APPENDIX A

Well Installation and Maintenance Plan

CONTENTS

TABLES

ATTACHMENTS

ACRONYMS AND ABBREVIATIONS

A	amperage
bgs	below ground surface
CA DWR	California Department of Water Resources
DO	dissolved oxygen
DOT	Department of Transportation
gpm	gallons per minute
I.D.	inside diameter
IDW	investigative-derived waste
JPL	Jet Propulsion Laboratory
mV	millivolts
NASA	National Aeronautics and Space Administration
NFESC	Navy Facilities Engineering Service Center
O.D.	outside diameter
ORP	oxidation reduction potential
POC	point of contact
PVC	polyvinyl chloride
TDH	total dynamic head
TDS	total dissolved solids
USCS	Unified Soil Classification System
U.S. EPA	United States Environmental Protection Agency
V	voltage
VOC	volatile organic compound

1.0 WELL INSTALLATION

1.1 Drilling Method

Each extraction/injection monitoring well will be drilled to the required depth below ground surface (bgs) using a 12.25-inch outside diameter (O.D.) mud-rotary drilling bit. This diameter of borehole is sufficient to place the well construction materials (i.e., 6.625-inch or 8.625-inch O.D. casing and screen) and allow for an appropriate filter pack and sealing materials which should be a minimum of 2 inches in thickness between the casing/screen and borehole wall. Approximately 20 ft of steel conductor casing will be set at the surface of each borehole to maintain the near surface integrity. The conductor casing will be removed after the well is constructed and all backfill materials have been placed. During drilling and well construction, drill cuttings will be separated from the drilling mud using a mud shaker. The separated mud is recycled into the drilling process and the cuttings are stored in a roll-off bin. Additional details regarding containerization and disposal of investigative-derived waste (IDW) are provided in Section 1.3.6.

All drilling equipment and materials, including drilling bits and pipes, drilling mud, and backfill materials, will be either new or cleaned in the field using a high pressure steam cleaner. Clean water supplied from a nearby clean water source (e.g., water spigot) will be used during drilling and well construction activities. During drilling, grab soil samples will be collected from the mud shaker for lithologic logging purposes and then disposed of with the soil cuttings. Soil samples will be logged using the Unified Soil Classification System (USCS). Soil boring logs will be incorporated into a bound field notebook. The field notebook will be used to document all sampling activities. These notebooks will be maintained as permanent records. An attempt will be made during the drilling process to collect one saturated and one unsaturated soil sample from each boring for use in determining selected physical parameters, such as hydraulic conductivity, porosity, and bulk density, as well as chemical analysis for perchlorate and volatile organic compounds (VOCs) by United States Environmental Protection Agency (U.S. EPA) Methods 314.0 and 8260B, respectively. All samples will be analyzed by a California-certified and Navy Facilities Engineering Service Center (NFESC) approved laboratory. In order to collect these samples, the downhole drilling equipment will be tripped so that soil sampling equipment can be inserted down the well for sample collection. An 18-inch long, 2-inch or 2.5-inch inside diameter (I.D.) split-spoon sampler attached to a 300-pound hammer will be used to collect undisturbed soil samples that will be used for analysis of physical and chemical parameters. The drilling and sampling methods described above are standard methods for installation of extraction and injection wells and collection of environmental soil samples in alluvial aquifers similar to the subsurface conditions present beneath the Jet Propulsion Laboratory (JPL) facility. Additionally, during well construction and development, the drilling mud will eventually be removed from the well.

Detailed descriptions of the mud rotary drill process and field documentation procedure are provided in National Aeronautic and Space Administration's (NASA) regulator approved *Work Plan for Performing a Remedial Investigation/Feasibility Study at NASA JPL* (Ebasco, 1993).

1.2 Geophysical Borehole Logging

The following sections provide details regarding geophysical logging methods that will be conducted in each borehole following the completion of well drilling activities. Upon completion of drilling and prior to the well installation, the borehole will be logged using geophysical methods to assist the field geologist with the identification of borehole lithologies, water-bearing intervals, and stratigraphic correlation with existing JPL monitoring and treatment system wells. Geophysical methods employed include: Gamma

Log, Caliper Log, Single-Point Resistance Log, and Spontaneous Potential Log. The purpose and use of these methods are provided in each of the respective subsections.

1.2.1 Gamma Log

This method records the amount of natural gamma radiation emitted by the rocks surrounding the borehole. Clay- and shale-bearing zones often emit relatively high gamma radiation because they contain weathering products that include uranium and thorium. Clay and shale layers are aquitards and it is important to identify their locations within the aquifer to optimize the extraction and injection of groundwater. This method is also useful to compare with the geologic log created during the drilling process.

1.2.2 Caliper Log

This method records borehole diameter. Changes in the borehole diameter are related to well construction, such as casing or drill-bit size, and to fracturing or caving along the borehole wall. Borehole diameter is useful in interpreting the other geophysical logs because it can affect the log response of the other methods. Caliper logs can detect poorly consolidated sands that tend to collapse in the borehole. These sands are generally very porous, water producing zones within the aquifer.

1.2.3 Single-Point Resistance Log

This method records the electrical resistance from points within the borehole to an electrical ground at the surface. Typically, resistance increases with increasing grain size and decreases with increasing borehole diameter, fracture density, and dissolved-solids concentrations of the water. Single-Point resistance logs require a fluid-filled borehole and are only run in the saturated zone of the aquifer. This method is useful in determining the location of water bearing zones because fluid-filled soil pores are less resistive than solid rock or low permeability soils (e.g. clays and silts). Identifying the water-bearing zones within the aquifer will be helpful in optimizing the well construction for more efficient groundwater extraction and injection. This method is also useful to correlate with the geologic log created during the drilling process.

1.2.4 Spontaneous Potential Log

This method records potentials or voltages developed between the borehole fluid and the surrounding formation material and fluids. Spontaneous potential logs can be used in the determination of porous and permeable beds within the aquifer. The spontaneous potential log are used in combination with single-point resistance logs to identify shales and sandstones (non-porous and porous, respectively) within the aquifer. This information is useful for identifying high water-bearing zones to optimize the extraction and injection of groundwater. This method is also useful to compare with the geologic log created during the drilling process.

1.3 Well Construction

Well construction will satisfy the requirements of the California Department of Water Resources (CA DWR), Water Well Standards, Bulletin 74-90, Supplement to Bulletin 74-81.

1.3.1 Well Casing Blank

The injection well casing will consist of 215 feet of 8.625-inch O.D., 7.625-inch I.D. Schedule (Sch) 80 polyvinyl chloride (PVC) casing. PVC casing is strong enough to resist collapse and is immune to electrolytic and galvanic corrosion that can occur with steel casing. It is resistant to biological growth and is also chemically resistant to virtually all chemicals found in the groundwater beneath the JPL facility including the acids that are used during well rehabilitation.

