Development and Surveying

New wells will be developed after the grout has cured for a minimum of 48 hours. Wells will be developed by surging, bailing, and pumping to reduce or remove drilling-induced formation smear from the borehole walls, to remove sediment that may have accumulated during well installation, consolidate the filter pack, and to enhance the hydraulic connection between the formation target zone and the well. In most cases, a bailer or pump will be used to remove sediment and turbid water from the bottom of the well. A surge block will then be lowered up and down within the screened interval to flush the filter pack of fine sediment and remove smear from borehole walls. Following surging, the well will be bailed or pumped again to remove sediment and turbid water. Water will be removed from the well at a rate greater than the anticipated future pumping rate and water quality parameters including pH, turbidity, specific conductance and temperature will be recorded. Drawdown will also be recorded with an interface probe or water level meter. The development will proceed until sediment is removed sufficiently to achieve a turbidity measurement of 5 NTU (or less). The well installation report will specify if the target turbidity cannot be achieved.

Following well installation and completion, each well will be surveyed by a licensed surveyor to determine the location of the well and to establish the elevation at the top of casing and ground surface with reference to the site datum. Survey data will be incorporated into the database and onto the site base map.

Decontamination of Drilling Equipment

All drilling and well development equipment will be cleaned prior to use, and between wells. Drilling equipment will be steam cleaned, rinsed with potable water, and air dried. If equipment is not immediately put back to use, equipment will be covered with clean plastic to protect the materials from contact with dust or other contaminants. Pumps or other non-dedicated field equipment that comes into contact with impacted media will be cleaned using a non-phosphate detergent followed by a tap water rinse and a final, deionized water rinse. Decontamination water will be collected for appropriate, subsequent off-site disposal. Spent PPE or other disposable materials (e.g., tubing) will be placed into a drum for subsequent disposal.

Documentation

Well installation and construction activities will be recorded in the field notebook. A well construction diagram will be completed for each well, reviewed by appropriate personnel for completeness and accuracy, and filed electronically in the project file. The CQA Officer will complete and submit an IEPA Well Completion form for each well.

References

Illinois Rules, Title 35 Section 620E.505(a)(5)(F).

Standard Operating Procedure C-4:

Photoionization Detector (PID) Screening

Standard Operating Procedure C-4: Photoionization Detector (PID) Screening

This standard operating procedure (SOP) is applicable to the use of a photoionization detector/flame ionization detector (PID/FID) instrument during soil sampling activities. The methodology is generic in nature and may be modified in whole or part to meet the handling and analytical requirements of the contaminants of concern, as well as the constraints presented by site conditions and equipment limitations. Modifications of sampling methodologies will be documented in the appropriate field logbook and discussed in reports summarizing field activities and analytical results. For the purposes of this procedure, soils are those mineral and organic materials not submerged in water for an extended period of time sufficient to support aquatic life.

Equipment/Apparatus

Equipment needed for PID/FID screening of soil samples may include:

- PID/FID instrument
- Clear glass jar
- Aluminum foil
- Ziploc bags

Procedure

When using PID/FID instrument the following procedure must be used:

- Half-fill **either** a glass jar, or a Ziploc® baggie.
  - When using glass jars:

    Fill jars with a total capacity of 8 oz. or 16 oz.

    Seal each jar with one (1) or two (2) sheets of aluminum foil with the screw cap applied to secure the aluminum foil.
  - When using Ziploc® baggies:

    Half fill bags from the split spoon or the excavation.

    Zip to close.
- Vigorously shake the sample jars or bags for at least thirty (30) seconds once or twice in a 10- to 15-minute period to allow for headspace development.
- If ambient temperatures are below 32 degrees Fahrenheit (0 degrees Celsius) headspace development is to be within a heated vehicle or building.
- Quickly insert the PID/FID sampling probe through the aluminum foil. If plastic bags are used, unzip the corner of the bag approximately one to two inches and insert the probe or insert the probe through the plastic. Record the maximum meter response (should be within the first 2 to 5 seconds). Erratic responses should be discounted as a result of high organic vapor concentrations or conditions of elevated headspace moisture.
- Record headspace screening data from both jars or bags for comparison.

- Calibration will be checked/adjusted daily. In addition, all manufacturers' requirements for instrument calibration will be followed.
- If sample jars are re-used in the field, jars will be cleaned according to field decontamination procedures. In addition, headspace readings must be taken to ensure no residual organic vapors exist in the cleaned sample jars.
- Plastic bags will not be reused.