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OPERABLE UNIT 1
EXPANDED TREATABILITY STUDY WORK PLAN

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JET PROPULSION LABORATORY
PASADENA, CALIFORNIA

EPA ID# CA9800013030

PREPARED FOR:

National Aeronautics and Space Administration
Management Office, Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91101

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FIGURES

TABLES

amsl	above mean sea level
BDAT	best demonstrated available technology
bgs	below ground surface
Cal-EPA	State of California Environmental Protection Agency
CalTech	California Institute of Technology
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
ClO_4^-	perchlorate
CWC	California Water Code
DHS	Department of Health Services
DO	dissolved oxygen
DTSC	Department of Toxic Substances Control
EAO	Environmental Affairs Office
EM	electromagnetic imaging
EPA	United States Environmental Protection Agency
FBR	fluidized bed reactor
FID	flame ionization detector
GAC	granular activated carbon
GC/MS	gas chromatograph/mass spectrometer
gpd	gallons per day
gpm	gallons per minute
GPR	ground-penetrating radar
hp	horse power
IC	ion chromatography
ICP	inductively coupled plasma
IRZ	in situ reactive zone
ISE	ion sensitive electrode
JPL	Jet Propulsion Laboratory
LDR	land disposal restriction
LGAC	liquid-phase granular activated carbon
MCL	maximum contaminant level
MOA	memorandum of agreement
NA	not applicable
NASA	National Aeronautics and Space Administration

NAVFAC	Naval Facilities Engineering Command
NEMA	National Electrical and Mechanical Association
NFESC	Naval Facilities Engineering Service Center
NMO	NASA Management Office
NPL	National Priorities List
O&M	operation and maintenance
ORP	oxidation reduction potential
OU-1	Operable Unit 1
OU-3	Operable Unit 3
PCB	polychlorinated biphenyl
PLC	programmable logic control
psig	pounds per square inch gage
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
RWQCB	Regional Water Quality Control Board
SAP	sampling and analysis plan
SARA	Superfund Amendments and Reauthorization Act
scfm	standard cubic feet per minute
TBD	to be determined
TCD	thermal conductivity detector
TOC	total organic carbon
USA	Underground Services Alert
VOC	volatile organic compound
WDR	waste discharge requirement

1.0 Introduction

This plan was prepared for the National Aeronautics and Space Administration (NASA). An expanded treatability study is proposed to support development of a full-scale remedial action to address chemicals of interest in Operable Unit 1 (OU-1), on-facility groundwater.

The groundwater beneath the Jet Propulsion Laboratory (JPL) facility contains elevated levels of chemicals that may represent a continuing source. The goal of the expanded treatability study is to test the effectiveness of the most promising technology selected from the series of pilot tests conducted at the site. The expanded treatability study will help to address significant levels of chemicals of interest in OU-1 to protect beneficial uses of the aquifer and to reduce the period of performance of actions taken in Operable Unit 3 (OU-3). The study will target an 8-acre by 100-ft-thick portion of the site (i.e., the test area), located in the north-central section of the NASA JPL facility.

An initial feasibility evaluation was conducted to determine potential remedial techniques for OU-1. The evaluation indicated that the preferred remedial technique includes targeted mass removal using groundwater extraction near the suspected chemical release with groundwater reinjection. Also, treatment technologies were evaluated to achieve groundwater reinjection requirements. Liquid-phase granular activated carbon (LGAC) is a U.S. Environmental Protection Agency (EPA) presumptive remedy for volatile organic compounds (VOCs) (EPA, 1996) and is the most cost-effective VOC treatment technology given the conditions at the site. The evaluation indicated that ex situ biological treatment may be effective to achieve reinjection requirements for perchlorate (ClO_4^-). Therefore, the proposed remedial technique includes targeted mass removal using groundwater extraction, aboveground treatment using LGAC adsorption and fluidized bed reactor (FBR) technology, and groundwater reinjection.

NASA is the lead federal agency for selecting, implementing, and funding remedial activities at the JPL; and NAVFAC is providing technical services, including contracting, under a Memorandum of Agreement (MOA). The EPA, State of California Environmental Protection Agency (Cal-EPA), Department of Toxic Substances Control (DTSC), and the California Regional Water Quality Control Board (RWQCB) Los Angeles Region provide oversight and technical assistance.

The remainder of this Work Plan is divided into six sections. This section discuses the overall study approach, the treatability study objectives, and the performance evaluation criteria. Section 2.0 provides background information on the federal regulations, state regulations, and legal considerations related to water rights. Section 3.0 summarizes the results of the groundwater modeling efforts that were completed to evaluate optimal pumping rates and locations for the extraction and injection wells. Section 4.0 describes the design for the expanded treatability study system. Section 5.0 summarizes the tasks required to implement the expanded treatability study, and Section 6.0 provides a proposed project schedule.

1.1 Expanded Treatability Study Objectives

The objectives of the expanded treatability study are as follows:

- **Test the Effectiveness of the Most Promising Remedial Technique for OU-1.** The expanded treatability study will allow for evaluation of the effectiveness of targeted mass removal via groundwater extraction, treatment, and reinjection. The proposed remedial technique of LGAC and FBR was selected for further study based on previous pilot testing activities completed at the site. The expanded treatability study will also help to resolve several implementability issues related to groundwater reinjection.

- **Reduce Chemical Mass in the OU-1 Test Area.** The general test area has been defined as the portion of the dissolved phase plume with VOC concentrations greater than 100 times the maximum contaminant level (MCL) and ClO_4^- concentrations greater than 400 µg/L. This 8-acre by 100-ft-thick portion of the site contains over 68% of the dissolved plume chemical mass, while representing less than 3% of the volume of the dissolved chemical plume. Addressing this area in OU-1 will not only target the majority of the chemical mass associated with the site, but also potentially decrease the duration of the actions taken in OU-3.

- **Design a Flexible System that Could be Part Of The Final Remedial Action for OU-1.** The treatability study is proposed in phases to provide an opportunity to collect additional data and to develop remediation and optimization strategies to support full-scale system implementation of the final OU-1 remedial action.

1.2 Project Phasing

The expanded treatability study has been divided into two phases. Phase I will involve the installation of one multilevel extraction well, installation of two multilevel injection wells, and use of existing monitoring wells in OU-1. The extracted groundwater will be treated using the ex situ groundwater treatment train, consisting of LGAC adsorption, an FBR, aeration, and multimedia filtration. Phase II of the expanded treatability study tentatively involves the installation of one additional extraction well and two additional injection wells. A conceptual diagram of OU-1 Phases I and II, along with future full-scale expansion plans for Operable Unit 3 (OU-3) is shown in Figure 1-1.

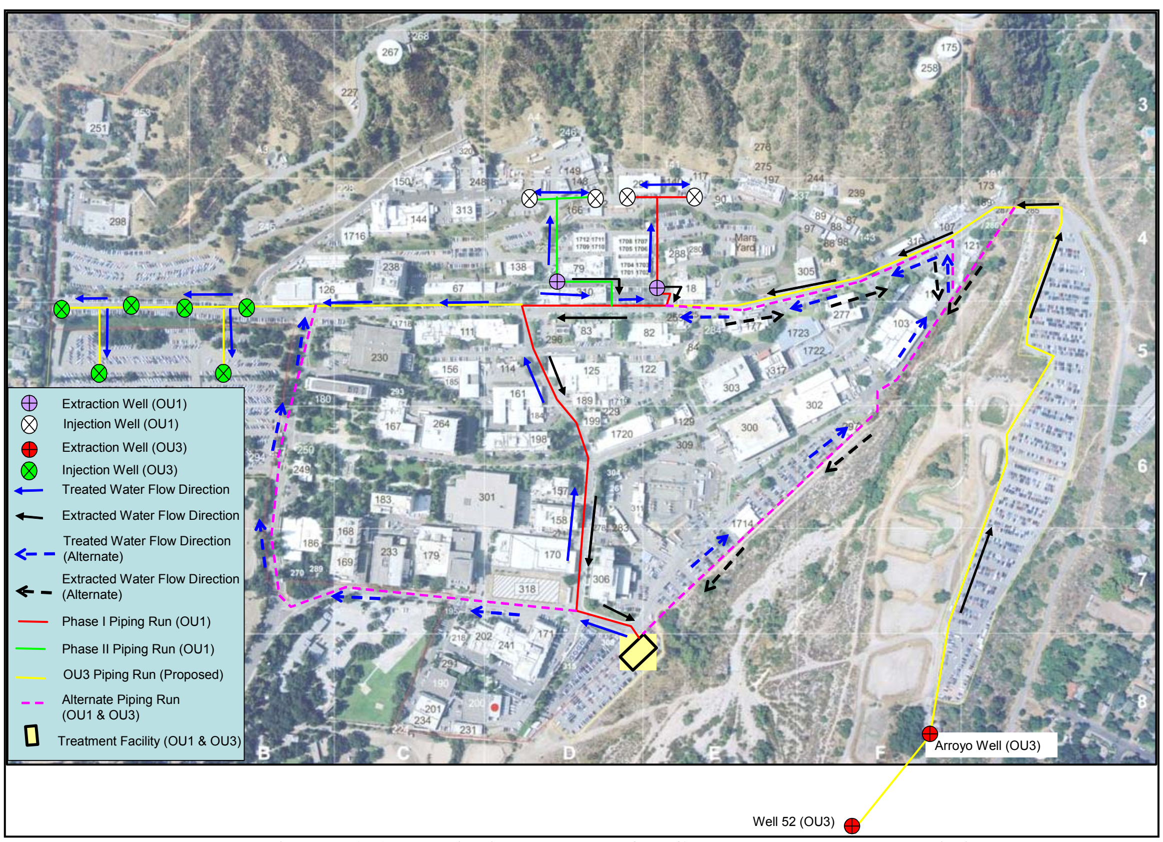

Figure 1-1. Preliminary Plan for System Layout and Piping

Figure 1-2 is a close-up of the demonstration site and illustrates the approach planned for the expanded treatability study.

