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OU-1 Optimization Installation Report

National Aeronautics and Space Administration
Jet Propulsion Laboratory
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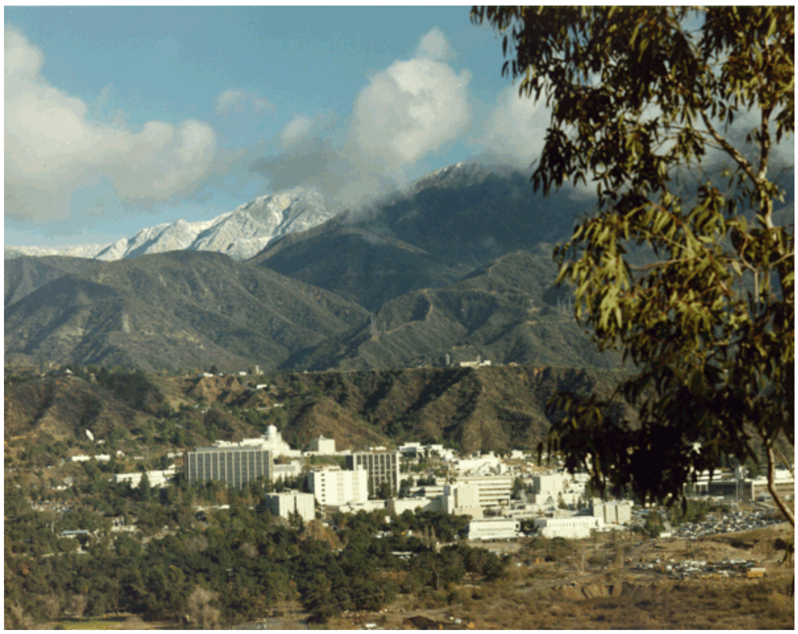;

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FIGURES

TABLES

APPENDICES

amsl	above mean sea level
bgs	below ground surface
CA DWR	California Department of Water Resources
Cascade	Cascade Drilling
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CPU	central processing unit
DO	dissolved oxygen
DOT	Department of Transportation
EAO	Environmental Affairs Office
EMT	Environmental Management Technologies
Evoqua	Evoqua Water Technologies
EW	extraction well
FBR	fluidized bed reactor
ft.	feet
GACIN	system influent
gpm	gallon per minute
HP	horsepower
I.D.	inside diameter
I/O	input/output
IX	ion exchange
JPL	Jet Propulsion Laboratory
LGAC	liquid-phase granular activated carbon
MCL	maximum contaminant level
NASA	National Aeronautics and Space Administration
NPL	National Priorities List
O.D.	outside diameter
OU	Operable Unit
PLC	programmable logic control
POC	point of contact
PVC	polyvinyl chloride
RD/RA	Remedial Design/Remedial Action

ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
Sch	schedule
TFOUT	system outlet
USA	Underground Service Alert
U.S. EPA	United States Environmental Protection Agency
USCS	Unified Soil Classification System
VOC	volatile organic compound

1. INTRODUCTION

This report was prepared for the National Aeronautics and Space Administration (NASA) to document Operable Unit 1 (OU-1) optimization installation activities at the Jet Propulsion Laboratory (JPL). The NASA-JPL site is on the United States Environmental Protection Agency (U.S. EPA) National Priorities List (NPL), and subject to the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA). Optimization of OU-1 included the installation of a fourth extraction well (EW), installation of an ion exchange (IX) system to transition perchlorate treatment at the Source Area Treatment System from a fluidized bed reactor (FBR) to IX for long term operation, and the abandonment of a monitoring well, MW-2. The optimization activities at OU-1 are considered a voluntary enhancement to NASA's overall treatment approach. In this optimization, NASA directly administered the work associated with designing, permitting, and constructing the well and associated infrastructure. Activities associated with OU-1 optimization were completed in accordance with the regulator approved Final OU-1 Optimization Work Plan (NASA, 2018b).

The remainder of this report is divided into 11 sections. Section 2.0 describes OU-1 treatment system optimization at JPL. Section 3.0 describes new extraction well installation and Section 4.0 describes the new extraction well development activities. Section 5.0 presents infrastructure improvements. Section 6.0 presents EW-4 startup and testing. Section 7.0 describes system monitoring. Section 8.0 presents treatment system transition preparation and Section 9.0 presents system shakedown testing. Section 10.0 describes MW-2 abandonment. Section 11.0 includes references. Appendices 3-1 through 3-12 contain information pertaining to well construction activities. Appendices 4-1 through 4-6 pertain to well development activities. Appendices 5-1 through 5-3 contain documentation pertaining to construction activities. Appendices 6-1 through 6-5 include EW-4 pump installation and well redevelopment activities. Appendix 7-1 presents analytical laboratory reports. Appendix 8-1 and 8-2 presents details about the lowering the EW-4 submersible pump. Appendix 9-1 presents the construction as-builts and Appendix 9-2 presents a blank OU-1 treatment system daily logsheet. Appendices 10-1 through 10-4 presents MW-2 abandonment details.

2. SOURCE AREA TREATMENT SYSTEM OPTIMIZATION

The objectives of the OU-1 system optimization were to:

- Reduce life-cycle costs associated with the OU-1 system
- Optimize system operations and increase mass removal
- Provide flexibility to treatment system operations

Two primary optimization concepts were implemented for the OU-1 treatment system to improve effectiveness and operability: (1) installation of a new extraction well for enhanced perchlorate removal in OU-1 source area groundwater and (2) switching from biological treatment using FBR to physical treatment of perchlorate using IX for OU-1 source area groundwater. A third task completed during the OU-1 optimization effort was the abandonment of an existing monitoring well (MW-2).

As was stated in the OU-1 optimization work plan (NASA, 2018), installation of new wells and implementation of modified treatment processes were anticipated and documented as post-construction refinements in Section 12.2 of the approved Final Record of Decision (ROD; NASA, 2018a). As such and based on the U.S. EPA guidance (U.S. EPA, 1999), the new well and IX system fall within the category of *Minor Changes*. Minor changes are documented with a memorandum to the post-ROD administrative record file available at https://jplwater.nasa.gov/. The OU-1 Optimization Work Plan (NASA, 2018b) served this purpose.

The new extraction well, EW-4, was installed east/northeast of MW-13 and south-southwest of existing EW-3 (see Figure 2-1). The new IX equipment is located at the Source Area Treatment Plant.

Figure 2-1. Source Area Treatment System Expansion Layout

3. NEW EXTRACTION WELL INSTALLATION

In June 2018, NASA submitted a final Optimization Work Plan (NASA, 2018b) describing the rationale and work elements associated with OU-1 optimization. The new extraction well and IX system are considered a voluntary enhancement to NASA's overall treatment approach. All work activities associated with drilling, well construction, and well development/testing were conducted in accordance with the approved work plan. Well drilling and construction were completed June through July 2018. The well was designed by a State of California licensed professional geologist and well construction activities were conducted by State of California licensed drilling company.

Extraction well installation activities are described in the following subsections.

3.1 Preliminary Work (Geophysical Utility Survey)

Prior to performing any subsurface activities, the well location was scanned for underground utilities using geophysical methods. The initial survey was conducted by Spectrum Geophysics June 9, 2017 and spot checked again June 22, 2018. The utility-locating contractor employed several methods, including ground-penetrating radar, magnetometer, magnetic gradiometer, and/or electromagnetic imaging. The contractor field marked the ground surface with color-coded paint based on the type of utilities identified during the survey (i.e., red = electric, blue = water, green = sewer, yellow = gas, orange = communications, pink = unknown subsurface anomaly or detection, etc.). As required by California State law, Underground Services Alert (USA) was notified of the planned drilling activities. USA is a communication center that provides notice to utility owners that may potentially have underground utilities within the proposed well sites. USA requires notification a minimum of 48 hours prior to conducting any underground excavation. Following map review, geophysical utility locating, and USA clearance, the surface of the ground was clearly marked where underground utilities were discovered. The drilling location was selected to avoid impact to existing utilities and was consistent with the location described in the work plan. A utility map prepared by the Spectrum Geophysics is included in Appendix 3-1.