Similar to the existing extraction wells, the new extraction well casing will consist of 215 feet of 6.625-inch O.D., 6-inch I.D. low carbon steel. Removal of chemical precipitates and biological growth (which have been identified in the existing OU-1 extraction wells) using chemical and physical cleaning methods can be accomplished with this casing material.

1.3.2 Well Screen

Well screens will consist of 100 feet of 10-foot long, 8.625-inch and 6.625-inch O.D., stainless steel wire wrap screens for the injection and extraction wells, respectively. The screen slot size has been chosen to retain approximately 90% of the filter pack material after well development. The injection well screen will have 0.050-inch slots while the extraction well will have 0.040-inch slots. The slot size for each type of well was chosen to facilitate the flows necessary to operate the OU-1 treatment system. Another factor selecting the slot size is analysis of drill cutting samples of the zone to be screened. Based on past drilling activities at JPL and the surrounding area, the lithology generally consists of silty to gravelly sands. Stainless steel screens best meet the characteristics of having a large percentage of non-clogging slots, are resistant to corrosion, have sufficient strength to prevent collapse, are easily developed, and prevent sand production during pump.

1.3.3 Well Sump

The well sump will consist of a 10-foot long section of the casing material, placed at the bottom of the well as a sediment collection point. The well sump for the injection well will consist of 7.625-inch I.D. Sch 80 PVC casing. The well sump for the extraction well will consist of 6-inch I.D. low carbon steel casing.

1.3.4 Filter Pack

Filter-pack size is determined by evaluating the size of the surrounding aquifer material, the function of the well (e.g. injection or extraction), and the well screen slot size. In general, the size of the filter pack material should be large enough for adequate volumes of water to pass through, but small enough to retain the aquifer material and minimize sediment production within the well. Filter pack material (e.g. sand) is sized according to how it falls through a wire mesh, or sieve.

The filter pack in extraction wells will consist of #8 mesh sand. The sand will be uniform in size and slightly larger than the slots in the well screen. This will allow fine-grained material to be removed during well development without entering the well and decreasing its effectiveness.

The filter pack in injection wells will consist of medium aquarium gravel. This gravel is large enough to not pass through the injection well screen and provides ample permeability for the injected treated water to move quickly into the aquifer.

In order to minimize bentonite sealing materials from permeating into the filter pack and potentially impacting the effectiveness of the well screen, the filter pack material will extend a minimum of 10-ft above the screen zone. The filter pack will be emplaced from the surface using the tremie method.

1.3.5 Seal

A 5-ft thick transition seal consisting of ¼-inch, time release coated bentonite pellets will be added on top of the filter pack. The purpose of the transition seal is to prevent the annular seal (e.g. liquid bentonite grout) from entering the filter pack. After the transition seal is in place, the annular seal will be installed. The purpose of the annular seal is to eliminate the formation of a pathway between the screened zone and potential contamination from the surface and overlying materials. The annular seal will be placed into the annular space above the transition seal to approximately the ground surface. The top of the well casing will be secured with a well head completed using a flush-mount H-20 rated single door steel well vault. Sealing materials will be emplaced from the surface using the tremie method.

1.3.6 Waste (Sediment and Drilling Mud)

All drill cuttings and drilling mud removed from individual boreholes will be placed directly into soil bins. The containers will be temporarily stored on site and labeled with the following information: date, project name and number, generator name, point of contact (POC), applicable contact numbers, contents of container, and the well identification number. The method of disposal will be determined based on the analytical results from soil samples collected from the respective containers. As required at the JPL facility the following analysis will be ran on all samples prior to disposal: VOCs, SVOCs, Title 26 Metals plus strontium, Cyanide, Hexavalent Chromium, Total Petroleum Hydrocarbons and Perchlorate

2.0 WELL DEVELOPMENT

2.1 Well Development

After drilling a borehole and installing a well, it is necessary to remove the residual drilling fluid that forms a thin layer of mud on the sand grains of the borehole wall and filter pack material and is forced into the pore spaces and cracks in the aquifer. This plugging effect decreases the flow of water into or out of the well. This process is referred to as well development. Additionally, well development physically commingles the sorted gravel pack with the native formation, creating a hydraulic filter around the well screen which allows efficient passage of water into or out of the well. In general, the order of the development process for extraction and injection wells at JPL is as follows:

- Primary bail
- Brush
- Secondary bail
- Mud dispersant
- Dual-swab airlifting
- Mud dispersant
- Dual-swab airlifting
- Conventional surge pumping
- Injection development (injection well only).

Table 1 provides a description of the steps involved during initial well development. The remainder of this section provides a brief discussion of each of the above well development techniques.

Table 1. Well Development

Task	Description	Time
Primary Bailing	Bail solids from bottom of well with suction bailer.	2-3 hours
Brushing	Brush well from top to bottom in 20 foot intervals for 20 minutes each.	100 foot screen should be brushed for 100 minutes.
Secondary Bailing	Bail solids from bottom of well with suction bailer.	2-3 hours
Mud Dispersant	Mud dispersant treatment added to well. Dual-swab tool raised and lowered in well to agitate and mix dispersant distributing treatment into filter pack and borehole.	2 hours adding treatment to well. Well swabbed every two hours up to 24 hours; followed by removal.
Dual-Swab Airlifting	Swabbing, surging, and airlifting (75-175 gpm) of screened zone at select 10 foot intervals.	Pumping will occur at top of screened zone for 40 minutes (or until turbidity is ≤ 5 NTU) at a maximum pumping rate (between 75 – 175 gpm). The dual-swab airlift equipment will be raised and lowered throughout the screened zone. During airlifting the air supply will be shut off to surge the screen.
Bailing	Bail solids from bottom of well with suction bailer.	2-3 hours
Mud Dispersant	Mud dispersant treatment added to well. Dual-swab tool raised and lowered in well to agitate and mix dispersant distributing treatment into filter pack and borehole.	2 hours adding treatment to well. 12 hours of swabbing; followed by removal.
Dual-Swab Airlifting	Swabbing, surging, and airlifting (75-175 gpm) of screened zone at select 10 foot intervals.	Pumping will occur at top of screened zone for 40 minutes (or until turbidity is ≤ 5 NTU) at a maximum pumping rate (between 75 – 175 gpm). The dual-swab airlift equipment will be raised and lowered throughout the screened zone. During airlifting the air supply will be shut off to surge the screen.
Bailing	Bail solids from bottom of well with suction bailer.	2-3 hours
Conventional Pumping	Submersible pump is lowered into well and saturated zone is overpumped and surged.	Pump set at 300' and pump at max. rate achieved during airlift (i.e. 175 gpm) for 45 minutes
		Surge three times
		Pumping at 300'; pumping rate increased by 50 gpm to 225 gpm for 45 minutes
		Surge three times
		Pumping at 300'; pumping rate increased by 50 gpm to 275 gpm for 45 minutes
		Surge three times
		Pumping at 300'; pumping rate increased by 25 gpm to 300 gpm for 45 minutes
		Surge three times
Injection Development	Water is injected from a fire hydrant (or other source) and then pumped with a submersible pump until the turbidity is below 5 NTU	30 minutes of injection (from fire hydrant or other source capable of 200 gpm) and then pump for 40 minutes at 200 gpm
		30 minutes of injection (from fire hydrant or other source capable of 200 gpm) and then pump for 40 minutes at 200 gpm
		30 minutes of injection (from fire hydrant or other source capable of 200 gpm) and then pump for 40 minutes at 200 gpm
		Stop when turbidity < 5 NTU
Injection Testing	Step injection test; water is pumped into the aquifer for up to 10 hours, and water levels are monitored in injection and nearby wells. The pumping rate is tested at 75 gpm, 150 gpm, and the maximum injection rate, respectively, until the water level change is less than ± 1.0 feet or ± 2.31 psi.	Injection at 75 gpm
		Injection at 150 gpm
		Injection at maximum injection rate

