2013 GWETS
Optimization Project Work Plan

Nevada Environmental Response Trust Site
Henderson, Nevada

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Nevada Environmental Response Trust

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ENVIRON

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

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Date: 10/18/13

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1 Introduction

ENVIRON International Corporation (ENVIRON) has prepared this work plan on behalf of the Nevada Environmental Response Trust (the Trust) describing initial steps intended to increase the effectiveness of the Groundwater Extraction and Treatment System (GWETS) located at the Nevada Environmental Response Trust Site (the Site). This work plan is a continuation of groundwater capture and mass removal analysis originally presented in Appendix E of the 2012 Annual Performance Report (ENVIRON 2012b), which was subsequently presented in Appendix F of the Draft Remedial Investigation and Feasibility Study (RI/FS) Work Plan (ENVIRON 2012d). The Trust provided the Nevada Division of Environmental Protection (NDEP) with an initial scope of work and timeline for the GWETS Optimization Project in a letter dated June 21, 2013. NDEP subsequently approved the scope of work in a letter dated July 8, 2013. The Trust provided a revised project schedule to NDEP via electronic mail on September 6, 2013.

1.1 Objective and Scope

The primary goal of the 2013 GWETS Optimization Project is to optimize the mass removal rates and capture zones of the three well fields that comprise the GWETS. As shown on Figure 1, the GWETS well fields are the Interceptor Well Field (IWF), the Athens Road Well Field (AWF), and the Seep Well Field (SWF). To support the optimization study, the following work will be performed: 1) test and activate nine currently idle extraction wells located in the IWF and AWF, 2) perform additional well testing to further characterize hydraulic properties of the major geologic units at the IWF and AWF, 3) characterize the stream-aquifer interaction at the SWF, and 4) update and refine the existing groundwater flow model. Following completion of these tasks, extraction rates at each of the three well fields will be optimized using the results of data analysis and groundwater modeling.

Of the nine currently idle wells that will be activated as part of this work plan, seven are part of the IWF (I-AA, I-AB, I-AC, I-AD, I-W, I-X, I-Y) and two are in the AWF (ART-7B and PC-150). These nine wells are referred to in this work plan as the “Activated Wells”. Construction information for the Activated Wells along with other wells proposed for testing and/or monitoring as part of this scope of work is presented in Table 1. As shown on Figure 1, the IWF Activated Wells are located within the boundaries of the Site, while the AWF Activated Wells are located on City of Henderson (COH) property approximately one mile north of the Site. This work plan outlines steps necessary to test and initiate extraction at the Activated Wells and to perform further aquifer testing at other wells within the IWF and AWF. The work will include pre-field planning and permitting, mobilization, well testing (slug, step drawdown, and recovery), construction related to the connection of ART-7B and PC-150 to the GWETS, well startup, data evaluation and modeling, and reporting. Upon completion of the planned well testing program, the data will be compiled and analyzed to estimate the hydraulic conductivity and well extraction efficiency for the wells tested. The results will be used to update the NDEP-approved groundwater model.

Implementing the GWETS Optimization Project has the potential to increase mass removal of perchlorate and chromium, the primary contaminants of potential concern (COPC) in shallow groundwater. ENVIRON will work closely with the Trust and the GWETS Operator, Envirogen

Technologies Inc. (Envirogen), to ensure that any resultant increase in hydraulic or mass loading can be accommodated by the treatment systems.

1.2 Work Plan Organization

This work plan is divided into five sections. Section 2 provides background information on Site geology and hydrogeology as well as an overview of the GWETS. Section 3 discusses various aquifer characterization tasks near the IWF and AWF, as well as data analysis techniques for each aquifer testing method. This section also describes utility construction and required permitting related to the activation of two presently idle extraction wells, ART-7B and PC-150. Updates to the Site's groundwater flow model are outlined in Section 4. The model will initially be updated to reflect the current configuration and pumping rates of the GWETS, the extraction/injection systems operated by neighboring facilities, and water inputs. As explained in more detail within Section 4.1, the existing model will be updated to using second quarter 2012 conditions. The model will then be refined to incorporate the results of aquifer testing, the regional water balance, and a study of stream-aquifer interaction. The final model will be used to establish optimal groundwater extraction rates for wells within the IWF, AWF, and SWF. Section 5 outlines reporting and an anticipated schedule for the work outlined above.

2 Background

2.1 Physical Setting

Elevations across the Site range from 1,677 to 1,873 feet above mean sea level. The land surface across the Site generally slopes toward the north at a gradient of approximately 0.023 feet per foot (feet/foot). The developed portions of the Site have been modified by grading to accommodate building foundations, surface impoundments, and access roads. Further modifications to the Site were made as part of the Interim Soil Removal Action (ENVIRON 2012c) in which soils were typically excavated to depths of up to 10 feet below ground surface (bgs). In some cases, depths were extended to greater than 10 feet to remove discolored soils. Not all excavations were completely backfilled following excavation, resulting in some areas with depressions with 3:1 side slopes. In addition, storm water retention basins and conveyance channels were constructed in the central and northern portions of the Site. These storm water basins retain storm water run-off on-site for infiltration/evaporation. Off-site to the north, the topographic surface continues at approximately the same gradient to the vicinity of Sunset Road, at which point it flattens to a gradient of approximately 0.011 feet/foot extending to the Las Vegas Wash (ENSR 2005).

2.2 Geology and Hydrogeology

Local geology and hydrogeology are defined by data collected from more than 1,100 borings and wells that have been installed at the Site and surrounding area. The following descriptions are summarized from the preliminary conceptual site model (CSM) report (ENSR 2005) and updated with additional information from the RI/FS Work Plan (ENVIRON 2012d).

Local hydrology is influenced by two primary geologic units, Quaternary alluvial deposits (Qal) and the Upper Muddy Creek Formation (UMCf). In some areas, a transitional zone of reworked sediments from the UMCf, known as the Transitional Upper Muddy Creek Formation (xMCf) is encountered at the base of the Qal. The following subsections describe the local geology, hydrogeology, and the current status of the on-site treatment system. Most extraction wells within the IWF are screened within both the Qal and the UMCf, while AWF and SWF extraction wells are screened almost exclusively in the Qal.

2.2.1 Geology

<u>Alluvium.</u> The Qal consists of a reddish-brown heterogeneous mixture of well-graded sand and gravel with lesser amounts of silt, clay, and caliche. Clasts within the alluvium are primarily composed of volcanic material. Boulders and cobbles are common. Due to the mode of deposition, no distinct beds or units are continuous over the area. The thickness of the alluvial deposits ranges from less than 1 foot to more than 50 feet beneath the Site. Soil types identified in on-site soil borings include poorly sorted gravel, silty gravel, poorly sorted sand, well sorted sand, and silty sand. A major feature of the alluvial deposits is the stream-deposited sands and gravels that were laid down within paleochannels eroded into the surface of the Muddy Creek Formation during infrequent flood runoff periods. These generally uniform sand and gravel deposits exhibit higher permeability than the adjacent, well-graded deposits. In general, these paleochannels are linear and trend to the northeast.

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

Muddy Creek Formation. The Pleistocene UMCf occurs in the Las Vegas Valley as valley-fill deposits that are coarse-grained near mountain fronts and become progressively finer-grained toward the center of the valley. Where encountered beneath the Site, the Muddy Creek Formation is composed of at least two thicker units of fine-grained sediments of clay and silt (the first and second fine-grained facies) interbedded with at least two thinner units of coarse-grained sediments of sand, silt, and gravel (the first and second coarse-grained facies).

2.2.2 Hydrogeology

Shallow groundwater is generally encountered between 4 to 50 feet below ground surface (bgs) and is generally deepest in the southernmost portion of the Site, becoming shallower as it approaches the Las Vegas Wash to the north. The groundwater flow direction at the Site is generally north to north-northwesterly. North of the Site groundwater flow direction changes slightly to the north-northeast. This generally uniform flow pattern may be modified locally by subsurface alluvial channels (paleochannels) cut into the underlying UMCf, as well as man-made features such as an on-site bentonite-slurry groundwater barrier wall, or recharge trenches (not currently in use). NDEP has defined three water-bearing zones (WBZs) that are of interest at the Site and surrounding area: the Shallow WBZ, which extends to approximately 90 feet bgs, is unconfined to partially confined, and is considered the “water table aquifer”; the Middle WBZ, which extends from approximately 90 to 300 feet bgs; and the Deep WBZ, which is defined as the contiguous WBZ that is generally encountered between 300 to 400 feet bgs (NDEP 2009).

Environmental investigations at the Site have primarily focused on the Shallow WBZ, although recent investigations (Northgate 2009, 2010) have included a number of Middle WBZ wells to improve understanding of this zone’s hydrogeology and to vertically delineate various COPCs. Unless otherwise stated, discussions of groundwater in this work plan refer to the Shallow WBZ, which contains the saturated portions of the Qal and the UMCf. Hydraulic conductivity (lateral and vertical) of the UMCf are at least an order of magnitude less than those of the Qal (ENSR 2005). Investigations of the Middle WBZ at the Site and surrounding sites indicate, with few exceptions, a vertical upward gradient between the Middle and Shallow Zones that generally increases with depth (ENVIRON 2012d). During the most recent reporting period (May 2013), vertical gradients between the Middle and Shallow Zone wells ranged from three to 10 feet in the vicinity of the IWF (ENVIRON 2013). Vertical gradients measured near the AWF were +0.3 feet and -1.4 feet during this reporting period.

According to a summary of hydraulic conductivity data presented in the 2010 Capture Zone Evaluation (Northgate 2010), paleochannels within the Qal exhibit higher permeability than observed in the remainder of the unit, which leads to highly variable conductivity estimates for wells screened in the alluvium. Previous hydraulic conductivity estimates for the Qal in the vicinity of the site range from approximately 0.5 to 500 feet per day (feet/day) (Kleinfelder 2007) with a geometric mean hydraulic conductivity of 22.7 feet/day. Hydraulic conductivity is generally above 100 feet/day in areas where paleochannels have been previously interpreted (Northgate 2010).

Previous hydraulic conductivity estimates for the combined Qal/UMCf and transitional xMCf range from 0.08 to 102 feet/day, with a geometric mean of 1.7 feet/day (TIMET 2009; Geosyntec 2010; Northgate 2010). Previous hydraulic conductivity measurements of the UMCf range from 0.001 to 4.8 feet/day and have a geometric mean hydraulic conductivity of 0.08 feet/day (Geosyntec 2010; Northgate 2010).

A thorough review and interpretation of previous aquifer testing performed at the Site and surrounding sites will be conducted as part of this work plan.

2.3 Overview of the GWETS

The GWETS has been in place in essentially its current configuration since 2006, but extraction and on-site treatment of groundwater dates back to the late 1980s with the operation of the IWF and related treatment for removal of hexavalent chromium. The GWETS operates by capturing groundwater from the three extraction well fields and treating the captured groundwater via aboveground treatment facilities for subsequent discharge to Las Vegas Wash. Hexavalent chromium in extracted groundwater from the IWF is treated via chemical reduction and precipitation using ferrous sulfate at the Groundwater Treatment Plant (GWTP). GWTP effluent is discharged to a series of Fluidized Bed Reactors (FBRs), which also receive flow from the SWF and AWF for the biological removal of perchlorate using ethanol as a carbon source.

2.3.1 Current GWETS Configuration

The location of the IWF area is shown on Figures 1 and 2. A bentonite-slurry wall was constructed as a physical barrier across the higher concentration portion of the perchlorate/chromium plume on the Site in 2001 to enhance extraction. The barrier wall is approximately 1,600 feet in length and 60 feet deep. The IWF currently consists of a series of 23 active and seven idle groundwater extraction wells that are situated south (upgradient) of the barrier wall.

Figures 1 and 3 show the location of the AWF, which is approximately 8,200 feet north (downgradient) of the barrier wall and the IWF. The AWF was constructed as a series of 14 groundwater extraction wells screened in the Qal at seven paired well locations that span approximately 1,200 feet across two alluvial paleochannels located on either side of an UMCf ridge. The AWF was completed in March 2002 and continuous pumping began in mid-October of that year. The well pairs act in concert with one well pumping while the adjacent well is used to measure water levels and monitor the effect of pumping on the aquifer. In September 2006, a standalone well, ART-9, began full-time operation replacing ART-6A after groundwater elevations at the AWF dropped below a level where ART-6/6A could be effective.

Concentrations of perchlorate and chromium at the IWF are the highest of the three well fields given its location on-site. Between July 2012 and June 2013, the IWF operated at an average cumulative extraction rate of 68.6 gpm (ENVIRON 2013). For the same period, the AWF's cumulative extraction rate was 280.7 gpm (ENVIRON 2013). Concentrations of chromium and perchlorate at the AWF are significantly lower than those observed at the IWF.

The SWF is located approximately 4,500 feet north (downgradient) of the AWF near the Las Vegas Wash. When pumping began in July 2002, the SWF consisted of four extraction wells situated over the deepest part of the alluvial channel and a seep capture sump. Five additional wells (PC-117 to PC-121) were installed in February 2003 and an additional well (PC-133) was installed in December 2004 to complete the SWF. Since April 2007 the seep capture sump has not operated as a result of the effectiveness of the SWF in sufficiently lowering the local water table and eliminating the seep. The SWF perchlorate concentrations at the SWF are the lowest among the three well fields. For the period between June 2012 and June 2013, the SWF operated at an average cumulative extraction rate of 684.6 gpm (ENVIRON 2013).

The two off-site well fields, the AWF and the SWF, are served by three lift stations that convey groundwater to the on-site treatment plant via underground pipelines. The locations of these lift stations and pipelines are shown on Figure 1. Lift Station 1, located at the Las Vegas Wash, conveys groundwater extracted by the SWF to Lift Station 2 located on Pabco Road just south of Galleria Drive (formerly Athens Road). Lift Station 3, located within the AWF well line along Galleria Drive, conveys groundwater extracted by the AWF to Lift Station 2. Lift Station 2 pumps the combined flows from Lift Stations 1 and 3 to the on-site equalization area for treatment. Tables 2 and 3 summarize information on the pipelines and pumps, respectively, that comprise the GWETS based on available design drawings and input from the GWETS Operator. Additional construction and operational details of the GWETS will be compiled and evaluated as part of the implementation of this work plan.

From July 2002[1] through June 2012 the estimate of perchlorate mass removed and treated by the GWETS is approximately 6,185,000 pounds (equivalent to approximately 3,093 tons) (ENVIRON 2012b). The estimate of chromium mass removed and treated during this same time period is approximately 38,000 pounds (equivalent to approximately 19 tons).

2.3.2 Status of FBR Refurbishment

The GWETS Operator is currently performing rehabilitation of the FBRs and reducing water levels in the GW-11 pond. These have been identified by the GWETS Operator as critical tasks to ensure that the GWETS is capable of operating at its design treatment capacity and that must be completed prior to activation of idle wells as proposed herein.

According to the GWETS Operator, the FBR process design hydraulic flow is 1,000 gpm. The maximum loading (nitrate, chlorate, and perchlorate) to the FBR process is 1,800 equivalent pounds per day[2]. Furthermore, the GWETS Operator reports that the current configuration of

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[1] July 2002 was used as the start date for this performance evaluation since the extraction before this time was limited. This date corresponds to the time period when the AWF and SWF well fields were being installed and downgradient extraction from these well fields began.

[2] Equivalent pounds per day is calculated with the following formula:
Equivalent Pounds = ((0.9*NO3)+(0.17*ClO3)+(0.18*ClO4))*((gpm*1440)/1000)*8.34.

the GWTP, which treats groundwater extracted from the IWF, has a design maximum flow of 75 gpm at a maximum hexavalent chromium influent concentration of 15 milligrams per liter (mg/l).

The maximum operating capacity of the GW-11 pond is approximately 62.4 million gallons (Mgal) with an allowed three feet of freeboard, which corresponds to a maximum operating water elevation of 1,747 feet above mean sea level (amsl). As an emergency contingency, the GW-11 pond may be operated with two feet of freeboard provided that prior notice is given to NDEP and the Nevada Division of Water Resources (NDWR). The maximum operating capacity with two feet of freeboard is approximately 67.1 Mgal, with a corresponding water elevation of 1,748 feet amsl. The current water level elevation (as of October 18, 2013) is 1743.37 feet amsl, which corresponds to a water volume of approximately 46.1 Mgal. The most recent concentrations of perchlorate and total chromium in the GW-11 pond (sampled September 3, 2013) were reported as 56 mg/L and 0.017 mg/L, respectively. Ultimately, the goal is to reduce the volume of water in the GW-11 pond to the point where it can be operated as an equalization basin and only be used for emergency diversion of treatment plant effluent during upset conditions or system downtime.

Aquifer testing, which will involve modifications to well extraction rates, will be designed and conducted so as to mitigate the impact on GWETS operation. ENVIRON will work with the GWETS Operator to ensure adequate treatment capacity is available and NPDES permit limitations are met. ENVIRON, with input from the GWETS Operator, will continue to evaluate GWETS capabilities and potential limiting factors in optimization as part of this work plan including factors impacting well extraction rates, land availability, pump capacities, influent and effluent hydraulic capacities, discharge permitting, GW-11 volume, and the mass loading capacity of the treatment systems.

3 Well Testing and Activation

In order to increase the effectiveness and efficiency of the current GWETS system, ENVIRON is proposing to initiate extraction at the Activated Wells and to subsequently optimize the pumping of the three extraction well fields through analysis of data obtained in the field testing program described herein, and groundwater modeling as described in Section 4.

Since the Activated Wells, depicted in Figures 2 and 3, have not been used previously, testing is proposed at the Activated Wells in order to determine basic well performance characteristics, such as maximum extraction rate and well efficiency. This information will be used to select appropriately sized pumps and as a key input to the extraction rate optimization process. Well testing at other wells at the IWF and AWF is proposed in order to further characterize the hydraulic properties of the major geologic units at each well field. The information obtained from well testing of both Activated Wells and other wells will be used to refine the groundwater flow model in order to improve the ability of the model to estimate the capture zones of the well fields under different pumping scenarios.

Based on the maximum achievable extraction rate[3] estimated during well testing, permanent pumps will be specified for the two AWF Activated Wells (ART-7B and PC-150). Permanent pumps have already been installed in the seven Activated Wells in the IWF; the proposed well testing program will identify target flow rates for pumps in these wells. If the existing pumps are not capable of sustained pumping at the rates needed to perform well testing, then the pumps will be removed and portable pumps will be used to complete the testing.

3.1 Pre-field Planning and Mobilization

ENVIRON will initiate pre-field planning in coordination with subcontractors as described in the sub-tasks below.

3.1.1 Health and Safety Plan (HASP)

ENVIRON will implement the Site's site-specific HASP which will cover all proposed activities. ENVIRON's existing HASP for the Site will be revised, as necessary, to address additional health and safety hazards posed by the activities described in this work plan.

3.1.2 Site Management Plan (SMP) Compliance

Certain tasks outlined in this work plan have the potential to impact the operation of the GWETS or expose workers to contaminated groundwater. The following sections discuss requirements described by the SMP (ENVIRON 2012a) that are expected to apply to this project.