3.2 Drilling and Well Construction

3.2.1 Borehole Clearance

On June 25, 2018 Cascade Drilling (Cascade) employed a Vacmaster® System 3 air-vacuum excavation system (i.e., air knife rig) to excavate a 25-inch by 25-inch borehole to a depth of 10 feet (ft). This method ensured that no underground utilities or obstructions were present. Soil cuttings were logged continuously by the site geologist and the excavated soil was placed into Department of Transportation (DOT)-approved soil roll-off bins.

3.2.2 Mobilization

On June 25, 2018 Cascade mobilized mud rotary drilling equipment to the site including, but not limited to, GEFCO Speedstar 50K mud rotary drill rig, pipe truck, support truck, equipment trailers, shaker table, hoses, plumbing, drill collars, drill bits, forklift, compressor, generator, pumps, drilling fluid supplies, etc.

3.2.3 Pilot Borehole Drilling

Cascade began pilot borehole drilling June 26, 2018 utilizing the mud rotary drilling method with a 9.875-inch diameter bit. In this drilling method, the drilling fluid moves down the drill string and exits the bit. The fluid lubricates and keeps the bit cool. The drilling fluid flows up the annular space between the drill pipe and borehole wall while transporting the cuttings to the ground surface. The fluid is pumped to the shaker table where the cuttings are separated into a hopper and the drilling fluid passes through the screen into a mud tank where it is recirculated down the drill string. During drilling operations, the drilling fluid was monitored every 50 ft for viscosity, weight, wall cake thickness, water loss, sand content and pH. This monitoring provided the driller with the ability to maintain borehole stability, fluid loss, and equipment integrity. The separated mud was recycled into the drilling process and the cuttings were stored in a roll-off bin. Copies of the daily driller's logs are presented in Appendix 3-2. The processed soil cuttings were removed from the hopper and stored in roll-off bins. The pilot hole was drilled to a depth of 320 feet below ground surface (bgs) on June 28, 2018. A picture from pilot hole drilling is provided as Figure 3-1. Drilling operations are summarized in Table 1.

Table 1. Pilot Hole Drilling Summary

Date	Description	Drilling Depths
June 25, 2018	Air knifed and set temporary steel casing	0 to 10 ft bgs
June 26, 2018	Drilled pilot hole with 9.875-inch diameter bit	10 to 120 ft bgs

Date	Description	Drilling Depths
June 27, 2018	Drilled pilot hole with 9.875-inch diameter bit	120 to 230 ft bgs
June 28, 2018	Drilled pilot hole with 9.875-inch diameter bit and performed geophysical logging	230 to 320 ft bgs

Figure 3-1. Pilot Hole Drilling

3.2.4 Borehole Logging

During pilot borehole drilling, soil samples were collected from the mud shaker for lithologic logging purposes and placed into gallon sized zip lock bags. The soil samples were logged by licensed professional geologist using the Unified Soil Classification System (USCS). Drill cuttings were evaluated after every 5 feet or less of drilling and described to document the underlying stratigraphy. Lithologic descriptions of the soil cuttings were recorded on the field boring log form and included the following information: physical characterization and grain-size distribution of the sample, stratigraphic boundaries, color changes, thickness of individual units, samples or cuttings collected, odor and any other conditions encountered during drilling (i.e., changes in drilling rate, difficulties, etc.). The boring log is presented in Appendix 3-3.

3.2.5 Geophysical Logging

On June 28, 2018, upon completion of the pilot borehole drilling, the open borehole was logged by Pacific Surveys, LLC, using geophysical methods to assist the field geologist with the identification of borehole lithologies, water-bearing intervals, and stratigraphic correlation with existing JPL monitoring wells and nearby extraction and injection wells. During the geophysical logging, the sides of the open borehole were held in place by the hydrostatic pressure of the drilling mud, which remained in place throughout the process. To accurately interpret results from the logging, the properties of the drilling mud or fluid were subtracted out during analysis of the data. The geophysical methods included gamma ray, single-point resistance, short-normal and long normal resistivity, spontaneous potential, temperature logs. The geophysical logs are presented in Appendix 3-4.

3.2.6 Borehole Reaming

Cascade began borehole reaming June 28, 2018 utilizing the mud rotary drilling method with a 15.5-inch diameter bit. The processed soil cuttings were removed from the hopper and stored in roll-off bins. Borehole reaming was completed on July 3, 2018 to a total depth of 320 ft bgs. The driller's logs are presented in Appendix 3-5. Borehole reaming operations are summarized in Table 2.

Table 2. Borehole Reaming Summary

Date	Description	Drilling Depths
June 28, 2018	Initiated borehole reaming with 15.5-inch bit	10 to 45 ft bgs
June 29, 2018	Continued borehole reaming with 15.5-inch bit	45 to 200 ft bgs
July 2, 2018	Continued borehole reaming with 15.5-inch bit	200 to 292 ft bgs
July 3, 2018	Completed borehole reaming with 15.5-inch bit	292 to 320 ft bgs
July 4, 2018	Holiday (No Site Activities)	--
July 5, 2018	Completed caliper log of reamed borehole	--

3.2.7 Caliper Logging

Upon completion of the borehole reaming, the open borehole was logged by Pacific Surveys, LLC, using a Comprobe® Caliper Tool. This is a well logging tool which provides a continuous measurement of the size, shape, and diameter of the entire length of the reamed borehole. The measurements are an important indicator of cave-ins or swelling of clays in the borehole. The caliper log also ensures that the new well screen and casing can be installed into the reamed borehole. The caliper log is presented in Appendix 3-6.

3.3 Well Construction

Following borehole reaming and caliper logging, the sump, well screen and blank casing were installed into the open borehole in 5-, 10-, and 20-ft-long sections. Each threaded section was tightened and lowered into the open borehole. Stainless steel centralizers were installed every 50 ft to maintain the minimum radial thickness of the annulus and ensure the well screen and blank casing were in the center of the borehole.

The well was constructed with Schedule 80 poly vinyl chloride (PVC) blank casing from 0 to 180 ft bgs, 304L stainless steel wire-wrap screen (0.040-inch slot) from 180 to 300 ft bgs, and 304L stainless steel blank casing (sump) with welded bottom cap from 300 to 310 feet. Copies of the well materials delivery tickets are presented in Appendix 3-7.

Well construction activities are summarized in Table 3.

Table 3. Well Construction Summary

Date	Description
7/5/2018	Installed sump, well screen, blank casing, filter pack and annular seal.

Date	Description
7/6/2018	Installed sanitary seal and temporary surface completion (i.e., flush mount). Loaded supplies on flatbed truck in preparation for demobilization.
7/9/2018	Equipment cleaning (pressure washing and steam cleaning), site cleanup, and drilling equipment demobilization.

3.3.1 Blank Well Casing

Like the existing NASA extraction well (EW-3), EW-4 was constructed with 180 feet of 8.625-inch outside diameter (O.D.), 7.625-inch inside diameter (I.D.) Schedule 80 PVC blank 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. 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.

3.3.2 Well Screen

EW-4 was constructed with 120 ft of 20-ft long, 8.625-inch O.D., stainless steel wire wrap screen. The 0.040-inch screen slot size was chosen to retain approximately 90% of the filter pack material after well development. 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.