2.1.1 Primary Bail

During this process, a suction bailer is lowered into the well until it fills with water and sediment. It is then pulled to the surface and emptied. The bailer's up and down motion causes a surging action which will initiate development in the area around the screen. As a result of the surging action and mud removal, water from the aquifer will then flow towards the well and bring in more drilling fluid. This process is continued until the majority of the drilling mud is removed from inside the well.

2.1.2 Brush

Brushing simply involves running a hard bristle brush up and down the length of the well screen to remove fines and sediment encrusted on the well casing and screen. Similar to bailing, the up and down movement of the brush produces a surging effect, continuing the development process. The diameter of the brush is slightly larger than the I.D. of the well, and should be made of a hard plastic or other material that will not abrade, gouge, or otherwise damage the casing or screen of the well. Brushing the well begins at the top of the well screen and moves toward the bottom of the well in 20-foot intervals. Each 20-foot interval is brushed for 20 minutes before moving on to the next interval. Upon completion of brushing, the total depth of the well is measured to determine how much sediment has accumulated as the result of the brushing activity. Any sediment that has accumulated at the bottom of the well is removed with a bailer.

2.1.3 Secondary Bail

After brushing, the suction bailer is lowered into the well to remove fines and sediment that have accumulated as a result of brushing.

2.1.4 Mud Dispersant

Following the completion of bailing, the majority of the drilling mud has been removed from inside the well. Next, a concentrated liquid polymer dispersant is applied to the well to facilitate removal of the residual mud and clay material present beyond the well screen and into the filter pack. The dispersant will be applied following the manufacturer's recommendations. The following is an example of the mixture calculation for the mud dispersant previously used during development of the existing OU-1 injection wells (i.e., Aqua-clear™ PFD):

Aqua-clear™ PFD (gal or L) = 0.002 × Borehole Water Volume (gal or L)

Therefore, 1 Gal Aqua-clear™ PFD should be mixed with 500 gals of water.

The mud dispersant will be mixed at the surface in a clean, graduated poly tank. Once the mixture has been thoroughly blended, it will be applied to the screened zone via a tremie pipe. To improve the effectiveness of the mud dispersant treatment, the well will be swabbed with a dual-swab every two hours for up to 24 hours (note: the available product information does not recommend letting the mixture sit overnight). The swabbing action ensures the distribution of the chemical treatment through the screened zone and filter-pack. After completing swabbing, the well will be tagged to calculate the amount of material that has accumulated in the bottom of the well.

The bottom of the well will then be bailed with a suction bailer to remove any sediment which may have accumulated. The solids will be placed into a 55 gallon drum, and the water will be temporarily stored in appropriate waste containers. Following the completion of swabbing and bailing, the residual mud and dispersant will be removed from the well using the dual-swab airlifting tool or similar pumping tool. A second mud dispersant treatment followed by dual-swab airlifting will be conducted immediately after the first treatment. Additional details regarding the dual-swab airlifting process are provided below.

2.1.5 Dual-Swab Airlifting

The dual-swab airlifting method helps to concentrate the surging action of the swab, and pumping brings loosened material out of the well instead of merely washing it back into the filter pack on the down stroke (Smith, 1995). The tool used for this method consists of a 1-inch airline inside of a 4-inch eductor pipe attached to an open center double surge block. The double surge block will consist of two surge tools connected to each other by a 10-foot long, 4-inch diameter slotted pipe. The educator fitting is installed above the surge blocks inside the pipe. Through the airline, air is pumped down inside the eductor pipe from the surface and past the mouth of the educator pipe causing a vacuum in the surge zone which allows water and solids to be brought to the surface. This method involves moving the dual-swab tool up and down within the well over an approximately 10-15 foot interval while simultaneously pumping the well.

This pumping method requires adequate submergence of the airline to effectively lift the water to the surface for discharge. The pumping rate is dependant on the percent submergence of the airline below the water level present during pumping. For example, using the equipment listed above, at 80% submergence (i.e., casing water level of approximately 43 ft bgs in the OU-1 injection wells) a pumping capacity of 175 gallons per minute (gpm) could be achieved. The average water level observed in the OU-1 source area is approximately 200 ft bgs. In order to achieve pumping rates between 75 and 175 gpm at the shallowest screen level (i.e., 215 ft bgs) in the OU-1 injection wells, pump submergence between 40% to 80% would be required. This approach assumes casing water levels of between 129 to 43 ft bgs, respectively. During past attempts to artificially recharge the existing OU-1 injection wells while performing dual-swab airlifting, injection from the OU-1 treatment system was unsuccessfully attempted due to the low flow rates caused by the lack of equipment to direct the injection water down the casing while performing this development technique. Therefore, during future dual-swab airlifting, a well-head adaptor consisting of an appropriately sized T-sweep will be used to connect the injection line to the well-head. Using this equipment, the injection water will be directed into the casing while the dual-swab airlift tool is inserted through the top of the adapter. To the extent possible, water from the OU-1 treatment plant will be injected into the well in an attempt to create an artificial head (i.e. artificially raising the water level in the well through injection). System flow meters will be used to quantify and regulate flow into the well casing. Using water level measurements taken from inside the well, the flow control valve will be slowly opened until the maximum submergence (i.e., 80%) of the airline is achieved or the flow control valve is fully open.

