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## ACRONYMS/ABBREVIATIONS

1,1-DCA	1,1-Dichloroethane
1,2-DCA	1,2-Dichloroethane
1,1-DCE	1,1-Dichloroethene
APCL	Applied Physics and Chemistry Laboratory
As	Arsenic
ASTM	American Society for Testing and Materials
bgs	Below Ground Surface
Ca	Calcium
CADHS	California Department of Health Services
CA RWQCB	California Regional Water Quality Control Board
CCl <sub>4</sub>	Carbon Tetrachloride
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cl	Chloride
ClO <sub>4</sub> <sup>-</sup>	Perchlorate
CO <sub>3</sub> <sup>2-</sup>	Carbonate
COC	Chain of Custody
Cr	Chromium
Cr(VI)	Hexavalent Chromium
DQO	Data Quality Objective
DTSC	Department of Toxic Substance Control
EPA	Environmental Protection Agency
Fe	Iron
gal/min	Gallons per minute
HCO <sub>3</sub> <sup>-</sup>	Bicarbonate
IAL	Interim Action Level
JPL	Jet Propulsion Laboratory
K	Potassium
L	Liter
LDC	Laboratory Data Consultants, Inc.
MCL	Maximum Contaminant Level
Mg	Magnesium

µg/L	Micrograms per Liter
mg/L	Milligrams per Liter
mL	Milliliter
MS	Matrix Spikes
MSD	Matrix Spike Duplicates
msl	Mean Sea Level
MTBE	Methyl tertiary butyl ether
MW	Monitoring Well
Na	Sodium
NASA	National Aeronautics and Space Administration
NDMA	N-Nitrosodimethylamine
NO <sub>3</sub> <sup>-</sup>	Nitrate
NTU	Nephelometric Turbidity Unit
OU	Operable Unit
Pb	Lead
PCE	Tetrachloroethene
PQL	Practical Quantitation Limit
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
SO <sub>4</sub> <sup>2-</sup>	Sulfate
SOTA	SOTA Environmental Technology, Inc.
SVOC	Semi Volatile Organic Compound
TCE	Trichloroethene
TDS	Total Dissolved Solids
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
Westbay	Westbay Instruments, Inc.

## **EXECUTIVE SUMMARY**

Presented in this report are the results of the July 2001 groundwater sampling event completed as part of a groundwater monitoring program at the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) under contract with Naval Facilities Engineering Command. This sampling event was conducted from July 2 through August 1, 2001.

During this event, groundwater samples were collected from 19 JPL monitoring wells, both on- and off-facility, and analyzed for volatile organic compounds (VOCs), metals (total chromium and hexavalent chromium), and perchlorate. A summary of the sampling procedures is included in Section 2.0, and analytical results are presented in Section 3.0.

MW-2 has not been sampled since it was replaced with well MW-14 (Figure 1-1) as a JPL sampling point. MW-7 was also not sampled during this event because a pilot test was in progress.

The July 2001 results indicate that three VOCs (i.e., carbon tetrachloride, trichloroethene, and tetrachloroethene) were detected at concentrations above the State or Federal Maximum Contaminant Levels (MCLs) for drinking water. In addition, perchlorate concentrations exceeded the State Interim Action Level (IAL) for drinking water. Total chromium was detected in nine wells with one detection exceeding the State and Federal MCL. Hexavalent chromium was not detected in any of the wells. At this time, neither State nor Federal regulatory agencies have established MCLs for hexavalent chromium.

Water levels were measured in each well before and after sampling activities to evaluate groundwater gradients and flow directions present during sampling. Water-level measurements are discussed in Section 5.0. Groundwater flow was interpreted to be primarily to the south across JPL, turning eastward around the nearby City of Pasadena municipal production wells, which is consistent with the April 2001 event.