3.3.3 Filter Pack

Filter-pack size was 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 the new extraction well consisted of #8 mesh sand (same as EW-3). The sand is uniform in size and slightly larger than the slots in the well screen. This allows fine-grained material to be removed during well development without entering the well and decreasing its effectiveness.

To minimize bentonite sealing materials from permeating into the filter pack and potentially impacting the effectiveness of the well screen, the filter pack material extends 10-ft above the screen zone. The filter pack was installed from the surface using the tremie method.

3.3.4 Annular Seal

A 16-ft-thick annular seal consisting of Baroid Holeplug® 3/8-inch chips was installed on top of the filter pack. The purpose of the annular seal is to prevent the sanitary seal (e.g., liquid bentonite grout) from entering the filter pack. Sealing materials were emplaced from the surface using the tremie method and allowed to sit overnight.

3.3.5 Sanitary Seal

A cement grout annular seal was installed that extends from 154 ft bgs to the ground surface. The purpose of the sanitary seal is to eliminate the formation of a pathway between the ground surface and the screened zone as well as ensuring structural integrity of the well. The top of the well casing was temporarily secured with a 12-inch diameter flush mount. The flush mount was replaced by a pre-cast concrete vault with H-30 traffic-rated access lid during OU-1 optimization construction activities.

A summary of well construction details is provided in Table 4. The driller's well construction logs and the well construction diagram are provided in Appendix 3-8 and 3-9, respectively.

Table 4. EW-4 Well Construction Summary

Description	EW-4
Pilot Hole Drilling	June 25 – 28, 2018
Borehole Reaming	June 28 – July 5, 2018
Well Construction	July 5 – 6, 2018
Well Depth (ft bgs)	310
Casing/Sump Material	Sch 80 PVC and Stainless Steel
Screened Interval (ft bgs)	180-300
Screen Material (wire-wrapped)	340L Stainless Steel 0.040-inch slot
Sump Depth (ft bgs)	300-310
Well Diameter	8 inches

3.4 Soil Waste Disposal

3.4.1 Waste Containment

All soil cuttings generated during air knifing, pilot borehole drilling, and borehole reaming were placed directly into DOT-approved soil roll-off bins provided by Environmental Management Technologies (EMT). The containers were 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 name/number. Due to the small size of the jobsite, full soil roll-off bins were transported to a parking lot next to the JPL parking structure for temporary staging by EMT and empty soil roll-off bins were delivered to the jobsite.

3.4.2 Waste Characterization

One composite waste sample was collected during drilling activities and submitted to BC Laboratories, Inc., in Bakersfield, California, for volatile organic compounds (VOCs), perchlorate, semi-volatile organic compounds (SVOCs), metals, petroleum hydrocarbons (diesel, oil, and gas range), pH, and toxicity. Laboratory reports are provided in Appendix 3-10. Based on the laboratory results, the waste was classified as non-hazardous waste in accordance with the Code of Federal Regulations (40 CFR 261.31 to 261.33 and 261.21 to 261.24) and the 22 California Code of Regulations (CCR).

3.4.3 Waste Transportation and Disposal

Approximately twenty-nine (29) tons (three [3] roll-off bins) of drill cuttings were transported by a licensed transporter. Two soil roll-off bins were picked up from the east parking lot July 16 and the third was removed from the EW-4 well site July 20, 2018 and transported to the South Yuma County Landfill, located in Yuma, Arizona for off-site disposal. This facility is a U.S. EPA-certified and CERCLA-approved waste disposal facility. The South Yuma County Landfill waste profile sheet is provided in Appendix 3-11. All waste transported off-site was accompanied by the non-hazardous waste manifest, signed by an authorized JPL representative. The disposal of the waste was in accordance with federal, state, and local laws, regulations, and instructions. Copies of the non-hazardous waste manifests and weight tickets are included as Appendix 3-12.

4. EW-4 WELL DEVELOPMENT

EW-4 development activities were completed by Cascade July 9 – 17, 2018. The purpose of well development was to remove residual drilling mud to the extent practical and establish hydraulic communication between the borehole wall and the filter pack material surrounding the well screen. 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. EW-4 well development consisted of the follow activities:

- Bail
- Swab and brush
- Mud dispersant treatment
- Swab and Bail
- Water jetting
- Swab and Bail
- Submersible pumping
- Video logging

4.1 Temporary Containment and Filtration

On July 10, 2018 Rain for Rent delivered 1 x 21,000-gallon bi-level tank, 1 x 9,000 gallon mini open-topped frac tank, 1 x DV100C pump, 1 x BF400 bag filter unit, hoses, fittings, and flow meter/totalizer. The temporary containment and filtration system (see picture in Figure 4-1) was installed to contain and remove fines from EW-4 purge water during well development. The Rain for Rent containment and filtration equipment delivery slips are presented in Appendix 4-1.

Two pre-existing tanks that were delivered July 5 (e.g., 1 x 9,000-gallon mini frac tank) and July 6 (1 x 6,900 poly tank) and used to contain drilling mud during well installation were also used to contain turbid water removed during initial development activities.

Figure 4-1. Temporary Treatment System

4.2 Development Activities

The developer mobilized the development trailer to the site the afternoon of July 9, 2018.

4.2.1 Bail, swab, brush, mud dispersant treatment, and water jetting

On July 10, 2018, the well was bailed to remove drilling mud and then swabbed and brushed.

On July 11, 2018, the well bottom was bailed clean, followed by swabbing and brushing, and then the well was bailed clean again. Next, a mud dispersant treatment was performed followed by swabbing the blank casing, the entire screen, and then swabbing and brushing 20 ft sections of the screen for 30 minutes each.

On July 12, 2018, the well was swabbed for 10 minutes per 20 ft zone and then the well was bailed clean. Next, a jetting tool was lowered to 180 ft bgs and the zone from 180 to 194 ft was water jetted for 20 minutes. Next, the jetting tool was lowered to the bottom of the screen and jetting was performed in 4 x 20 ft zones from 300 to 220 ft bgs.

The following day (July 13, 2018) water jetting was performed in two zones (220 to 200 ft bgs and 200 to 180 ft bgs). The jetting tool was removed from the well and the well was swabbed and bailed clean. A total of 1,900 gallons of potable water was used during water jetting of the screened zone. During bailing activities, a total of 2,200 gallons of muddy water was removed and transferred to the poly and mini frac tanks (containing drilling mud) via trash pump and hoses.

4.2.2 Pumping

Next a Grundfos (150S 150-7) submersible pump was installed into the well to 300 ft bgs on July 13, 2018. The following day the well was pumped at 50, 60, 80, and 85 gallons per minute (gpm), respectively and periodically surged. Pumping was discontinued when surging no longer increased turbidity readings. Next, the pump was raised to 252 ft bgs and pumped at 85 gpm and then it was lowered and pumped at 85 gpm to clean out the sump.

Purge water generated during submersible pumping was processed by the temporary containment and filtration system. Well discharge water was pumped into the open-topped mini frac tank and then pumped through a bag filter unit and into the 21,000-gallon frac tank. A total of 13,880 gallons of water was removed from EW-4 during well development.

Next, the pump was removed from the well and the well was allowed to sit overnight in preparation for the video log. Cascade's daily work reports, development /purge records, and the well development summary table are presented in Appendices 4-2, 4-3, and 4-4, respectively. A development summary table is presented in Table 5.