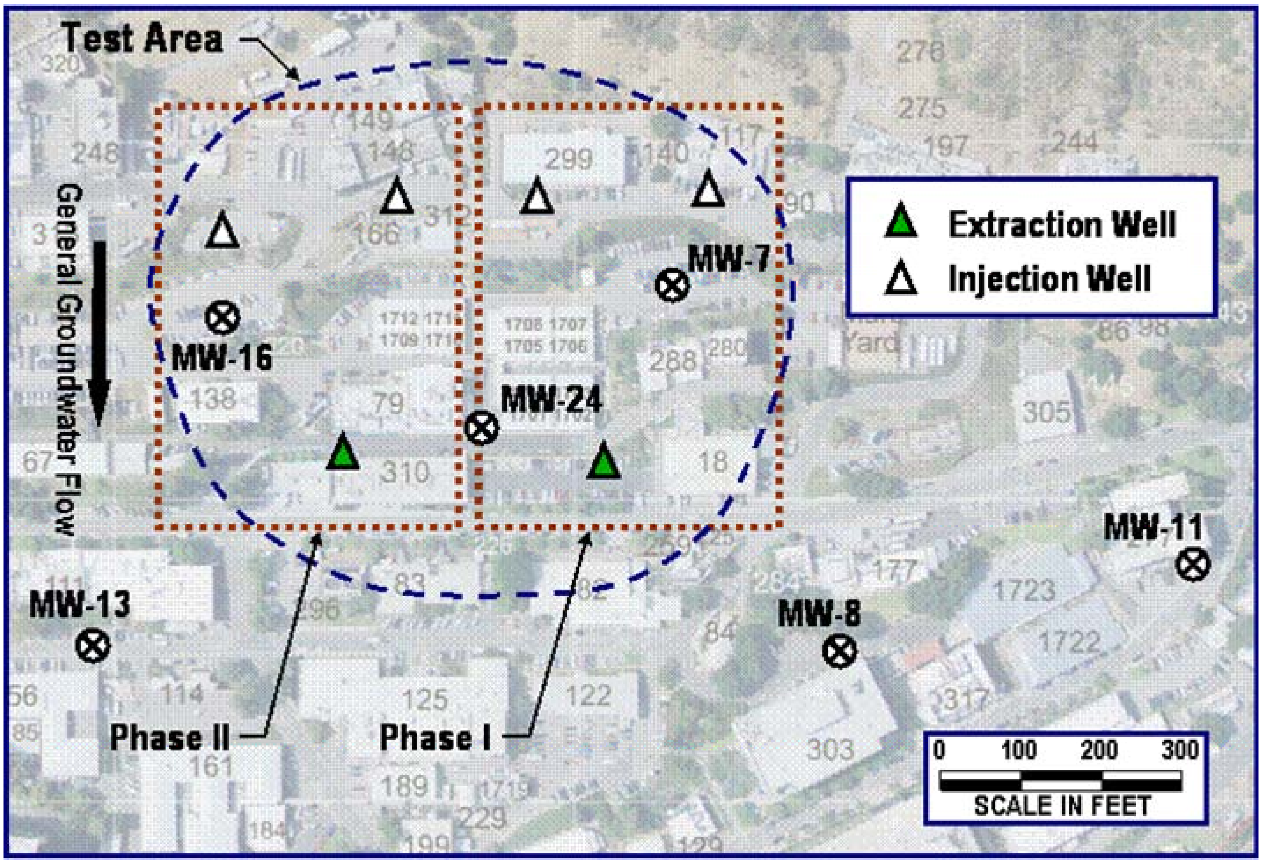

Figure 1-2. Project Phasing

1.3 Technology Overview

While cost-effective VOC treatment technologies are known (EPA, 1996), consensus on the best ClO_4^- treatment technologies is developing. Two primary aboveground methods for ClO_4^- treatment have emerged: FBR and ion exchange. The initial feasibility evaluation supports the use of an FBR to remove ClO_4^- from groundwater at NASA JPL. The primary advantages include: (1) a number of full-scale systems have been successfully implemented at other sites, (2) the technology was successfully demonstrated at the field-scale at NASA JPL, (3) biological treatment methods are typically less expensive in terms of O&M costs compared to ion exchange, and (4) ClO_4^- is destroyed rather than transferred to another media.

Use of FBRs for ClO_4^- removal from groundwater has a proven track record for effectiveness, reliability, and control based on a review of full-scale operations at other sites. Three full-scale FBR systems for ClO_4^- removal from groundwater are currently operational. The full-scale performance of FBRs was reviewed based on reports from the 6,000-gallon-per-minute (gpm) Aerojet system, the 50-gpm Long Horn Army Ammunition Plant system, and the 400-gpm Naval Weapons Industrial Reserve Plant McGregor system. In addition, a 6-gpm pilot-scale system was successfully tested at NASA JPL in 2000. The pilot-scale system consistently reduced the average influent ClO_4^- concentration from 770 μg/L to

<4 μg/L. No unplanned excursions were experienced during the 52-day FBR pilot test. In addition, no problems were reported with maintaining a stable biomass or in controlling the bed height or biofilm growth (U.S. Filter/Envirogen, 2001). The pilot test, therefore, successfully demonstrated that an FBR could be implemented at NASA JPL to treat ClO_4^- and meet target reinjection levels. In addition, based on vendor quotes, the O&M costs for an FBR system are less expensive than a throwaway ion exchange system.

Although use of an FBR treatment train has a relatively high likelihood of success, some uncertainties still exist regarding the full-scale implementation of ex situ biological treatment at NASA JPL. Further information is needed regarding the implementability of groundwater reinjection at this site. Due to the adjudication of water rights in the Raymond Basin Watershed, the treated groundwater will be returned to the aquifer. Groundwater reinjection has not been tested at the field-scale at NASA JPL to date. More performance data will be needed to select optimal injection rates and to track changes in the aquifer that may result from the continuous reinjection of treated water. The expanded treatability study will allow for an assessment of potential reinjection implementability issues including mechanical clogging with particulate matter, scaling through chemical precipitation, and biofouling from the buildup of microbial byproducts.

To implement the expanded treatability study, various regulatory issues and legal considerations must be examined in regard to the injection of treated groundwater. Because the JPL is on the National Priorities List (NPL), the site is subject to the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA). As such, federal regulations and policy governing reinjection of water into the subsurface will be adhered to, in conjunction with complying with the substantive requirements of state regulations and policy (EPA, 1992). Legal considerations of reinjection must also be examined because the JPL facility is located in the adjudicated Raymond Basin Watershed.

2.1 Federal Regulations and Policy

Section 3020 of the Resource Conservation and Recovery Act (RCRA) applies to the underground injection in the context of RCRA and CERCLA cleanups. RCRA section 3020(a) bans underground injection into or above a geologic formation that contains an underground source of drinking water. However, RCRA section 3020(b) exempts from that ban provided that certain conditions are met (EPA, 2002). These conditions include the following:

- The reinjection is part of a response action under section 104 or 106 of CERCLA, or part of RCRA corrective action intended for site cleanup;
- The groundwater is treated to substantially reduce chemicals prior to such reinjection; and
- The cleanup will, upon completion, be protective of human health and the environment.

The applicability of RCRA land disposal restrictions (LDRs) to groundwater reinjection performed during an RCRA corrective action or CERCLA response action is also a consideration (see RCRA sections 3004 (f), (g), and (m), and 40 Code of Federal Regulations (CFR) Parts 148 and 268). Groundwater undergoing reinjection may contain regulated chemicals; thus, the issue could be raised as to whether reinjection of groundwater should meet treatment standards identified as best demonstrated available technology (BDAT). An interpretation of the applicability of the RCRA LDRs is provided in an EPA memorandum titled "Applicability of Land Disposal Restrictions to RCRA and CERCLA Ground Water Treatment Reinjection" (EPA, 1989). This memorandum explains that, even though the LDR provisions address the same activity as RCRA section 3020, EPA interprets the provisions of RCRA section 3020 to be applicable instead of LDR provisions (EPA, 1989).

Another potential issue is whether LDR treatment standards are relevant and appropriate for treated groundwater that is reinjected as part of a CERCLA response action. The EPA believes that the ultimate purpose of treatment is to restore the groundwater to drinking water conditions; thus, standards that have been developed to establish drinking water quality levels (e.g., MCLs) are to be used (EPA, 1989). Therefore, promulgated drinking water standards should be used where available. If no promulgated drinking water standard exists, then relevant and appropriate requirements such as health-based standards or LDR treatment standards should be used (EPA, 1989).

2.2 State Regulations and Policy

General waste discharge requirements (WDRs) associated with groundwater reinjection during remedial activities are provided by the California RWQCB Los Angeles Region in Order No. R4-2002-0030, *General Waste Discharge Requirements for Groundwater Remediation at Petroleum Hydrocarbon Fuel and/or Volatile Organic Compound Impacted Sites* (RWQCB, 2002). These general WDRs are applicable to in-situ groundwater remediation or the extraction of groundwater with aboveground treatment and reinjection of treated groundwater to the same aquifer zone. The requirements contained in Order No. R4-2002-0030 are consistent with all water quality control policies, plans, and regulations in the California Water Code (CWC); and the revised Water Quality Control Plan (Basin Plan) for the Los Angeles Region (RWQCB, 1994). The general WDRs are intended to protect and maintain the existing beneficial uses of the receiving groundwater (RWQCB, 2002) and are consistent with the anti-degradation provisions of State Water Resources Control Board Resolution No. 68-16.

RWQCB Order No. R4-2002-0030 requires that groundwater reinjection shall not adversely impact the receiving groundwater in terms of water quality and chemical concentrations at a "compliance point, downgradient outside the application area." Discharge limitations for pH, mineral content, coliform count, salts, heavy metals, organic pollutants, and nitrogen content, as well as taste and odor, are described in the general WDRs. Similarly, discharge limitations for chemical constituents are MCLs specified in Title 22 of the California Code of Regulations, which are incorporated in the Basin Plan on Table 64431-A of section 64431 (inorganic chemicals), Table 64431-B of section 64431 (fluoride), and Table 64444-A of section 64444 (organic chemicals).

2.3 Application of Federal and State Regulations to Expanded Treatability study at OU-1

Groundwater reinjection activities associated with the aboveground LGAC adsorption and FBR treatment will be in compliance with federal regulations and policy surrounding RCRA section 3020(b) and the substantive requirements of state regulations and policy surrounding RWQCB Order No. R4-2002-0030. Following federal regulatory guidelines, the ex situ biological treatment of groundwater proposed at JPL will be done to substantially reduce chemical concentrations prior to reinjection, and the cleanup will be protective of human health and the environment. Applicable limits for treated water are summarized in Table 2-1. The electron donor to be used will be the same as, or similar in nature to, carbon sources/electron donors listed in RWQCB Order No. R4-2002-0030, Provision A(c)(4).

2.4 Legal Considerations

JPL is located in the Monk Hill Sub-Basin of the Raymond Basin. In 1944, the Superior Court of California approved the Raymond Basin Judgment, which adjudicated the rights to groundwater production to preserve the safe yield of the groundwater basin. Adjudication refers to the practice of land owners and other parties allowing the courts to settle disputes over how much groundwater can rightfully be extracted. The courts determine an equitable distribution of water that will be available for extraction each year. In these adjudicated groundwater basins, the courts appoint a Watermaster to administer the court judgment. The Raymond Basin Management Board, made up of representatives of the water purveyors, oversees the management and protection of the Raymond Basin. A total of six Raymond Basin water purveyors operate wells within four miles of JPL.

Because the expanded treatability study includes the extraction of groundwater and NASA does not have water rights under the Raymond Basin Judgment, extracted groundwater will be reinjected into the same aquifer. Battelle will provide data reporting the quantities of water extracted and reinjected to NASA, the Navy, and the Raymond Basin Management Board.

Table 2-1. Summary of Groundwater Discharge Limits for Treated Water

Compound	Units	Applicable Limits for Treated Water [a]
Perchlorate		None[b]
Carbon tetrachloride	μg/L	0.5
1,1-Dichloroethene	μg/L	6
1,2-Dichloroethane	μg/L	0.5
Tetrachloroethene	μg/L	5
Trichloroethene	μg/L	5
1,4-Dioxane		None[c]
Arsenic	μg/L	50
Trivalent chromium	μg/L	50
Hexavalent chromium	μg/L	50
Fluoride	mg/L	2
Nitrogen (as nitrate-nitrogen plus nitrite-nitrogen)	mg/L	45
Nitrate-nitrogen (NO_3-N)	mg/L	10
Nitrite-nitrogen (NO_2-N)	mg/L	1
pH	units	6.5 to 8.5
Color	units	15
Odor threshold	units	3
Turbidity	units	5
Sulfate	mg/L	40 or background
Chloride	mg/L	15 or background
Total dissolved solids	mg/L	300 or background

(a) Discharge limitations as provided in Order No. R4-2002-0030 or specified in Title 22 of the California Code of Regulations unless otherwise designated.