3.1.2.1 Extraction Rate Modifications

As described in Section 3.1 of the SMP, prior to the implementation of any temporary modifications to extraction rates within the AWF and IWF the changes must be approved by both the Trust and NDEP. Aquifer testing, which will involve temporary modifications to well

[3] Extraction wells in the IWF and AWF will continue to pump throughout aquifer testing. Therefore, it is expected that the calculated maximum achievable pumping rates for the Activated Wells will be less than the rates achievable in the absence of sustained pumping at the well fields.

extraction rates, will be carried out in coordination with the GWETS Operator in order to mitigate impacts to the GWETS. Acceptance of this work plan by NDEP and the Trust will serve as approval of these modifications for the purposes of the SMP.

Permanent modifications to well extraction rates that are expected be recommended as part of the 2013 GWETS Optimization Project will be proposed to the Trust and NDEP for approval following completion of the well testing, data evaluation/interpretation, and modeling tasks described in this work plan.

3.1.2.2 Preparation of Contingency Plan and Protection of Existing Well Infrastructure

In accordance with Section 5.3 of the SMP, construction activities near ART-7B and PC-150 must include appropriate measures to protect the integrity of existing pipelines and wells. Where possible, plans will allow for the continued operation of the GWETS system, minimizing any shutdowns of system components. All plans must be approved by NDEP and the Trust prior to the start of work.

Before starting any activity within 50 feet of any component of the groundwater monitoring extraction and treatment systems, a Contingency Plan will be prepared and implemented. The Plan will outline actions that would be taken if damage is caused to any remediation system component in a manner that causes the release of untreated groundwater. It will identify any emergency equipment necessary to control or contain potential releases of untreated groundwater during construction or well testing activities. The Contingency Plan will be prepared during utility design to address the specific construction activities being performed and will be submitted to NDEP and the Trust for review and approval prior to the start of construction.

3.1.2.3 Contractor Requirements

As required by Section 3.3 of the SMP, any third-party contractor with workers that may come into contact with groundwater at the Site will be required to prepare their own project-specific HASP. Each project-specific HASP must be consistent with State and Federal Occupational Safety and Health Administration (OSHA) standards for hazardous waste operations (29 Code of Federal Regulations 1910.120) and any other applicable health and safety standards.

3.2 Well Testing

Hydraulic properties of the key geologic units will be characterized using several types of conventional aquifer testing, including slug, step-drawdown, and recovery test methods. A variety of hydraulic testing efforts have been undertaken at the Site and surrounding properties since at least the early 1980s. As part of modeling efforts described in Section 4 of this work plan, ENVIRON will compile, analyze, and interpret previous aquifer testing work performed at the Site.

The proposed well testing program has been organized into four primary tasks: 1) Shakedown testing will be conducted at seven of the Activated Wells within the IWF to prepare them for further well testing; 2) Slug testing at the AWF will further characterize hydraulic properties of areas not currently targeted for extraction; 3) Step-drawdown testing of the Activated Wells will be used to determine basic well characteristics and aquifer hydraulic properties; and 4) Recovery testing of selected existing extraction wells will be used to determine aquifer hydraulic properties. These four testing components are described in more detail in the following sections.

3.2.1 Shakedown Testing of Seven Activated Wells in the IWF

Wells I-AA, I-AB, I-AC, I-AD, I-W, I-X, I-Y were previously installed by other consultants and/or contractors. Reportedly, the pumps, sensors, and controls installed in these wells have not been thoroughly tested to evaluate if they function properly. Based on quarterly groundwater sampling work performed by the GWETS Operator, ENVIRON has determined that pumps installed in wells I-AC and I-AD turn on, but do not extract water. The remaining wells (I-AA, I-AB, I-W, I-X, I-Y) appear capable of pumping for short periods of time, however a full evaluation of these wells has not been completed.

ENVIRON will perform shakedown testing by comparing the construction of each IWF Activated Well with as-built drawings to be provided by the GWETS Operator. Deviations from the drawings, including missing equipment or obvious damage, will be noted and corrected as necessary. After the initial inspection, each well will be started to test the function of pumps, sensors, and controls by gradually adjusting the pumping rate. Groundwater levels will be monitored manually with an electronic water indicator in order to ensure that water levels do not fall below the screened interval or the level of the pump. This shakedown testing will identify malfunctioning wells and will include recommendations for any additional work necessary to correct deficiencies. The appropriate repairs will be made by ENVIRON, with the assistance of the GWETS Operator or contractors, as necessary.

3.2.2 Slug Testing

Four wells at the AWF (PC-134A, PC-137, PC-148, and PC-149) have been identified for slug testing. Slug tests will be used to quickly estimate the hydraulic conductivity of the formation in wells that are not targeted for extraction because they are located in areas outside of the paleochannels which form the major flow pathways. This information will be used to refine current understanding of the distribution of hydraulic conductivity across the well field, both in areas of higher conductivity that are targeted for extraction and areas of lower conductivity that provide natural barriers to groundwater transport of contaminants.

The slug tests will be conducted at each selected well by quickly lowering (falling-head test) and/or removing (rising-head test) a solid slug (a known length of pipe that is filled with sand and capped) into the well, resulting in an instantaneous change in water level. The falling-head test will be initiated by rapidly introducing a solid slug into the well. In general, the slug size will be chosen to produce an initial displacement of one to two feet, but may vary depending on conditions encountered in the field. After water levels have returned to equilibrium, the slug will be rapidly removed from the well to initiate a rising-head test. Both the rising-head and falling-head tests will be repeated with a different size slug to confirm the results, unless especially slow recovery times make a second set of tests impractical. The recovery of hydraulic head to the initial level will be monitored and recorded.

Before initiating the slug test, the static water level of the well will be measured and recorded. A pressure transducer with an integral data logger (Solinst Levelogger Gold, or similar) will then be installed in the well and the water level allowed to stabilize. The transducer will be securely deployed by a direct-read cable allowing real-time viewing of data. Manual water level measurements will be collected using an electronic water level indicator with gradations to the nearest 0.01 foot before testing to determine static water levels, as well as during the tests to confirm the transducer data. Local barometric pressure will be recorded throughout the slug testing using a barometric pressure transducer (Solinst Barologger, or similar) deployed in a nearby monitoring well above the level of the water table. Pressure readings from the transducer in the tested well will be corrected for changes in barometric pressure as necessary.

Between wells, all non-dedicated equipment that has been in contact with groundwater will be decontaminated by washing with a detergent solution (Alconox or equivalent) followed by rinsing with deionized water.

After the completion of each test, the water level data will be downloaded from the transducer data logger for analysis. The hydraulic conductivity and transmissivity of each well will be estimated in AQTESOLV software (Duffield 2007) using the Bouwer and Rice, KGS, or other appropriate curve fitting method for unconfined aquifers. The curves will be fit to the data in the recommended head range, if possible, to reduce effects resulting from the filter pack material. More complex methods, which account for unsteady flow or well skin effects, will be used if deemed necessary based on initial data analysis.

3.2.3 Step Drawdown Testing of Activated Wells

Step drawdown testing is proposed for all of the Activated Wells (I-W, I-X, I-Y, I-AA, I-AB, I-AC, I-AD, ART-7B, and PC-150). The data from these tests will be used to establish sustainable flow rates in the wells and also to provide data on the hydraulic conductivity of the surrounding formation. A step-drawdown test will be performed at each selected well by pumping at a set of sequentially increasing pumping rates and measuring the change in water level in the pumping well and nearby observation wells. During these tests, drawdown will be monitored within the test well and also within at least three nearby wells using pressure transducers with integral datalogging capabilities (Solinst Levelogger Gold or similar). The proposed monitoring network for each step drawdown test is outlined on Table 4 and depicted in Figures 6 and 7. Operating extraction wells designated as monitoring wells for the purposes of aquifer testing will be deactivated at least 24 hours prior to the start of pumping.

At the start of each test, the static water level of the wells will be measured and recorded. A submersible pump will be set in the pumping well with the intake set two feet above the base of the well screen. The pressure transducer with an integral data logger will be installed in the well and the water level allowed to stabilize. The transducer will be securely deployed by a direct-read cable allowing real-time viewing of data. Manual water level measurements will be collected using an electronic water level indicator with gradations to the nearest 0.01 foot before testing to determine static water levels as well as during the tests to confirm the transducer data. Local barometric pressure will be recorded throughout the step drawdown testing using a barometric pressure transducer (Solinst Barologger, or similar) deployed in a nearby monitoring well above the level of the water table. Pressure readings from the transducer in the test well will be corrected for changes in barometric pressure as necessary.

During the step drawdown testing, the flow rates will be continually measured and adjusted to maintain constant steps. A calibrated inline flow meter will be used to monitor flow rates. The flow rate measurements may also be verified by measuring flow by filling graduated measuring containers with pump discharge water over 5, 10, 20, or 30-second time intervals. For each pumping step, the flow rate will be maintained for at least 30 minutes, or until drawdown has stabilized. Proposed pumping rates are shown in Table 5. At least three pumping rates will be used at each well.

Step drawdown testing conducted at wells in the AWF (ART-7B and PC-150) will require the installation of temporary discharge lines designed to convey the extracted groundwater to Lift Station #3. Temporary piping and/or hose for PC-150 will be installed at the ground surface to the short distance (less than 50 feet) to Lift Station #3. Temporary connections will be made to the existing discharge piping of extraction well ART-7 or ART-7A to allow for the conveyance of extracted groundwater from well ART-7B (immediately adjacent to wells ART-7 and 7A) to Lift Station #3. ENVIRON will coordinate the operation of pumps for well testing and the installation of temporary discharge lines. For shakedown testing and step drawdown testing in the IWF Activated Wells (I-W, I-X, I-Y, I-AA, I-AB, I-AC, and I-AD), the GWETS Operator will assist in the operation of pumps already installed in the wells and previously plumbed into the GWETS.

During the step drawdown testing, ENVIRON will collect a sample from each of the nine tested wells for analysis for perchlorate, total chromium, hexavalent chromium, total dissolved solids (TDS), chlorate, and nitrate as nitrogen. The results will be used to understand how the activation of new extraction wells will impact loading to the GWETS. Samples will be sent to Envirogen's subcontracted analytical laboratory, TestAmerica Laboratories, Inc. (TestAmerica), for analysis.

At the end of each test, all field equipment that has contacted groundwater will be decontaminated by washing with a detergent solution (Alconox or equivalent) followed by rinsing with deionized water. Water generated during step-drawdown testing will be discharged to the GWETS. Water pumped from the Activated IWF wells (I-W, I-X, I-Y, I-AA, I-AB, I-AC, and I-AD) will be pumped to the GWETS, in coordination with the GWETS Operator, using permanent discharge lines already installed at each well. ENVIRON will coordinate with a subcontractor to run pumps for the well testing of the AWF Activated Wells (ART-7B and PC-150). The GWETS Operator will install temporary connections to the existing facilities to convey the extracted water to Lift Station #3.

After the completion of each step drawdown test, the water level data will be downloaded from the transducer data loggers for analysis. The step drawdown test data will be analyzed in AQTESOLV using methods that can estimate linear (i.e. skin effects) and nonlinear well losses, such as the Hantush-Jacob and Dougherty-Babu methods. The results of the analysis will include estimates of the efficiency of the Activated Wells and estimates of the hydraulic properties of the aquifer.[4]

3.2.4 Recovery Testing of Existing Pumping Wells

Recovery testing is planned for seven extraction wells within the IWF (I-B, I-D, I-N, I-G, I-V, I-J, I-K) and four extraction wells within the AWF (ART-1, ART-4A, ART-9, ART-7). A recovery test is performed by temporarily turning off an existing pumping well while monitoring the change in water level within the idle pumping well and one or more nearby observation wells. During these tests, water levels will be monitored within the test well and also within at least three nearby monitoring wells. The data from these tests will be used to estimate the hydraulic conductivity of the formation, while also providing information on the extent to which cones of depression may overlap for neighboring wells.

To select wells for recovery testing, ENVIRON reviewed long-term pumping rates for each extraction well and selected wells where recent pumping rates were relatively stable. Relatively stable pumping rates are required in order to evaluate aquifer response using standard aquifer test methods. Wells were selected to exhibit a variety of flow rates and are distributed relatively evenly across each well field.

Prior to conducting each recovery test, pressure transducers with integral data loggers will be installed in the test well and in three or more monitoring wells in proximity to the test well. The water levels will be allowed to stabilize. The proposed monitoring network for each recovery test is shown on Table 6 and in Figures 8 and 9.

Manual water level measurements will be collected from the test well and monitoring wells immediately prior to the start of each recovery test. Manual water level measurements will be recorded periodically for the duration of the test. These measurements will be collected using an electronic water level indicator with gradations to the nearest 0.01 foot. The recovery test will be initiated by shutting off the extraction well pump. The pump shutdown time will be recorded.

The recovery test will continue until full recovery (> 90% of long-term drawdown) has been achieved, at which time the pump will be restarted and the transducers removed. Prior to initiating each recovery test, the long-term drawdown at the extraction well will be estimated by comparing historical water level trends at the test well and neighboring cross-gradient monitoring wells, or by modeling the long-term drawdown based on the average pumping rate and previous estimates of hydraulic conductivity in the vicinity of the extraction well.

At the end of each test, all field equipment that has contacted groundwater will be decontaminated by washing with a detergent solution (Alconox or equivalent) followed by rinsing

[4] The analytical methods provided in AQTESOLV for unconfined aquifers assume that the tested aquifer is homogeneous. The Activated IWF wells selected for testing are screened across both the Qal and UMCf formations, violating this assumption. If the step drawdown results do not appear to conform to commonly used analytical solutions, numerical methods (i.e. MODFLOW with PEST calibration) may be required to analyze the response data.

with deionized water. Any wastewater generated during decontamination will be discharged to the GWETS.

After the completion of each recovery test, the water level data will be downloaded from the transducer data loggers for analysis. The recovery data will be transformed and analyzed in AQTESOLV using the Agarwal procedure and one or more analytical solutions for pumping tests in unconfined aquifers (Theis, Neumann, Moench). The analytical results will include estimates of the hydraulic conductivity of the aquifer near each of the tested wells.[5]

3.3 Activation of Wells ART-7B and PC-150

Prior to initiating permanent extraction from the two AWF Activated Wells (ART-7B and PC-150), pumps, utility lines (plumbing and electrical), and vaults will be installed to connect the two wells to Lift Station #3 for conveyance of the extracted groundwater to the GWETS. Because these wells and Lift Station #3 are on COH property, ENVIRON will coordinate these activities with the COH and will work with the Trust to obtain any necessary access agreements or permits, as discussed below.

3.3.1 Utility Design and Construction Planning

Prior to utility design, a Site walk is planned to confirm conditions and establish locations for utility corridors. ENVIRON will coordinate utility design and construction of ART-7B and PC-150 with a construction contractor and will perform oversight of this work.

Limited excavation and trenching will be required for the installation of vaults and utility lines. ENVIRON has assumed that one of the piping and electrical runs from either ART-7 or ART-7A will be repurposed to connect ART-7B to the GWETS. Thus, only minor excavation for construction of a well vault is required at ART-7B. PC-150, located within the Lift Station #3 compound, will require a well vault as well as new piping and electrical connections to Lift Station #3. These utility lines will be installed underground, or within a subsurface concrete-lined pipe trench with steel plate cover, to avoid limiting access within the Lift Station #3 compound. Thus, installing PC-150 will require limited excavation for construction of the well vault and less than 50 feet of trenching for installation of utility lines. The exact configuration of utility lines will be determined during the design phase.

At least three business days prior to any groundbreaking, ENVIRON will notify Underground Service Alert (USA) of the location, extent, and dates of excavation. As necessary a private utility locator will be hired to perform non-intrusive locating of buried utilities. Location, size, and materials of existing utilities will be verified by exploratory excavation and/or air knife prior to construction. Utility design and protection of existing facilities will be detailed in the Contingency Plan as described in Section 3.1.2.2 of this work plan.

[5] The analytical methods provided in AQTESOLV for unconfined aquifers assume that the tested aquifer is homogeneous. However, because all but one of the IWF wells selected for testing are screened across both the Qal and UMCf formations, commonly used analytical solutions may not be applicable for analysis of response data and numerical methods (i.e., MODFLOW with PEST calibration) may be required.

3.3.2 Permitting

ENVIRON will acquire the appropriate permits from the COH prior to installation of vaults, pumps, and utility lines necessary to initiate extraction from the two AWF Activated Wells. In order to obtain the required electrical and plumbing permits, ENVIRON will submit two sets of proposed drawings, including proposed electrical plans, to the COH Building Department. In accordance with Building Department requirements, the plans will be stamped and approved by a licensed civil engineer from the State of Nevada prior to submission.

To determine if an encroachment permit is required, ENVIRON will verify the location of well ART-7B and determine if the well is located within an existing easement. If ART-7B is not within the boundaries of an existing easement, ENVIRON will work with the COH and the Trust to amend the current lease agreement. Such an amendment will require City Council approval. Once the location of ART-7B is established, the Public Works Department will determine if an encroachment permit is required based on design drawings submitted by ENVIRON. PC-150 is located within the Lift Station #3 compound, which is covered by an existing easement; therefore, no encroachment permit will be required for activation of this well.

3.4 Startup of Activated Wells

Based on the results of well testing, preliminary extraction rates will be selected for sustained operation. The Activated Wells will then be brought online one by one, making necessary adjustments to existing wells, until all of the IWF and AWF wells are operating sustainably. ENVIRON will work closely with the GWETS Operator to ensure that the treatment system efficiency is maintained by adjusting flows as necessary. During startup and for three weeks thereafter, water levels will be monitored within selected monitoring wells using pressure transducers with integral datalogging capabilities (equivalent to those used during well testing) in order to understand the effects of pumping from the Activated Wells. After the startup period, the Activated Wells will be routinely monitored consistent with the Site’s groundwater monitoring program.

3.5 Waste Management

Utility construction and excavation activities associated with the activation of ART-7A and PC-150 will take place within COH property and, therefore, are not covered by soil disturbance requirements listed in the SMP. In addition, trenching activities will not intersect the water table, which is approximately 30 feet bgs in the vicinity of the AWF (ENVIRON 2013).

Excavated soils generated during trenching will be stockpiled during construction and used to backfill trenched areas in compliance with applicable COH requirements. Any soils not re-used on-site and identified for off-site disposal or reuse will be stockpiled and sampled for all constituents required by the receiving facility. At a minimum it is expected that a single four-point composite sample will be collected and submitted to TestAmerica for analysis of perchlorate by USEPA 314.0 and total chromium by USEPA 6010B. Additional analytes may be added based on visual inspection of the soil, with input from COH personnel, or as requested by a disposal facility.