Table 5. EW-4 Well Development Summary

Date	Method	Total Gallons Removed
7/10/2018	Bail, Swab, and Brush	1,000
7/11/2018	Bail, Swab, Brush, Mud Dispersant Treatment, Swab, and Swab/Brush	550
7/12/2018	Swab, Bail, and Jetting	450
7/13/2018	Jetting, Swab, Bail, and Install Submersible Pump	200
7/16/2018	Pump and Surge at 50, 60, and 85 gpm	11,680
	Total Gallons Removed:	**13,880**

4.2.3 Video Logging

On July 17, 2018, a video log was completed by Pacific Surveys to visually inspect the blank casing, joints, screened interval, filter pack (behind screen slots), sump, and overall well condition. The video inspection confirmed well construction details, locations of joints, condition of wire-wrapped screen (open and undamaged with filter pack visible behind screen), water clarity, static water level (229.90 ft bgs) and depth to fill (309.50 ft bgs). A copy of the video survey report is presented in Appendix 4-5. Following the video survey, a submersible pump was installed into the middle of the saturated zone and three well volumes were purged. Baseline groundwater samples were collected from EW-4 and analyzed for VOCs; (EPA 8260B), chloride, nitrate as nitrogen, and sulfate (EPA 300.0), nitrite as nitrogen (EPA 353.2), perchlorate (EPA 314.0), hexavalent chromium (EPA 7199), and total recoverable arsenic, chromium, and lead (EPA 200.8). The laboratory report is presented in Appendix 4-6.

4.2.4 Water Transfers and Equipment Cleaning/Demobilization

Purge water was transferred from EW-4 containment to the OU-1 treatment system for processing utilizing a pickup truck with a 500-gallon poly tank. The water transfers occurred July 16 to 20, 2018 during which time a total of 12,000 gallons was transported for processing. The remaining 1,880 gallons of turbid water was transported offsite as described in Section 4.2.5 below. Cleaning of containment tanks, bag filter unit, hoses, and associated temporary containment and filtration system equipment was conducted by DG Safety Services July 25 to July 27, 2018. The poly and mini frac tanks were cleaned by DG Safety Services August 1 and August 2, 2018, and on August 3, 2018 Rain for Rent demobilized all containment and filtration equipment (e.g., 1 x 21,000-gallon bi-level tank, 1 x 9,000-gallon open-topped mini frac tank, 1 x 9,000-gallon mini frac tank, 1 x 6,900-gallon poly tank, DV100C pump, BF400 bag filter unit, and associated hoses, fittings, flowmeter/totalizer). The parking lot was swept and reopened for JPL use on August 3, 2018.

4.2.5 Liquid Waste Containment and Transportation

Drilling mud and high turbidity water generated during well construction and initial well development were pumped into a 9,000-gallon mini frac tank and 6,900-gallon poly tank. One composite sample was collected on July 11, 2018 and submitted to BC Laboratories and analyzed for VOCs, perchlorate, SVOCs, metals, petroleum hydrocarbons (diesel, oil, and gas range), pH, and toxicity. The laboratory report was submitted to EMT, the waste characterized, profiled, and non-hazardous waste profiles were generated. Drilling mud was transferred from the containment tanks to a 5,000-gallon capacity vacuum tanker by EMT from July 31 to August 2, 2018. A JPL representative signed the non-hazardous waste manifests, and a total of 11,600 gallons of drilling mud and high turbidity water was transported to South Yuma County Landfill in Yuma, Arizona, which is a CERCLA-approved waste facility for disposal. The laboratory report, waste profile, copies of waste manifests, and weight tickets are provided in Appendix 4-6.

5. INFRASTRUCTURE IMPROVEMENTS

Beginning in August 2018, infrastructure improvements were constructed at the site including underground and above-ground pipelines, well and pipeline tie-in vaults, IX vessels and associated plumbing, and electrical and programmable logic control (PLC) upgrades. Work activities associated with the transition from FBR to IX were completed in November 2020. Infrastructure improvements are described in the sections below.

5.1 Geophysical Utility Survey

As was described in Section 3.1 above, prior to performing any subsurface activities, the trench and excavation areas were scanned for underground utilities using geophysical methods. The initial survey was conducted by Spectrum Geophysics June 9, 2017 and spot checked again June 22, 2018. The utility-locating contractor employed several methods, including ground-penetrating radar, magnetometer, magnetic gradiometer, and/or electromagnetic imaging. As required by California State law, USA was notified of the planned drilling activities. USA is a communication center that provides notice to utility owners that may potentially have underground utilities within the excavation area. USA requires notification a minimum of 48 hours prior to conducting any underground excavation. Following map review, geophysical utility locating, and USA clearance, the surface of the ground was clearly marked where underground utilities were discovered. A utility map prepared by the Spectrum Geophysics is presented in Appendix 3-1.

5.2 Trenching and Excavating

Prior to conducting trenching or excavating activities, Ultra Engineering performed additional geophysical utility locating on September 27, 2018 to confirm locations of subsurface utilities. The pipeline trenching and vault excavation activities were conducted by Ultra Engineering September 27 to September 30, 2018, October 4, 5, 8, 9, 10, 12, 27, and 28, 2018 utilizing Ultra 4000 air knife rigs. Air knife excavating utilizes high-velocity airflow to penetrate, dislodge and break apart subsurface soils. Once the soils are loosened, they are removed from the trench or excavation with a powerful vacuum. This method is less likely to damage underground utilities when compared to mechanical excavation which is of utmost importance at JPL due to critical below-grade utility infrastructure. Damage to critical infrastructure could negatively impact facility operations. A trench was excavated from the new extraction well (EW-4) across Explorer Road (picture provided as Figure 5-1) and into the planter immediately west of JPL Fire. Another trench extended from EW-4 to the electrical disconnect location to the west. To reduce noise generated by the air knife rigs, twelve 8 ft x 8 ft sound barriers (i.e., Environmental Noise Control [ENC] style STC-25 portable E88 acoustical barriers), with straps and bases were used along the northwest and west sides of the work area. Two excavations were air knifed, one for the EW-4 well vault and another for the EW-3/EW-4 vault located behind JPL Fire.

Excavated soils and other materials were kept at least 2 ft from the trench edges. Excavated soils, asphalt and concrete were placed in soil roll-off bins (described below). Open trenches were secured with traffic cones and caution tape, and a ladder was placed in the trench of ingress/egress. In high traffic, steel traffic plates were placed over the open trench to allow vehicles to safely drive across.

Figure 5-1. Air Knife Trenching on Explorer Road

5.3 Pipeline Installation

Well pipeline installation activities were conducted by DG Safety Services September 30, 2018 to February 16, 2019. Construction activities included the installation of approximately 270 ft of 4-inch diameter Schedule 80 PVC pipe both above- (150 ft) and below-grade (120 ft). Below-grade piping was placed on fill sand bedding and backfilled with one sack slurry. Detectable warning tape was placed in the backfill material during backfill placement. Concrete thrust blocks were poured at vertical or horizontal pipe bends (i.e., 45- and 90-degree fittings) using concrete. Above-ground piping is secured to Unistrut pipe stands anchored to the Building 310 concrete retaining wall leading up the hill and behind the JPL Fire Station. Expansion joints are installed along the pipeline where the pipe transitions from above- to below-grade as well as every 50 ft to allow for thermal expansion and contraction. The above-grade pipeline includes the installation of a 4-inch check valve, pressure transducer, flow meter/totalizer, sample port and combination air valve. Two 4 ft x 4 ft x 3.25 ft deep Jensen precast concrete vaults with H20 traffic-rated galvanized spring assisted covers were installed as well. One was installed for the EW-4 well vault (located in parking lot) and the other is for the EW-3/EW-4 pipeline tie-in (located in planter adjacent to EW-3 well vault; picture shown in Figure 5-2). Piping in the preexisting EW-3 well vault was reconfigured to allow water to be conveyed from EW-4 to the OU-1 treatment system through preexisting below-grade conveyance piping.