The dual-swab tool will be inserted into the well and set at the top 10 feet of the screened zone (i.e., 215 – 225 ft bgs). Airlift pumping will occur at the maximum rate possible for a period of approximately 40 minutes or until the turbidity of the purge water is less than ≤ 5 NTU. Due to the turbidity of the airlifted water, the initial water will be pumped into a settlement tank before transferring to a containment tank. The dual-swab airlift equipment will be raised and lowered throughout the screened zone. During the airlift pumping, the air supply will be periodically shut off allowing the water column to flow back through the screen. The combination of swabbing, pumping and surging enhances the removal of trapped material in the screened zone and filter-pack.

Upon completion of dual-swab airlifting, a second mud dispersant treatment/dual-swab airlifting process may follow.

2.1.6 Conventional Surge Pumping

Conventional pump development involves pumping and surging the wells at a variety of rates until no further sand, turbidity, and drawdown declines are observed. Surge pumping will be attempted at up to 1.5 times the design capacity of the injection or extraction well. Therefore, the injection and extraction wells will be pumped at a rate of 300 gpm.

Conventional surge pumping will involve inserting a submersible pump (performance ≥300 gpm; without a back-flow preventer) into the well and set near the bottom of the screened interval. Pumping will begin at a rate at or near the pumping rate achieved during dual-swab airlifting. Throughout this process, starting with the initial pumping and each increase in pumping rate, the pump will be shut-off and the water in the discharge line allowed to drain back into the well and formation creating a surging effect.

Pumping and back-flushing will be repeated with incremental pumping rate increases of 75 gpm, until the maximum pumping rate of 300 gpm is achieved. Each pumping cycle will include back-flushing three times followed by continuous pumping for approximately 45 minutes. An in-line totalizer gauge will be used to measure the total purge water removed from the well.

While pumping, water quality parameters, including pH, conductivity, oxidation-reduction potential (ORP), temperature, dissolved oxygen (DO), and turbidity will be collected at least once every half hour and noted in the field book. Pumping will continue at 300 gpm until the water is observed by the field personnel to be clear and free of debris. At this point, parameter readings will be collected every three minutes using a handheld field meter and a flow through cell. Pumping will continue until the parameters stabilize (i.e. three successive readings within ±0.2 for pH, ±5% for conductivity, ±20 millivolts (mV) for ORP, ±3% for temperature, ±0.2 mg/L for DO, and ±10% for turbidity [should be ≤5 NTU)]). Upon parameter stabilization, development of the extraction well will be considered complete.

Turbid water produced during this process will be pumped into an intermediate tank for sediment settling, before being pumped into an open topped water storage tank. The open topped water tank is important to facilitate easy cleaning of the tank before being returned to the tank vendor.

2.1.7 Injection Development (Injection Well Only)

Due to the specialized use of the injection well, one additional development step will be completed. This step involves injection of water at a rate at or above the design injection rate (e.g. 200 gpm maximum) followed by pumping. During injection development, the well is continually clogged through injection, then unclogged through pumping, removing the mobile material that moved during the injection. The gravel-pack and formation are re-packed to withstand forces away from the well bore (injection).

Injection development will be attempted by using an isolation pump tool consisting of a pump located in the pipeline between a dual-swab packer assembly. The dual-swab packers will be connected to a 3-inch diameter injection/extraction pipe attached to a nearby fire hydrant or the OU-1 injection pipeline, if available. Using this equipment, water will be injected from the surface and recovered utilizing the down well pump. Injection intervals up to 30 minutes followed by pumping intervals up to 40 minutes will be attempted until turbidity readings of ≤5 NTU are achieved. In an attempt to assess the maximum injection capacity of the well, an injection flow control valve will be set at the maximum discharge rate and groundwater levels will be monitored and recorded. Injection rates will be monitored using a flow meter attached inline from the water source.

2.1.8 Waste (Development Purge Water and Sediment)

When developing a well that has been drilled using the mud rotary process, the drilling mud is removed from the borehole prior to removing the drilling equipment from the borehole. However, residual drilling mud can remain in the borehole and the formation. During the initial development process at other wells at the JPL facility, it was noticed that the purge water was highly turbid. Therefore, it is crucial to allow the sediment to settle out of the initial purge water in an open-top container. After the sediment has sufficient time to settle to the bottom of the container, the clear water will then be decanted into a second container for holding prior to final disposition. This process will be employed during the initial development of the wells at the JPL facility.

Sediment (e.g., sand, silt, clay, etc.) that has been removed during bailing and airlifting activities will be placed directly into 55-gallon Department of Transportation (DOT) approved steel drums. The containers will be labeled as stated in Section 1.3.6 above. The drums will be temporarily stored at the JPL facility pending disposal classification. The method of disposal will be determined based on the analytical results from soil samples collected from the respective boreholes during drilling and well installation activities.

Clear water and water that has been treated with Aqua-clear^{TM} PFD has been successfully processed by the water treatment system in the past and will be processed in the same manner in future well development or rehabilitation activities.

2.2 Injection Testing

At the completion of the development, the injection well will be tested to develop an operational baseline for future performance tracking and maintenance. Data collected during this test will be used to measure the hydraulic response to injection cycles. A step injection well test will be conducted to estimate the maximum injection capacity of the well and the response of the aquifer system to the stresses during injection. The maximum injection test pumping rate is dependent upon the capacity of the OU-1 treatment system. Depending on the injection capacity of the well, the injection test may be conducted under pressurized conditions. During the test, the initial injection rate will be set at 150 gpm. Once the groundwater level in the injection well has stabilized, the injection rate will be incrementally increased, potentially up to the maximum injection rate or up to the capacity of the system, whichever is achieved first.

During the injection test, flow rates will be recorded every 10 minutes using an in-line flow totalizer. Groundwater levels will be recorded with a pressure transducer placed in the well and in the two closest standpipe groundwater monitoring wells. The pressure transducers will be programmed to take incremental readings throughout the entire testing procedure. This data will be used to create a water level rise curve that demonstrates the mounding of the groundwater in the vicinity of the injection well.

2.3 Inorganic and Organic Analyses

Following the completion of well development, groundwater samples will be collected from the discharge pipeline for inorganic and organic analysis. Results of these analyses are used to determine the clogging potential, encrustation or corrosion potential, and identify the types of organisms that are present in the groundwater that may lead to biofouling. These data will be used to define the baseline conditions in the aquifer and subsequent analyses will be used to evaluate the presence of biofouling, establish trends associated with changes in the groundwater over time, and provide useful information relating to well maintenance and rehabilitation requirements (e.g., chemical treatments).