For shakedown testing and step drawdown testing in the IWF Activated Wells (I-W, I-X, I-Y, I-AA, I-AB, I-AC, and I-AD), the GWETS Operator will assist in the operation of pumps already installed in the wells and previously plumbed into the GWETS. Groundwater generated through pumping tests at the IWF and decontamination rinse water will be treated by the GWETS and discharged to Las Vegas Wash under the existing NDPES permit.

Step drawdown testing conducted at wells in the AWF (ART-7B and PC-150) will require the installation of temporary discharge lines designed to convey the extracted groundwater to Lift Station #3. The discharge piping of extraction well ART-7 or ART-7A will be connected to allow for the temporary connection of extraction well ART-7B (immediately adjacent to wells ART-7 and 7A). As discussed in Section 3.1.2, a Contingency Plan will be prepared that outlines actions that would be taken if untreated groundwater were released during operation of the temporary discharge lines. After groundwater enters Lift Station #3 through the temporary discharge lines, the water will be pumped to the on-site treatment facility via existing infrastructure. Decontamination rinse water will be transported to the Site for treatment by the GWETS.

4 Groundwater Modeling

As part of the GWETS Optimization Study, the existing groundwater flow model will be refined and updated as described in this section. The updated and refined model will be used to estimate capture zones and perform other analyses to support the optimization of the GWETS extraction rates.

The existing model was developed by Northgate Environmental Management Inc. (Northgate) and documented in the Capture Zone Evaluation Report (Northgate, 2010). On April 4, 2013, the groundwater model was approved by NDEP for use in capture zone evaluation. The extent of existing model domain is shown in Figure 8. The active area of the model domain is wedge-shaped, narrowing from south to north towards the Las Vegas Wash covering an area of approximately 10,000 acres. The model domain extends from south of Lake Mead Parkway to the Las Vegas Wash, approximately 20,000 feet (about 4 miles) in length. Laterally, the model extends beyond the current property boundary of the NERT Site to include the existing groundwater capture systems of AMPAC and Olin Stauffer-Syngenta-Montrose (OSSM) to the west and the monitoring wells at the TIMET site to the east.

The current model is a steady-state model calibrated to site conditions existing during 2008/2009. In order to optimize the current GWETS, the model will be updated to current conditions and refined to better represent groundwater flow in the vicinity of the three extraction well fields. The refinements in the vicinity of the IWF and AWF will be based in part on the additional aquifer testing described in Section 3 of this work plan. Refinements near the SWF will be based in part on an evaluation of stream-aquifer interaction to be conducted using existing data. The model update and refinement will be performed in two phases as described below.

Phase I

During Phase I, the model will be updated to reflect the current configuration and pumping and injection rates of the GWETS, AMPAC, and OSSM remediation systems. A regional water balance will be prepared in order to confirm that the model is generally consistent with observed conditions. An initial evaluation of the stream-aquifer interaction in the vicinity of the SWF will also be conducted. This updated version of the model and the stream-aquifer interaction evaluation will be used to support the development of performance metrics that will be used during the optimization of the IWF, AWF, and SWF performance. The performance metrics will be documented in a technical memorandum, further discussed in Section 5.1, and submitted to NDEP for comment.

Phase II

The model will be refined during Phase II in order to incorporate the results of aquifer testing, the regional water balance, and the study of stream-aquifer interaction. As part of this phase, the model boundary conditions and hydraulic properties will be recalibrated to more accurately represent groundwater flow and evaluate the effectiveness of the GWETS. The updated and refined model will then be used to evaluate the performance of alternative extraction rates at the three well fields. The set of extraction rates that performs the best using the identified performance metrics will be recommended for future implementation.

A detailed description of the tasks proposed for Phases I and II is provided in the following sections.

4.1 Phase I Model Updates

The model was originally developed by Northgate using a pre-release version of the USGS code MODFLOW-NWT that was not publicly available. Since the original model development, the USGS has released an improved version of the MODFLOW-NWT code that is publicly available on its website. ENVIRON made minor modifications to the original Northgate model so that it would be compatible with the publicly available version. All future modeling work will use publicly available modeling codes.

A review of site wide hydrographs and rainfall records indicate that approximately steady-state groundwater conditions exist between late 2010 and early 2012. Higher water levels were measured in Site wells due to higher than average rainfall during late 2012 and first quarter 2013. Between April and June 2013, many of the active IWF pumping wells, which are located directly upgradient of the barrier wall, had water levels that were approximately five to 15 feet higher than the same period in 2012 (ENVIRON 2013). Based on this review, the existing model will be updated to represent second quarter 2012 conditions, which represents the most recent period of approximately steady-state groundwater conditions.

As described in the following sections, groundwater extraction rates, recharge trench flow rates, and Birding Pond recharge rates will be updated to reflect early 2012 steady-state conditions. In addition, at the request of NDEP, the bottom boundary conditions and the representation of the barrier wall downgradient of the IWF will be examined to confirm they are consistent with current conditions.

4.1.1 Groundwater Extraction and Recharge Trenches

Groundwater pumping rates will be updated to early 2012 conditions. The combined average pumping rates for second quarter 2012 for IWF, AWF, and SWF are 62 gpm, 275 gpm, and 577 gpm, respectively. The combined average pumping rate for OSSM wells is 148 gpm (Hargis and Associates, 2012). For AMPAC wells, the combined average pumping rate is 512 gpm (AMPAC 2013). The locations of the pumping wells are presented on Figure 10.

The model will be updated to reflect the current status of recharge trenches as of early 2012. The NERT recharge trenches, COH Rapid Infiltration Basins, BMI Pond, TIMET Pond, and AMPAC reinjection are inactive. OSSM is discharging the treated pumped water in recharge trenches located north of OSSM pumping wells (Figure 10). Based on the OSSM third quarter 2012 monitoring report, an average of 147 gpm of water was recharged into the groundwater during Jan-Sept 2012 (Hargis and Associate 2012).

4.1.2 Birding Pond Recharge

The model will be updated to current levels of surficial recharge from the unlined Birding Ponds operated by the COH. An average of 1.22 MGD of inflow was recorded by COH for the period

2008-2013. The pond has an area of 110 acres. Assuming COH is maintaining a consistent level of water in the pond and an evaporation rate of 81 inches per year, the recharge from the pond to the shallow groundwater aquifer is about 5.61 feet per year from the pond area. The estimate is higher as compared to the recharge rate of 0.8 feet per year (Appendix E, Table 1E, Northgate 2010) used in Northgate's model for the Birding Ponds.

4.1.3 Model Layers and Well Screen Elevations

Due to recent construction and soil excavation activities in the site area, the ground surface was re-surveyed by WS Atkins (Atkins) in May 2013. The upper model layers will be updated in some areas, in particular near the SWF. Also, the location of well screens (both pumping and monitoring) with respect to model layers will be updated. If necessary, the elevation of the ground surface in the model will be updated using the most recent LiDAR (Light Detection and Ranging) data available for the area.

4.1.4 Model Boundary Near the Wash

The downgradient model boundary near the Las Vegas Wash will be converted to a head-dependent flow boundary using River Package to better simulate the flow coming in and going out of the model domain from the Las Vegas Wash. In the original model, the stream boundary was simulated using constant head cells.

4.2 GWETS Performance Metrics

A proposed set of performance metrics for the GWETS Optimization will be summarized in a technical memorandum that will be submitted to NDEP for review. The memo will include a description of the methodology to be used in the calculation of each metric. The performance metrics will include the metrics requested by NDEP and additional metrics identified by ENVIRON that are consistent with the objectives of the GWETS Optimization Project as well as future optimization tasks.

In the October 10, 2013 letter from NDEP commenting on the Annual Performance Report, the metrics requested by NDEP were:

- The concentrations at which NERT is achieving 90% and 99% capture of perchlorate and chromium;
- Monthly perchlorate and chromium mass removal rates from the IWF, AWF, and SWF;
- Perchlorate and chromium capture efficiency of IWF, AWF, and SWF;
- Perchlorate and chromium plume mass estimates;
- Mass loading of perchlorate and chromium in the Las Vegas Wash at Northshore Road.

Additional metrics will be proposed that identify the amount of surface water from Las Vegas Wash and the COH Birding Ponds that is being extracted by the SWF. Also, a metric will be developed to show the fraction of mass loading in Las Vegas Wash at Northshore Road that originates from the NERT Site.

While the methodology for calculating the metrics will be presented in more detail in the performance metrics technical memo, a general description of ENVIRON's proposed approach for metrics requested by NDEP is as follows:

- In order to calculate several of the metrics, study area boundaries must be defined. For this purpose, ENVIRON proposes to use the plume mass estimate boundaries presented in Appendix A of the recent Annual Performance Report.
- The total mass flux within the study area being transported by groundwater flow across hypothetical east-west lines passing through the IWF, AWF, and SWF will be estimated using modeled groundwater flow rates and interpolated concentrations.
- The fraction of the total mass flux being captured by the IWF, AWF, and SWF will be estimated using capture zones from the groundwater model. Capture efficiency is the ratio of captured mass flux to total mass flux.
- Target capture zones that represent 90% and 99% capture efficiency will be shown on a figure and compared to the actual capture zones achieved by well fields as estimated by the groundwater model.
- Future estimates of perchlorate and chromium plume mass will follow an approach similar to that used in the recent Annual Performance Report.
- Mass loading at Northshore Road will be calculated as the product of the flow rate at the Northshore Road stream gage and perchlorate concentrations measured in Las Vegas Wash near the stream gage.

Following NDEP approval of the metrics memo, these metrics will be used during the optimization of the GWETS and incorporated into future deliverables such as the Annual and Semi-Annual Groundwater Monitoring Reports for Chromium and Perchlorate.

4.3 Phase II Model Refinement

Upon completion of the aquifer testing program, the updated model will be re-calibrated and verified against the field data and aquifer testing results. In this phase, the hydraulic properties of the geologic units in the model will be updated as needed. The calibration may further require adjusting the parameter values of other boundary conditions to reduce any disparity between the model simulations and field data, and to improve the overall accuracy of the model. Parameter estimation using the PEST software (Doherty 2010) will be used to recalibrate the model and determine the sensitivity of the model to the distributions and magnitudes of the inputs parameters.

The Phase II Refinement will include the following sub-tasks.

4.3.1 Model Targets

The model targets will be updated based on the updated measured groundwater elevation data for second quarter 2012. The measured groundwater elevations are available in the 2012 Annual Performance Report (ENVIRON 2012b).

4.3.2 Model Discretization

A finer discretization of the model grid around the well fields is required to better represent the drawdown around the pumping wells and to estimate the capture zone. This will be carried out by developing local scale models of the well field areas using telescopic mesh refinement (TMR) (Leake 1999). The procedure of TMR allows use of a small, detailed model in the area of interest by taking boundary conditions from a larger model. The approximate TMR model boundaries for IWF and AWF are shown on Figure 10. The SWF is located very close to the wash, hence the downgradient boundary of SWF TMR model will be Las Vegas Wash. These boundaries will be reviewed during model calibration and will be revised as necessary. The grid spacing in the TMR models will be defined based on the well spacing in each well field.

4.4 Capture Zone Evaluation and Pumping Optimization

Following the completion of the Phase II model refinement, the model will be used to evaluate capture zones and the stream-aquifer interaction of alternative pumping rates at each of the well fields. Three-dimensional capture zones will be estimated using particle tracking performed using the MODPATH code. Using the performance metrics described in the Performance Metrics Memo, alternative pumping schemes will be evaluated and ranked according to the various metrics. A recommended pumping scheme will be selected for each of the well fields. Additional wells will be proposed if needed to prevent plume migration past the existing systems. Alternative extraction system configurations (such as those that target the center of the plume) will be evaluated as part of the future Feasibility Study.

5 Reporting and Schedule

5.1 Reporting

The primary goal of the 2013 GWETS Optimization Project is to optimize the mass removal rates and capture zones of the three well fields that comprise the GWETS. In order to measure progress with respect to this objective, performance metrics will be developed as discussed in Section 4.2. Since the performance metrics are an integral component of the overall optimization strategy, a technical memorandum describing the proposed performance metrics will be submitted as an interim deliverable for NDEP review and comment. The performance metrics that will be proposed are intended to measure progress of the 2013 GWETS Optimization Project as well as future optimization tasks. Following NDEP's review and approval, the performance metrics will be incorporated into future Annual and Semi-Annual Performance Report deliverables beginning with the 2013 Semi-Annual Remedial Performance Report. It is anticipated that the 2013 Semi-Annual Remedial Performance Report will include a summary of Phase I model updates completed to that point as an appendix.

Following completion of the tasks described in this work plan, a report will be prepared to describe the results of the 2013 GWETS Optimization Project. The report will include discussion of the following: 1) the changes made to the current system; 2) how the well testing and modeling tasks inform the current understanding of the Site; 3) how the changes have affected the current system performance in relation to the performance metrics; and 4) recommendations for future operation.

Specific construction and well activation activities will be described. The well testing results will be included along with a description of how the raw data were analyzed. These results will be compared with previous aquifer testing performed by others at the Site and at surrounding properties in order to inform the Conceptual Site Model and refine the groundwater flow model. An initial analysis of capture zones following the changes to operations at the IWF and AWF will also be presented. The report will discuss the potential limitations regarding further optimization of the current GWETS system including factors impacting well extraction rates, land availability, pump capacities, influent and effluent hydraulic capacities, discharge permitting, GW-11 volume, and the mass loading of the treatment systems.

5.2 Anticipated Schedule

The activation of the wells depends on the FBR refurbishment activities that are currently being performed by the GWETS Operator. Such changes will need to be completed in order to accommodate the increased loading to the FBR that is anticipated to result from the 2013 GWETS Optimization Project.

As estimated by the Trust based upon current assumptions, modification of the GWETS and the related management of GW-11 pond levels by the GWETS Operator are expected to be completed as early as April, 2014, but could be delayed until August 2014. Following this work, it is expected that the wells could be activated.

Based on ENVIRON's current understanding of the status of the GWETS refurbishment activities and with the understanding that NDEP has identified this work a high priority, the following represents an estimated schedule for implementation of the project. As presented to NDEP in the Trust's June 21, 2013 letter, the schedule has been divided into four phases, as follows:

PHASE 1: 8 WEEKS

- Preparation and Submittal of Work Plan to NDEP: *complete by October 18, 2013*

PHASE 2: 12 WEEKS

- Update Groundwater Model to Current Conditions and Develop GWETS Performance Metrics: *(Concurrent with Phase 1 - Preparation and Review of Work Plan) complete by November 15, 2013*
- Mobilization for Well Testing: *2 weeks*
- Well Testing: *3 weeks*
- Utility Design: *2 weeks*
- Utility Permitting / COH Approval: *3 weeks*
- Utility Construction: *2 weeks*
- Refine Model Grid and Update Calibration: *5 weeks - concurrent with Utility Design, Permitting, and Construction*

PHASE 3: 2 WEEKS

- Startup of Activated IWF Wells: *1 week - contingent upon completion of FBR Refurbishment*
- Startup ART-7B and PC-150: *1 week- contingent upon completion of FBR Refurbishment*

PHASE 4: 9 WEEKS

- IWF/AWF Capture Zone Modeling Evaluation: *4 weeks - contingent upon completion of Phase 3*
- Well Startup and Capture Analysis Report Preparation: *4 weeks - contingent upon completion of preceding task*
- Trust Review of Report: *1 week - contingent upon completion of preceding task*

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Tables

TABLE 1: WELL CONSTRUCTION SUMMARY
2013 GWETS Optimization Project Work Plan
Nevada Environmental Response Trust Site
Henderson, Nevada