Figure 5-2. Above Ground Piping and Conduit Behind JPL Fire Department (Includes New Utility Vault)

5.4 Waste Containment and Transportation

JPL's Environmental Affairs Program Office required that all soil generated during excavation and trenching activities be treated as CERCLA waste. Therefore, all soil generated during excavation and trenching activities was placed directly into DOT-approved soil roll-off bins provided by EMT. The containers were labeled with the following information: date, project name and number, generator name, POC, applicable contact numbers, and contents of container. Eight samples were collected and submitted to BC Laboratories and analyzed for VOCs, perchlorate, SVOCs, petroleum hydrocarbons (diesel, oil, and gas range), pH, and toxicity. The laboratory reports were submitted to EMT, the waste characterized, profiled, and non-hazardous waste manifests were generated. Due to the small size of the jobsite, full soil roll-off bins were transported to a parking lot adjacent to the JPL parking structure for temporary staging by EMT and empty soil roll-off bins were delivered to the jobsite. A total of eight soil roll-off bins were utilized to contain 95.2 tons of trenching and excavation soils.

Soil roll-off bins were picked up October 26, 2018 (three bins), November 19, 2018 (three bins), and December 28, 2018 (two bins). JPL representatives signed the non-hazardous waste manifests, and the bins were transported to South Yuma County Landfill in Yuma, Arizona which is a CERCLA-approved waste facility for disposal. The laboratory report, waste profile, copies of waste manifests, and weight tickets are provided in Appendix 5-1.

5.5 Electrical

Above grade electrical installation activities were conducted by DG Safety Services September 30, 2018 to February 7, 2019. Construction activities included the installation of three galvanized electrical conduits (i.e., 1 x 2-inch and 2 x 1-inch diameter) measuring approximately 150 ft in length. The conduits are accompanied by junction boxes and 90° elbow access ports to facilitate pulling wire and inspection. The above grade conduits are secured to Unistrut pipe stands anchored to the Building 310 concrete retaining wall leading up the hill and behind the JPL Fire Station. A new electrical disconnect was installed adjacent to EW-4 in the planter and protected by concrete filled steel bollards. All electrical conduits, junction boxes, access ports, and the EW-4 disconnect installed by DG Safety Services were inspected by Hunter Electric.

Hunter Electric installed all wire, motor starter and motor saver to supply and control power to the EW-4 submersible pump.

5.6 Ion Exchange System Installation

Activities associated with IX installation were conducted by DG Safety Services, Spectrum Geophysics, and Evoqua Water Technologies (Evoqua) from June 22, 2018 through May 28, 2020. Installation activities included on-pad utility locating performed by Spectrum Geophysics and IX vessel delivery by Evoqua on June 22, 2018. On-pad modifications were performed from August 31, 2018 to February 29, 2020 (specifically: August 31, September 1 and 2, 2018, February 16 and 19, 2019, July 29 – 31, 2019, August 8, 9, 15, and 22, 2019, December 11, 16, 29, 30, and 31, 2019, January 1, 3, 5, 12, 29, 30, and 31, 2020, February 5, 7, 10 – 14, 17 – 20, 24, 26, 28 – 29, 2020). Activities included drilling and setting IX vessel anchor bolts, placement of four IX48HF vessels on pad, installation of IX influent/effluent manifold, pipe stands, Unistrut pipe supports, IX influent and effluent conveyance piping, IX vessel hoses, pressure gauges, flowmeters, and valves, and plumbing modifications downstream of the FBR. On May 15, 2020, all four IX48HF vessels were filled with a total of 240 cubic ft of Dowex® PSR-2 resin using a 9k Telehandler (9,000 lbs. reach capacity, 43-ft height, and 30-fot reach) reach fork to lift super sacks and load vessels from top. The IX system consists of two IX vessel banks (Banks A and B) in lead/lag configuration for a total of four IX vessels. Bank A is located on the west side of the LGAC vessels and Bank B is located on the east side of the LGAC vessels. The Evoqua IX48HF vessel brochure, Dowex® PSR-2 resin, and Evoqua Water Technologies Work and Service Orders are provided in Appendix 5-2.

5.7 Noise Monitoring

Noise monitoring was conducted throughout all phases of construction associated with OU-1 optimization. Noise monitoring data show that all OU-1 optimization construction activities were in compliance with Pasadena Municipal Code (Title 9 – Public Peace, Morals and Welfare, Article IV – Offenses Against Public Peace, Chapter 9.36 – Noise Restrictions). Noise reading log sheets are presented in Appendix 5-3.

6.1 EW-4 Pump Installation

Cascade installed the submersible pump in EW-4 on January 2 and 3, 2019. The static water level on January 2, 2019 was measured at 246.78 ft below top of casing (btoc) and the total depth of the well was measured at 307.65 ft btoc. The submersible pump assembly consisted of a Grundfos 150S150-8 (pump), Hitachi H18 G27632E 15 horsepower (HP)(motor), fourteen joints of 20-ft-long by 3-inch diameter Certa-Lok PVC drop pipe, 280 ft of ¼-inch stainless steel airline and motor lead secured to the drop pipe with stainless steel banding. The EW-4 submersible pump setting is summarized in Table 6. Cascade's daily work report and pump sheet are presented in Appendix 6-1.

Table 6. EW-4 Submersible Pump Setting (January 3, 2019)

Description	Make/Model	Depth Setting
Submersible Pump	Grundfos 150S150-8	Pump intake: 284.33 ft. btoc
Motor	Hitachi H18 G27632E 15 HP	287.33 ft btoc
Drop Pipe	3-inch Diameter Certa-Lok PVC	0 to 280 ft btoc
Stainless Steel Airline	¼-inch Stainless Steel Jacketed Airline	0 to 280 ft btoc

6.2 EW-4 Startup Testing

On May 26, 2019 Hunter Electric wired the EW-4 submersible pump. Well startup testing was initiated on May 28, 2019 but was stopped due to a leaking pipe that required repair. A second startup test was successfully completed on June 21, 2019. Additional tests were performed during the months of July and August 2019 that indicated excessive drawdown from the newly installed well which sat idle for approximately 11 months during pipeline and electrical installation. As a result, redevelopment was scheduled for November 2019 and described in the following section.

6.3 EW-4 Redevelopment

Cascade performed redevelopment of EW-4 from November 18 to November 22, 2019. Well redevelopment was performed because excessive drawdown was observed during initial well startup in July/August 2019. Activities included removing the submersible pump, motor, motor lead, stainless steel airline, and drop pipe. Next Pacific Surveys performed a video log of the well during, which the static water level was measured at 233.80 ft bgs and the total well depth was measured at 309.40 ft. bgs. The video survey report is presented in Appendix 6-2. Following the video log the well screen was swabbed and brushed in 10-ft zones for 10 minutes each. On November 19, 2019 sediment was bailed from the well bottom and a solution consisting of 1-gallon of Aqua-Clear® PFD (concentrated phosphate-free liquid polymer mud dispersant) was blended with 50 gallons of water. The solution was tremied into the well screen followed by swabbing and brushing in 10-ft zones for 30 minutes each. The same day Rain for Rent mobilized and setup temporary containment and filtration equipment which consisted of one 9,000-gallon roll-off tank, one 21,000-gallon tank, two DV100C pumps, one BF400 bag filter unit, and associated hoses, fittings, meters, and bag filters. Rain for Rent equipment delivery tickets are presented in Appendix 6-3. On November 20, 2019, the well bottom was bailed followed by jetting the well screen with potable water in 20-ft-long intervals for 20 minutes each. Next a submersible pump was installed, and the well was pumped at 70 gpm until the purge water was clear. Submersible pumping was continued the following day at 110 gpm, 95 gpm, 87 gpm, 82 gpm, and 75 gpm while monitoring drawdown and turbidity. A total of 26,467 gallons of water was removed from EW-4 during redevelopment activities and a redevelopment summary is presented in Table 7. The daily work reports, development and purge records, and redevelopment table are presented in Appendix 6-4. On November 22, 2019, the submersible pump and associated downhole equipment was reinstalled in the well and Cascade demobilized from the site. The pump install sheet is presented in Appendix 6-5. From November 25 through November 27, 2019 purge water was transferred from the temporary containment/filtration system to the OU-1 treatment system for processing. The purge water was conveyed to the OU-1 treatment system using the newly installed EW-4 conveyance pipeline. The temporary containment/filtration system was cleaned on November 27, 2019 and demobilized on December 2, 2019.