The physicochemical (inorganic) data analyses include Phenolphthalein Alkalinity (Standard Method (SM) 2320), pH (SM 4500-H^+), Chlorides (SM 4500-Cl^-), Total Dissolved Solids (TDS), Total Hardness (SM 2340/EDTA), Carbonate Hardness (Calculated), Non-carbonate Hardness (Calculated), Calcium (SM 3500-Ca), Magnesium (SM 3500-Mg), Phosphate (SM 3500-P), Iron (SM 3500-Fe), Copper (SM 3500-Cu), Nitrate (SM 3500-NO_3^-), Tannin/Lignin (SM 5550), Sulfate (SM 4500-SO_4^{2-}), Silica as SiO_2 (SM 4500-SiO_2), Manganese (SM 3500-Mn), Saturation Index, and Redox Potential (SM 2580). Descriptions of the physicochemical analytical methods are provided in Table 2.

The biological assay analyses will include assessment of the total bacterial count per milliliter (SM 9211/Bioluminescence Test), the anaerobic bacterial load on the system (SM Modified 9221B), the presence of sulfur reducing bacteria (SM 9240D/9221C), the presence of iron oxidizing bacteria, branching or filamentous bacteria, protozoans (SM 9215 D, SM Modified 9221B, SM 9211/Bio-luminescence Test), and the identification of the two largest populations of bacteria present (Method Biolog Microlog System). These data will be used to determine the types of organisms that are present in the well as a baseline for later biofouling evaluation.

Table 2. Summary of Physicochemical Methods Relevant to Well Maintenance

Constituent Analysis	Purpose of Analysis
Fe (total, Fe^{2+}/Fe^{3+}, Fe minerals and complexes)	Indications of clogging potential, presence of biofouling, Eh shifts. Fe transformations are the most common among redox-sensitive metals in the environment
Mn (total, Mn^{4+}/Mn^{2+}, minerals and complexes)	Indications of clogging potential, presence of biofouling, Eh shifts. Less common but locally important in some wellfields.
S (total, $S^{2-}/S^0/SO_4^{2-}$, S minerals and complexes)	Indications of corrosion and clogging potential, presence of biofouling, Eh shifts.
Eh (redox potential)	Direct indication of probable metallic ion states, microbial activity. Usually bulk Eh, which is a composite of microenvironments.
pH	Indication of acidity/basicity and likelihood of corrosion and/or mineral encrustation. Combined with Eh to determine likely metallic mineral states present.
Conductivity	Indication of TDS content and a component of corrosivity assessment.
Major ions	Carbonate minerals, F, Ca, Mg, Na, and Cl determine the types of encrusting minerals that may be present and are used in saturation indices. One surrogate for many cations in total hardness.
Turbidity	Indication of suspended particles content, suitable for assessment of relative changes indicating changes in particle pumping or biofouling.
Sand/silt content (v/v, w/v)	Indication of success of development/redevelopment, potential for abrasion and clogging.

Note: Generally, the Fe^{2+}/Fe^{3+} ratio (easily measured using conventional field analysis instruments) is the most useful. In some settings, Mn oxidation (resulting in more difficult-to-remove minerals) and the sulfur system may be dominant.
U.S. Army Corps of Engineers, 2000

2.4 Video Survey

Upon completion of well development and during each well maintenance event, a video survey will be completed in the wells to confirm the "as-built" construction of the well, to inspect for any damage (i.e., casing breaks, holes, etc.), examine the screened zone to ensure the well has been properly developed, and assess the well for potential fouling elements (e.g., biological growth, mineralization, and sedimentation). During a down-hole video survey, a camera is lowered into the well and the image is observed on a video monitor and simultaneously recorded on a VHS tape (which can be transferred to a DVD once the log is complete). The depth of the camera is superimposed onto the video image and is also recorded. Once the log is completed, three hardcopy reports (including photos), and three color video log (VHS and DVD) copies will be obtained and stored onsite.

2.5 Spinner Log

Spinner probes are commonly used in water-producing wells to measure well hydraulics (i.e., water flow patterns). A static spinner log is conducted with the well pump equipment turned off while the groundwater is under static conditions. Conversely, a dynamic spinner log is completed while the well pump is operating under normal conditions. The flow log reveals zones where water enters and exits the well screen and allows for flow contributions from individual zones to be measured and documented. Spinner log data are correlated with geophysical log data (i.e., single-point resistance log) and the lithologic log from the well installation to evaluate flow conditions within the well during static and pumping (dynamic) conditions (extraction wells only). This information is then used to identify specific zones within a well that have higher flow potential.

A static spinner log will be completed in the injection well. Both a static and dynamic spinner log will be attempted in the extraction well. Based on the results of the spinner log analysis, depth discrete groundwater samples will be collected from high flow zones (if present) within the extraction well to create a baseline vertical contaminant profile. These data, combined with similar data collected in the future, can be utilized during system optimization evaluations for repositioning the extraction pumps to target zones that exhibit higher levels of site chemicals of concern. Because pumping equipment is not planned for the injection wells, dynamic spinner logging will not be conducted.

2.6 Well and Pump Performance Monitoring

Deteriorating conditions in wells can be complex and a result from a number of factors. The screens can become clogged with fine-grained sediment, air, mineral deposits, or biological/bacteria growth. The best way to combat these factors is to recognize them early and identify an appropriate and effective maintenance plan. Tests should be done to detect the electromechanical, physical, chemical, and microbial conditions within the well. Record-keeping of pumping and well service is also essential. Table 3 lists important information that should be collected during performance monitoring.

To facilitate the performance monitoring program for the OU-1 wells, background injection and extraction well data are critical. Therefore, the following records will be kept onsite and available for review for the preventive maintenance program:

- Physical locations and “as-built” descriptions of wells and equipment
- As-built diagram of the well’s construction, with any modifications over time
- Lithologic logs, well drilling and construction logs, and any other logging data (i.e. geophysical logs) applicable to the well drilling and design
- Development logs (to provide benchmark data), available laboratory analytical data collected during development
- Records of pumping/injection tests (aquifer and slug tests) and geophysical structure (i.e. spinner log)
- Dates of replacement of components, manufacturer and type of component
- Electrical, power and pump mechanical information

- Water quality data from wellhead samples, plus biofilm collector results, listed by date
- Details of well rehabilitation activities, including dates, diagnosis, if any, treatment methods, results, time involved, and costs
- Color borehole TV survey videotapes/DVDs.