Well Name	Current Well Type	Proposed Action*	Screened Unit	Date Completed	Ground Elevation (ft msl)	Top of Casing Elevation (ft msl)	Top of Screen Elevation (ft bgs)	Bottom of Screen Elevation (ft bgs)	Top of Screen Depth (ft msl)	Bottom of Screen Depth (ft msl)	Screen Length (ft)	Total Depth of Well (ft bgs)	UMCf Contact (ft msl)	Casing Diameter (inches)	Screen Slot Size (inches/100)
Interceptor Well Field															
I-AA	Extraction	Activate	UMCf	12/4/2007	1751.08	1753.93	23.7	43.7	1727.38	1707.38	20	46.0	1721.1	6	0.02
I-AB	Extraction	Activate	Qal/UMCf	8/14/2009	1750.57	1753.89	25.0	45.0	1725.57	1705.57	20	51.0	1723.4	6	0.02
I-AC	Extraction	Activate	Qal/UMCf	6/15/2010	1750.12	1752.76	24.5	44.5	1725.62	1705.62	20	50.0	1717.1	6	0.02
I-AD	Extraction	Activate	Qal/UMCf	6/16/2010	1752.94	1755.39	24.5	44.5	1728.44	1708.44	20	50.0	1721.9	6	0.02
I-B	Extraction	Test	Qal/xMCf/UMCf	10/1/1986	1750.00	1752.70	17.8	42.5	1732.20	1707.50	24.7	43.0	1723.0	6	0.02
I-D	Extraction	Test	Qal/xMCf/UMCf	10/1/1986	1750.00	1752.70	16.0	44.5	1734.00	1705.50	28.5	45.0	1721.0	6	0.02
I-G	Extraction	Test	Qal/xMCf/UMCf	12/1/1986	1749.20	1752.50	9.5	38.8	1739.70	1710.40	29.3	39.3	1721.2	6	0.02
I-J	Extraction	Test	Qal/xMCf/UMCf	12/1/1986	1746.59	1750.09	11.2	40.5	1735.39	1706.09	29.3	41.0	1718.6	6	0.02
I-K	Extraction	Test	UMCf	12/1/1986	1743.80	1746.04	7.0	35.2	1736.80	1708.60	28.2	35.8	1719.3	6	0.02
I-N	Extraction	Test	Qal/xMCf/UMCf	10/1/1993	1747.80	1751.40	7.0	37.0	1740.80	1710.80	30	38.0	1713.8	6	0.02
I-V	Extraction	Test	Qal/xMCf/UMCf	2/1/1999	1749.46	1752.13	12.0	42.0	1737.46	1707.46	30	45.0	1717.0	6	0.02
I-W	Extraction	Activate	Qal/xMCf/UMCf	9/1/2000	1749.12	1751.50	20.0	50.0	1729.12	1699.12	30	50.5	1727.1	6	0.02
I-X	Extraction	Activate	Qal/xMCf/UMCf	9/1/2000	1746.22	1748.60	20.0	50.0	1726.22	1696.22	30	50.5	1713.2	6	0.02
I-Y	Extraction	Activate	Qal/xMCf/UMCf	9/1/2000	1748.89	1751.40	20.0	50.0	1728.89	1698.89	30	50.5	1720.9	6	0.02
M-130	Monitoring	Monitor	Qal/UMCf	3/19/2005	1746.55	1749.23	20.0	40.0	1726.55	1706.55	20	40.0	1721.5	2	0.01
M-131	Monitoring	Monitor	UMCf	12/2/2007	1751.05	1754.13	28.7	38.7	1722.35	1712.35	10	39.0	1721.1	2	0.01
M-134	Monitoring	Monitor	UMCf	12/1/2007	1749.39	1752.14	59.7	69.7	1689.69	1679.69	10	70.0	1719.4	2	0.01
M-135	Monitoring	Monitor	UMCf	11/30/2007	1749.17	1751.85	28.7	38.7	1720.47	1710.47	10	39.0	1719.2	2	0.01
M-164	Monitoring	Monitor	UMCf	5/20/2010	1745.19	1747.61	59.7	69.7	1685.49	1675.49	10	70.0	1710.2	2	0.01
M-165	Monitoring	Monitor	UMCf	5/19/2010	1741.25	1743.84	109.7	119.7	1631.55	1621.55	10	120.0	1719.3	2	0.01
M-166	Monitoring	Monitor	Qal/UMCf	4/24/2010	1751.49	1751.09	21.7	31.7	1729.79	1719.79	10	32.0	1724.0	2	0.01
M-167	Monitoring	Monitor	Qal/UMCf	4/24/2010	1749.84	1749.95	19.7	29.7	1730.14	1720.14	10	30.0	1725.3	2	0.01
M-168	Monitoring	Monitor	Qal/UMCf	4/23/2010	1748.71	1748.46	21.7	31.7	1727.01	1717.01	10	32.0	1722.2	2	0.01
M-170	Monitoring	Monitor	Qal/UMCf	4/23/2010	1750.51	1750.66	24.7	34.7	1725.81	1715.81	10	35.0	1721.5	2	0.01
M-172	Monitoring	Monitor	Qal/UMCf	4/23/2010	1750.39	1750.58	26.7	36.7	1723.69	1713.69	10	37.0	1719.9	2	0.01
M-173	Monitoring	Monitor	Qal/UMCf	4/22/2010	1749.83	1749.88	24.7	39.7	1725.13	1710.13	15	40.0	1720.3	2	0.01
M-174	Monitoring	Monitor	Qal/UMCf	4/22/2010	1742.16	1742.29	17.7	27.7	1724.46	1714.46	10	28.0	1717.7	2	0.01
M-175	Monitoring	Monitor	Qal/UMCf	4/21/2010	1742.79	1742.74	18.7	28.7	1724.09	1714.09	10	29.0	1717.8	2	0.01
M-176	Monitoring	Monitor	Qal	4/21/2010	1745.45	1745.35	19.7	29.7	1725.75	1715.75	10	30.0	1715.4	2	0.01
M-177	Monitoring	Monitor	Qal/UMCf	4/21/2010	1743.26	1743.23	19.7	29.7	1723.56	1713.56	10	30.0	1718.8	2	0.01
M-56	Monitoring	Monitor	Qal/xMCf/UMCf	9/1/1986	1749.65	1750.83	15.0	40.0	1734.65	1709.65	25	40.0	1725.2	2	0.01
M-58	Monitoring	Monitor	Qal/xMCf/UMCf	9/1/1986	1748.72	1751.25	15.0	45.0	1733.72	1703.72	30	45.0	1719.2	2	0.01
M-60	Monitoring	Monitor	UMCf	12/1/1986	1749.31	1750.94	17.8	42.8	1731.51	1706.51	25	43.0	1721.8	2	0.01
M-64	Monitoring	Monitor	Qal/xMCf/UMCf	12/1/1986	1748.80	1749.76	12.7	37.3	1736.10	1711.50	24.6	37.5	1725.8	2	0.01
M-65	Monitoring	Monitor	Qal/xMCf/UMCf	12/1/1986	1751.84	1753.91	14.4	39.0	1737.44	1712.84	24.6	39.2	1722.8	2	0.01
M-66	Monitoring	Monitor	Qal/xMCf/UMCf	12/1/1986	1751.70	1754.24	17.5	42.3	1734.20	1709.40	24.8	42.5	1719.2	2	0.01
M-67	Monitoring	Monitor	Qal/xMCf/UMCf	12/1/1986	1743.64	1745.91	7.8	37.8	1735.84	1705.84	30	38.0	1721.1	2	0.01
M-68	Monitoring	Monitor	Qal/xMCf/UMCf	12/1/1986	1747.16	1750.23	11.2	39.8	1735.96	1707.36	28.6	41.0	1722.7	2	0.01
M-69	Monitoring	Monitor	Qal/xMCf/UMCf	12/1/1986	1747.80	1749.75	19.9	39.3	1727.90	1708.50	19.4	40.0	1718.3	2	0.01
M-70	Monitoring	Monitor	Qal/xMCf/UMCf	12/1/1986	1746.00	1748.25	15.3	40.0	1730.70	1706.00	24.7	40.2	1715.5	2	0.01
M-71	Monitoring	Monitor	Qal/xMCf/UMCf	12/1/1986	1744.87	1747.04	17.5	42.0	1727.37	1702.87	24.5	42.2	1712.4	2	0.01
M-72	Monitoring	Monitor	Qal/xMCf/UMCf	12/1/1986	1744.62	1746.49	10.1	34.8	1734.52	1709.82	24.7	35.0	1720.1	2	0.01
M-74	Monitoring	Monitor	UMCf	12/1/1986	1742.51	1744.38	9.2	38.8	1733.31	1703.71	29.6	39.0	1718.5	2	0.01
M-78	Monitoring	Monitor	Qal/xMCf/UMCf	8/1/1987	1749.54	1751.50	21.5	41.5	1728.04	1708.04	20	43.6	1718.0	2	0.01

TABLE 1: WELL CONSTRUCTION SUMMARY
2013 GWETS Optimization Project Work Plan
Nevada Environmental Response Trust Site
Henderson, Nevada

Well Name	Current Well Type	Proposed Action*	Screened Unit	Date Completed	Ground Elevation (ft msl)	Top of Casing Elevation (ft msl)	Top of Screen Elevation (ft bgs)	Bottom of Screen Elevation (ft bgs)	Top of Screen Depth (ft msl)	Bottom of Screen Depth (ft msl)	Screen Length (ft)	Total Depth of Well (ft bgs)	UMCf Contact (ft msl)	Casing Diameter (inches)	Screen Slot Size (inches/100)
Athens Road Well Field															
ART-1	Extraction	Test	Qal	10/1/2001	1615.57	1614.47	14.0	54.0	1601.57	1561.57	40	56.0	1562.6	6	0.04
ART-1A	Monitoring	Monitor	Qal	3/1/2003	1615.80	1614.40	19.0	54.0	1596.80	1561.80	35	56.0	1561.8	8	0.04
ART-2A	Monitoring	Monitor	Qal	3/1/2003	1618.33	1616.81	21.0	56.0	1597.33	1562.33	35	58.0	1561.3	8	0.04
ART-3A	Monitoring	Monitor	Qal	3/1/2003	1619.14	1617.60	18.0	53.0	1601.14	1566.14	35	55.0	1566.1	8	0.04
ART-4	Monitoring	Monitor	Qal	10/1/2001	1618.29	1617.39	19.4	44.4	1598.89	1573.89	25	46.4	1573.9	6	0.02
ART-4A	Extraction	Test	Qal	2/1/2003	1618.29	1617.46	18.4	43.4	1599.91	1574.91	25	45.4	1574.9	8	0.04
ART-6	Monitoring	Monitor	Qal	10/1/2001	1620.13	1615.31	17.9	37.9	1602.25	1582.25	20	39.9	1582.3	6	0.04
ART-7	Extraction	Test	Qal	10/1/2001	1617.98	1615.37	19.0	39.0	1598.98	1578.98	20	41.0	NR	6	0.04
ART-7A	Monitoring	Monitor	Qal	3/1/2003	1618.02	1614.78	19.7	39.7	1598.32	1578.32	20	41.7	NR	8	0.04
ART-7B	Monitoring	Activate	Qal	6/28/2010	1618.06	1619.62	29.5	44.5	1588.56	1573.56	15	50.0	1573.1	8	0.04
ART-9	Extraction	Test	Qal	5/1/2006	1618.68	1614.90	23.0	43.0	1595.66	1575.66	20	45.5	1576.2	8	0.04
PC-122	Monitoring	Monitor	Qal	2/1/2004	1618.43	1618.02	23.9	38.9	1594.55	1579.55	15	38.9	1580.6	2	0.02
PC-134A	Monitoring	Test	UMCf	6/22/2010	1618.84	1618.57	59.7	69.7	1559.14	1549.14	10	70.0	1569.8	2	0.01
PC-135A	Monitoring	Monitor	Qal	7/2/2010	1618.77	1618.58	30.7	50.7	1588.07	1568.07	20	51.0	1567.8	2	0.02
PC-136	Monitoring	Monitor	Qal	12/18/2007	1618.78	1618.04	21.0	41.0	1597.76	1577.76	20	40.6	1578.5	2	0.01
PC-137	Monitoring	Test	UMCf	12/17/2007	1618.77	1618.45	63.3	73.3	1555.49	1545.49	10	73.3	1579.2	2	0.01
PC-142	Monitoring	Monitor	Qal	6/18/2010	1617.14	1619.64	21.7	31.7	1595.44	1585.44	10	32.0	1585.1	2	0.02
PC-144	Monitoring	Monitor	Qal/UMCf	7/1/2010	1618.93	1618.63	29.7	39.7	1589.23	1579.23	10	40.0	1581.4	2	0.02
PC-148	Monitoring	Test	UMCf	6/19/2010	1617.79	1617.96	24.5	44.5	1593.29	1573.29	20	50.0	1592.8	6	0.01
PC-149	Monitoring	Test	Qal/UMCf	6/23/2010	1618.93	1618.93	24.5	44.5	1594.43	1574.43	20	50.0	1586.9	6	0.01
PC-150	Monitoring	Activate	Qal	6/30/2010	1618.36	1619.09	19.5	39.5	1598.86	1578.86	20	45.0	1579.4	6	0.02
PC-55	Monitoring	Monitor	Qal	5/1/1998	1618.67	1618.46	15.3	55.3	1603.39	1563.39	40	56.3	NR	4	0.02

Notes:
All data is from the All Wells Database maintained by NERT and other BMI property owners.
*These wells have been identified for monitoring, testing, and activation within this work plan.
BMI = Black Mountain Industrial Complex
ft = feet
ft msl = feet above mean sea level
ft bgs = feet below ground surface
NERT = Nevada Environmental Response Trust
Qal = Quaternary Alluvium
UMCf = Upper Muddy Creek Formation
xUMCf = transitional Upper Muddy Creek Formation

TABLE 2: SUMMARY OF GWETS PIPELINES

2013 GWETS Optimization Project Work Plan
Nevada Environmental Response Trust Site
Henderson, Nevada

Flow	Location	Pipeline Section	Diameter (in)	Estimated Length (ft)
Influent	Lift Station 1 to Lift Station 2	Continuous section	10	8200
	Lift Station 3 to Lift Station 2	LS3 to Pabco Rd	10	630
		Pabco Rd to LS2	8	1730
	Lift Station 2 to GWETS	LS2 to south end of Pabco Rd	12	6780
		South end of Pabco Rd to GW-11 pond	12	3680
	IWF East Feed	Single pipe conveying flows from the following wells: I-D, I-M, I-E, I-N, I-X, I-F, I-Q, I-G, I-T, I-U, I-H, I-P, I-W, I-O, I-V, I-I, I-Z, I-J, I-K, I-AC, and I-AD	6	1320
	IWF West Feed	Single pipe conveying flows from the following wells: I-AA, I-AB, I-AR, I-B, I-R, I-Y, I-L, I-S, and I-C	4	450
	AWF Well Lines to Lift Station 3	Single pipe to each pumping well	4	various lengths
	SWF Well Lines to Lift Station 1	Single pipe to each pumping well	4	various lengths
Effluent	FBR to Effluent Discharge Point at Las Vegas Wash	FBR to GW-11 pond	8	700
		GW-11 Pond to South End of Pabco Road	12	3680
		South End of Pabco Road to LS2	10	6780
		LS2 to LS1	10	8200
		LS1 to Discharge Point	12	710

Notes:

The information presented in this table is summarized from communications with current and former GWETS Operators as well as from available design drawings—not all of which were Drawings of Record, or so-called “as-builts”. The information in this table has not been field-verified. Additional information will be reviewed (and field verified when deemed appropriate) as part of the implementation of this work plan to confirm and add to the information presented.

AWF = Athens Road Well Field

IWF = Interceptor Well Field

SWF = Seep Well Field

FBR = fluidized-bed reactor

ft = feet

GWETS = Groundwater Extraction and Treatment System

in = inches

LS1 = Lift Station #1

LS2 = Lift Station #2

LS3 = Lift Station #3

TABLE 3: SUMMARY OF GWETS PUMPS

2013 GWETS Optimization Project Work Plan
Nevada Environmental Response Trust Site
Henderson, Nevada

Pump Location		Number of Pumps	Power (hp)	Flow Rate
Extraction Wells				
SWF Pumping Wells [a]	PC-115R	1	5	91.5 gpm
	PC-116R	1	7.5	124.8 gpm
	PC-117	1	5	92.6 gpm
	PC118	1	5	76.3 gpm
	PC-119	1	5	65.0 gpm
	PC-120	1	5	0.0 gpm
	PC-121	1	5	0.0 gpm
	PC-133	1	1.5	2.2 gpm
	PC-99R2	1	20	58.0 gpm*
	PC-99R3	1	5	
AWF Pumping Wells [b]	ART-1	1	2	33 gpm
	ART-2	1	3	71 gpm
	ART-3A	1	1.5	54 gpm
	ART-4A	1	1.5	10 gpm
	ART-7	1	0.75	32 gpm
	ART-8	1	5	85 gpm
	ART-9	1	0.75	47 gpm
IWF Pumping Wells [b]	I-AR	1	0.5	1 gpm
	I-B	1	0.5	1.5 gpm
	I-C	1	0.5	6 gpm
	I-D	1	0.5	2 gpm
	I-E	1	0.5	1.5 gpm
	I-F	1	0.5	5.7 gpm
	I-G	1	0.5	0.5 gpm
	I-H	1	0.5	1.2 gpm
	I-I	1	0.5	5 gpm
	I-J	1	0.5	8 gpm
	I-K	1	0.5	4 gpm
	I-L	1	0.5	2.5 gpm
	I-M	1	0.5	2.6 gpm
	I-N	1	0.5	3.5 gpm
	I-O	1	0.5	2.5 gpm
	I-P	1	0.5	3 gpm
	I-Q	1	0.5	2.5 gpm
	I-R	1	0.5	2.5 gpm
	I-S	1	0.5	5 gpm
	I-T	1	0.5	0.4 gpm
	I-U	1	0.5	0.8 gpm
	I-V	1	0.5	4.8 gpm
	I-Z	1	0.5	8 gpm
Water Conveyance				
Lift station #1 vertical turbine pumps		2	50	625 gpm
Lift station #2	Vertical turbine	1	100	approx. 925 gpm
	Submersible pump	1	100	900 gpm
Lift station #3 submersible pumps		2	10	350 gpm

TABLE 3: SUMMARY OF GWETS PUMPS

2013 GWETS Optimization Project Work Plan
Nevada Environmental Response Trust Site
Henderson, Nevada

Pump Location	Number of Pumps	Power (hp)	Flow Rate
Treatment System Pumps			
Raw Water feed pump P-102a/b	1	100	1000 gpm
Pond transfer pump P-104	2	5	75 gpm
Chrome plant effluent to FBR feed pumps P-103a/b	1	2	100 gpm
FBR fluidization pumps	14	30	2000 gpm
FBR media return pumps	5	1	30 gpm
DAF pressurization pumps	2	25	206 gpm
DAF float pumps	2	2	20 gpm
Effluent pumps p-601/602	1	30	1000 gpm
Sand filter reject pumps	2	5	150 gpm
Effluent booster pumps	2	100	1000 gpm
Sludge transfer pump	1	10	213 gpm
Sludge filter press pumps, air operated	2	--	150 gpm
Sludge filtrate pump	1	1.5	20 gpm
Chrome plant Feed pumps	2	5	100 gpm
Chrome plant pumps to and from the BT tanks (no longer in use)	--	6	50 gpm
Chemical pump lift station #3 ferrous injection	1	0.05	--
Chemical pump ethanol, front stage	5	--	20 gph
Chemical pump ethanol, back stage	4	--	8 gph
Chemical pump caustic	9	0.1	0.12-7.6 gph
Chemical pump urea	5	--	1.67 gph
Chemical pump Phosphoric Acid	9	--	0.08-0.54 gph
Chemical pump micronutrient blend, output varies with tube size	2	--	75 ml/min
Chemical pump Hydrogen peroxide, output varies with tube size	2	--	20 ml/min
Chemical pump Ferric chloride, output varies with tube size	2	--	10 ml/min
Chemical pump ferric chloride pump for the conditioning tank	1	--	40 gpm

Notes:

The information presented in this table is summarized from communications with current and former GWETS Operators as well as from available design drawings—not all of which were Drawings of Record, or so-called “as-builts”. The information in this table has not been field-verified. Additional information will be reviewed (and field verified when deemed appropriate) as part of the implementation of this work plan to confirm and add to the information presented.

[a] Average flow rates are provided for the SWF wells.

[b] Maximum sustainable flow rates are provided for the AWF and IWF wells.

* Wells PC-99R2 and PC-99R3 are connected and operate as a single pumping well.