## 1.0 INTRODUCTION

This report summarizes the results from the July 2001 groundwater sampling event completed as part of the Groundwater Monitoring Program currently being conducted at the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL). This work is being performed by SOTA Environmental Technology, Inc. (SOTA) under contract with Naval Facilities Engineering Command, Contract No. N68711-98-D-5537 D.O. No. 0012-01. The JPL Monitoring Program was initiated in 1996 in response to a request from the United States Environmental Protection Agency (USEPA). The program began during the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Remedial Investigation of on-facility and off-facility groundwater at JPL. The purpose of the program is to monitor the elevation, flow direction, and quality of the groundwater beneath and adjacent to the JPL site.

From July 2 through August 1, 2001, SOTA personnel collected samples from 19 on-facility and off-facility JPL monitoring wells. In addition, the water-level elevation at each well was measured on July 2-3, 2001 (prior to sampling) and on August 1, 2001 (after sampling) to evaluate groundwater flow directions and gradients.

The locations of the JPL groundwater monitoring wells are shown in Figure 1-1. Monitoring wells MW-3, MW-4, MW-11, MW-12, MW-14, and MW-17 through MW-24 are deep multi-port wells, each containing five screened intervals equipped with a Westbay Instruments, Inc. (Westbay) multi-port casing system. Monitoring wells MW-5, MW-6, MW-8, MW-10, MW-13, and MW-16 are relatively shallow standpipe wells, each containing a single screened interval located just below the water table. A summary of the well construction details for the JPL groundwater monitoring wells is included in Table 1-1.

MW-2 has not been sampled since it was replaced with well MW-14 (Figure 1-1) as a JPL sampling point. MW-7 was also not sampled during this event because a pilot test was in progress. MW-1, MW-3 (screen 1), MW-9, MW-11 (screen 5), MW-15, MW-17 (screen 1), MW-18 (screen 1), MW-22 (screen 5), and MW-24 (screen 5) were not sampled due to changes in the sampling program as agreed to by the Environmental Protection Agency (EPA), Department of Toxic Substance Control (DTSC), and California Regional Water Quality Control Board (CA RWQCB).

All of the JPL groundwater samples were shipped to Applied Physics and Chemistry Laboratory (APCL) in Chino, California, for chemical analysis. APCL is certified by the California Department of Health Services (CADHS) and approved for use by the Naval Facilities Engineering Command, Quality Assurance/Quality Control (QA/QC) program. Sample collection procedures and sample analysis were conducted by SOTA in accordance with the Work Plan for Performing a Remedial Investigation/Feasibility Study prepared by Ebasco (Ebasco, 1993a), which was approved by the regulatory agencies.

In addition to groundwater samples, field quality assurance/quality control (QA/QC) samples, including trip blanks, equipment blanks, duplicate samples, and a field blank were collected for laboratory analysis. Sampling records for each shallow well and field data sheets for deep multi-

port wells are included in Appendix A. Piezometric pressure profiling records for each deep multi-port well are included in Appendix B. Laboratory analytical reports and associated chain-of-custody forms are included in Appendix C and Data Validation Reports are provided in Appendix D.

## **2.0 FIELD SAMPLING PROCEDURES**

Two different procedures were used in collection of groundwater samples at JPL, one designed for the shallow wells and the other for the deep multi-port wells. These procedures are outlined below.

### **2.1 Shallow Monitoring Wells**

The sampling procedure described below was applied to all the shallow JPL monitoring wells: MW-5, MW-6, MW-8, MW-10, MW-13, and MW-16.

The primary equipment used to sample the shallow wells included dedicated 2-inch diameter Grundfos Redi-Flo2<sup>®</sup> pumps, a pump controller, and a 220-volt generator. All of the dedicated Grundfos Redi-Flo2<sup>®</sup> pump systems were previously decontaminated, prior to their permanent installation. Details of the decontamination procedures for the Grundfos Redi-Flo2<sup>®</sup> pump systems are outlined in the OU-1 Field Sampling and Analysis Plan (Ebasco, 1993b).

Prior to sample collection, the water in each shallow well casing was purged (by pumping at about 2.5 gal/min) to remove groundwater that may have been exposed to the atmosphere and thus may not be representative of undisturbed aquifer conditions. This purged groundwater was discharged into 500 or 1,000-gallon polyethylene storage tanks for subsequent disposal by SOTA personnel pursuant to USEPA guidance (EPA, 1991 and EPA, 1992).