(b) No promulgated drinking water, health-based, or LDR treatment standards exists for ClO_4^-. Based on previous field-scale implementation, FBR systems are capable of removing perchlorate down to non-detectable levels (i.e., <4 μg/L).

(c) No promulgated drinking water, health-based, or LDR treatment standards exists for 1,4-dioxane. Based on monitoring data, 1,4-dioxane levels in the extracted groundwater are expected to be near 5 μg/L.

A groundwater flow model was developed and used to perform groundwater flow and transport simulations and evaluate the performance of the proposed expanded treatability study system. More specifically, the model was used to increase the efficiency of the proposed system by gaining a better understanding of the optimal well spacing and pumping rates. Simulations were performed to investigate extraction well capture zones and estimate the amount of drawdown/mounding in the extraction/injection wells.

3.1 Model Development

A new model was prepared to evaluate the OU-1 expanded treatability study area. This model was based on the water supply model developed by CH2MHill (2002) for OU-3 evaluation and was constructed using FEFLOW™ (Diersch, 2002). The new model was necessary to effectively simulate the proposed remediation system and provide:

- Increased model resolution in the test area
- Capability to model multiple extraction/injection intervals within hydrostratigaphic unit 1
- More accurate groundwater flow gradient in the OU-1 test area
- Extended northern boundary of the model domain to include MW-7, MW-16, and the proposed injection wells.

The domain of the new model was selected based on the area of interest. The model was constructed using the hydrologic parameters used in the CH2MHill's OU-3 model (see Table 3-1). The northern boundary was chosen to better represent the current understanding of the JPL Thrust Fault, and the other boundaries were placed at suitable distances from the injection and extraction wells (see Figure 3-1). The model consists of four layers or slices, which are necessary to model flow conditions created by multilevel wells. The upper three slices represent intervals in the uppermost hydrostratigraphic unit, and the bottom layer corresponds to hydrostratigraphic unit 2. Constant head boundary conditions were specified at the northern and southern extent of the model, and no-flow boundaries represented the eastern and western extents. A southerly gradient of 0.002 ft/ft was simulated according to observed water levels, plume maps, and previous modeling. Because the remediation system involves reinjection of any extracted groundwater, the pumping is not likely to have a significant influence on the water budget of the system.

Table 3-1. Groundwater Flow and Transport Simulation Parameters

Parameter	Slice			
	1[(a)]	2	3	4
Hydrostratigraphic Unit	1	1	1	2
Layer Top (ft amsl)	1,200	990	960	930
Layer Bottom (ft amsl)	990	960	930	900
Thickness (ft)	210	30	30	30
Horizontal Hydraulic Conductivity (ft/d)	22	22	22	28
Vertical Hydraulic Conductivity (ft/d)	0.92	0.92	0.92	0.062
Porosity	0.30	0.30	0.30	0.30
Storage Coefficient	0.2	0.2	0.2	0.2

(a) Recharge rate: 0.74 ft/yr
amsl = above mean sea level.

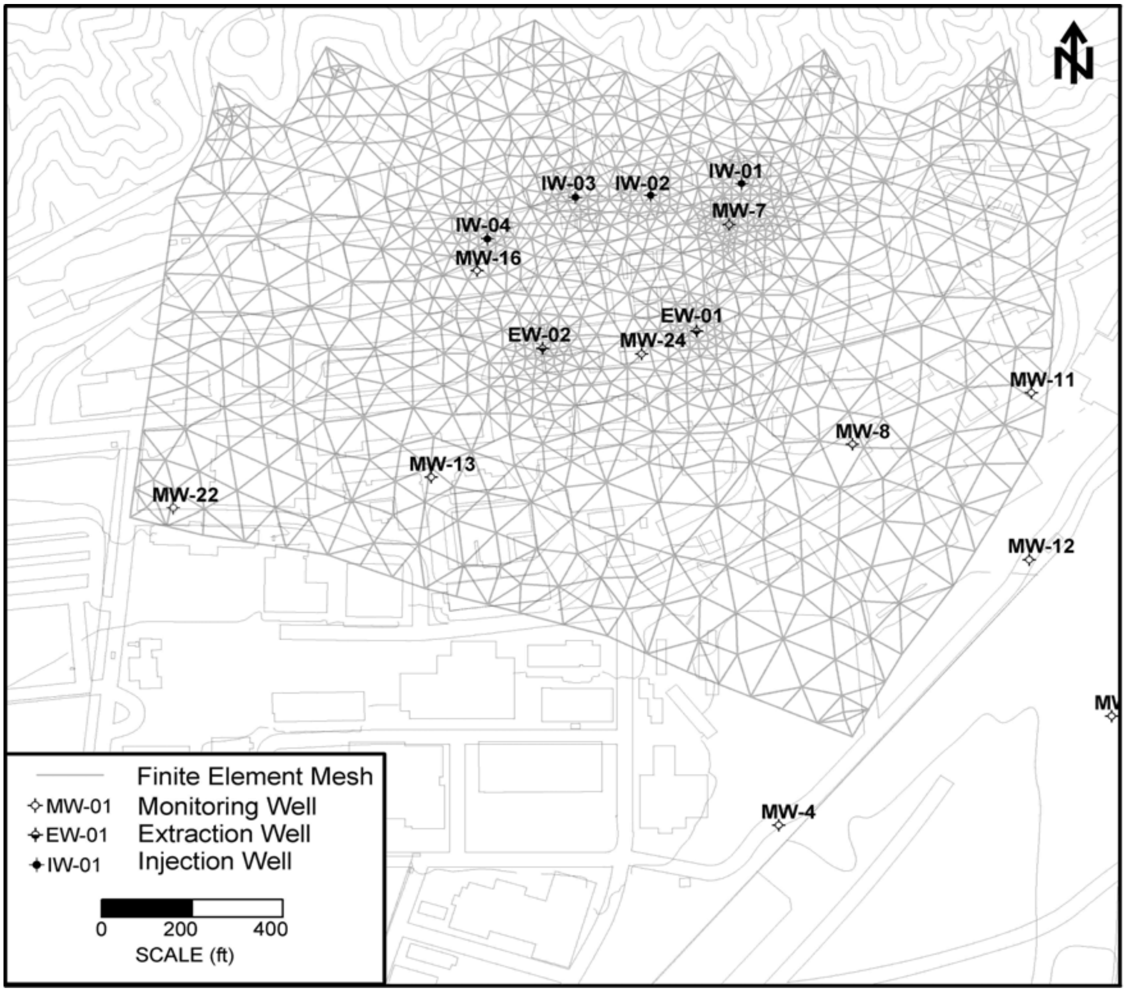

Figure 3-1. Domain and Layering of Groundwater Simulations

The groundwater flow simulations performed with the new model involve the following assumptions:

- Groundwater flow through porous materials may be expressed in Darcy's flow law.
- Flow conditions are steady state.
- Boundary conditions represent actual groundwater conditions.
- Geologic materials are fairly homogeneous.
- Output represents the average result within a model element or block.

Given these assumptions, there are limitations to the model. The model does not account for transient changes in groundwater conditions such as precipitation, pumping, or seasonal water level trends. The model does not account for heterogeneity in the aquifer such as sand channels, perched aquifers, or fining trends in sediments. Drawdown and mounding predictions may not accurately simulate conditions in a well since results represent average conditions in a modeling block. However, simulations performed using the new model are considered appropriate for the intended use. In addition, because the proposed treatment system represents a closed system, transient changes in groundwater conditions are unlikely to have a noticeable effect on the model predictions.

3.2 Groundwater Flow and Transport Simulation Results

The proposed expanded treatability study system consists of four upgradient injection wells and two downgradient extraction wells installed during two separate phases (see Figure 1-1). It was modeled that each of the injection and extraction wells would be screened in three separate 30-ft intervals. Groundwater flow and transport simulations were performed for several well and pumping arrangements to assess capture zones (see Table 3-1 for simulation parameters), mounding and drawdown in the wells, and particle travel times for different scenarios. Backward particle tracking from extraction wells indicates the capture zone, whereas forward particle tracking shows the fate of the injected groundwater. Forward particle tracking from the injection wells was also used to estimate travel times of the injected groundwater.

Six different pumping/injection scenarios were evaluated as shown in Table 3-2. Results from the modeling simulations indicated that an extraction rate of approximately 30 gpm per screened interval (i.e., up to 90 gpm per extraction well location) provided the best combination of treatment zone size and minimization of drawdown and mounding (i.e., Case 2).

Results from particle tracking simulations for Case 2 are summarized in Table 3-2 and in Figure 3-2. The simulations indicated that predicted drawdown and mounding around the injection/extraction wells was less than 2.6 ft. The capture zone width and height were 1,150 and 90 ft, respectively. Also, the simulations indicated that the majority of the injected water is captured by the extracted wells. Travel times for particles originating from injection wells that are not captured by extraction wells indicate that it would take approximately 14.5 years to reach the boundary of the model.

Table 3-2. Extraction/Injection Scenarios and Results

Well	Extraction/Injection Flow Rate (gpm) [Screen1/Screen2/Screen3]				
	Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**
EW-01	10/10/10	30/30/30	60/60/60	20/20/20	60/60/60
EW-02	10/10/10	30/30/30	60/60/60	0	0
IW-01	5/5/5	15/15/15	30/30/30	5/5/5	15/15/15
IW-02	5/5/5	15/15/15	30/30/30	5/5/5	15/15/15
IW-03	5/5/5	15/15/15	30/30/30	5/5/5	15/15/15
IW-04	5/5/5	15/15/15	30/30/30	5/5/5	15/15/15
Pore Volumes Extracted/Year	0.32	0.97	1.92	0.32	0.97
Minimum Travel Time from Injection Well To Model Boundary (days)	4,200	5,300	>10,000	3,000	2,500
Maximum Drawdown (ft)	2.3	2.6	14.1	4.3	13.5
Maximum Mounding (ft)	1.1	1.0	6.6	1.2	3.3