-- = no information available

AWF = Athens Road Well Field

IWF = Interceptor Well Field

SWF = Seep Well Field

BT = Balance Tanks

DAF = dilution attenuation factor

FBR = fluidized-bed reactor

gpm = gallons per minute

gph = gallons per hour

GWETS = Groundwater Extraction and Treatment System

hp = horsepower

ml/min = milliliters per minute

NDEP = Nevada Division of Environmental Protection

TABLE 4: MONITORING CONFIGURATIONS FOR STEP DRAWDOWN TESTS

2013 GWETS Optimization Project Work Plan
Nevada Environmental Response Trust Site
Henderson, Nevada

Extraction Well (estimated pumping rate)	Monitoring Well	Distance From Extraction Well (ft)	Groundwater Level May 2013 (ft)	UMCF contact (ft)	Screen Interval (ft)	
					Top	Bottom
I-AA (1 gpm)	I-AA	0.0	1722.17	1721.08	1727.38	1707.38
	M-131	16.3	1722.68	1721.05	1722.35	1712.35
	M-166	56.3	1723.68	1723.99	1729.79	1719.79
	I-AB	54.3	1722.77	1723.39	1725.57	1705.57
	M-135	121.0	1719.35	1719.17	1720.47	1710.47
	M-134	122.0	1719.49	1719.39	1689.69	1679.69
I-AB (1 gpm)	I-AB	0.0	1722.77	1723.39	1725.57	1705.57
	M-166	12.1	1723.68	1723.99	1729.79	1719.79
	I-AA	54.3	1722.17	1721.08	1727.38	1707.38
	I-B	60.5	1716.69	1723.00	1732.20	1707.50
	M-131	69.8	1722.68	1721.05	1722.35	1712.35
	M-69	103.2	1718.45	1718.30	1727.90	1708.50
I-AC (1 gpm)	I-AC	0.0	1723.71	1717.12	1725.62	1705.62
	M-68	48.6	1724.45	1722.66	1735.96	1707.36
	M-130	49.5	1722.32	1721.55	1726.55	1706.55
	I-K	91.3	1720.69	1719.30	1736.80	1708.60
	I-AD	95.9	1726.18	1721.94	1728.44	1708.44
	M-177	101.9	1721.94	1718.76	1723.56	1713.56
I-AD (1 gpm)	I-AD	0.0	1726.18	1721.94	1728.44	1708.44
	M-68	89.2	1724.45	1722.66	1735.96	1707.36
	I-AC	95.9	1723.71	1717.12	1725.62	1705.62
	M-130	127.4	1722.32	1721.55	1726.55	1706.55
I-W (2.5 gpm)	I-W	0.0	1721.57	1727.12	1729.12	1699.12
	M-58	31.1	1721.67	1719.22	1733.72	1703.72
	M-173	67.2	1722.05	1720.33	1725.13	1710.13
	M-72	109.7	1715.05	1720.12	1734.52	1709.82
	M-66	125.0	1724.14	1719.20	1734.20	1709.40
I-X (2.5 gpm)	I-X	0.0	1716.99	1713.22	1726.22	1696.22
	I-N	38.3	1725.12	1713.80	1740.80	1710.80
	M-78	63.0	1725.43	1718.04	1728.04	1708.04
	M-172	55.1	1724.74	1719.89	1723.69	1713.69
	M-71	102.4	1712.61	1712.37	1727.37	1702.87
	M-164	110.7	1714.67	1710.19	1685.49	1675.49
	M-65	113.5	1725.91	1722.84	1737.44	1712.84

TABLE 4: MONITORING CONFIGURATIONS FOR STEP DRAWDOWN TESTS
2013 GWETS Optimization Project Work Plan
Nevada Environmental Response Trust Site
Henderson, Nevada

Extraction Well (estimated pumping rate)	Monitoring Well	Distance From Extraction Well (ft)	Groundwater Level May 2013 (ft)	UMCF contact (ft)	Screen Interval (ft)	
					Top	Bottom
I-Y (4.1 gpm)	I-Y	0.0	1724.94	1720.89	1728.89	1698.89
	M-167	13.4	1725.16	1725.34	1730.14	1720.14
	I-B	52.3	1716.69	1723.00	1732.20	1707.50
	M-168	74.4	1725.85	1722.21	1727.01	1717.01
	M-69	109.1	1718.45	1718.30	1727.90	1708.50
ART-7B (31 gpm)	ART-7B	0.0	1584.20	1573.06	1588.56	1573.56
	ART-7A	10.9	1585.98	NR	1598.32	1578.32
	PC-136	70.4	1584.11	1578.48	1597.76	1577.76
	PC-137	75.2	1582.69	1579.19	1555.49	1545.49
	PC-122	99.2	1585.03	1580.55	1594.55	1579.55
PC-150 (5 gpm)	PC-150	0.0	1588.73	1579.36	1598.86	1578.86
	ART-4	67.3	1575.27	1573.91	1598.89	1573.89
	PC-144	120.2	1587.71	1581.43	1589.23	1579.23
	PC-134A	144.8	1589.04	1569.84	1559.14	1549.14
	PC-135A	152.8	1588.73	1567.77	1588.07	1568.07
	PC-149	203.5	1588.98	1586.93	1594.43	1574.43

Notes:

ft = feet

gpm = gallons per minute

NR = not recorded

UMCf = Upper Muddy Creek Formation

TABLE 5: PROPOSED PUMPING RATES FOR STEP DRAWDOWN TESTS

2013 GWETS Optimization Project Work Plan
Nevada Environmental Response Trust Site
Henderson, Nevada

Extraction Well (estimated pumping rate)	Available Saturated Thickness (ft)*	Pumping Steps (gpm)
I-AA (1 gpm)	15.0	0.4
		0.8
		1.2
		1.6
I-AB (1 gpm)	17.5	0.4
		0.8
		1.2
		1.6
I-AC (1 gpm)	18.1	0.4
		0.8
		1.2
		1.6
I-AD (1 gpm)	18.0	0.4
		0.8
		1.2
		1.6
I-W (2.5 gpm)	23.0	0.5
		1
		2
		3
I-X (2.5 gpm)	31.3	0.5
		1
		2
		3
I-Y (4.1 gpm)	26.5	1
		2
		4
		6
ART-7B (31 gpm)	NA	5
		10
		20
		30
PC-150 (5 gpm)	10.4	1
		2
		4
		6

Notes:

*Available saturated thickness at the extraction well based on May 2013 water level measurements.

ft = feet

gpm = gallons per minute

NA = not applicable

TABLE 6: MONITORING CONFIGURATIONS FOR RECOVERY TESTS
2013 GWETS Optimization Project Work Plan
Nevada Environmental Response Trust Site
Henderson, Nevada

Extraction Well (average pumping rate) [a]	Monitoring Well	Distance From Extraction Well (ft)	Groundwater Level May 2013 (ft amsl)	UMCF Contact (ft amsl)	Screen Interval (ft amsl)	
					Top	Bottom
I-D (1.6 gpm)	I-D	0.0	1725.11	1721.00	1734.00	1705.50
	M-170	10.0	1725.51	1721.51	1725.81	1715.81
	M-64	78.6	1724.16	1725.80	1736.10	1711.50
	M-70	100.6	1715.40	1715.50	1730.70	1706.00
I-G (0.95 gpm)	I-G	0.0	1712.25	1721.20	1739.70	1710.40
	M-60	48.8	1723.20	1721.81	1731.51	1706.51
	M-56	50.8	1723.92	1725.15	1734.65	1709.65
	M-65	177.6	1725.91	1722.84	1737.44	1712.84
I-J (6.6 gpm)	I-J	0.0	1713.54	1718.59	1735.39	1706.09
	M-176	14.7	1721.75	1715.45	1725.75	1715.75
	M-175	106.8	1721.97	1717.79	1724.09	1714.09
	M-67	128.5	1724.46	1721.14	1735.84	1705.84
I-K (4.0 gpm)	I-K	0.0	1720.69	1719.30	1736.80	1708.60
	M-177	13.6	1721.94	1718.76	1723.56	1713.56
	M-165	97.5	1718.92	1719.25	1631.55	1621.55
	M-68	99.2	1724.45	1722.66	1735.96	1707.36
	M-74	102.3	1715.66	1718.51	1733.31	1703.71
	M-130	103.4	1722.32	1721.55	1726.55	1706.55
I-N (1.1 gpm)	I-N	0.0	1725.12	1713.80	1740.80	1710.80
	M-78	24.8	1725.43	1718.04	1728.04	1708.04
	I-X	38.3	1716.99	1713.22	1726.22	1696.22
	M-172	92.6	1724.74	1719.89	1723.69	1713.69
	M-71	120.4	1712.61	1712.37	1727.37	1702.87
	M-164	130.8	1714.67	1710.19	1685.49	1675.49
	M-65	133.7	1725.91	1722.84	1737.44	1712.84
I-B (1.7 gpm)	I-B	0.0	1716.69	1723.00	1732.20	1707.50
	I-Y	52.3	1724.94	1720.89	1728.89	1698.89
	M-167	58.5	1725.16	1725.34	1730.14	1720.14
	M-166	60.1	1723.68	1723.99	1729.79	1719.79
	I-AB	60.5	1722.77	1723.39	1725.57	1705.57
	M-69	79.1	1718.45	1718.30	1727.90	1708.50
I-V (5.6 gpm)	I-V	0.0	1720.44	1716.96	1737.46	1707.46
	M-58	50.0	1721.67	1719.22	1733.72	1703.72
	M-174	53.3	1722.56	1717.66	1724.46	1714.46
	I-W	80.4	1721.57	1727.12	1729.12	1699.12
ART-1 (23 gpm)	ART-1	0.0	1578.77	1562.57	1601.57	1561.57
	ART-1A	7.2	1589.85	1561.80	1596.80	1561.80
	PC-55	67.4	1590.67	NR	1603.39	1563.39
	ART-2A	83.6	1589.58	1561.33	1597.33	1562.33
	PC-142	109.1	1591.54	1585.14	1595.44	1585.44

TABLE 6: MONITORING CONFIGURATIONS FOR RECOVERY TESTS

2013 GWETS Optimization Project Work Plan
Nevada Environmental Response Trust Site
Henderson, Nevada

Extraction Well (average pumping rate) [a]	Monitoring Well	Distance From Extraction Well (ft)	Groundwater Level May 2013 (ft amsl)	UMCF Contact (ft amsl)	Screen Interval (ft amsl)	
					Top	Bottom
ART-4A (0.65 gpm)	ART-4A	0.0	1575.27	1574.91	1599.91	1574.91
	ART-4	6.2	0.00	1573.91	1598.89	1573.89
	ART-3A	75.8	1581.95	1566.14	1601.14	1566.14
	PC-150	73.5	1588.73	1579.36	1598.86	1578.86
	PC-134A	90.3	1589.04	1569.84	1559.14	1549.14
	PC-135A	96.7	1588.73	1567.77	1588.07	1568.07
ART-9 (51 gpm)	ART-9	0.0	1578.95	1576.18	1595.66	1575.66
	ART-6	52.7	1585.13	1582.25	1602.25	1582.25
	PC-136	48.7	1584.11	1578.48	1597.76	1577.76
	PC-137	56.2	1582.69	1579.19	1555.49	1545.49
	PC-122	149.6	1585.03	1580.55	1594.55	1579.55
ART-7 (30 gpm)	ART-7	0.0	1587.04	NR	1598.98	1578.98
	ART-7A	6.8	1585.98	NR	1598.32	1578.32
	PC-136	74.3	1584.11	1578.48	1597.76	1577.76
	PC-137	79.5	1582.69	1579.19	1555.49	1545.49
	PC-122	98.7	1585.03	1580.55	1594.55	1579.55
	ART-6	103.7	1585.13	1582.25	1602.25	1582.25

Notes:

[a] Pumping rate shown is the average rate between 9/1/13 and 10/1/13.

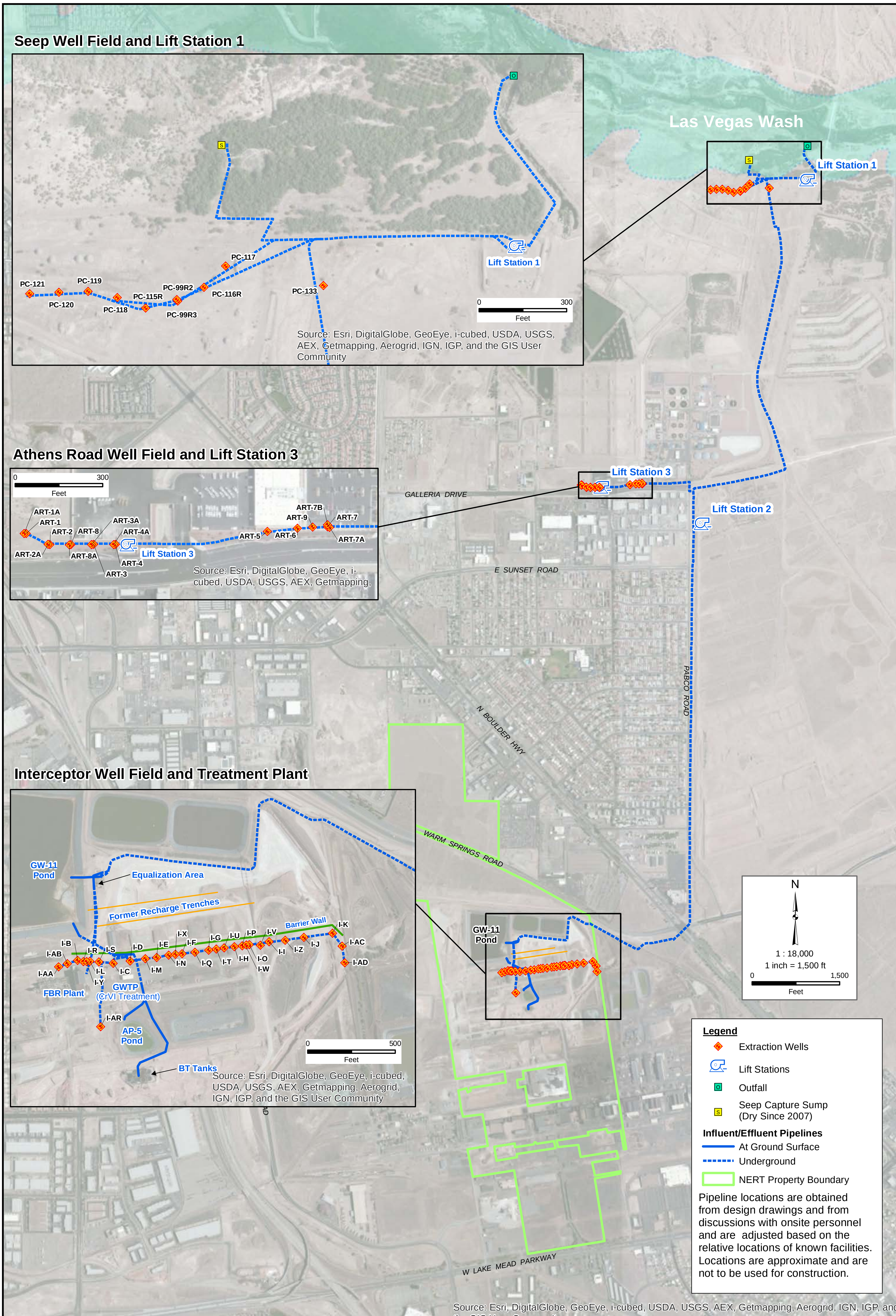
ft = feet

ft amsl = feet above mean sea level

gpm = gallons per minute

UMCF = Upper Muddy Creek Formation

Figures



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Groundwater Extraction and Treatment System Map

Nevada Environmental Response Trust Site, Henderson, Nevada

Figure 1

Drafter: EA | Date: 10/18/2013 | Contract Number: 21-29100H10 | Approved by: | Revised:

Legend

- Shallow Water Bearing Zone Well
- Middle Water Bearing Zone Well
- Extraction Wells
- Activated Wells
- Barrier Wall

N

1 inch = 150 feet

0 25 50 100 150 Feet

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Activated Wells, Interceptor Well Field

Nevada Environmental Response Trust Site
Henderson, Nevada

Figure **2**

Drafter: KPL | Date: 10/18/2013 | Contract Number: 21-29100J | Approved by: | Revised:

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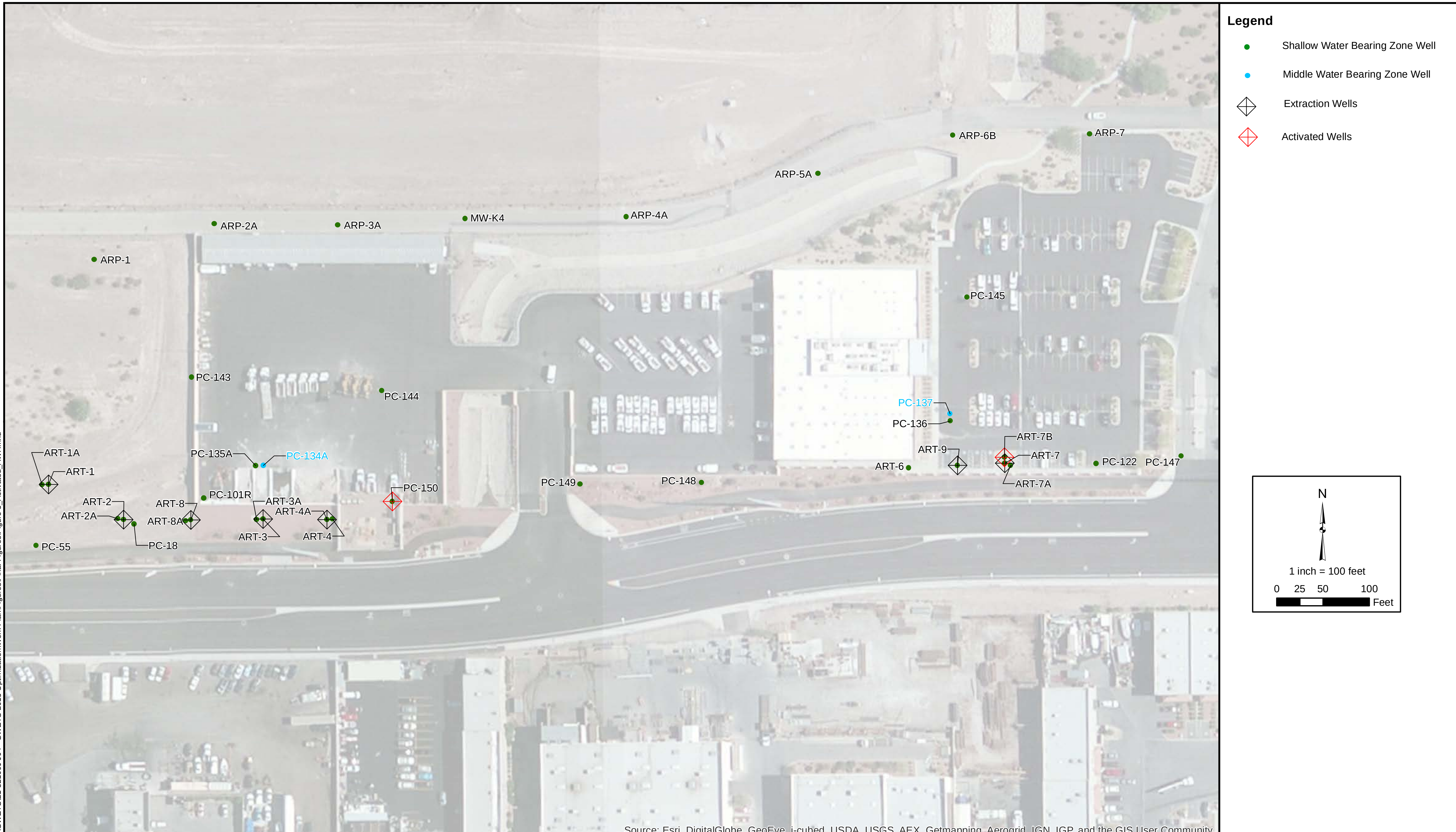

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Activated Wells, Athens Road Well Field

Nevada Environmental Response Trust Site
Henderson, Nevada

Figure 3

Drafter: LAT | Date: 10/18/2013 | Contract Number: 21-29100J | Approved by: | Revised:

Path: H:\LePetomane\NERT\GWETS\21-32100J 304 - GWETS 2013 Optimization\Work Plan\Figures\Final Figures\Figure 4_Hydraulic Tests_IWF.mxd