In addition to the data listed above, the system operator will collect the following information and data in order to observe and track injection and extraction system performance and efficiency:

- Water levels will be manually collected with a water level probe weekly from the wells surrounding the extraction and injection wells
- Injection and extraction well water levels will be taken daily with pressure transducers and weekly readings will be collected manually
- System and motor electrical testing (i.e. circuit voltage [V], motor amperage [A], phase [Φ], and resistance ohms [Ω]). Meters will be installed and the data will be manually collected by the system operator
- Well head pressure readings (i.e. injection pressure)
- Injection and Extraction flow rates (daily and at any rate change)
- Inorganic and organic analyses will be conducted following development and rehabilitation. Inorganic analyses include alkalinity, pH, chlorides, total dissolved solids (TDS), total hardness, Ca, Mg, phosphate, Fe, Cu, nitrate, tannin/lignin, sulfate, Si, Mn, saturation index, and redox potential. Organic analyses include total bacteria per milliliter, anaerobic bacterial load on the system, the presence of sulfur and/or iron reducing bacteria, the presence of iron oxidizing bacteria, protozoans, and the identification of the two largest populations of bacteria.

Measuring water levels is important in determining well discharge or acceptance into the aquifer as well as monitoring mounding (injection wells), or drawdown (extraction wells). In addition, monitoring water levels/injection pressure in the injection wells can indicate clogging of the filter pack and screened zone.

Monitoring the system's electrical power is important to detect problems within the electrical system and prevent excessive motor aging, poor performance, and maintaining motor and system efficiency.

Monitoring well head pressure and injection/extraction flow rates can indicate well efficiency. Lower flow rates may be indicative of inefficient pump performance or screen and filter pack clogging. Table 4 provides a description of the causes of poor well performance.

Table 3. Performance Monitoring

Task	Description	Frequency	Records	What does data indicate?
Water Levels	Manual collection of water levels in wells surrounding injection and extraction wells.	Weekly	Field book	Determines well discharge or acceptance into the aquifer as well as mounding (injection wells), or drawdown (extraction wells).
Injection and Extraction Water Levels	Pressure transducer readings of water levels and wellhead pressure.	Daily	Field book	Water levels can also indicate clogging in the filter pack and screened zone.
Injection and Extraction Flow-rates	Automatic flow readings collected at system control panel.	Daily	Field book	Lower flow rates may indicate clogging or biofouling.
Inorganic and Organic Analyses	Laboratory data analyses of physicochemical and biological assay components of injection and extraction system water. The results indicate the correct treatment of the well during rehabilitation (i.e. chemical treatments).	Quarterly	Lab report	Physicochemical analyses indicate corrosion or encrustation potential (long-term tracking can show increases and decreases over time) and biological assay indicates biofouling, the types of organisms present, and long-term monitoring shows increases and decreases in biofouling.
Electrical	System and motor electrical testing (circuit voltage [V], motor amperage [A], phase [Φ], and resistance ohms [Ω]).	Daily readings	Field book	Detect problems within the electrical system and prevent excessive motor aging, poor performance, and maintaining motor and system efficiency.

Table 4. Definitions of Poor Well Performance and Causes

Problems	Causes
Sand/Silt Pumping: Pump and equipment wear and plugging.	Inadequate screen and filter-pack selection or installation, incomplete development, screen corrosion, collapse of filter pack due to washout resulting from excessive vertical velocity in the filter pack, presence of sand or silt in fractures intercepted by a well completed "open-hole," incomplete casing bottom seat (casing-screen break) or casing-screen break due to settlement, ground movement, or poor installation. Pumping in excess of gravel pack and system capacity (oversized pump, pipe breakage lowering pumping head, etc.).
Silt/Clay Infiltration: Filter clogging, sample turbidity.	Inadequate well casing seals, infiltration through filter pack, or "mud seams" in rock, inadequate development, or casing-screen break due to settlement, ground movement, or poor installation. Formation material may be so fine that engineered solutions are inadequate.
Pumping Water Level Decline: Reduced yields, increased oxidation, well interference, impaired pump performance.	Area or regional water-level declines, pumping in excess of sustainable well capacity, well interference, or well plugging or encrustation. Sometimes a regional decline will be exaggerated at a well due to plugging.
Injection water level rise and reduced acceptance rate or increased injection system head.	Area or regional water-level rise; injection in excess of sustainable well capacity; well plugging or encrustation; encrustation, plugging, or corrosion, and perforation of discharge lines; increased total dynamic head (TDH) in water delivery system.
Lower (or Insufficient) Yield: Unsatisfactory system performance.	Dewatering or caving in of a major water-bearing zone, pump wear or malfunction, encrustation, plugging, or corrosion and perforation of discharge lines, increased TDH in water delivery or treatment system.
Complete Loss of Production: Failure of system.	Most typically pump failure. Also loss of well production due to dewatering, plugging, or collapse.
Chemical Encrustation: Increased drawdown, reduced output or reduced injection acceptance rate.	Deposition of saturated dissolved solids, usually high Ca, Mg, carbonate, and sulfate salts or iron oxides, or FeII sulfides. May occur at chemical feed points, e.g., feeding caustic soda to raise pH into a Ca-rich water.
Biofouling Plugging: Increased drawdown, reduced output or reduced injection acceptance rate, alteration of samples, clogging of filters and lines.	Microbial oxidation and prescription of Fe, Mn, and S (sometimes other redox-changing metals that are low solubility when oxidized) with associated growth and slime production. Often associated with simultaneous chemical encrustation and corrosion. Associated with simultaneous chemical encrustation and corrosion. Associated problem: well "filter effect": samples and pumped water are not necessarily representative of the aquifer. Often works simultaneously with other problems such as silting.
Pump/Well Corrosion: Loss of performance, sanding, or turbidity.	Natural aggressive water quality, including H2S, NaCl-type waters, biofouling electrolysis due to stray currents. Aggravated by poor engineered material selection.
Well Structural Failure: Well loss and abandonment.	Tectonic ground shifting, ground subsidence, failure of unsupported casing in caves or unstable rock due to poor grout support, casing or screen corrosion and collapse, casing insufficient, local site operations.

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3.0 WELL REHABILITATION

When the performance monitoring data suggests decreases in injection or extraction well efficiency below the levels required to operate the OU-1 system, the well will require rehabilitation by chemical and/or mechanical means to return it to optimal flow rates. A brief summary of the steps involved during well rehabilitation are included in Table 5. The following sections provide descriptions and methods of well rehabilitation.

3.1 Equipment Removal and Inspection

The injection or extraction well should be shut-down a minimum of 24 hours prior to the removal of equipment in order to allow the well to return to a static condition. Power to the pumps should be secured using lock-out and tag-out procedure to prevent shock or electrocution. Injection well valves should be turned off to prevent water from leaking into the well vault. The electrical wires connecting the transducer or pump should be disconnected. The well head equipment will need to be disconnected from the well casing. Once completed, this equipment will be hoisted from the well using the development rig. Following removal, the field crew will document any discoloration on the piping, biological deposition or encrustation (i.e. slime), mineral growth and/or deterioration to the downwell equipment in the field notebook and take pictures as necessary. The removed equipment will be staged near the well site on plastic sheeting to minimize the potential for surface contamination.