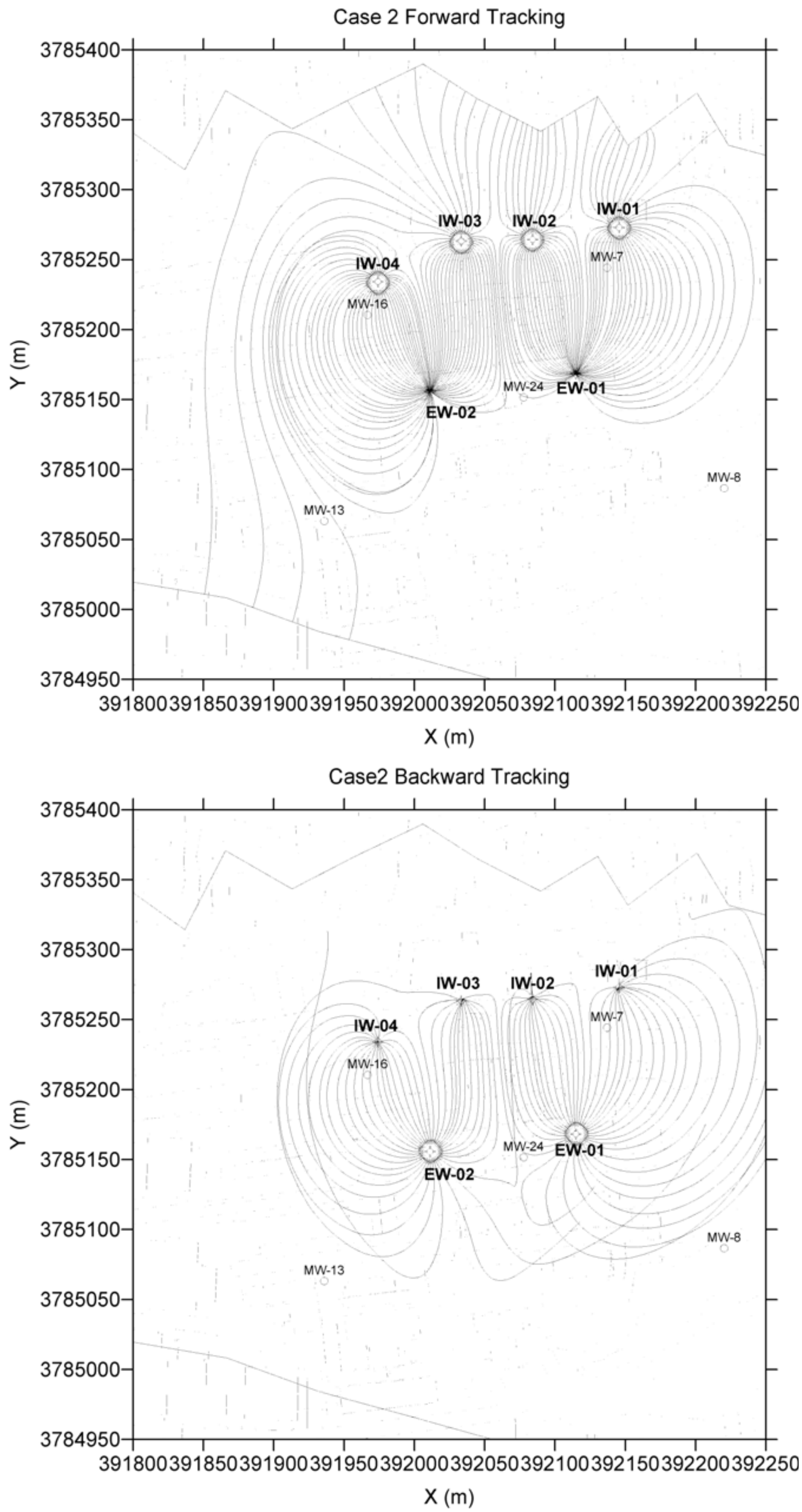

Figure 3-2. Particle Tracking for Case 2

This section discusses the design of the expanded treatability study system. The overall system layout is provided, along with the construction details for the extraction well, injection wells, and underground piping. Also, the key components of the aboveground treatment train are described. Other design issues discussed include the system control strategy and support facilities and utilities.

Design details including the sizing and specification of pumps, tanks, piping, and other equipment/materials and detailed drawings and specifications are provided in Appendix A.

4.1 System Layout

The system layout for Phase I of the expanded treatability study is shown in Figure 4-1. The Phase I pilot system will consist primarily of one extraction well, two injections wells, underground piping, the treatment system, and ancillary equipment.

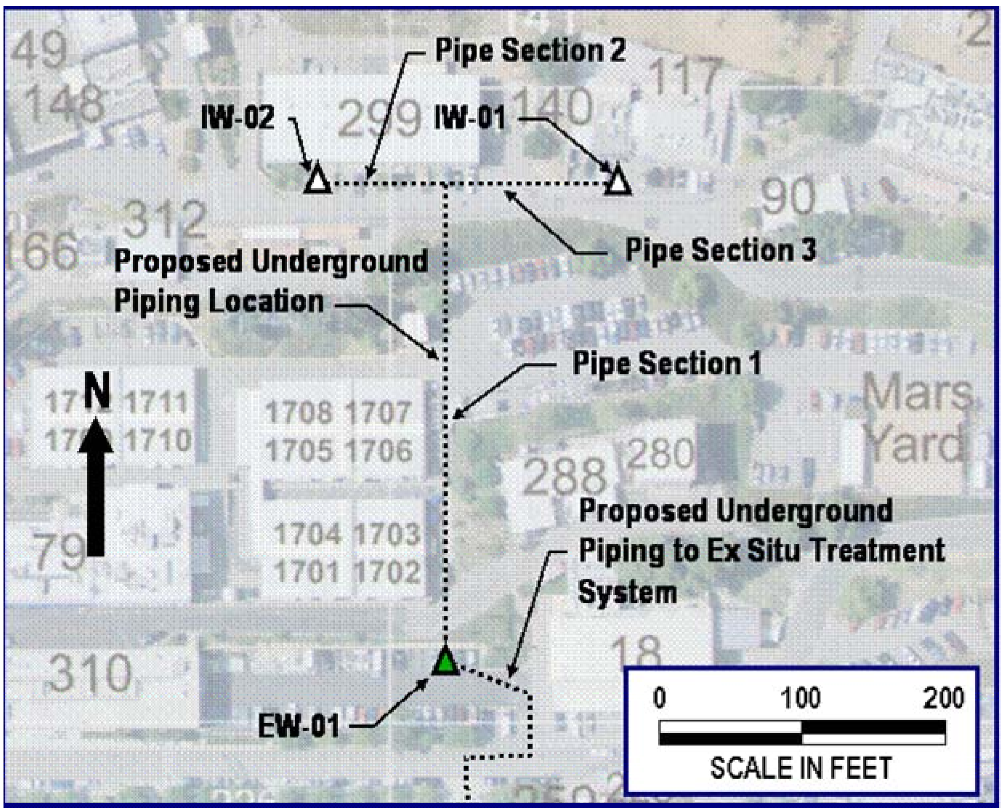

Figure 4-1. Phase I Layout

The Phase I extraction well (EW-01) will be located east of Building 18 in the adjacent parking lot. The two injection wells will be located upgradient of the extraction well at a distance of approximately 330 ft. The first injection well (IW-01) is located adjacent to the east side of Building 140, and the second injection well (IW-02) is located adjacent to the south side of Building 299.

The footprint of the aboveground treatment system is expected to be approximately 24 ft by 80 ft for a 250-gpm system. The system and associated support facilities will be located in the parking lot along the southeastern boundary of the JPL facility. The groundwater treatment train will consist of two LGAC adsorption units for VOC removal, an FBR unit for ClO_4^- removal, a post aeration tank, and a multimedia filter. The process flow diagram is provided in Figure 4-2.

4.2 Extraction Well Design

Figure 4-3 shows a typical extraction well completion diagram. A licensed drilling subcontractor will be hired to perform the necessary drilling activities required for the installation of the groundwater extraction well. The extraction well (EW-01) will consist of a set of three individual extraction wells screened at the intervals shown in Table 4-1. The depth to the water table is approximately 210 ft below ground surface (bgs) in the test area. However, it can vary by up to 60 ft due to seasonal fluctuations. The set of extraction wells will be screened entirely in the upper 100 ft of the saturated zone, which extends to approximately 900 ft amsl. Each level of the extraction well will be completed as a separate installation. Each well will be 6 inches in diameter and constructed using a Schedule 80 polyvinyl chloride (PVC) riser. Each well will have a 30 ft length of stainless steel, wire-wrapped screen placed at the depths listed in Table 4-1. A solid screw-on sump will be attached to the bottom of the screen to collect fines and particulates from the aquifer that settle to the bottom of the well. Silica sand will be installed around the well screen to act as a filter pack. A silica sand filter pack will be placed at a minimum of 2 ft above the well screen. A bentonite seal, at least 2 ft thick, will then be placed on top of the filter pack. A cement grout will be pumped into the annulus between the well and borehole, and the well will be grouted from the bentonite seal to the ground surface. The well riser will be outfitted with flush-mount, bolt-down steel manholes. The volumes and quantities of materials required to construct each well will be determined and recorded before the placement of the material. An inventory of each material used will be kept during well installation to ensure that the wells were properly installed. The final step in extraction well construction and installation will be well development. Well development will involve the use of surge blocks to effectively remove fine-grained sediments from the filter pack into the well where they will be evacuated with a bailer and/or pump. Surging will be conducted in stages across successively lower segments of the screen, while periodically removing the sediment-laden water from the well. Appropriate monitoring and record keeping methods will be used to ensure proper well development.

During installation, at least two soil samples will be collected for ClO_4^- analysis from each well location, as described in Appendix B. Sample locations will be determined in the field based on observed conditions.

As shown in Figure 4-2, each extraction well interval will be equipped with a submersible pump. The pump will be controlled using the programmable logic control (PLC) at the groundwater treatment system. A manual valve will be used to reduce the pumping rate from each interval as necessary. In addition, each extraction well interval will be outfitted with a flow rate meter and flow totalizer to track flow from the given interval and a pressure transducer to monitor drawdown. Each extraction well will have a cartridge filter to remove particulate matter as necessary. See Section 4.8 for more information on the system instrumentation and controls.