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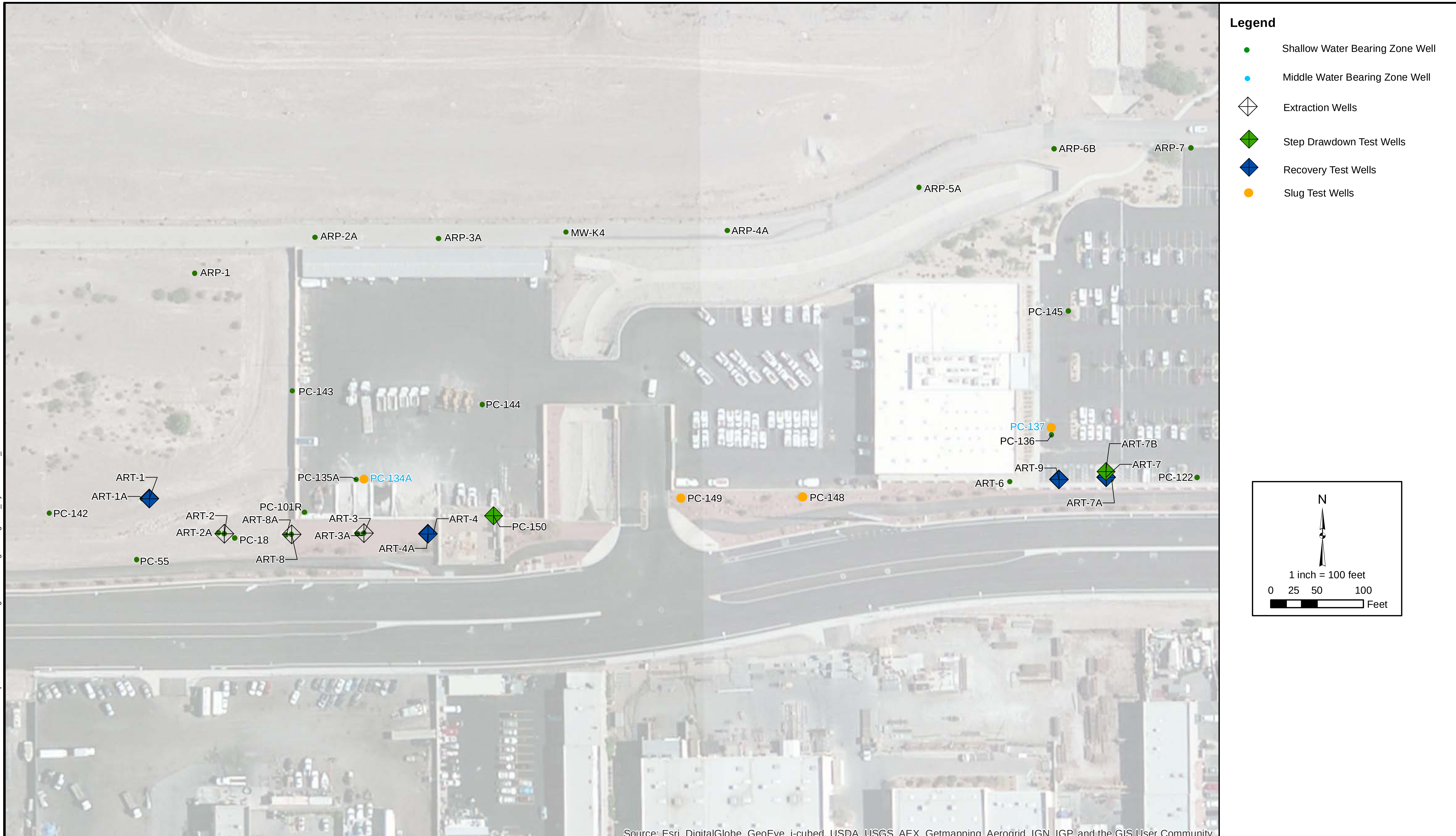
Proposed Hydraulic Testing, Interceptor Well Field
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure **4**

Drafter: KPL	Date: 10/18/2013	Contract Number: 21-29100J	Approved by:	Revised:



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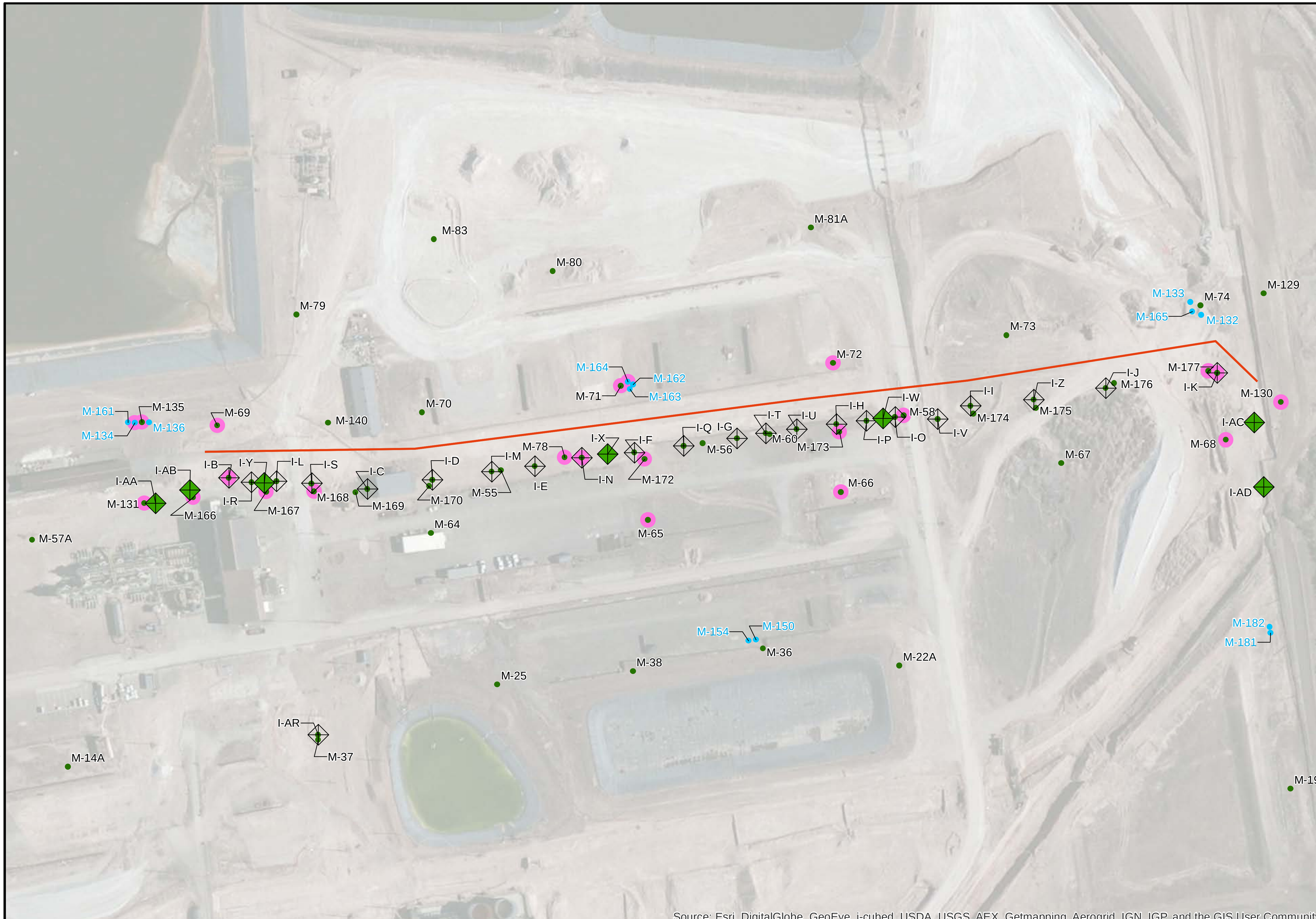
Proposed Hydraulic Testing, Athens Road Well Field
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure 5

Drafter: KPL | Date: 10/17/2013 | Contract Number: 21-29100J | Approved by: | Revised:



Legend

- Shallow Water Bearing Zone Well
- Middle Water Bearing Zone Well
- Extraction Wells
- Step Drawdown Test Wells
- Monitoring Wells for Step Drawdown Test
- Barrier Wall

N

1 inch = 150 feet

0 25 50 100 150 Feet

Path: H:\LePetomane\NERT\GWETS\21-32100J 304 - GWETS 2013 Optimization\Work Plan\Figures\Final Figures\Figure 6_Step Drawdown_IWF.mxd

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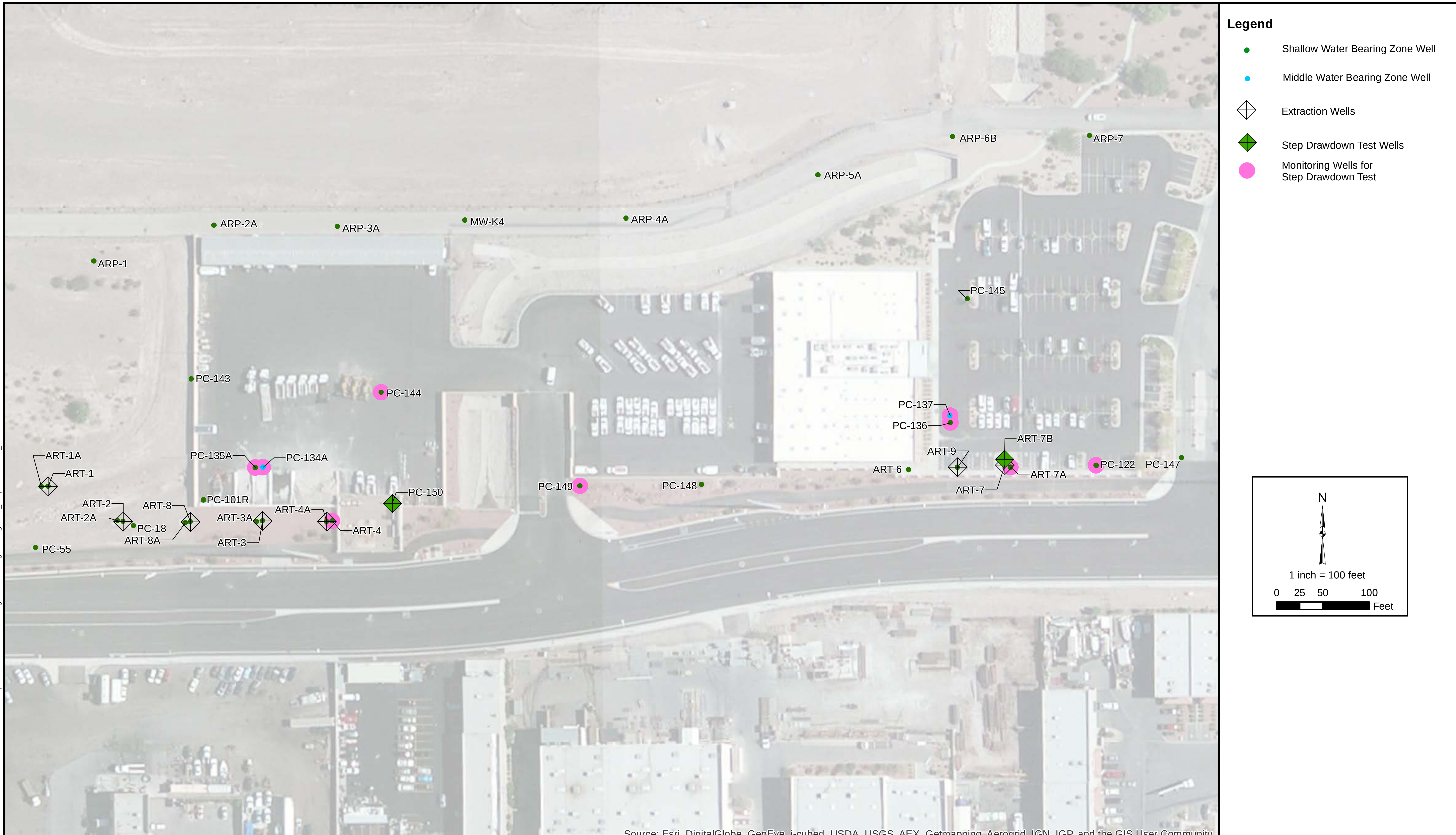
Well Network for Step Drawdown Tests, Interceptor Well Field
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure 6

Drafter: KPL	Date: 10/18/2013	Contract Number: 21-29100J	Approved by:	Revised:



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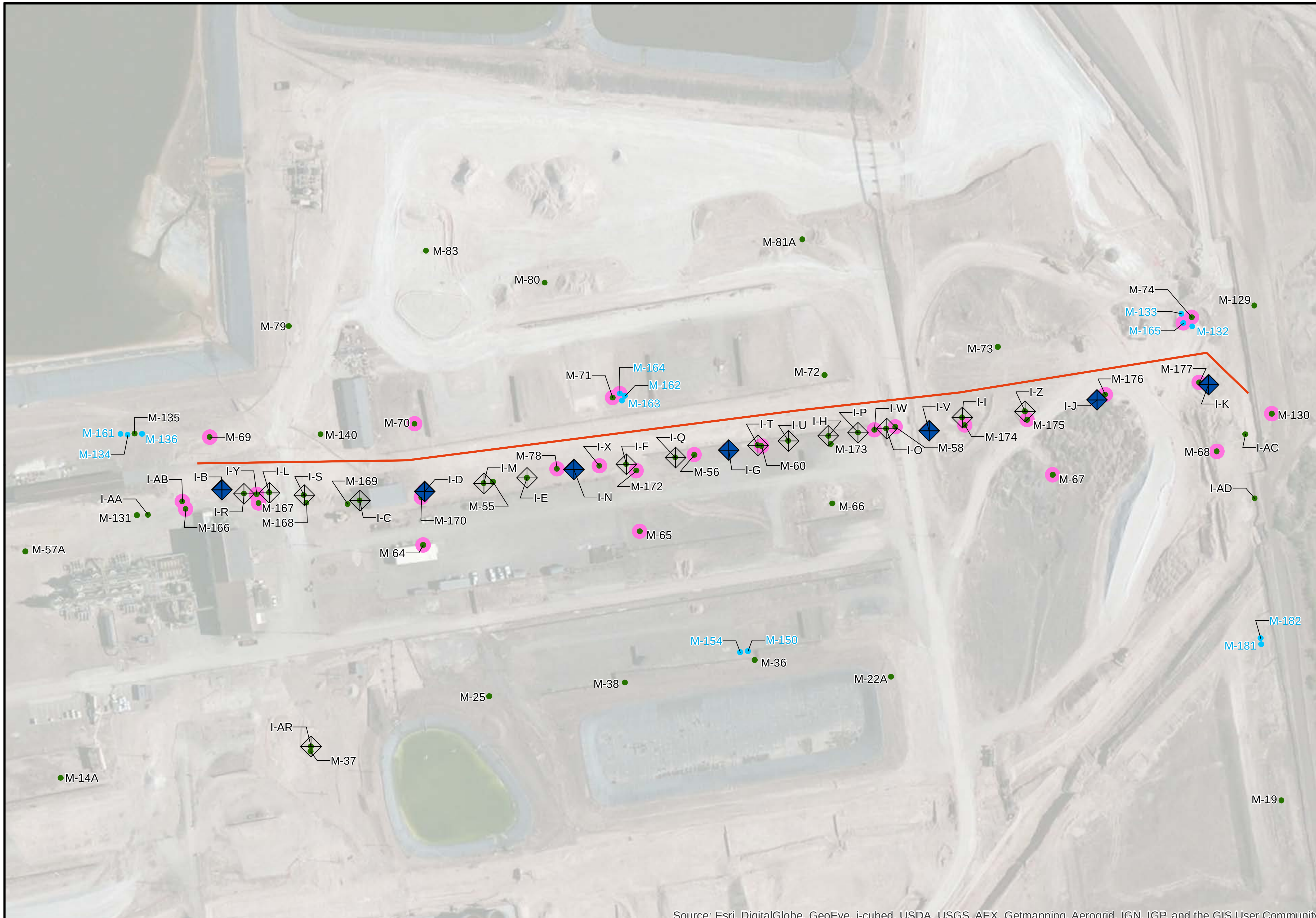
Well Network for Step Drawdown Tests, Athens Road Well Field

Nevada Environmental Response Trust Site
Henderson, Nevada

Figure **7**

Drafter: LAT | Date: 10/18/2013 | Contract Number: 21-29100J | Approved by: | Revised:



Legend

- Shallow Water Bearing Zone Well
- Middle Water Bearing Zone Well
- Extraction Wells
- Recovery Test Wells
- Monitoring Wells for Recovery Test
- Barrier Wall

N

1 inch = 150 feet

0 25 50 100 150 Feet

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Well Network for Recovery Tests, Interceptor Well Field

Nevada Environmental Response Trust Site
Henderson, Nevada

Figure **8**

Drafter: KPL	Date: 10/18/2013	Contract Number: 21-29100J	Approved by:	Revised:

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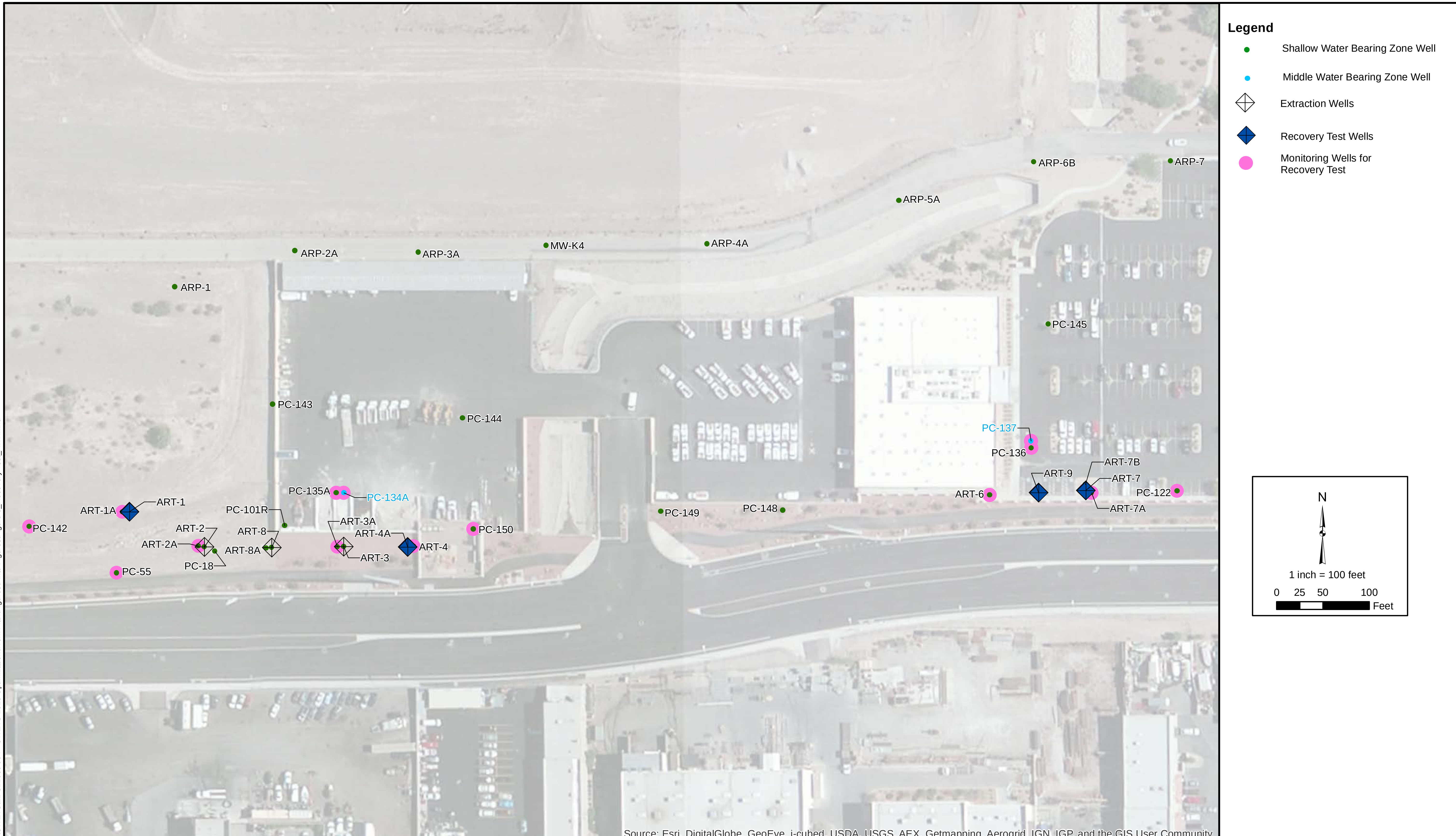