3.2 Video Survey

A video log will be taken in order to determine the well condition. The extent of biofouling, sedimentation and encrustation will be documented. Notes will be taken including the depth to water, percentage of screen blockage (include depths, color and type of material), overall water quality, and damage to casing or screen. Section 2.4 provides a detailed description of the video survey process.

3.3 Inorganic and Organic Analysis

After the completion of the video log, physicochemical and biological assay data analyses will be collected. The results of these analyses will be compared to the baseline data that was collected during initial development of the well, and used to determine the nature of the problems and the countermeasures. Based on these data, rehabilitation and maintenance measures can be fine-tuned based on observed changes. Analytical methods used for these analyses are provided in Section 2.3.

The physicochemical (inorganic) data analyses include Phenolphthalein Alkalinity, pH, Chlorides, TDS, Total Hardness, Carbonate Hardness, Non-carbonate Hardness, Calcium, Magnesium, Phosphate, Iron, Copper, Nitrate, Tannin/Lignin, Sulfate, Silica as SiO_2, Manganese, Saturation Index, and Redox Potential. The Iron, Manganese, and Sulfur (total, Fe^{2+}/Fe^{3+}, Fe minerals and complexes, total, Mn^{4+}/Mn^{2+}, minerals and complexes, and total, $S^{2-}/S^{0}/SO_4^{2-}$, S minerals and complexes) are analyzed in order to predict the clogging potential, presence of biofouling, and redox potential shifts (Eh shifts). The analyses of pH indicate acidity or basicity which predicts corrosion or encrustation. In addition, pH is combined with Eh to determine the likely metallic mineral states present. Conductivity is used to indicate the total dissolved solids content and is a component of the corrosivity assessment.

The biological assay is used to determine the presence of biofouling, the types of organisms that are present, and if the well has increased or decreased in biofouling over time (based on long-term monitoring).

The biological assay analyses will include assessment of the total bacterial count per milliliter, the anaerobic bacterial load on the system, the presence of sulfur reducing bacteria, the presence of iron oxidizing bacteria, branching or filamentous bacteria, protozoans, and the identification of the two largest populations of bacteria present.

Groundwater samples will be collected from the injection water stream, screened zone (aquifer), and the extraction water stream prior to rehabilitation. The injection and extraction samples should be collected from the sampling ports, and the aquifer sample should be collected using a submersible pump. Biological assay samples do not require refrigeration if they are received by the laboratory within 24 hours of sampling. In addition, no preservatives are to be used in the sampling bottles.

3.4 Bailing

During this process, a suction bailer is lowered into the well until it fills with water and sediment. It is then pulled to the surface and emptied. Water from the aquifer will then flow towards the well and bring in more drilling fluid. The bailer's up and down motion causes a surging action which initiates development in the area around the screen.

Prior to initiating the bailing procedure, the water level, and total depth of well will be measured to the nearest 0.01 ft, noting the amount of sediment in the well (as compared to the total depth in the "as-built"). Next, the sediment will be removed from the bottom of the well using the suction bailer and the contents will be emptied into a 55 gallon drum. The color, clarity and smell of the water will be noted in the field notebook. After the sediment has been removed from the bottom of the well, the total well depth will be measured again. Throughout this process, purge water present in the 55-gallon drum will be decanted to a water storage container and the amount of material (i.e. sand/silt, etc.) present in the bottom of the drum will be noted (i.e., the amount of sediment removed from the well). The amount of accumulated sediment in the well should progressively decline following successive rehabilitation events. If similar increased sediment volumes are noted in a well during successive rehabilitation events, the OU-1 treatment system will be evaluated for debris discharge and/or more aggressive development methods will be considered.

3.5 Brushing

Brushing simply involves running a hard bristle brush up and down the length of the well screen to remove sediment encrusted on the well casing and screen. Similar to bailing, the up and down movement of the brush produces a surging effect, continuing the development process. Section 2.1.2 includes a detailed description of the brushing process.

3.6 Biofouling Treatment

Following the completion of brushing and bailing, a chemical solution is applied to the well to facilitate the breakdown of biofilm, and to disperse mineral salts that are present in the well screen and the filter pack. The chemical treatment will be applied following the manufacturer's recommendations.

To ensure the proper distribution of the chemical treatment in the screened zone, the treatment mixture will be tremied into the upper, middle, and bottom third of the well screen. To improve the effectiveness of the chemical treatment, the well will be swabbed every two hours. The agitation caused by swabbing ensures the distribution of the chemical treatment through the screened zone and filter-pack. The solution should remain in the well between 18 to 48 hours depending on the severity of the biofouling and/or encrustation. In addition, it's important that the pH of the treatment solution stay below 2.0. If the chemical mixture is left in the well overnight, a water and acid mixture should be added to the well to ensure that the pH remains below 2.0. The following morning, the pH should be tested and, if it is greater than 2.0, it should be lowered with the acid and water mixture. After this has been completed, the well should be swabbed for at least one hour.

Next, an airlift pump system will be lowered into the bottom of the well to remove the chemicals, biofilm and mineral salts. During the airlift pumping process, the pH of the discharge water will be monitored, and the airlifting will continue until the pH of the discharge water is >5.

Upon completion of the airlifting, a second chemical treatment will be performed, as described in the section above.

3.7 Mud Dispersant

In contrast to initial well development, during well rehabilitation only one mud dispersant treatment will be performed (however, in some cases [e.g., excessive drilling mud present in the well] a second treatment will be necessary). In theory, the mud dispersant treatment will follow the completion of the initial rehabilitation steps of brushing, sediment removal, and biofouling treatment. In order for the mud dispersant to penetrate into the filter pack and beyond, fouling materials (i.e. biological growth, mineral encrustations, etc.) need to be removed and the available flow paths restored.

Section 2.1.4 provides a detailed discussion regarding the mud dispersant application and removal process.

3.8 Dual-Swab Airlift

During well rehabilitation, dual-swab airlifting will be utilized after the mud dispersant treatment application to remove accumulated sediment and groundwater containing the treatment chemicals. Groundwater containing the treatment chemicals will be removed to the extent practical to minimize potential impacts to the treatment system (e.g., downgradient extraction).

Initially, the dual-swab tool will be inserted into the well and set at the top 10 feet of the screened zone (i.e., 215 – 225 ft bgs). Airlift pumping will occur at the maximum rate possible for a period of approximately 40 minutes or until the turbidity of the purge water is less than ≤ 5 NTU. Due to the turbidity of the airlifted water, the initial water will be pumped into a settlement tank before being transferred to a containment tank. The dual-swab airlift equipment will be raised and lowered throughout the entire screened zone. During the airlift pumping, the air supply will be periodically shut off allowing the water column to flow back through the screen. The combination of swabbing, pumping and surging enhances the removal of trapped material in the screened zone and filter-pack.