Table 7. EW-4 Redevelopment Summary

Date	Method	Total Gallons Removed
11/18/2019	Remove Pump, Swab, and Brush	0
11/19/2019	Bail, Mud Dispersant Treatment, Swab, and Swab/Brush	15
11/20/2019	Bail, Jetting, Bail, Install Submersible Pump, and Pump at 70 gpm	3,093
11/21/2019	Pump at 110, 95, 87, 82, and 75 gpm	23,359
11/22/2019	Reinstall Pump	0
	Total Gallons Removed:	**26,467**

6.4 EW-4 Shakedown Testing and Operation

EW-4 was operated on a periodic basis from early December 2019 to mid-January 2020. The purpose of operating EW-4 was to further develop the well and monitor drawdown during pumping. Daytime operation of EW-4 occurred from January 7 to 10, 2020 and January 13 to 15, 2020 with system operator oversight. This was necessary as the bag filters were plugging and required periodic changeouts. Continuous operation of EW-4 was initiated on January 20, 2020 while simultaneously running EW-2 and EW-3.

7. SYSTEM MONITORING

Beginning the week of January 20, 2020, EW-2, EW-3, and EW-4 were operated together. Extracted water was treated by the source area treatment system utilizing the original configuration (i.e., liquid-phase granulated activated carbon [LGAC] for VOC removal and FBR for perchlorate removal). The purpose of this operational configuration was to determine hexavalent chromium and perchlorate chemical concentration trends. In the OU-1 optimization work plan, two criteria were identified that had to be met to transition from FBR to IX:

1. Hexavalent chromium concentrations at the system influent must be reliably below 80% of the state maximum contaminant level (MCL; 50.0 µg/L) when any individual or combination of extraction wells is (are) operating.
2. Combined influent perchlorate concentration must be 100.0 µg/L or less.

Beginning the week of January 20, 2020, weekly samples were collected and analyzed for VOCs (EPA 8260B), perchlorate (EPA 314.0), and hexavalent chromium (EPA 7199). Monthly samples were analyzed for the same constituents with the addition of chloride, nitrate as NO_3, and sulfate (EPA 300.0), and nitrite (EPA 353.2). The first step of the transition criteria assessment was to evaluate hexavalent chromium results at the system influent (i.e., GACIN). From January 23, 2020 to April 15, 2020, hexavalent chromium concentrations at the system influent ranged from 1.3 µg/L to 2.0 µg/L with an average concentration of 1.7 µg/L, which is significantly below the state MCL of 50.0 µg/L. System effluent samples (i.e., TFOUT) were also monitored. The second step of the transition criteria assessment was to monitor perchlorate at the system influent denoted by FBRIN/FBRINDUP. From January 23 to April 15, 2020, perchlorate concentrations at the system influent ranged from 34 µg/L to 52 µg/L with an average of 39.38 µg/L. The FBR effluent (i.e., FBROUT) sample results were also monitored. Hexavalent chromium and perchlorate results at system influent and effluent are presented in Table 8 and a summary of transition criteria results is presented in Table 9. The laboratory reports are presented in Appendix 7-1.

Table 8. Hexavalent Chromium and Perchlorate Results

Hexavalent Chromium Results (µg/L)

Date	GACIN		TFOUT	
1/23/2020	**1.5**	**J**	**4.7**	
1/30/2020	**1.5**	**J**	**7.2**	
2/6/2020	**1.8**	**J**	**1.3**	**J**
2/13/2020	**1.3**	**J**	**0.89**	**J**
2/20/2020	**1.6**	**J**	**3.1**	
2/27/2020	**1.7**	**J**	2.0	U
3/5/2020	**1.5**	**J**	2.0	U
3/12/2020	**1.8**	**J**	**0.85**	**J**
3/19/2020	**1.9**	**J**	**7.5**	
3/25/2020	**1.6**	**J**	2.0	U
4/1/2020	**1.9**	**J**	2.0	U
4/8/2020	**2.0**		**1.3**	**J**
4/15/2020	**1.7**	**J**	2.0	U

Perchlorate Results (µg/L)

Date	FBRIN	FBRINDUP	FBROUT	
1/23/2020	**34**	**34**	4.0	U
1/30/2020	**36**	**37**	4.0	U
2/6/2020	**44**	**44**	4.0	U
2/13/2020	**52**	**50**	4.0	U
2/20/2020	**36**	**37**	4.0	U
2/27/2020	**37**	**35**	4.0	U
3/5/2020	**46**	**44**	4.0	U
3/12/2020	**36**	**34**	4.0	U
3/19/2020	**37**	**38**	4.0	U
3/25/2020	**35**	**34**	4.0	U
4/1/2020	**34**	**34**	4.0	U
4/8/2020	**50**	**50**	4.0	U
4/15/2020	**38**	**38**	4.0	U

Notes:
Bold values = detection
J = estimated value
U = Not Detected

Table 9. Transition Criteria Results Summary

Constituent	Concentration Range	Average Concentration	Transition Criteria	Transition Criteria Met?
Hexavalent Chromium	1.3 µg/L to 2.0 µg/L	1.7 µg/L	Concentrations < state MCL (50.0 µg/L)	**Yes**
Perchlorate	34 µg/L to 52 µg/L	39.38 µg/L	Concentrations < 100.0 µg/L	**Yes**

8. TREATMENT SYSTEM TRANSITION PREPARATION

8.1 System Shutdown

On November 2, 2020, the system was shutdown to prepare it for FBR to IX transition. Following shutdown of the FBR treatment system, the tanks, pipelines, and associated equipment were drained including the FBR tank, FBR skid, trimite filter, aeration tank, clarifier, chemical feed tanks, and associated pumps, compressors, and blowers.

8.2 Programmable Logic Control Replacement

The preexisting Allen-Bradley PLC that was installed at the OU-1 treatment system in 2004 and operated through 2020 was discontinued by the manufacturer. Because the preexisting PLC is obsolete, the manufacturer no longer provides technical support, spare parts are difficult to find, and typically only refurbished or used spares are available for sale. To ensure PLC reliability and to limit downtime moving forward, upgrading to a modern PLC platform was selected as the best option. On November 10 and 11, 2020, Control Automation Design removed the existing PLC components from the enclosure. New PLC equipment was installed on November 12, 2020, which included the central processing unit (CPU), all input/output (I/O) modules and rack, 10-inch operator interface, autodialer with 4 inputs, and miscellaneous cables and connectors.

8.3 Tank 401 Modifications

Tank 401 is a stainless-steel tank with a nominal height of 24 ft outside diameter of 11.5 ft with a total capacity of 17,870 gallons. It is located immediately downstream of the FBR and was used to raise the dissolved oxygen (DO) level in treated groundwater to promote degradation of any excess electron donor and to maintain aerobic conditions in the multi-media filter. The tank was fitted with a fine bubble diffuser grid to aerate the water and raise the DO levels in FBR effluent water. Due to phasing out the FBR for perchlorate treatment, the tank was repurposed as a treated water tank (replacing Tank 501) to supply injection well water. On November 24, 2020, Tank 401 was cleaned by EMT. After the tank was cleaned, all internal components including the manifolds, PVC piping, flanges, pipe supports, and twelve aeration stones were removed. Next all external components were disconnected and removed, including the blower (disconnected but not removed), airlines, vapor carbon vessel and associated plumbing. To repurpose the tank, several modifications were completed that included installing an air vacuum/air release valve and tank level indicator, reconfiguring the 6-inch diameter overflow piping, and installing a new sodium hypochlorite chemical feed system.