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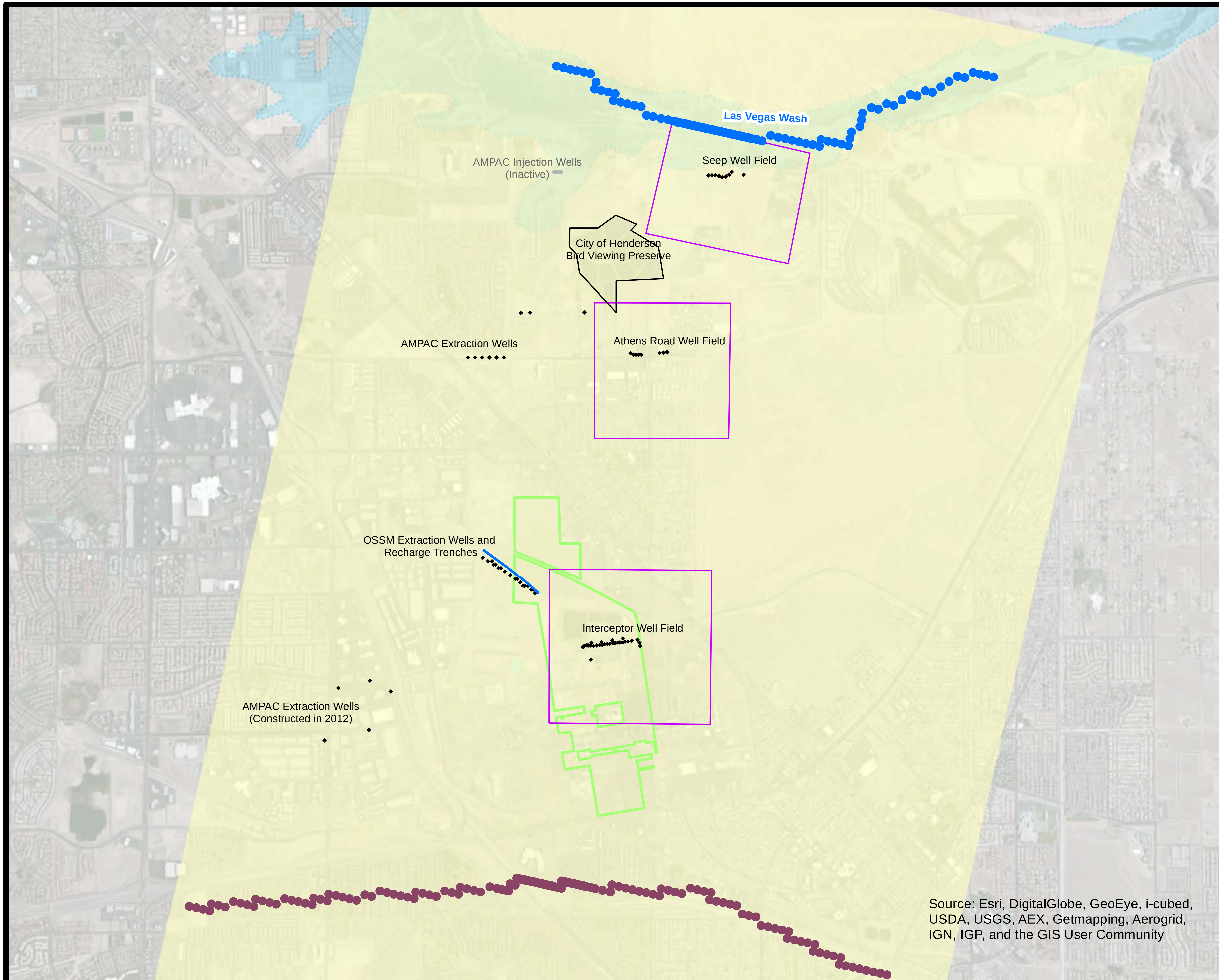
Well Network for Recovery Tests, Athens Road Well Field
Nevada Environmental Response Trust Site
Henderson, Nevada

Figure 9

Drafter: KPL | Date: 10/18/2013 | Contract Number: 21-29100J | Approved by: | Revised:



Legend

- Upgradient Boundary
- Downgradient Boundary
- TMR Model Boundary
- NERT Property Boundary
- Model Domain
- Recharge Trench
- Extraction and Injection Wells

Note: The telescopic mesh refinement (TMR) boundaries are used to create local scale models of the well field areas.

NERT = Nevada Environmental Response Trust
AMPAC = American Pacific Corporation
OSSM = Olin/Stauffer/Syngenta/Montrose

N
W E
S

0 0.5 1 Miles

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GROUNDWATER MODEL EXTENT
Nevada Environmental ResponseTrust Site
Henderson, NV

Date: 10/17/2013	Contract Number: 21-32100J		Figure
Drafter: AS	Approved:	Revised:	10

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Appendix A

Field Guidance Document: Aquifer Testing

Table of Contents

1.0 INTRODUCTION

This Field Guidance Document defines the recommended procedures established by ENVIRON for performing the following types of aquifer hydraulic tests: (1) slug tests, (2) aquifer pumping tests, and (3) recovery tests. Although this document describes procedures for typical projects, it should be understood that for certain projects more or less prescriptive procedures may be warranted based on the project-specific data quality objectives. To ensure that high-quality data is obtained, personnel involved in field activities should ensure that they understand the scope of work and the level of detail necessary for each field activity prior to mobilizing to perform the work.

This Field Guidance Document is intended as a guidance document and does not supersede ENVIRON Health and Safety procedures or Site-Specific Health and Safety Plan (HASP) requirements. All ENVIRON employees shall follow the guidelines, rules, and procedures contained in site-specific HASPs prior to adhering to any procedures recommended in this Field Guidance Document. The ENVIRON Principal-in-Charge / Project Director (PIC) and Project Manager (PM) must ensure that all project personnel review and sign the applicable HASP, and that the completed HASP and relevant project information is maintained in the project file. The signatures of the PIC and PM indicate approval of the methods and precautions outlined in the HASP. The ENVIRON PIC and PM must also ensure that all personnel involved in field activities adhere to the procedures outlined in this and other applicable Field Guidance Documents. However, in the event of conflict between this Field Guidance Document and site-specific HASP(s) and/or project-specific Field Guidance Documents, the procedures outlined in the site- or project-specific document(s) prevail.

2.0 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 activities described in this Field Guidance Document 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 PM 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.

3.0 EQUIPMENT/MATERIALS

A list of common equipment and materials necessary for conforming to this Field Guidance Document and pertinent to all aquifer tests include:

- Site-specific HASP, and any personal protective or other equipment required by the HASP
- Site information (maps, contact numbers, etc.)
- Well information (previous water levels, well depths and screen intervals, previous purge logs, etc.)
- Electronic water level meter to take manual measurements (Solinst or similar)
- Data-logging pressure transducers (e.g., Solinst Levellogger™)
- Direct-read transducer cables and/or low-stretch nylon or Kevlar cord for hanging transducers
- Steel measuring tape
- Laptop computer
- Decontamination supplies (e.g. phosphate-free detergent, deionized water)
- Well keys (if necessary)
- Stopwatch (this functionality is available on many newer cell phones)
- Duct tape or other adhesive tape
- Extra batteries
- Field Forms and/or Field Logbook
    - *Field Investigation Daily Log*
    - *Water Level Measurement Log*
    - *Equipment Calibration Log*

Additional equipment pertinent to slug tests, pumping tests, and recovery tests are discussed in those particular sections.

4.0 RECORD-KEEPING

At a minimum, the following should be recorded in the project logbook, Field Investigation Daily Log, and/or in test-specific field forms during the course of an aquifer test:

- A brief description of important activities such as Health and Safety tailgate meetings
- Time of arrival and departure from the site
- Relevant well construction details such as top of casing elevation, ground surface elevation, measuring point elevation, and well depth

- Field-verified well construction details such as measured well depth
- Distances from tested well to observation wells (if applicable)
- Unusual activities that may affect results (e.g., high winds, storms, items dropped into well, seismic events)
- Equipment models used and description of any equipment failures

Additional test-specific events and measurements to be recorded in the field forms are discussed in the pertinent sections. Data file nomenclature and file saving protocols should be determined prior to initiating any test program involving electronic measurement and logging of data.

5.0 SLUG TESTING PROCEDURES

This section provides guidance for performing slug tests. This section does not cover the analysis of slug test results.

A slug test is a single-well testing method that is commonly used as a quick and cost-effective means to estimate the hydraulic conductivity of an aquifer or water-bearing zone in close proximity to the well. A slug test is performed by instantaneously raising or lowering the water level in the well by inserting or removing a "slug" of known volume and then monitoring and recording the recovery of hydraulic head to the initial level.

There are a variety of methods by which the water level in the well can be lowered or raised by a "slug" composed of air, water, or a solid material. The use of slugs made up of air is complicated due to the need for special equipment to apply pressure or a vacuum to the well. In addition, the well screen must be entirely below the static water level to avoid short-circuiting of air to the surrounding formation. The use of slugs made up of water is often infeasible because of (1) the need to dispose of contaminated groundwater pumped from the well, (2) the difficulty of instantaneously removing a slug of water from a well, and (3) the potential bias in groundwater sampling results due to the dilution of groundwater with the addition of clean slug water. For practical purposes, this section focuses on slug tests conducted using a solid slug.

In addition to being relatively quick and cost-effective, slug tests are often chosen instead of pumping tests because they can be performed in lower permeability zones not appropriate for pumping tests and do not require the disposal of large quantities of potentially contaminated water. Some disadvantages of slug tests are that hydraulic conductivity estimates (1) are sensitive to near-well conditions (e.g., poor well development, gravel pack, and skin effects), (2) only apply to the immediate vicinity of the well, and (3) are not able to identify boundary conditions, hydraulic anisotropy, storage coefficients, or pumping characteristics of the well.

5.1 Planning and Design Considerations

Aquifer characteristics and well construction details should be evaluated prior to the start of testing to ensure wells selected for testing will adequately characterize the aquifer. At a minimum, the conceptual site model should include whether the aquifer is confined or unconfined, wells fully or partially penetrate the aquifer, the water table intersects or lies above the well screen, and the permeability of the aquifer.

The slug size should be determined using procedures specified in Butler (2013) to ensure that the formation response will be sufficient to enable analysis of the response data. In general, an initial displacement of the water column of one to three feet is sufficient to enable analysis of the response data. Smaller displacements may not yield a sufficient response in the aquifer and larger displacements may result in large frictional losses and unnecessarily long test durations. In very high conductivity formations, displacements other than those noted may be needed to reduce the effects of nonlinear response mechanisms. Larger slugs may also be required for wells screened across the water table to account for the effects of filter pack drainage.

If practical, it is desirable to confirm the reproducibility of the results by repeating the slug test either with the same slug or with a slug that produces an initial displacement that differs by at least a factor of two; however, this is not always achievable in the field.

5.2 Performing the Slug Test

This section describes the protocol for performing a slug test.

5.2.1 Equipment

In addition to the equipment specified in Section 2.0, the following equipment shall be used while conducting slug tests:

- Appropriately-sized slugs constructed of inert materials and impervious to water
- Pulley system with static nylon or coated-steel cord to raise and lower slugs
- Solid slugs or other equipment for initiating slug tests
- Polyethylene sheeting
- Field Forms and/or Field Logbook
    - *Slug Test Field Log (Attachment 1)*

5.2.2 Water Level Measurement

- Verify the total well depth with the electronic water level meter or steel tape and record the result. It is not uncommon to measure well depths that differ from as-built well depths in well construction tables.

- Prior to initiating the slug test, a pressure transducer with integral data logger should be installed in the test well and any identified observation wells. The transducer should be securely deployed by a direct-read cable if real-time viewing of data is needed. Otherwise, transducers should be deployed using inert, low-stretch nylon or Kevlar cord. The transducer should be installed above the bottom of the well with enough room to accommodate the slug and to avoid disturbance of the transducer. The transducer should be installed at an appropriate depth for which it is calibrated accounting not only for the static hydraulic head, but also for the rise and fall of the hydraulic head during testing.
- Allow water levels to stabilize. The static water level in the well should be measured and monitored long enough to evaluate whether or not any trends exist that could interfere with testing. In general, pre-test water levels should be monitored and recorded for at least a period longer than the duration of the test (ASTM, 2008). Ultimately, the duration of pre-test monitoring will be based on field conditions and the project-specific data quality objectives.
- Confirm data and settings from previous tests have been cleared. Program data loggers to record water level measurements during the test period. Generally, the measurement schedule is selected to have an initially high rate, followed by a period of reduced measurement frequency as the test progresses. The initial frequency at the time the test is initiated must be sufficient to record the initial displacement produced by insertion of the slug. A high frequency is also required for the period when the slug is removed. For the remainder of the test, the measurement frequency selected will depend on the conductivity of the formation tested, with higher frequencies required for tests in more conductive formations. Tests in less conductive formations will require longer test durations, and the limits of the data logger data storage capacity will need to be taken into account.
- Collect manual water level measurements using an electronic water level indicator with gradations to the nearest 0.01 foot before testing to determine static water levels as well as during the tests to confirm the transducer data. Wristwatches used to record the time of manual water level measurements should be synchronized with the computer used to program the data loggers.
- After the completion of the test(s), download the water level data from the transducer data logger for analysis and ensure the file is saved. This is routinely stored in .txt, .csv, or .xls file formats for importation into Microsoft Excel®, or similar spreadsheet programs. It is also useful to download any time-series figures created by the data logger software during the test; these typically include graphs of pressure head versus time and temperature versus time.
- Pressure readings from the transducer will be adjusted for changes in barometric pressure as necessary. A transducer dedicated to record atmospheric pressure should be placed within one of the test wells or in close vicinity to the test wells. Atmospheric pressure should also be recorded when water levels are recorded.

5.2.3 Slug Insertion and Withdrawal

- Securely attach the cord in the pulley system to the eyelet drilled into one end of the slug. More than one slug may need to be connected end-to-end in order to achieve the desired volume.
- Measure and mark the cord with a permanent pen or secure tape to indicate when the bottom of the slug has been lowered to just above the water table.
- Lower the slug into position in the well just above the water table. Be careful not to hit the pressure transducer cable as you lower the slug and record any disturbances.
- Ensure that a transducer is installed in the well below the water table and has started logging. Start logging if necessary and allow for pre-test data collection.
- Upon collection of suitable pre-test data, initiate the falling-head test by rapidly introducing the solid slug into the well, simulating an instantaneous change in water level. Care should be taken not to drop the slug, but to quickly lower the slug, to avoid excessive splash. The falling-head test start time shall be recorded.
- Compare the estimate of initial displacement based on well dimensions with the observed initial displacement in the field, which can be calculated from the pressure head versus time graph displayed with the real-time viewing data logger software. Record the observed initial displacement.
- Continue to monitor progress with the real-time viewing data logger software, if available, or by frequently checking the water level using an electronic water level indicator until water levels have returned to equilibrium.
- Before initiating the rising-head test, download the data from the falling-head test and re-program the measurement frequency schedule on the data logger. Allow at least one minute to pass after reprogramming before initiating the rising-head test. More time may be allowed as necessary to gather pre-test data.
- Initiate the rising-head test by rapidly removing the slug from the well and secure the slug above the pre-determined static water level by tying off the cord. The rising-head test start time and observed initial displacement shall be recorded.
- For wells exhibiting extremely long recovery times, the test may be stopped prior to full water level recovery, and a partial data record used for analysis. Ideally, the recovery period should continue until full recovery (> 90% of long-term drawdown) has been achieved.
- If time permits, both the falling-head and rising-head tests should be repeated.

5.2.4 Equipment Decontamination

All equipment should be decontaminated prior to and after contacting groundwater by washing with a non-phosphate detergent solution (Alconox or equivalent), followed by rinsing with deionized water or by using a steam cleaner if available. Decontamination water will be collected and stored in labeled sealed buckets or drums on-site for future disposal by the client unless other arrangements have been made.

5.3 References

American Society for Testing and Materials (ASTM). 2010. Standard Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques. ASTM D4043-96(2010)e1, West Conshohocken, Pennsylvania.

American Society for Testing and Materials (ASTM). 2008. *Standard Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers*. ASTM D4044-96(2008), West Conshohocken, Pennsylvania.

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Duffield, G.M. 2007. AQTESOLV for Windows Version 4.5 User's Guide. HydroSOLVE, Inc. Reston, VA.

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U.S. Department of the Interior. 1995. Ground Water Manual, A Water Resources Technical Publication, Second Edition. Bureau of Reclamation.

6.0 AQUIFER PUMPING TEST PROCEDURES

This section provides guidance regarding the design and performance of step-drawdown and constant-rate aquifer pumping tests. This section does not cover analysis of aquifer pumping test results.

Step-Drawdown Pumping Tests

A step-drawdown test is performed by pumping a well at a set of sequentially increasing pumping rates and measuring the change in water level in the pumping well, and optionally, in one or more observation wells. At least three pumping steps should be used, with each pumping step maintained ideally until the drawdown in the pumping well has stabilized (this may be impractical for tests in low conductivity formations). Data from step-drawdown pumping tests are used to predict the potential yield of an extraction well, identify performance criteria such as well loss and well efficiency, and provide estimates of the hydraulic conductivity of the surrounding formation.