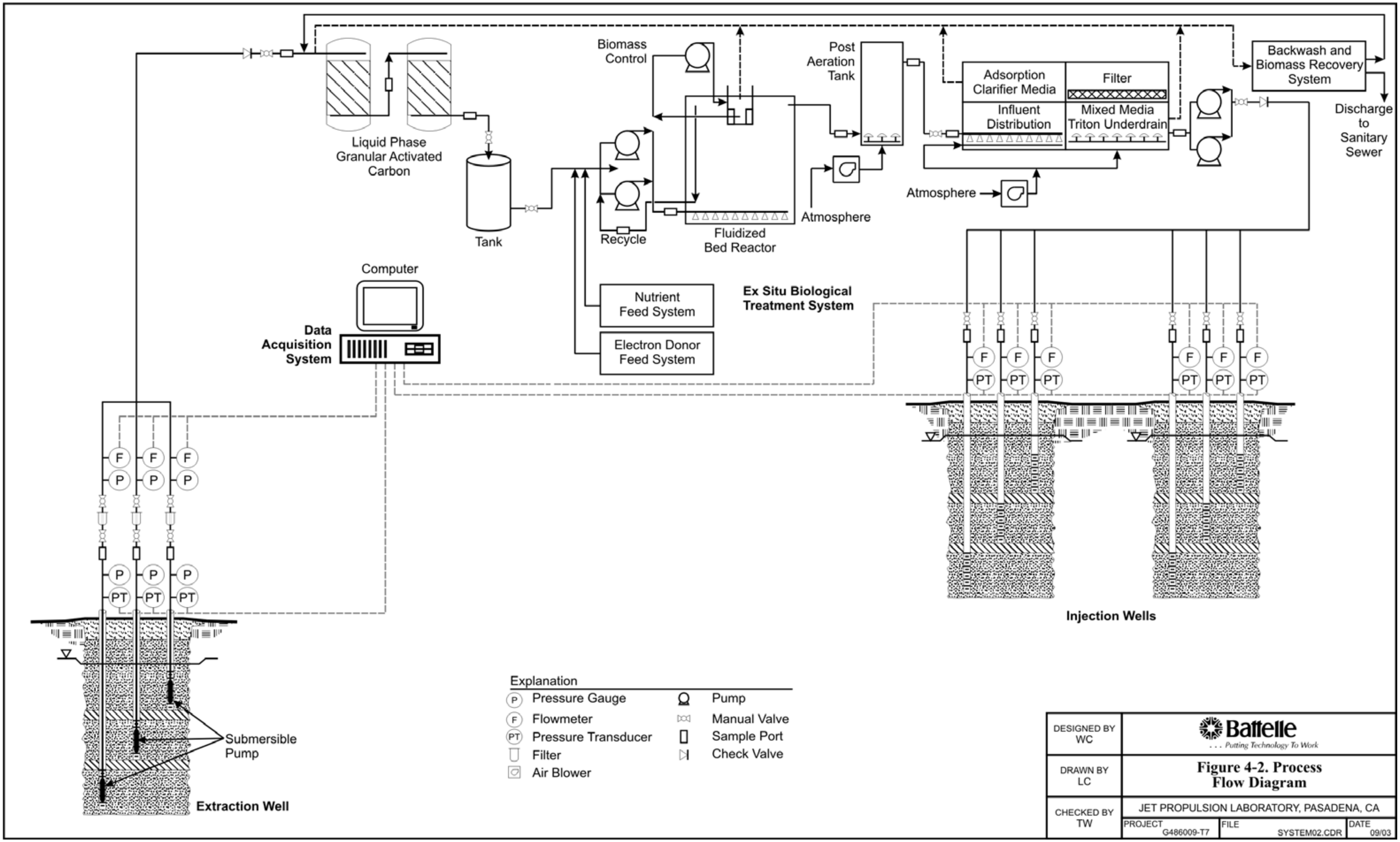

Figure 4-2. Process Flow Diagram

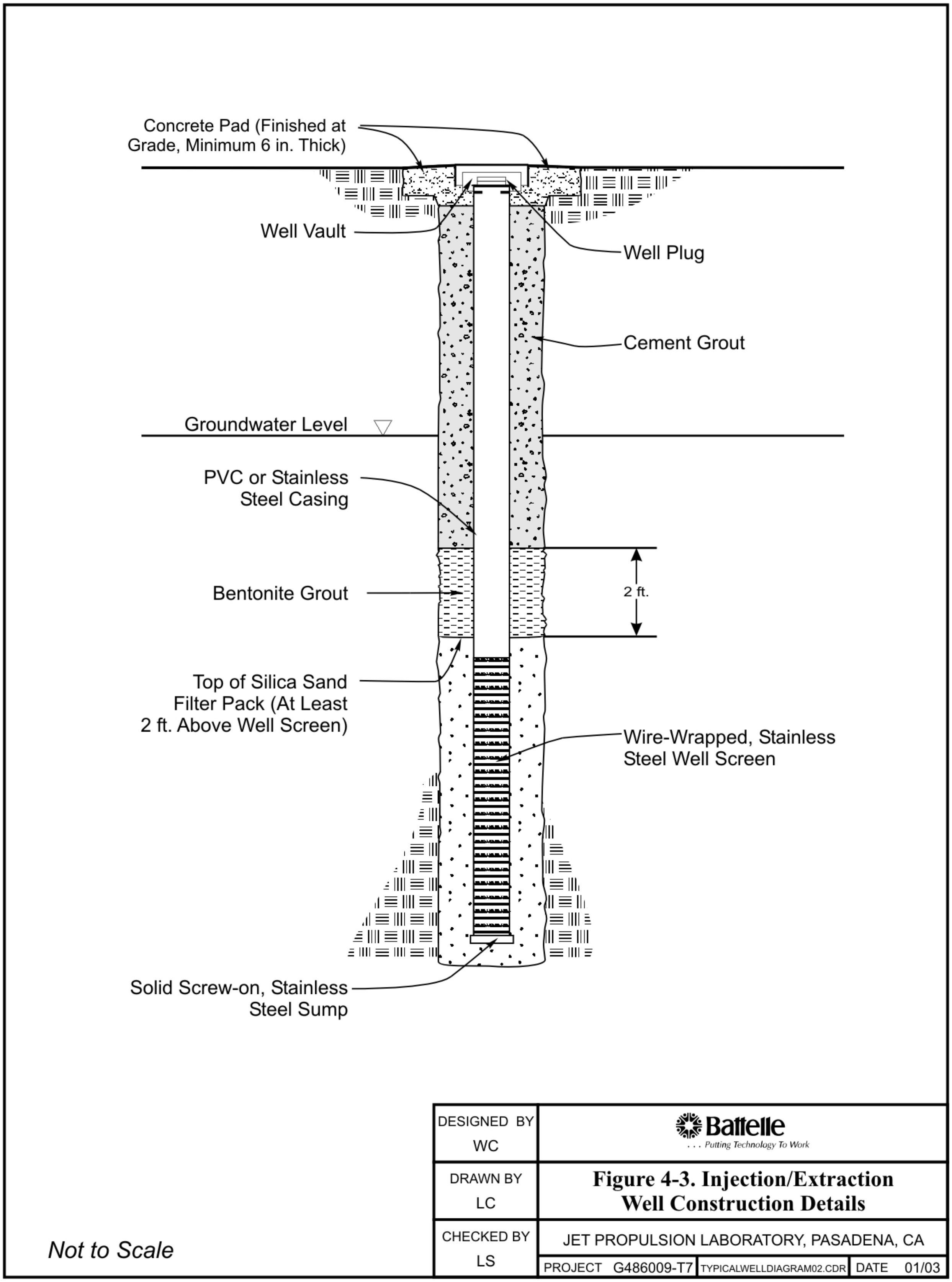

Figure 4-3. Well Construction Diagram

Table 4-1. Extraction Well Construction Details

Well Number	Screen Depth (ft bgs)	Casing Depth (ft bgs)	Casing I.D. (inches)	Casing Material
EW-01A	195 to 225	226	6	Schedule 80 PVC
EW-01B	230 to 260	261	6	Schedule 80 PVC
EW-01C	265 to 295	296	6	Schedule 80 PVC

4.3 Injection Well Design

The Phase I injection wells for the expanded treatability study will be completed in the same manner as the extraction well described above. Each injection well (IW-01 and IW-02) will consist of a set of three individual injection wells screened at intervals as shown in Table 4-2. The pumps at the groundwater treatment system will be used to reinject the treated groundwater into the aquifer. The pumps will be controlled from the PLC at the groundwater treatment system. A manual valve will be used to reduce the pumping rate to each injection well interval as necessary. In addition, each injection well interval will be outfitted with a flow rate meter and a flow totalizer to track flow to the given interval and a pressure transducer to monitor mounding. See Section 4.8 for information on instrumentation and controls.

Table 4-2. Injection Well Construction Details

Well Number	Screen Depth (ft bgs)	Casing Depth (ft bgs)	Casing I.D. (inches)	Casing Material
IW-01A	195 to 225	226	6	Schedule 80 PVC
IW-01B	230 to 260	261	6	Schedule 80 PVC
IW-01C	265 to 295	296	6	Schedule 80 PVC
IW-02A	195 to 225	226	6	Schedule 80 PVC
IW-02B	230 to 260	261	6	Schedule 80 PVC
IW-02C	265 to 295	296	6	Schedule 80 PVC

The injection wells that were installed for the in situ reactive zone (IRZ) demonstration project (Arcadis, 2002) may also be incorporated into the expanded treatability study, to the extent practicable. These wells may be used as reinjection points for treated groundwater and/or for the monitoring of water levels within the aquifer.

4.4 Monitoring Wells

Six monitoring wells will be sampled periodically, in coordination with site-wide groundwater monitoring program, throughout the expanded treatability study to track the performance of the system and also to monitor for potential lateral and/or vertical migration of the chemical plume. The existing monitoring wells that will be used are shown in Figure 1-1 and include MW-7, MW-8, MW-11, MW-13, MW-16, and MW-24. A summary of the key well construction details for these monitoring wells is provided in Table 4-3.

4.5 Underground Pipeline

Groundwater will be pumped from the extraction well (EW-01) and routed through an underground pipeline to the groundwater treatment system. The untreated groundwater will be pumped at a design flow rate of approximately 250 gpm through the pipeline to the treatment system. The treated water will then be recharged to the aquifer through three sections of pipeline to IW-01 and IW-02. The first section of the reinjection pipeline will be designed to convey a flow of at least 250 gpm. The second and third sections of the reinjection pipelines will be designed to convey a flow of at least 125 gpm each.

Table 4-3. Existing Monitoring Well Construction Details

Well	Well Type	Well Depth (ft bgs)	Screened Interval (ft bgs)	Top of Casing Elevation (ft amsl)	Screen Number	Screen Slot Size (inch)	Casing Material
MW-7	Shallow Standpipe	275	225-275	1212.88	NA	0.010	4" low carbon steel
MW-8	Shallow Standpipe	205	155-205	1139.53	NA	0.010	4" low carbon steel
MW-11	Deep Multi-Port	680	140-150 250-260 420-430 515-525 630-640	1139.35	1 2 3 4 5	0.010 0.010 0.010 0.010 0.010	4" low carbon steel
MW-13	Shallow Standpipe	235	180-230	1183.47	NA	0.010	4" PVC
MW-16	Shallow Standpipe	285	230-280	1236.27	NA	0.010	4.5" PVC
MW-24	Deep Multi-Port	725	275-285 370-380 430-440 550-560 675-685	1200.91	1 2 3 4 5	0.010 0.010 0.010 0.010 0.010	4" low carbon steel

Figure 4-1 shows the anticipated pipeline routing for the Phase I expanded treatability study system. The pipeline route is primarily under roads and parking lots from the north-central portion of the NASA JPL campus to the southeastern property boundary. As discussed in Section 5.1, significant project coordination and site preparation efforts will be required to place and install the underground piping. A licensed construction subcontractor will be hired to perform the necessary trenching activities. Utility clearances, as discussed in Section 5.1.3, will be performed and necessary arrangements will be made prior to performing any trenching activities.

It is anticipated at this time that 6-inch diameter, Schedule 80 PVC piping will be used to convey groundwater extracted from EW-01. All extraction and injection wells will be outfitted with check valves to prevent backflow (see Figure 4-2). During Phase I, it is estimated that excavation and backfill will be required of at most 3,800 linear ft of trench, 3 ft deep, and 2 ft wide. In addition, another 600 ft of piping would be added for the Phase II extraction/injection well piping. If visual staining of native material is noted, the stained soil will be placed in a drum, analyzed, and disposed off site as appropriate. Otherwise, the native material will be used as backfill. The PVC conveyance pipe will be pressure tested during installation to ensure that there are no leaks in the line prior to backfill. All trenching of road crossings and/or parking lots will include the removal and replacement of the existing asphalt and/or concrete. Where appropriate, system piping will be run aboveground.