Upon completion of dual-swab airlifting, a second mud dispersant treatment/dual-swab airlifting process may follow. Section 2.1.5 provides a detailed description of the equipment used during the dual-swab airlifting process.

3.9 Conventional Surge Pumping

This stage of rehabilitation involves pumping and surging the wells at a variety of rates until no further sand, turbidity, and drawdown declines are observed. Section 2.1.6 provides a detailed description of conventional pump development.

3.10 Equipment Re-installation

Using the development rig, the PVC casing (injection well) and steel casing and pump (extraction well) will be reset into the well. Once the equipment is lowered into place, the well head flange plates will be bolted, and associated piping reconnected to the injection or extraction line. The electrical wires connecting the transducer or pump should be re-connected, and tested. Finally the equipment should be leak tested and injection and extraction rates tested.

3.11 Waste (Rehabilitation Water and Sediment)

Purge water that is generated during the rehabilitation process will be highly turbid, and in some cases may contain acid or mud dispersant chemicals. Without treatment, water that has been treated with acid to remove biofouling and/or scaling is not compatible with the fluidized bed reactor water treatment system at OU-1. Therefore, prior to processing this water through the OU-1 treatment plant, the purge water will be stored in appropriate containers, sediment will be allowed to settle out, and the water will be neutralized (i.e., pH = 7). After the water is neutralized, it will process through the OU-1 treatment system and be reinjected into the aquifer.

Section 2.1.8 describes the procedure for dealing with the solid and liquid waste that is generated during the well development and well rehabilitation process.

3.12 Injection Testing

At the completion of the well rehabilitation, the injection well will be tested to determine the success of the rehabilitation procedure. Data collected during this test will be used to measure the hydraulic response to injection cycles. A detailed description of the procedure is described in Section 2.2.

Table 5. Well Rehabilitation

Task	Description	Time
Well Shutdown	Turn off well and associated valves 24 hours prior to equipment removal.	24 hours in advance.
Equipment Removal and Evaluation	Disconnect electrical equipment, disconnect well head plumbing, remove injection well piping or extraction well piping, and pull equipment from well. Note any discoloration, fouling, encrustation, and overall condition of equipment removed from the well.	½ day (4 hours)
Inorganic and Organic Analyses	Collection of water samples for inorganic and organic laboratory analyses.	2-3 hours
Video Log	Video log of well casing and screen to determine well conditions. Note clarity of water column, biofouling, encrustation, and percentage of screen clogging.	2-3 hours
Bailing	Bail solids from bottom of well with suction bailer.	2-3 hours
Brushing	Brush well from top to bottom in 20 foot intervals for 20 minutes each.	100 foot screen should be brushed for 100 minutes.
Bailing	Bail solids from bottom of well with suction bailer.	2-3 hours
Biofouling Chemical Treatment	Bioacid dispersant and acid treatment introduced to well screen and agitated.	18 – 48 hours
Airlifting	Swabbing, surging, and airlifting (75-175 gpm) near bottom of screened zone (e.g. 305’ btoc) .	Pumping will occur at the bottom of the screened zone until the pH of the discharge water is ≥ 5.
Biofouling Chemical Treatment	Second bioacid dispersant and acid treatment introduced to well screen and agitated.	18 – 48 hours
Airlifting	Swabbing, surging, and airlifting (75-175 gpm) near bottom of screened zone (e.g. 305’ btoc).	Pumping will occur at the bottom of the screened zone until the pH of the discharge water is ≥ 5.
Bailing	Bail solids from bottom of well with suction bailer.	2-3 hours
Mud Dispersant	Mud dispersant treatment added to well. Surge tool raised and lowered in well to agitate and mix dispersant distributing treatment into filter pack and borehole.	2 hours adding treatment to well. Well swabbed every two hours up to 24 hours; followed by removal.
Dual-Swab Airlifting	Swabbing, surging, and airlifting (75-175 gpm) of screened zone at select 10 foot intervals.	Pumping will occur at top of screened zone for 40 minutes (or until turbidity is ≤ 5 NTU) at a maximum pumping rate (between 75 – 175 gpm). The dual-swab airlift equipment will be raised and lowered throughout the screened zone. During airlifting the air supply will be shut off to surge the screen.
Bailing	Bail solids from bottom of well with suction bailer.	2-3 hours
Mud Dispersant and Dual-Swab Airlifting	Repeat two above steps (if necessary)	Same as above.

Table 5. Well Rehabilitation (continued)

Task	Description	Time
Conventional Pumping	Submersible pump is lowered into well and saturated zone is overpumped and surged.	Pump set at 300’ and pump at max. rate achieved during airlift (i.e. 175 gpm) for 45 minutes
		Surge three times
		Pumping at 300’; pumping rate increased by 50 gpm to 225 gpm for 45 minutes
		Surge three times
		Pumping at 300’; pumping rate increased by 50 gpm to 275 gpm for 45 minutes
		Surge three times
		Pumping at 300’; pumping rate increased by 25 gpm to 300 gpm for 45 minutes
		Surge three times
Equipment Re-installation	Equipment is re-installed into well, and well is performance tested.	4 – 6 hours
Injection Testing	Step injection test; water is pumped into the aquifer for up to 10 hours, and water levels are monitored in injection and nearby wells. The pumping rate is tested at 75 gpm, 150 gpm, and the maximum injection rate, respectively, until the water level change is less than ± 1.0 feet or ± 2.31 psi.	Injection at 75 gpm Injection at 150 gpm Injection at maximum injection rate

4.0 SELECTED REFERENCES

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Smith, S.A. 1995 “Monitoring and Remediation Wells: Problem Prevention, Maintenance, and Rehabilitation.” Taylor & Francis, London.

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ATTACHMENT 1

PERFORMANCE LOG

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Source Area Demonstration Study Well Performance Log

1. Electrical			
Date:	Time:		Comments
Circuit Voltage (V):	Phase (Φ):		
Amperage (A):	Resistance Ohms (Ω):		
2. Injection and Extraction Water Levels			
IW-1	**IW-2**	**IW-3**	Comments
Time:	Time:	Time:	
DTW:	DTW:	DTW:	
EW-1	**EW-2**	**EW-3**	Comments
Time:	Time:	Time:	
DTW:	DTW:	DTW:	
3. Injection and Extraction Flow Rates			
IW-1	**IW-2**	**IW-3**	Comments
Time:	Time:	Time:	
Flow Rate:	Flow Rate:	Flow Rate:	
EW-1	**EW-2**	**EW-3**	
Time:	Time:	Time:	
Flow Rate:	Flow Rate:	Flow Rate:	

Field Team Leader Signature____