Constant-Rate Pumping Tests

A constant-rate pumping test is performed by pumping an aquifer for an extended period of time and recording water level changes at the pumping well and in nearby observation wells. The goal of a constant-rate pumping test is to estimate the hydraulic properties of an aquifer including transmissivity, hydraulic conductivity and storativity. In addition, the extended period of pumping allows for the potential identification of aquifer boundaries such as flow barriers (e.g. faults, impermeable materials) and hydraulic connections to sources of recharge (e.g. surface water features). Generally, a step-drawdown test is performed prior to a constant-rate test to establish the flow rate to be used.

6.1 Planning and Design Considerations

Aquifer characteristics and well construction details should be evaluated prior to the start of testing to ensure selected pumping and observation wells will adequately characterize the aquifer in accordance with the test objectives. The conceptual site model should incorporate: whether the aquifer is confined or unconfined; whether wells fully or partially penetrate the aquifer; whether the water table intersects or lies above the well screen; previously determined aquifer characteristics (e.g., permeability, transmissivity, thickness, hydraulic gradients); the location and type of aquifer boundaries; surface water features; and the presence of nearby pumping or injection wells. Knowledge of site conditions will help determine which analytical method to use (ASTM, 2010). This Field Guidance Document does not cover analysis of aquifer pumping test results, but the chosen analytical method may prescribe specific requirements with regard to well selection; these requirements should be observed.

The well development and construction history of wells should also be evaluated prior to selection of the well network to ensure there are no issues that might interfere with interpretation of test results. For example, an improperly developed well can yield hydraulic conductivity estimates that are biased low due to interference by drilling mud or formation fines.

Once potential wells are identified for the testing program, preliminary estimates of drawdown should be made based on known or estimated site conditions. In general, pumping wells should have an adequate number of potential observation wells nearby that are expected to exhibit significant drawdown. Observation well locations may also be chosen in order to identify aquifer boundaries or anisotropy.

It is also necessary to identify nearby extraction and injection wells that could interfere with the pumping test. These wells should either be turned off well in advance or operated at a constant rate for the duration of the test. It may be prudent to disable automatic pump controls.

The pumping rate(s) selected for the pumping well should be sufficient to stress the aquifer, but prevent the well from becoming dry for the duration of the test. Drawing the water level below the perforations in the screen potentially has adverse effects (e.g., cascading water and air entrainment in the well). It is essential to maintain a constant pumping rate for the duration of each pumping step or pumping period. If pumping stops or deviates significantly from the target pumping rate, it is necessary to restart the test after the aquifer has fully recovered. In general, the pumping rate should not be allowed to vary by more than 5 to 10% (ASTM, 2008).

The pumping rate should be monitored very closely at the beginning of each pumping step and then adjusted less often as the test progresses. An instantaneous flow meter is typically used to monitor the pumping rate and should be verified with manual measurements using a graduated cylinder or bucket and a stopwatch. The magnitude of the target pumping rate will determine what types of controls are used to regulate the pumping rate. Higher flow rates generally necessitate both a primary valve installed on the discharge line and a second valve that can be used to make finer adjustments to the flow rate. Lower flow rates can be manipulated with a rheostatic control on the pump, a valve installed in the discharge line, or both of these mechanisms.

Consider installing a “stilling tube” (a small-diameter PVC pipe) to encase the pressure transducer and electronic water level meter tape in order to reduce interference caused by turbulence in the well due to pumping and cascading water. This is particularly important for pumping at higher flow rates.

ENVIRON typically coordinates with a subcontractor to operate the pumps for the well testing, but it is important to confirm that the power supply and pumping equipment are capable of maintaining a constant pumping rate for the duration of the test. In some cases it may be warranted to obtain a backup generator (when using a diesel or gasoline generator) and in exceptional cases it may be warranted to have the local power company provide temporary power (long-term tests in residential areas).

The pump should be sized to operate for sustained periods at the range of flows necessary to perform the tests. The pump should have a maximum capacity higher than the maximum anticipated pumping rate, but should also be able to effectively cool itself properly at the lowest anticipated pumping rate to avoid heat-induced pump failure during the test. A check valve should be installed that prevents backflow of water into the well once pumping is stopped in order to ensure high quality data is obtained at the beginning of the recovery period.

Plans must be made to contain, store, transport, and/or discharge/dispose of the water generated during pump tests in accordance with local, state, and federal laws as well as in accordance with project-specific requirements. Handling investigation-derived waste is a critical task that must be planned in advance particularly for pump testing projects where large volumes of water are expected to be generated.

6.2 Performing the Pumping Test

6.2.1 Equipment

Equipment needs vary based on the field activity and project. ENVIRON typically collaborates with subcontractors to perform aquifer pumping tests, thus eliminating the need to obtain certain types of equipment such as submersible pumps and holding tanks. In addition to the equipment specified in Section 2.0, the following equipment shall be used to conduct pumping tests:

- Graduated cylinders or buckets
- Field Forms and/or Field Logbook
    - *Pump Test Field Log (Attachment 2)*
- Submersible pump with flow regulator, and tubing
- Generator (if electricity is not available)
- Flow meters
- Heavy duty extension cords
- Polyethylene sheeting
- Large capacity barrels or trailer-mounted holding tanks and/or other means to store and transport pumped groundwater
- Secondary containment for water storage tanks and diesel or gasoline generators (if used).

6.2.2 Water Level Measurement

- Prior to initiating the pumping test, pressure transducers with integral data loggers should be installed in the test well and surrounding observation wells to be monitored and the water level allowed to stabilize. The transducers may be securely deployed by a direct-read cable allowing real-time viewing of data. For actively pumping wells stilling tubes may be necessary to protect the transducer. Confirm data and settings from previous tests have been cleared and that new settings have been programmed.

- The static water level in each well should be measured and recorded long enough to evaluate whether or not any trends exist. In general, pre-test water levels should be monitored and recorded for at least one week or a period longer than the duration of the test (ASTM, 2008; USEPA, 1993). Ultimately, the duration of pre-test monitoring will be based on field conditions and the project-specific data quality objectives.
- Program data loggers to record water level measurements during the test period. Generally, the measurement schedule is selected to have an initially high rate, followed by a period of reduced measurement frequency as the test progresses. The frequency selected must be sufficient to record the initial displacement produced at the start of each pumping step and at the start of the recovery period, but not so frequent that the storage limits of the data logger data storage capacity will be exceeded. Similar measurement frequencies should be chosen for the pumping and recovery periods. The following table of measurement frequencies can be used as a general guideline; however, more frequent measurements are typically made (ASTM, 2008):

Elapsed Time	Measurement Frequency
0 to 3 minutes	Every 30 seconds
3 to 15 minutes	Every minute
15 to 60 minutes	Every 5 minutes
60 to 120 minutes	Every 10 minutes
2 to 3 hours	Every 20 minutes
3 to 15 hours	Every hour
15 to 60 hours	Every 5 hours

- Manual water level measurements shall be collected from the test well and monitoring wells immediately prior to the start of each pumping test and recorded on the appropriate field forms or in a logbook. Manual water level measurements should be recorded periodically for the duration of the test. These measurements should be collected using an electronic water level indicator with gradations to the nearest 0.01 foot. Wristwatches used to record the time of manual water level measurements should be synchronized with the computer used to program the data loggers.
- After the completion of the test(s), download the water level data from the transducer data logger for analysis. This is routinely stored in .txt, .csv, or .xls file formats for importation into Microsoft Excel®, or similar spreadsheet programs. Verify the file is saved. It is also useful to download any time-series figures created by the data logger software during the test; these typically include graphs of pressure head and temperature versus time.
- Pressure readings from the transducer should be compensated for changes in barometric pressure as necessary. A transducer dedicated to record atmospheric pressure should be placed

within one of the test wells or in close vicinity to the test well. Atmospheric pressure should also be recorded when water levels are recorded.

6.2.3 Pumping Period

- At the start of each test, the initial volume of the water in the pump discharge tank will be measured and recorded.
- A properly-sized submersible pump will be set in the pumping well with the intake set two feet above the base of the well screen.
- During step drawdown or constant rate testing, the flow rate will be continually measured and adjusted to maintain a constant rate for each step. If the flow rates to be used are low (less than 2.0 gallon per minute [gpm]), the most reliable method of measuring them will be by filling graduated cylinders over 5, 10, 20, or 30-second time intervals. For flows over 2.0 gpm, a calibrated inline flow meter may be used to monitor flow rate. Multiple means of measuring flow are recommended in order to confirm results. Flow rate measurements shall be recorded.
- For step drawdown tests, each pumping step shall be maintained until the drawdown in the pumping well has stabilized, however this may be impractical for tests in low conductivity formations. For constant rate pumping tests, pumping shall continue as necessary in order to meet the established project-specific data quality objectives.

6.2.4 Recovery Period

- After the final pumping step, the pump will be switched off and water levels will be allowed to recover.
- Water level monitoring will continue during the recovery period. Ideally, the recovery period should continue until full recovery (> 90% of long-term drawdown) has been achieved; however, this is not always feasible in low permeability geologic materials.

6.2.5 Equipment Decontamination

At the end of each test, all field equipment that has contacted groundwater will be decontaminated by washing with a detergent solution (Alconox or equivalent) followed by rinsing with deionized water or a steam cleaner if available. Decontamination water will be collected and stored in labeled sealed buckets or drums on-site for future disposal by the client unless other arrangements have been made.

6.3 References

American Society for Testing and Materials (ASTM). 2010. Standard Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques. ASTM D4043-96(2010)e1, West Conshohocken, Pennsylvania.

American Society for Testing and Materials (ASTM). 2008. Standard Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems. ASTM D4050-96(2008), West Conshohocken, Pennsylvania.

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State of California Environmental Protection Agency (Cal/EPA). 1995. Aquifer Testing for Hydrogeologic Characterization, Guidance Manual for Ground Water Investigations. July.

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U.S. Environmental Protection Agency (EPA). 1993. *Suggested operating procedures for aquifer pumping tests*. Ground Water Issue, EPA/540/S-93/503. February.

7.0 RECOVERY TESTING PROCEDURES

This section discusses recovery testing conducted as a standalone test at an operating extraction well. Recovery testing conducted as part of the recovery phase of an aquifer pumping test is discussed in Section 5.0. Recovery test results assist in the determination of hydraulic conductivity and storativity of the formation, while also providing information on the extent to which cones of depression may overlap for neighboring wells.

7.1 Planning and Design Considerations

Wells are selected for recovery testing based on a review of long-term pumping rates for each extraction well. Recovery tests should only be conducted at extraction wells where recent pumping rates are relatively stable.

Prior to initiating each recovery test, the long-term drawdown at the extraction well should be estimated by comparing historical water levels trends at the test well and neighboring cross-gradient monitoring wells, and/or by modeling the long-term drawdown based on the average pumping rate and previous estimates of hydraulic conductivity in the vicinity of the extraction well. This information is required to compute the residual drawdown during the course of the test.

7.2 Performing the Recovery Test

7.2.1 Equipment

In addition to the equipment specified in Section 2.0, the following equipment shall be used to conduct recovery tests:

- Field Forms and/or a Field Logbook
    - *Pump Test Field Log (Attachment 2)*

7.2.2 Water Level Measurement

- Verify the total well depth with the electronic water level meter or steel tape and record the result. It is not uncommon to measure well depths that differ from as-built well depths in well construction tables.
- Prior to conducting the recovery test, pressure transducers with integral data loggers should be installed in the test well (if possible) and in one or more monitoring wells in proximity to the test well. The transducers should be securely deployed by direct-read cables allowing real-time viewing of data if possible. Otherwise, transducers should be deployed using inert, low-stretch nylon or Kevlar cord. Water levels shall be allowed to stabilize.
- Data loggers shall be programmed to record water level measurements during the test period at the specified frequency. The frequency selected must be sufficient to record the initial displacement produced at the start of the recovery test, but not so frequent that the storage

limits of the data logger data storage capacity will be exceeded. The following table of measurement frequencies can be used as a general guideline; however, more frequent measurements are typically made (ASTM, 2008):

Elapsed Time	Measurement Frequency
0 to 3 minutes	Every 30 seconds
3 to 15 minutes	Every minute
15 to 60 minutes	Every 5 minutes
60 to 120 minutes	Every 10 minutes
2 to 3 hours	Every 20 minutes
3 to 15 hours	Every hour
15 to 60 hours	Every 5 hours

- Manual water level measurements shall be collected from the test well and monitoring wells immediately prior to the start of each recovery test and recorded on the appropriate field forms and/or logbook. Manual water level measurements should be recorded periodically for the duration of the test. These measurements should be collected using an electronic water level indicator with gradations to the nearest 0.01 foot.
- Initiate the recovery test by shutting off the extraction well pump. Record the exact pump shutdown time and depth to water.
- Ideally, the recovery test should continue until full recovery (> 90% of long-term drawdown) has been achieved; however, this is not always feasible in low permeability geologic materials.
- Upon completion of the recovery test, restart the pump and record the exact time and depth to water on the Pump Test Field Log.
- After the completion of the test(s), download the water level data from the transducer data loggers for analysis and verify the file is saved. This is routinely stored in .txt, .csv, or .xls file formats for importation into Microsoft Excel®, or similar spreadsheet programs. It is also useful to download any time-series figures created by the data logger software during the test; these typically include graphs of pressure head and temperature versus time.
- Pressure readings from the transducer should be compensated for changes in barometric pressure as necessary. A transducer dedicated to record atmospheric pressure should be placed within one of the test wells or in close vicinity to the test well. Atmospheric pressure should also be recorded when water levels are recorded.

7.2.3 Equipment Decontamination

At the end of each test, all field equipment that has contacted groundwater should be decontaminated by washing with a detergent solution (Alconox or equivalent) followed by rinsing with deionized water or steam cleaning if available. Decontamination water will be collected and stored in labeled sealed buckets or drums on-site for future disposal by the client unless other arrangements have been made.

7.3 References

American Society for Testing and Materials (ASTM). 2010. *Standard Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques*. ASTM D4043-96(2010)e1, West Conshohocken, Pennsylvania.

American Society for Testing and Materials (ASTM). 2008. Standard Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems. ASTM D4050-96(2008), West Conshohocken, Pennsylvania.

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U.S. Department of the Interior. 1995. Ground Water Manual, A Water Resources Technical Publication, Second Edition. Bureau of Reclamation.

U.S. Environmental Protection Agency (EPA). 1993. *Suggested operating procedures for aquifer pumping tests*. Ground Water Issue, EPA/540/S-93/503. February.

ATTACHMENTS

Field Forms

1. *Slug Test Field Log*
2. *Pump Test Field Log*
3. *Field Investigation Daily Log*
4. *Water Level Measurement Log*
5. *Equipment Calibration Log*

SLUG TEST FIELD LOG

PRELIMINARY FIELD DRAFT REVIEW PENDING

PROJECT NAME: ______________________________ FIELD PERSON: ______________________________

PROJECT NUMBER: ______________________________ PROJECT MANAGER: ______________________________

PROJECT LOCATION: ______________________________ DATES: ______________ TO ______________

	WELL NUMBER:
SLUG MATERIAL: ______________________________	FALLING HEAD START TIME: ______________________________
SLUG DIMENSIONS: ______________________________	RISING HEAD START TIME: ______________________________

TOP OF CASING (TOC): ____________________ (ft. amsl) SLUG DEPTH: ____________________ (ft. bgs)

GROUND SURFACE: ____________________ (ft. amsl) TRANSDUCER DEPTH: ____________________ (ft. bgs)

DEPTH TO WATER (DTW): ________________ (ft.) TOTAL WELL DEPTH: ____________ (ft.) MEASURED WELL DEPTH: __________ (ft.)

TIME			**OBSERVATION WELLS**			**NOTES**
	TRANSDUCER READING (feet)	**DEPTH TO WATER** (feet below TOC)				

PUMP TEST FIELD LOG

PRELIMINARY FIELD DRAFT REVIEW PENDING

PROJECT NAME: ____

PROJECT NUMBER: ____

PROJECT LOCATION: ____

FIELD PERSON: ____

PROJECT MANAGER: ____

DATES: ________________ TO _________________

PUMPING WELL: ____

PUMP/TUBING TYPE: ____

FLOW MEASUREMENT METHOD: ___________________________

LAST CALIBRATION DATE:______________________________________

WELL NUMBER:

OBSERVATION WELLS: _____________________________________

PUMP START TIME: ____

PUMP END TIME: ____

TOP OF CASING (TOC): _______________________ (ft. amsl)

GROUND SURFACE: _________________________ (ft. amsl)

DEPTH TO WATER (DTW): ____________________ (ft.) TOTAL WELL DEPTH: ______________ (ft) MEASURED WELL DEPTH: ___________ (ft)

PUMP DEPTH: ________________________ (ft bgs)

TRANSDUCER DEPTH: _____________________ (ft bgs)

TIME	PUMPING WELL			OBSERVATION WELLS					NOTES
	PUMPING RATE (gpm)	TRANSDUCER READING (feet)	DEPTH TO WATER (feet below TOC)						

ENVIRON
2200 Powell Street, Suite 700
Emeryville, California 94608
(510) 655-7400
(510) 655-9517 (fax)

FIELD INVESTIGATION DAILY LOG

PRELIMINARY FIELD DRAFT - REVIEW PENDING

PROJECT NAME: ____________________ FIELD PERSON: ____________________

PROJECT NUMBER: ____________________ PROJECT MANAGER: ____________________

PROJECT LOCATION: ____________________ DATE: ____________________

DAILY SUMMARY: ____________________

WEATHER CONDITIONS: ____________________

VISITORS/SUBCONTRACTORS: ____________________

MILITARY TIME	ACTIVITIES

Prepared By (name/signature): ____________________ Date: ____________________

Reviewed By (name/signature): ____________________ Date: ____________________

ENVIRON
2200 Powell Street, Suite 700
Emeryville, California 94608
(510) 655-7400
(510) 655-9517 (fax)

WATER LEVEL MEASUREMENT LOG

PRELIMINARY FIELD DRAFT REVIEW PENDING

PROJECT NAME: ______________________ MEASUREMENT DATE: ______________________

CONTRACT NUMBER: ______________________ FIELD PERSON: ______________________

EQUIPMENT MODEL/TYPE	SERIAL NUMBER	LAST CALIBRATION DATE

MEASURING POINTS AND DATUM USED: ______________________

WELL NUMBER	TIME	MEASURING POINT	DEPTH TO GROUNDWATER (FT BGS)	DEPTH TO FREE PRODUCT (FT BGS)	FREE PRODUCT THICKNESS (FT)	CONDITION OF WELL

ENVIRON
2200 Powell Street, Suite 700
Emeryville, California 94608
(510) 655-7400
(510) 655-9517 (fax)

EQUIPMENT CALIBRATION LOG

PRELIMINARY FIELD DRAFT REVIEW PENDING

PROJECT NAME: ______________________ FIELD PERSON: ______________________

PROJECT NUMBER: ______________________ PROJECT MANAGER: ______________________

PROJECT LOCATION: ______________________ FORM DATES: FROM ____________ TO ____________

DATE	EQUIPMENT MODEL/TYPE	SERIAL NUMBER	TEMP. (°C)	STANDARD	PRECALIBRATED READING	CALIBRATED READING