8.4 EW-4 Submersible Pump Lowered

From May 22 to October 2, 2020, the pumping water level in EW-4 declined by 50.82 feet. Groundwater elevations at JPL typically reach the lowest points (after the dry season) between October and January and the highest points (after the rainy season) between March and June. EW-4 was turned off on October 5, 2020 because the pump began breaking suction and lowering the pump was planned. It should be noted that the submersible pumps in EW-2 and EW-3 had sufficient submergence and continued to operate while EW-4 was offline.

On December 1, 2020, Cascade removed the submersible pump and associated downhole components (i.e., pump, motor, stainless steel airline, motor lead, and drop pipe). On the morning of December 2, 2020, Pacific Surveys performed a video log during which the static water level was measured at 250.70 ft bgs and the total well depth was measured at 307.90 ft bgs. The video survey report is presented in Appendix 8-1. Following the video log, Cascade reinstalled the submersible pump approximately 15 feet deeper than the previous setting. The pump sheet is presented in Appendix 8-2. Table 10 presents the details of the new pump setting.

Table 10. EW-4 Submersible Pump Setting (December 2, 2020)

Description	Make/Model	Depth Setting
Submersible Pump	Grundfos 150S150-8	Pump Intake: 300.50 ft bgs
Motor	Hitachi H18 G27632E 15 HP	Motor Bottom: 303.50 ft bgs
Drop Pipe	Certa-Lok PVC	0 to 295 ft bgs
Check Valve	Merrill 1000 Series Stainless Steel	195 ft bgs
Stainless Steel Airline	¼-inch S.S. Jacketed Airline	0 to 296.50 ft bgs

9. SYSTEM SHAKEDOWN TESTING

Since FBR to IX transition criteria had been met (described in Section 7), treatment system shakedown testing with IX instead of FBR for perchlorate treatment was initiated December 7, 2020. During testing, only IX Bank A and EW-4 were operated. The system was operated in hand mode while the system operator was onsite to monitor the system for leaks. After successful shakedown testing, IX Bank A was operated in hand mode from December 14, 2020 through January 20, 2021. EW-3 operation was resumed on January 18, 2021 and operated with EW-4.

IX Bank B was tested on January 22, 2021 while running EW-3 and EW-4. Continued testing of IX Banks A and B along with EW-2, EW-3, and EW-4 was conducted January 25, 2021.

9.1 PLC Startup

Control Automation Design initiated PLC startup on January 26, 2021. Since an additional sensor installation was required before full-scale automated system operation, the system was operated in hand mode with operator oversight from January 27 through February 26, 2021.

9.2 Final System Configuration and Status

The optimized system consists of one new extraction well (four extraction wells total), a bag filter unit (pre-existing) for sediment filtration, LGAC (pre-existing) for VOC removal, IX (new) for perchlorate treatment, and a repurposed tank to supply treated water for injection at three existing injection wells. A treatment system flow diagram is presented in Figure 9-1. Fully automated system operation was initiated on March 1, 2021. The as-built drawings documenting OU-1 optimization are presented in Appendix 9-1.

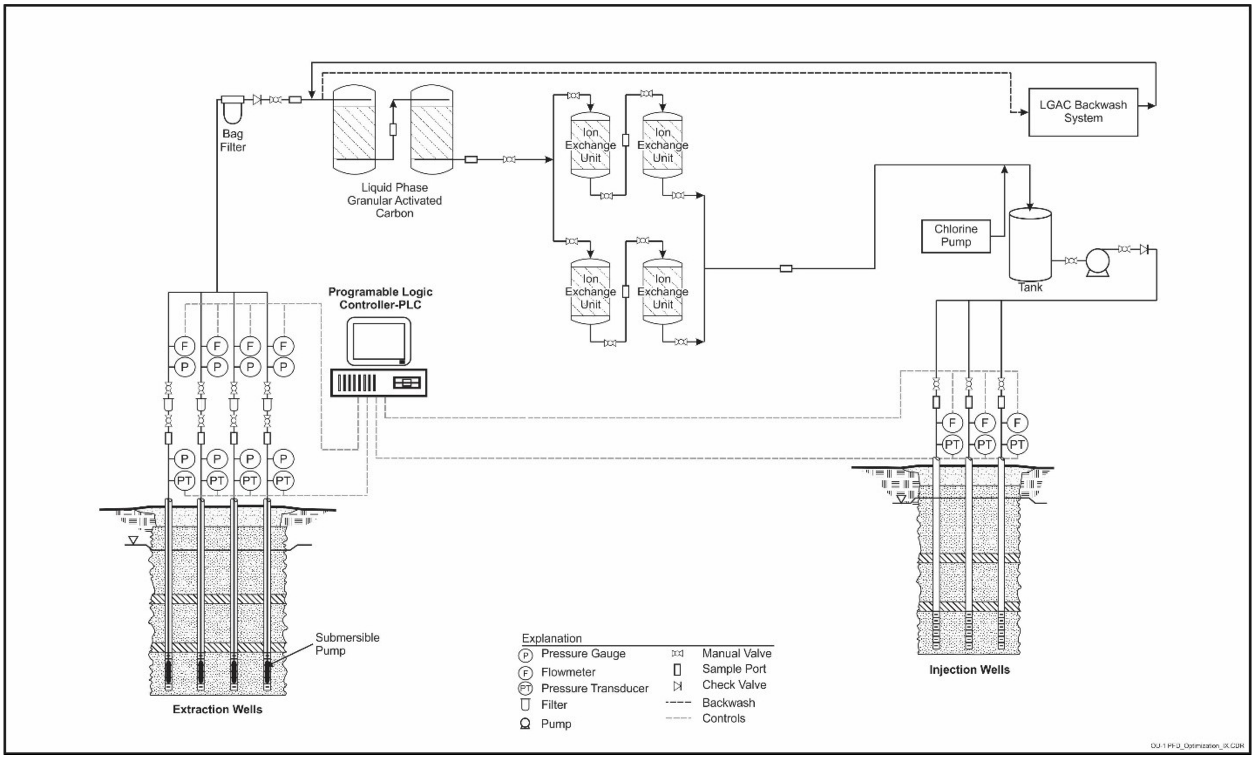

Figure 9-1. OU-1 Process Flow Diagram Utilizing IX for Perchlorate Treatment

9.3 System Monitoring

System parameters will be collected daily by the system operator to ensure adequate system performance. These readings include flowrates, pressures, and totalizer readings from the extraction wells, system influent, IX vessels, system effluent, and injection wells; differential pressures at the bag filter unit, LGAC and IX vessels; and tank and sump levels. Static water levels will be collected from five source area monitoring wells (i.e., MW-7, MW-8, MW-13, MW-16, and IRZ-IW2) on a weekly basis. Pumping (or static if extraction well is offline) water levels will be collected from the extraction wells using the airline method to ensure sufficient pump submergence to prevent breaking suction. A blank copy of the daily log sheet is presented in Appendix 9-2. In addition, weekly, monthly, and quarterly samples will be collected from up to thirteen separate sampling locations and submitted for laboratory analysis. A list of sampling locations is presented in Table 11, and Table 12 summarized laboratory analysis requirements.