Temperature, pH, electrical conductivity, and turbidity of the water removed from each well were monitored during purging. Pursuant to the approved workplan (Ebasco, 1993b), a minimum of three casing volumes of water was purged and temperature, pH, electrical conductivity and turbidity were monitored for stabilization. When two successive measurements made approximately 5 minutes apart were within 10 percent of each other, groundwater samples were collected using the dedicated pump. During sampling for VOCs, the pumping rate was reduced to minimize sample agitation and volatilization. All information concerning sampling was noted on the Well Development/Well Sampling Log forms included in Appendix A.

All sample bottles were filled completely (though not allowed to overflow), capped, labeled, and immediately placed in a cooler with ice. Samples collected for VOCs had zero headspace.

Calibration, or standardization of the field instruments used to measure temperature, pH, electrical conductivity, and turbidity, was performed to the manufacturer's specifications at the beginning of each sampling day.

### **2.2 Deep Multi-Port Monitoring Wells**

Sampling of the deep multi-port monitoring wells at JPL required specialized sampling equipment manufactured by Westbay. This equipment included a pressure profiling/sampling probe with a surface control unit. Field personnel using this equipment were trained by Westbay personnel to ensure proper use. Copies of the detailed operations manuals for the Westbay

pressure profiling/sampling probe are included in the OU-1 and OU-3 Field Sampling and Analysis Plans (Ebasco, 1993b; 1994).

The Westbay sampling probe and sample-collection bottles were decontaminated prior to sampling each screened interval in the deep multi-port wells according to the following procedures:

- Each 250-mL stainless-steel sample-collection bottle was washed in a solution of non-phosphate detergent (Liquinox<sup>®</sup>) and distilled water followed by washing each bottle in a solution of an acidic detergent (Citranox<sup>®</sup>) and distilled water.
- Each bottle was rinsed with distilled water.
- The interior surfaces of the Westbay sampling probe, and the hoses and valves associated with the Westbay sample bottles, were decontaminated by forcing several volumes of a solution of Liquinox<sup>®</sup> and distilled water through them followed by forcing several volumes of a Citranox<sup>®</sup> and distilled water solution through them. A final rinse with distilled water was carried out. Each of these decontamination procedures was completed using clean plastic spray bottles used only for this purpose.

Purging before sampling is not required in the deep multi-port monitoring wells because the groundwater sample was collected directly from the aquifer, thus ensuring that the groundwater sample has not been exposed to the atmosphere. However, at each screened interval an initial sample was collected in order to check temperature, pH, electrical conductivity, and turbidity in the field. Samples for laboratory analysis were then collected and transferred to sample containers as described in Section 2.1. Results of the field analyses were recorded on groundwater sampling field data sheets, which are included in Appendix A. Calibration of field instruments was carried out according to procedures described previously.

### **2.3 Field Quality Assurance/Quality Control Samples**

Field QA/QC samples were collected to verify the quality of sampling procedures. The field QA/QC program included the collection of duplicate samples, equipment blanks, trip blanks, and a field blank. Laboratory QA/QC samples were used by the laboratory according to analytical method requirements.

Duplicate samples for VOCs, metals, and perchlorate ( $\text{ClO}_4^-$ ) analyses were collected from shallow groundwater monitoring wells MW-5, MW-10, MW-16 and deep multi-port monitoring wells MW-14 (Screen 2), MW-19 (Screen 2), and MW-24 (Screen 3).

Matrix-Spike (MS) and Matrix-Spike Duplicate (MSD) samples were collected for 10% of samples analyzed for VOCs, perchlorate, and metals. These samples were used for laboratory QA/QC requirements.



One equipment blank was collected from the Westbay sample-collection bottles during each day of sampling the deep multi-port wells. Equipment blanks consisted of distilled water, passed through the sampling equipment after the equipment had been decontaminated. Equipment blanks were analyzed for the same constituents as the groundwater samples to identify potential cross contamination due to inadequate decontamination. Equipment blanks were not collected during sampling of the shallow wells as only dedicated sampling equipment was used.