4.6 Treatment Equipment

The key components of the groundwater treatment train include an LGAC adsorption system, a groundwater storage tank, an FBR, a post-aeration tank, and a multimedia sand filter. Figure 4-2 provides an overall schematic of the treatment system, and the major system components are discussed in the following subsections.

4.6.1 LGAC Adsorption Units

Two LGAC adsorption units, placed in series, will be used to remove VOCs from the extracted groundwater prior to treatment with the FBR. The LGAC will be used to reduce carbon tetrachloride, 1,1-dichloroethene, trichloroethene, tetrachloroethene, and other VOCs in groundwater to the appropriate levels. The current plan is to place the LGAC units before the FBR in the treatment train. However, this will be evaluated in preparation of the final design package. The LGAC adsorption units have been sized to handle at least 250-gpm flow rate and total VOC concentrations of 100 µg/L and consist of two, 8-ft-diameter tanks with approximately 10,000 lbs of granular activated carbon (GAC) each.

4.6.2 Groundwater Storage Tank

An aboveground polyethylene storage tank, with secondary containment, will be installed after the LGAC adsorption units to provide flow equalization and to act as a reservoir for VOC-treated groundwater. The tank will be sized to hold at least 20 minutes of system flow or 5,000 gallons.

4.6.3 Fluidized Bed Reactor

An FBR is an attached growth bioreactor in which microbes are supported and grow on a sand or GAC matrix within the reactor. Microbial growth is promoted within the FBR by adding electron donor source and a specially blended nutrient solution of nitrogen and phosphorus, which is added into the influent groundwater flow. Using the electron donor source, facultative anaerobic microbes within the reactor first consume the dissolved oxygen available in the influent groundwater. After the dissolved oxygen has been depleted, ClO_4^- -degrading microorganisms begin to reduce the nitrate to nitrogen gas and water and the ClO_4^- to chloride and water.

The expanded treatability study system will consist of one stainless steel FBR unit sized at 11.5 ft in diameter and 24 ft tall. This sizing is based on a flow rate of 250 gpm, an influent nitrate concentration of 21.9 mg/L, and an influent ClO_4^- concentration of 6.8 mg/L. FBR system sizing is typically based on treatment of the average nitrate and ClO_4^- levels in groundwater at the maximum anticipated flow rate. If the influent concentrations are greater than the design criteria, either equalization will be used to dilute the influent concentration or the flow to the bioreactor will be reduced to equalize the loading rate to the reactor. Approximately 32,000 lbs of GAC will be used as the filter media within the reactor. The FBR will be seeded with a proprietary biological inoculum provided by the proposed subcontractor, Shaw/Envirogen. More information on the configuration of the FBR system is provided in Appendix A.

The primary components of the FBR system include the chemical feed system, the reactor and fluidization pumps, and the biomass separation system. A brief discussion of these components is provided below.

The chemical feed system will consist of a nutrient feed unit and an electron donor feed unit. The nutrients added include nitrogen and phosphorus. Ethanol and acetic acid are the most common electron donor sources used in FBRs. It is assumed at this time that acetic acid will be selected as the electron donor source. In addition, a pH control unit is provided to stabilize the influent groundwater pH to within the 6 to 8 optimal operating range.

The total flow through the FBR consists of both the forward flow of untreated groundwater and the recycle flow of treated groundwater. Two fluidization pumps are used to pass the total influent flow up through the bioreactor to cause fluidization of the reactor media. Fluidization means that the media particles are suspended and not in direct contact with other particles. Fluidization increases the surface area available for microbial growth and therefore increases the efficiency of ClO_4^- reduction per unit volume of the reactor. A fluid distribution system, with a header and lateral system, ensures a uniform upflow velocity across the bottom of the bed. As the water travels up through the media, the bed is hydraulically expanded and fluidized. The flow rate must be high enough to achieve at least a 25% to 30% expansion of the bed.

The FBR also includes a biomass separation system. In general, as biomass continues to grow on the FBR media, the particle surface area will increase and the media particles will become less dense. The lowest density particles with the highest attached biomass will then move up to the top of the FBR causing further bed expansion. For this reason, a biomass control system is installed at the top of the reactor to remove the excess biomass and to maintain the target bed height. The biomass control system is designed to operate on an intermittent basis, as necessary, based on operating conditions. The system relies upon an airlift tube to pump the media from the top of the fluidized bed into a mixing chamber. Within the lift tube and mixing chamber, the coated media are agitated, thereby causing the biomass to separate from the media. The cleaned media are then returned to the reactor through a return pipe and settles down in the fluidized bed. The separated biomass from the mixing chamber is drawn off and discharged in the sanitary sewer (with approval) or transported to an appropriate off-facility disposal facility.

Treated effluent from the FBR is collected through submerged headers and is directed toward the effluent discharge or recycle. The headers are submerged to minimize turbulence within the effluent collection system that could re-introduce dissolved oxygen into the recycle stream. The recycle nozzle is set lower than the effluent nozzle to allow 100% recycle flow without the loss of volume.

4.6.4 Post-Aeration Tank

After treatment in the FBR, a post-aeration system will be used to raise the dissolved oxygen level in the treated groundwater to 4 to 5 mg/L to promote the degradation of any excess electron donor and to maintain aerobic conditions in the multimedia filter. For a 250-gpm system, the size of the post-aeration tank is a 9-ft-diameter by 20-ft-tall vessel constructed of fiberglass-reinforced plastic. The tank will contain a fine bubble diffuser grid to sparge the water and raise the dissolved oxygen levels in the FBR effluent.

4.6.5 Multimedia Filter

A multimedia (usually anthracite coal, silica sand, and garnet) filter system will be used both to filter the bioreactor effluent to remove any residual biomass and other suspended solids and to facilitate the aerobic consumption of any remaining electron donor prior to groundwater reinjection. The media filter utilizes three or more granular materials of varying sizes and specific gravities to allow for deep bed filtration. Deep bed filtration is a process that allows particles to be removed throughout the entire depth of the bed because media pore spaces at the bottom of the filter are smaller than those at the top. The size of the filter vessel is 28 ft long, 9 ft wide, and 8.5 ft tall. The filter will be outfitted with an air scour for periodic backwashing of the system. A polymer addition system will be used, if necessary, to promote coagulation of suspended solids.

4.7 Instrumentation and Controls

An Allen-Bradley PLC with operator interface will be used to monitor and control the operation of the groundwater extraction and injection pumps, and the groundwater treatment system. The controls will be routed to a National Electrical and Mechanical Association (NEMA) 4 Panel that will include the appropriate system motor controls, indicator lights, and alarms. Figure 4-2 indicates where flow meters, pressure transducers, pressure gauges, and sample ports will be located within the system. Table 4-4 provides an overview of the instrumentation components for the pumping operations that are external to the groundwater treatment train. The groundwater treatment system (i.e., LGAC, FBR, post-aeration tank, and multimedia filter units) will have separate instrumentation and controls as specified by the manufacturer, Shaw/Envirogen. As Figure 4-2 shows, flow meters will be placed at several locations to measure flow into and out of the expanded treatability study system as follows:

- Flow from each of the three screened intervals of extraction well one (EW-01);
- Flow to each of the three screened intervals of injection well one (IW-01);
- Flow to each of the three screened intervals of injection well two (IW-02); and

The PLC will control the submersible groundwater extraction pumps by monitoring the water table level using an appropriate pressure transducer setup to ensure that drawdown is not excessive or outside of anticipated normal limits. The submersible pumps and the entire system will be shut down when the low-level system shutoff alarm is triggered. In addition, flow rate signals from each well interval will be transmitted to the PLC where flow rate will be indicated and totalized. Three elapsed-time meters will be used to record the number of hours each groundwater extraction pump has operated. Fiber optic lines will be used to communicate between the individual well sites and the control panel located near the groundwater treatment system. In addition, pressure gauges will be placed on each extraction well line to determine the pressure drop across the filter cartridges, which are used to remove particulates from the extracted groundwater. This information will be important in determining when the cartridge filters need to be replaced. These pressure gauges will be manually monitored and not part of the PLC system.

The PLC will control the groundwater reinjection pumps by monitoring the water table level using an appropriate pressure transducer setup to ensure that groundwater mounding is within anticipated, normal limits. The reinjection pumps and the entire system will be shut down when the high-level system shutoff alarm is triggered. In addition, flow rate signals to each well interval will be transmitted to the PLC where flow rate will be indicated and totalized. Two elapsed-time meters will be used to record the number of hours each groundwater injection pump has operated. Radio telemetry, or equivalent, will be used to communicate between the individual well sites and the control panel located near the groundwater treatment system.

The groundwater storage tank (located after the LGAC units) will be equipped with a liquid level cutoff switch that will shut down the groundwater extraction pumps if the level of water in the tank reaches a pre-determined height. The tank will contain a high-high level switch, a high-level switch, and a low-level switch. The high-high level switch will deactivate the extraction pumps to avoid overflow of the tank. The outlets from the tank going to the FBR system will be located below the high-level switch, and this switch will activate the groundwater extraction pumps for more pumping. If the water level reaches the low-level indicator, the system will automatically shut down and an alarm will be triggered on the control panel to indicate that a system error has occurred.

Table 4-4. Pumping Instrumentation and Controls

Item	Quantity	Medium	Fitting Size	Fitting Material	Type of Operation	Range of Operation
Submersible Pump Switch	3	NA	NA	NA	On/off	NA
Submersible Pump Hour Meter	3	NA	NA	NA	Operational Time	NA
Ext. Well Flow Meter	3	Water	6"	PVC	Flow Rate	0-200 gpm
Ext. Well Flow Totalizer	3	Water	6"	PVC	Total Flow	NA
Ext. Well Pressure Transducer	3	Water	6"	PVC	Water Level	0-30 ft H_2O
Injection Well Flow Meter	6	Water	6"	PVC	Flow Rate	0-200 gpm
Injection Well Flow Totalizer	6	Water	6"	PVC	Total Flow	NA
Injection Well Pressure Transducer	6	Water	6"	PVC	Water Level	0-30 ft H_2O
Injection Well Pump Switch	2	NA	NA	NA	On/Off	NA
Injection Well Pump Hour Meter	2	NA	NA	NA	Operational Time	NA
Storage Tank Fluid Level	1	Water	NA	Poly Tank	Level Switch	Low,High, High-High

Note: NA = Not Applicable

Other potential instrumentation components under consideration include active on-line monitoring of the FBR influent and effluent levels for nitrate, ClO_4^-, dissolved oxygen (DO), oxidation-reduction potential (ORP), sulfide, and total organic carbon (TOC). This would be accomplished using the appropriate ion selective electrodes (ISE) and other field equipment.

4.8 Support Facilities and Utilities

A trailer will be set up on-facility to store monitoring, safety, and maintenance related equipment. The trailer area will include, at a minimum, a restroom, a sink, a sample refrigerator, a workbench, storage shelves, an eye wash, fire extinguishers, and first aid kits. A qualified subcontractor will be used to place the on-facility trailer and to provide utility hookups. In addition, a sewer hookup for the treatability study system may be needed to dispose of the nonhazardous waste solids generated by the FBR biomass separation system and backwashing of the multimedia filter.