Table 11. Treatment System Sample Locations and Purpose

Sample Location	Description	Purpose
EW-1	Extraction Well #1	Monitor chemical concentrations from each extraction well.
EW-2	Extraction Well #2	
EW-3	Extraction Well #3	
EW-4	Extraction Well #4	
GACIN	System and LGAC Influent	Monitor combined influent chemical concentrations.
GACMID	Sample Port (x1) Between Lead and Lag LGAC Vessels	Monitor VOC concentrations to determine breakthrough which initiates media changeout.
IXIN and IXINDUP (A and B)	IX Influent	Monitor chemical concentrations at IX influent.

Sample Location	Description	Purpose
IXMID (A and B)	Sample Ports Located Between Lead and Lag IX Vessels	Monitoring perchlorate concentrations to determine breakthrough which initiates media changeout.
IXOUT (A and B)	IX Effluent	Downstream of perchlorate treatment; confirms perchlorate removal.
SYSOUT	Treatment System Effluent	Monitors water quality of treated water for reinjection.

Table 12. Post OU-1 Optimization Treatment System Laboratory Analyses

Sampling Location	VOCs EPA 8260B	Perchlorate EPA 314.0	Nitrate as NO_3 EPA 300.0	Cl and SO_4 EPA 300.0	NO_2 EPA 353.2	CrVI EPA 218.6	1,4-Dioxane EPA 8270C	Ca and Mg EPA 200.7	Total Dissolved Solids EPA 160.1	Total Suspended Solids EPA 160.2	Turbidity EPA 180.1	Metals[1] EPA 200.7, 200.8, 245.1
GACIN	M	--	--	--	--	--	Q	Q	--	Q	Q	Q
GACMID	W	--	--	--	--	--	--	--	--	--	--	--
IXIN-A	--	W	M	M	M	--	--	--	--	--	--	--
IXIN-A-DUP	--	W	M	M	M	--	--	--	--	--	--	--
IXMID-A	--	W	--	--	--	--	--	--	--	--	--	--
IXOUT-A	W	W	M	M	M	--	Q	--	--	--	--	--
IXIN-B	--	W	M	M	M	--	--	--	--	--	--	--
IXIN-B-DUP	--	W	M	M	M	--	--	--	--	--	--	--
IXMID-B	--	W	--	--	--	--	--	--	--	--	--	--
IXOUT-B	W	W	M	M	M	--	Q	--	--	--	--	--
SYSOUT	--	--	--	--	--	--	--	Q	Q	Q	Q	Q
EW-2	Q	W	--	--	--	M	Q	--	--	--	--	--
EW-3	Q	W	--	--	--	M	Q	--	--	--	--	--
EW-4	Q	W	--	--	--	M	Q	--	--	--	--	--

Notes:

W = Weekly; M = Monthly; and Q = Quarterly

(1) Antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc.

10. MONITORING WELL ABANDONMENT

As was presented in the OU-1 optimization work plan (NASA, 2018b), MW-2 was installed in 1989 by MARMAC Geotechnical Consultants, Inc., under contract the U.S. Army Corps of Engineers, to evaluate groundwater quality immediately upgradient of JPL. The well was located in the southwestern corner of JPL's west parking lot. It was drilled by Beylik Drilling, Inc. using an Ingersoll Rand TH100 drill rig equipped for mud rotary drilling. A shallow 10 ft deep by 10-inch diameter steel conductor casing was installed and a 9 7/8-inch diameter boring was drilled to a depth of 179 ft bgs.

The monitoring well was constructed of approximately 127 ft of 4-inch Schedule 40 PVC blank casing, 40-ft-long 4-inch diameter machine-slotted (0.020-inch slot) Schedule 40 PVC well screen (127 to 167 ft bgs), and 8-ft-long sump with threaded end cap (167 to 177 ft bgs). A concrete seal extended from ground surface to the top of a 4-ft-thick bentonite seal (0 to 96 and 96 to 100 ft bgs, respectively), and the gravel pack consisted of Monterey No. 3 sand from 100 to 179 ft bgs. The surface completion consisted of a flush mount well vault.

The monitoring well was not constructed deep enough to intersect the water table and was replaced in March 1994 by deep multi-port monitoring well MW-14. MW-14 is located approximately 65 ft north northeast of MW-2 and was constructed to a depth of 588 ft bgs. MW-14 consists of five screened intervals and a Westbay® multi-port casing system that allows for simultaneous or independent monitoring of different aquifer zones. Since 1996, groundwater elevations in MW-14 have averaged 1001.14 ft above mean sea level (amsl), which was below the screen bottom in MW-2. MW-14 has been sampled on a quarterly basis since 1996 and has served as a replacement of MW-2.

During a May 15, 2018 site visit, it was determined that a protected native California Oak tree whose trunk was located 16.75 ft away with a canopy 7.50 ft above the monitoring well would prevent the use of a drilling rig to abandon the monitoring well by over drilling as previously planned. Therefore, MW-2 abandonment was completed by pressure grouting.

All MW-2 well abandonment activities were conducted on July 20, 2018, which was a JPL Regular Day Off (RDO) to ensure the work area would be clear of vehicles and traffic. Noise mitigation was not a concern due to the distance between the well location and nearby sensitive receptors (i.e., residential homes and the Flintridge Riding Club).

First, Pacific Surveys completed a video log of the 4-inch diameter Schedule 40 PVC well. The video survey determined that the well was free of obstructions and contained no groundwater, and the well casing and screen were in good shape (aside from the partial joint separation in blank casing at 7.5 ft bgs). The video survey report is presented in Appendix 10-1. Next, Cascade saw cut the asphalt surrounding the monitoring well surface completion (i.e., flush mount) and jackhammered and removed asphalt and concrete surrounding the wellhead.

During the demolition work, it was discovered that well was constructed with a 10-inch diameter steel conductor or surface casing. This detail was not included in the well completion schematic, but was reported in the boring log, which described a 10-inch diameter steel casing extending to a depth of 17 ft bgs. The annular space between the PVC well casing and the surface casing was filled with a cement seal. To complete the well abandonment according to the approved work plan, a large excavation would have been necessary to allow torch cutting and removing the casing to 6 ft bgs. Because this procedure posed a safety hazard to a would-be welder in an excavation, the site geologist determined a different approach that would meet California Department of Water Resources (CDWR) requirements for sealing the upper 5 ft of the abandoned well in an urban area. To achieve this, the

Cascade crew air knifed to a depth of 5 ft around the outside of surface casing. The final dimensions of the excavation were 18-inches x 19-inches x 5 ft deep. Next the geologist provided the total volume of grout necessary to fill the well and filter pack (e.g., ~198 gallons). The calculation spreadsheet and copy of the original MW-2 well completion diagram are presented in Appendix 10-2.

The Cascade crew then mixed batches of grout, which consisted of approximately 40 gallons of potable water blended with ¼ sack of Hydrogel® bentonite and 5 x 47 lbs. sacks of Type I, II, and V portland cement. This was blended in a drum fitted with a mixer and was tremied into the well. Once the well casing was filled with grout, a pressure head was attached to the top of the PVC well casing and the well was pressurized to 30 pounds per square inch (psi) for 30 minutes. Afterward, the pressure head was removed, and the well casing was topped off with grout completely filling the casing. A total of 200 gallons of grout were used to abandon the monitoring well which is consistent with preliminary calculations. Next the crew mixed sacks of 4,000 psi concrete and poured it into the excavation surrounding the surface casing. The concrete was filled to the ground surface completely encapsulating the upper five feet of steel surface casing and PVC well casing effectively sealing the upper 5 ft of the abandoned well meeting the urban area regulatory requirement. The concrete was stained black to match the surrounding asphalt and brush finished. Next the crew cleaned up and demobilized from the site.

The well abandonment figure is provided in Appendix 10-3 and Cascade's daily work report is presented in Appendix 10-4.

11. REFERENCES

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