Table 4-5 describes the preliminary electrical power requirements for the expanded treatability study system. A licensed electrician will be subcontracted to install power to the on-facility trailer and treatability study equipment as necessary.

Table 4-5. Power Requirements

Item	Power Requirements
Groundwater Treatment System	480 V, 3 Phase, 4 Wire, 150 Amps
Groundwater 10 HP Extraction Pumps	460 V, 3 Phase, 4 Wire, 50 Amps
Power Tool Supply	120 V, 1 Phase, 60 Amps

5.0 SYSTEM IMPLEMENTATION

During system implementation, the criteria that will be used in assessing the performance of the expanded treatability study system are as follows:

- **Maximize Chemical Mass Removal And Minimize Extraction Flow Rate**. This criterion will be met by focusing extraction only from those screens with the highest chemical concentrations.
- **Reduce Chemical Concentrations In Test Area Monitoring Wells.** The objective of this criterion is to achieve significant reduction of chemical levels in the test area.

The specific tasks that will be required for implementation of the expanded treatability study at NASA JPL are summarized below.

5.1 Coordination and Site Logistics

This project will require careful coordination with the Navy, NASA, and California Institute of Technology (CalTech) facility personnel to ensure the successful installation, construction, and operation of the system. Battelle will coordinate the activities necessary to prepare the site for the installation of wells, trenches, structures, and utilities to support the expanded treatability study, including surveying, underground utility clearance, and coordinating provisions for waste management and disposal.

5.1.1 Project Coordination

Battelle will coordinate with the Navy and NASA to complete all pre-fieldwork, installation, operation, and monitoring activities. The project coordination and site logistics will include the following activities:

- Obtaining the necessary work plan review by the appropriate federal, state, and local regulatory authorities. Their concurrence will be important in ensuring that all regulatory issues have been adequately addressed.
- Coordinating with the Navy, NASA, and CalTech facility personnel to obtain the appropriate dig and construction approvals.
- Installing the extraction and injection wells at the site.
- Selecting locations for system equipment and support facilities including a temporary storage area for supplies and generated wastes.
- Coordinating facility access clearance for project personnel, equipment, and vehicles.
- Coordinating system installation (including utility locating, well installation, piping installation, site surveying, and waste management) and system operation and maintenance activities.
- Allocating and scheduling analytical laboratory resources.
- Obtaining permission for sewer discharge of non-hazardous solids including recovered biomass from the FBR.

Upon receipt of NASA, Navy, and regulatory approval of this work plan, Battelle will conduct a pre-fieldwork site walk to point out proposed locations of system facilities and equipment. As necessary, Battelle will coordinate with the CalTech Environmental Affairs Office (EAO) and the

JPL security office for facility access, utility map review, equipment storage area designation, well and piping placement, electrical connection points, and other facility logistical support.

Additional system design details will be determined in consultation with NASA and the Navy prior to system implementation including:

- Extraction/injection well installation method (i.e., drilling method)
- Concrete pad design
- Underground piping design
- Final treatment system capacity
- Final electrical specifications.

5.1.2 Surveying

Following system installation, a California-licensed surveyor will be hired to locate the newly installed extraction well and injection well locations, the underground piping route, and the concrete pad footprint. In addition, all well elevations will be surveyed to assist in the determination of water table elevations within the treatability study area.

5.1.3 Utility Clearance

Battelle will review all available utility maps prior to finalizing the expanded treatability study system layout including well locations and underground piping routes. Battelle will schedule a meeting with the CalTech Facilities Engineering and Construction Section to discuss the proposed drilling locations and to review the utility maps of the locations. To the extent possible, well locations and piping runs will be strategically sited to avoid existing utilities. In addition, prior to performing any subsurface activities, the treatability study area will be scanned for underground utilities. The utility-locating contractor will employ several methods, including ground-penetrating radar (GPR), magnetometer, magnetic gradiometer, and/or electromagnetic imaging (EM). As required by California State law, Battelle will notify Underground Services Alert (USA), a communication center that provides notice to utility owners that may potentially have underground utilities traversing the JPL facility. 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 will be clearly marked where underground utilities are discovered. The utilities identified during these studies will be incorporated into the design drawings. To the extent possible, if any proposed work locations are affected by the presence of buried utilities, the affected locations will be offset to avoid impact to them. Prior to the initiation of drilling activities, Battelle will attempt to hand dig a pilot hole to a depth of approximately 5 ft bgs at each proposed well location to ensure that no underground utilities are present.

5.1.4 Waste Management

The primary wastes generated from implementing the expanded treatability study are listed below.

- Drill cuttings and well development water
- Monitoring well purge water
- Spent carbon
- Decontamination rinse water
- Biomass recovered from the FBR and backwash water from the multimedia filter

The amount of waste generated will vary based on actual field operations. Waste samples will be analyzed for VOCs, ClO_4^-, polychlorinated biphenyls (PCBs), pesticides, metals, and hexavalent chromium. Based on the laboratory results, the waste will be classified as hazardous or 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 California Code of Regulations (22 CCR). Battelle will prepare all required waste profiles and manifests for the waste. An appropriate EPA-certified waste disposal facility will be selected and a licensed transporter will haul the waste off-site for disposal. All waste transported off-site will be accompanied by the appropriate hazardous or non-hazardous waste manifest, signed by the CalTech EAO. The disposal of waste will be in accordance with federal, state, and local laws, regulations, and instructions.

Biomass recovered from the FBR and backwash water from the multimedia filter will be disposed of in the sanitary sewer. Battelle will coordinate with NASA, the Navy, and CalTech regarding connection to the sanitary sewer and approval to discharge.

5.2 System Installation and Shakedown

During system installation and shakedown, the expanded treatability study system and all associated equipment will be procured, delivered to the site, installed, and tested. This work will be performed primarily by Battelle staff; however, staff from several subcontractors will assist in the installation and startup of the groundwater treatment system. It is estimated that the procurement phase will occur over a three-month period and that the system installation and shakedown phase will occur over a two-month period. The work will proceed on installation of the expanded treatability study infrastructure as follows:

- Install the Phase I extraction well and injection wells;
- Survey installed well locations and elevations;
- Complete trenching for all piping and utilities, and install and test groundwater conveyance piping;
- Construct the concrete pad that will be used to support the treatability study equipment;
- Install and plumb the treatment system, including setup of the appropriate instrumentation and controls;
- Set up all associated support facilities including the field trailer and waste storage areas;
- Complete electrical and other utilities hookup; and
- Perform system startup and shakedown.

The FBR system startup and shakedown phase will require approximately two to three weeks to provide time for the biomass to be seeded and established within the reactor. The FBR will be monitored to determine when an adequate biomass has been established and therefore when the target nitrate and ClO_4^- effluent levels can be achieved. The FBR will be operated in recycle mode during this period until it can be demonstrated that adequate nitrate and ClO_4^- reduction has been achieved. Following this startup mode, active testing of the groundwater extraction well pumping can proceed. The target pumping rates in each well interval will be established to achieve the desired inflow rates from each groundwater extraction well interval. A week-long hydraulic shakedown test of the system will be necessary to ensure proper pump rates and, good hydraulic control within the system and to test that the automatic shutdown switches operate properly. Hydraulic testing may also include performance tests of the new extraction/injection wells to determine key hydraulic properties of the aquifer within the vicinity of these wells.

5.3 System Operation and Maintenance

Proper O&M will be a critical factor in optimizing the performance of the expanded treatability study system. During the expanded treatability study, a full-time operator will be on site five days a week to ensure proper operation of the system. The primary responsibilities of the operator will include:

- Verifying that the system is running and operating normally;
- Troubleshooting problems with the system as they arise;
- Performing routine system inspections and maintenance as specified in the manufacturer's O&M manual; and
- Performing monitoring and sample collection to determine the effectiveness of the treatment systems and in compliance with appropriate regulations.

Under normal daily operating conditions, the primary functions of the system will be automated including the following steps:

- Groundwater pumping from the extraction well (EW-01)
- Delivery of the extracted groundwater to the groundwater treatment train including the LGAC units, the FBR, the post-aeration tank, and the multimedia filter
- Delivery of treated groundwater to the injection wells (IW-01 and IW-02).

The operator(s) will be on site, as necessary, to make sure that the system is operating as intended and to perform any manual tasks specified by the manufacturer.

5.4 System Monitoring

In addition to the routine O&M described above, the operator will also be responsible for conducting sampling and analysis to evaluate the effectiveness of the biological treatment technology. More detailed information on system monitoring is presented in the Sampling and Analysis Plan (SAP) that is included in Appendix B. This section provides an overview of the parameters that will be tracked during baseline monitoring, performance monitoring, and compliance monitoring for the expanded treatability study system. In addition, hydraulic monitoring will be conducted to track hydraulic control within the subsurface and to monitor for biofouling and/or plugging of the injection wells.

5.4.1 Baseline Monitoring and Monitoring Well Network Sampling

Baseline monitoring and periodic sampling of the monitoring well network will be important in tracking the treatment effectiveness. Table 5-1 summarizes the parameters and associated EPA analytical methods that will be used for baseline monitoring and subsequent monthly sampling of the monitoring well network

5.4.2 Performance and Compliance Monitoring for the Treatment System

Table 5-2 summarizes both the performance and compliance monitoring planned for the groundwater treatment system. The parameters and associated EPA analytical methods are listed, along with the proposed sample collection frequencies at each sampling point. Once steady-state conditions have been reached, the sample collection frequencies listed in Table 5-2 may be reduced.

Table 5-1. Summary of Analytical Methods for Baseline Monitoring and Monitoring Well Network Sampling

Parameter	Analytical Method	Method Number	Monitoring Well Network
Field Parameters (pH, DO, ORP, temperature, specific conductance)	ISE	Field	Baseline + 1/quarter
ClO_4^-	IC	314	Baseline + 1/quarter
Ions (nitrate, nitrite, orthophosphate, sulfate, chlorate, chloride, bromide)	IC	300	Baseline + 1/quarter
VOCs	GC/MS	8260B	Baseline + 1/quarter

IC= ion chromatograph; GC = gas chromatograph; MS = mass spectrometer; ISE= ion selective electrode,

The LGAC system performance will be evaluated based on influent and effluent VOC concentrations. The midpoint between the two LGAC units will be sampled to assess breakthrough and the LGAC replacement frequency. The FBR system performance will be evaluated primarily based on influent and effluent nitrate and ClO_4^- concentrations and turbidity. Other parameters such as pH, ORP, DO, sulfide, and TOC will be monitored in the field to adjust FBR operating parameters as necessary. The influent and effluent DO levels will be measured at the post-aeration tank to track its operation. The multimedia filter will also be monitored to track electron donor degradation and its removal efficiency for suspended solids.

In addition, each extraction well interval will be monitored using field equipment and sampled on a weekly basis for ClO_4^-, inorganic ions, and VOCs. The system inlet (e.g., the combined flow at the LGAC inlet) and the system outlet (e.g., the multimedia filter outlet) will also be analyzed on a monthly basis to meet the regulatory requirements for the reinjection of groundwater.

Table 5-2. Summary of Analytical Methods for Groundwater Treatment System Performance and Compliance Monitoring

Parameter	Analytical Method	Method Number	Extraction Well Intervals	LGAC Inlet	LGAC Mid	FBR Inlet	FBR Outlet	Multimedia Filter Inlet	Multimedia Filter Outlet
Field Parameters (pH, DO, ORP, temperature, specific conductance)	ISE	Field	5/week	NA	NA	5/week	5/week	5/week	NA
ClO_4^-	ISE	Field	5/week	NA	NA	5/week	5/week	NA	NA
Nitrate	ISE	Field	5/week	NA	NA	5/week	5/week	NA	NA
Sulfide	ISE	Field	NA	NA	NA	5/week	5/week	NA	NA
TOC	Meter	Field	5/week	NA	NA	5/week	5/week	NA	NA
ClO_4^-	IC	314	1/week	1/week	NA	1/week	1/week	NA	NA
Ions (nitrate, nitrite, orthophosphate, sulfate, chlorate, chloride, bromide)	IC	300	1/week	1/week	NA	1/week	1/week	NA	NA
Sulfide	Titrimetric	376.1	NA	NA	NA	1/week	1/week	NA	NA
Nitrogen	Colorimetric	351.2	NA	NA	NA	1/week	1/week	NA	NA
VOCs	GC/MS	8260B	1/week	1/week	1/week	1/week	NA	NA	NA
1,4-Dioxane	MS	8270C	1/week	1/week	1/week	1/week	NA	NA	NA
Metals (Title 22: Sb, As, Ba, Be, Cd, Cr, Co, Cu, Pb, Hg, Mo, Ni, Se, Ag, Tl, Vn, and Zn; plus Fe and Mn)	ICP	6010B	NA	1/month	NA	NA	NA	NA	1/month
Hexavalent Chromium	IC	7199	NA	1/month	NA	NA	NA	NA	1/month
Alkalinity	Titrimetric	310.1	NA	1/month	NA	NA	NA	NA	1/month
Total Dissolved Solids	NA	160.1	NA	1/month	NA	NA	NA	1/month	1/month
Total Suspended Solids	NA	160.2	NA	1/month	NA	NA	NA	1/month	1/month
Turbidity	Nephelometric	180.1	NA	1/month	NA	NA	NA	1/month	1/month
Biological Oxygen Demand	NA	405.1	NA	1/month	NA	NA	NA	NA	1/month
Chemical Oxygen Demand	Colorimetric	410.4	NA	1/month	NA	NA	NA	NA	1/month

5.4.3 Hydraulic Monitoring

Groundwater levels will be monitored within the expanded treatability study wellfield to assess the hydraulic capture zone of the system and to track potential clogging and/or biofouling of wells. Groundwater level measurements will start at least 24 hours before the startup of any extraction and/or injection well operations. Groundwater levels at the extraction well and injection wells will be recorded electronically through the use of pressure transducers connected to the PLC device located at the groundwater treatment system. These readings will be compared with manual measurements taken at least monthly. In addition, the groundwater levels in the monitoring well network will be measured manually on at least a monthly basis. Both the manual and automatic water level measurements will be recorded to the nearest 0.01 ft. The manual groundwater level measurements will be recorded on the appropriate field data forms or in the field notebook.

A pattern of continuously rising groundwater levels in the injection wells, without corresponding regional water table changes, may indicate clogging and/or biofouling of these wells. During the expanded treatability study, O&M of the system will involve proactive measures to track and minimize well clogging and/or biofouling. The injection well screens may require periodic cleaning by chemical, physical, and/or mechanical methods to remove microbial slimes and/or other solids. Some common approaches for biofouling control include using chemicals such as chlorine, ozone, chlorine dioxide, hydrogen peroxide, biocides, or pH control. Redevelopment of the well may also be necessary on a periodic basis. A combination of these chemical, physical, and mechanical methods may be used during system operation to maintain adequate groundwater injection capacity. The capacity of extraction wells can also be reduced over time due to clogging and/or biofouling; therefore, similar maintenance may be required.

5.5 Data Interpretation and Reporting

The data obtained from the treatability study will be tabulated, reviewed, and interpreted on a continuous basis. In addition, Battelle will prepare progress reports regarding the expanded treatability study system performance and the progress in meeting the treatment objectives and performance criteria. Initially, these progress reports will be submitted via e-mail on a quarterly basis.

The progress reports for the treatment system will include a summary of VOC, ClO_4^-, and nitrate mass removal. It will also include results from hydraulic monitoring and a summary of other pertinent operational information for the groundwater treatment system including operational hours, electron donor and nutrient dosing levels, biomass growth and recovery, and other key measures of system performance.

5.6 System Optimization, Expansion Strategy, and Exit Strategy

Figure 5-1 illustrates the overall approach for operating and optimizing the expanded treatability study system. It also illustrates the system expansion and exit strategies.

The optimization of the expanded treatability study system will follow the NAVFAC *Guidance for Optimizing Remedial Action Operation* (NAVFAC, 2001). This guidance document presents a step-by-step process for maximizing the cost-effectiveness of a remedial action without compromising program or data quality. The general steps for system optimization include the following:

- Review and evaluate remedial objectives.
- Evaluate remediation effectiveness.
- Evaluate the cost effectiveness.
- Consider remediation alternatives.
- Develop and prioritize optimization strategies.

The above steps will be used on a continuing basis to seek to improve the O&M of the expanded treatability study system.

Optimization of the treatment system will be accomplished primarily by varying process operating conditions. Field readings and laboratory analyses will then be used to evaluate the treatment train system response and performance. The overall strategy will be to focus on maximizing system throughput, while maintaining treated effluent water quality. The amount of groundwater extracted from each well interval within EW-01 will be increased and/or reduced based on optimizing influent chemical mass loading rates. In addition, the system O&M manual will contain specific procedures for optimizing operation of the LGAC adsorption units, the FBR, the post-aeration tank, and the multimedia filter.

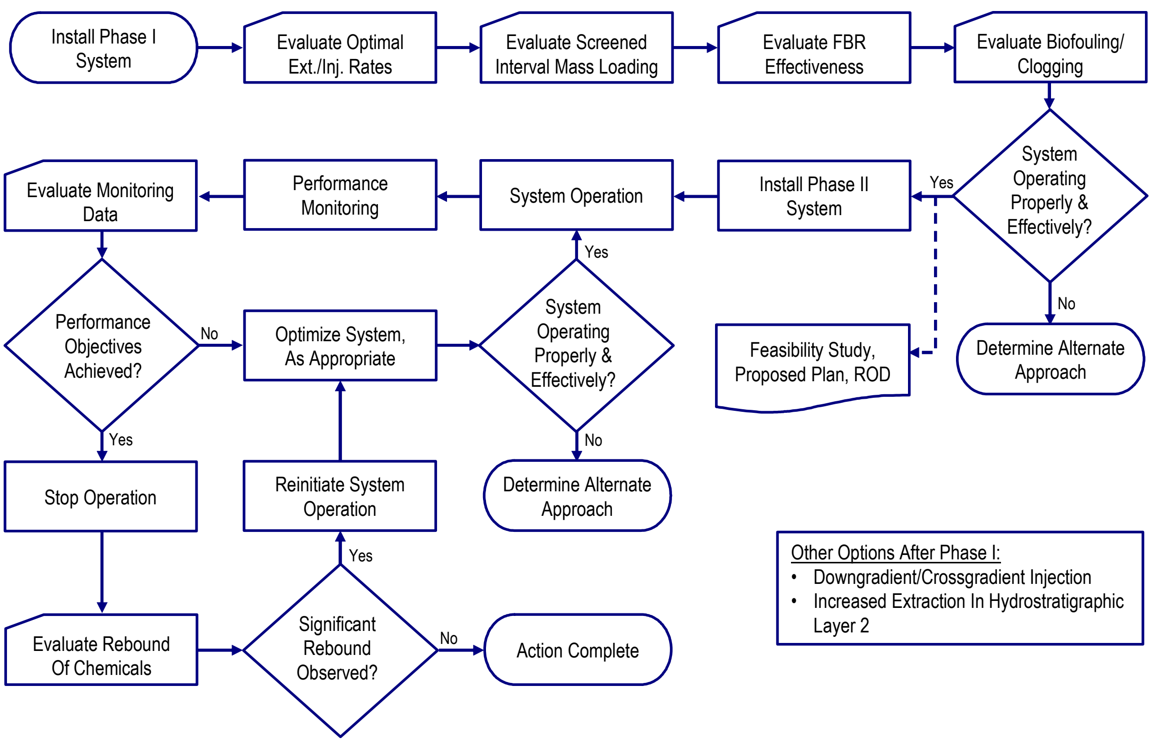

Figure 5-1. Flowchart of Expanded Treatability Study Optimization, Expansion, and Exit Strategy

After operation and optimization of the Phase I expanded treatability study, a technical memorandum will be prepared to provide a recommendation for further treatability study expansion (i.e., Phase II). Phase II currently involves the installation of one additional extraction well and two additional injection wells; however, additional options include downgradient or crossgradient groundwater injection or increased extraction from hydrostratigraphic layer 2. Phase II of the system will proceed concurrently with preparation of the OU-1 Feasibility Study, Proposed Plan, and Record of Decision (ROD) as shown in Figure 5-1.

The determination of "significant rebound" (see Figure 5-1) will be based on several factors including: (1) a comparison of the rebounded value to the pre-rebound concentrations, (2) site-specific chemical fate and transport results, (3) risk, and (4) cost-effectiveness (considering the remedial action for OU-3). NASA will coordinate closely with the regulatory agencies for review and approval prior to initiating any actions to permanently terminate and/or dismantle the system.

The proposed project schedule for implementing the tasks outlined in Section 5.0 is provided below.

Table 6-1. Proposed Expanded Treatability Study Project Schedule

No.	Task Name	Duration (Days)	Start Date	End Date
1	Preliminary Activities and Site Logistics			
1.1	Design Presentation to EPA, DTSC, and RWQCB	1	04/03/03	04/03/03
1.2	Draft Work Plan	90	01/03/03	04/03/03
1.3	Work Plan Finalization	207	04/07/03	10/31/03
1.4	Coordination Meeting With NASA/Navy/CalTech	1	10/21/03	10/21/03
1.5	Utility Clearance and Survey	5	11/03/03	11/07/03
2	System Installation and Shakedown			
2.1	Procurement Phase	122	07/01/03	10/31/03
2.2	Extraction Well Installation	7	11/10/03	11/16/03
2.3	Injection Well Installation	14	11/17/03	11/30/03
2.4	Concrete Pad Construction	14	12/08/03	12/22/03
2.5	Underground Piping Installation	14	12/08/03	12/22/03
2.6	Trailer Installation	7	11/24/03	11/30/03
2.7	Treatment System Installation	10	01/29/04	02/08/04
2.8	Instrumentation and Controls Installation	10	01/29/04	02/08/04
2.9	Electrical and Utilities Installation	23	01/14/04	02/06/04
2.10	System Startup and Shakedown	24	02/09/04	03/04/04
3	System Operation, Optimization, and Maintenance	TBD	03/04/04	TBD
4	System Monitoring	TBD	03/04/04	TBD
5	Data Interpretation and Reporting	TBD	03/04/04	TBD
6	System Expansion	TBD	TBD	TBD

Note: Schedule is tentative and subject to subcontractor availability.
TBD = To be determined

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