Trip blanks were used to identify potential cross contamination of groundwater samples during transport. A trip blank, consisting of ASTM Type II water placed in two 40-mL glass vials by the laboratory, was transported with the empty sample bottles to the field and back to the laboratory with the groundwater samples. One trip blank was submitted for VOC analysis with each shipment of groundwater samples to the laboratory.

During this sampling event, a field blank was collected on July 26, 2001. The field blank was used to evaluate whether site conditions may have effected the analytical results. The field blank, consisting of sample bottles filled with distilled water, was analyzed for VOCs.

### 3.0 ANALYTICAL RESULTS

JPL groundwater monitoring wells MW-3 through MW-6, MW-8, MW-10 through MW-14, and MW-16 through MW-24 were sampled from July 2 to August 1, 2001. MW-1, MW-3 (screen 1), MW-9, MW-11 (screen 5), MW-15, MW-17 (screen 1), MW-18 (screen 1), MW-22 (screen 5), and MW-24 (screen 5) were not sampled due to changes in the sampling program as agreed to by the EPA, DTSC, and RWQCB.

The groundwater samples collected during this sampling event were analyzed for volatile organic compounds (VOCs), total chromium (Cr), hexavalent chromium [Cr(VI)], and perchlorate (ClO<sub>4</sub>). A summary of the samples collected and the analyses performed on each sample is presented in Table 3-1. Analytical laboratory reports and associated chain-of-custody forms are included in Appendix C.

Nine chemicals have been most commonly reported above the laboratory detection limits (carbon tetrachloride (CCl<sub>4</sub>), trichloroethene (TCE), tetrachloroethene (PCE), 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethene (1,1-DCE), Freon 113, Chloroform, and perchlorate). The concentrations of these compounds have been plotted if at any time they exceeded their respective MCL from August/September 1996 through July 2001. The plots are presented in Figures 3-13 through 3-54.

#### 3.1 Volatile Organic Compounds Results

Groundwater samples collected during the July 2001 sampling event were analyzed for over 60 different VOCs in accordance with EPA Method 524.2. To present the results on concentration contour maps, the JPL aquifer was divided into four aquifer layers based primarily on correlations interpreted from lithologic cross sections. Listed in Table 3-2 are the JPL monitoring well screens and their corresponding aquifer layers. Results of the analyses for VOCs in the July 2001 samples are summarized in Table 3-3 along with the State and Federal Maximum Contaminant Levels (MCLs) for drinking water as listed in Title 22 of the California Code of Regulations and in the EPA Health Advisory Guidelines. A small number of compounds were detected in the JPL samples, and only three VOCs [carbon tetrachloride, TCE, and PCE] were found in concentrations exceeding State and/or Federal MCLs (Table 3-3).

The concentrations of carbon tetrachloride, TCE, and PCE detected in each aquifer layer have been contoured on site maps to show the spatial distribution of each constituent (Figures 3-1 through 3-9). For instances where a constituent was not detected above the MCL in a particular aquifer layer, a contour map was not prepared for that constituent in that particular layer and a map showing only detections below the MCL was prepared instead. These instances include PCE, which did not exceed the MCL in layers 1 and 2 (Figures 3-7 and 3-8). Carbon tetrachloride concentrations detected in aquifer layers 1, 2, and 3 are contoured in Figures 3-1, 3-2, and 3-3, respectively. Figures 3-4 and 3-6 display contours of TCE concentrations detected in layers 1 and 3, respectively, and Figure 3-9 shows contours of PCE detected in aquifer layer 3. A summary of the VOC results compiled from the long-term sampling events completed to date is provided in Table 3-4.

Carbon tetrachloride in excess of the State MCL (0.5 µg/L) was found in eight on-facility wells and two off-facility wells (Table 3-3, Figures 3-1, 3-2, and 3-3). The Federal MCL (5.0 µg/L) was exceeded in four on-facility wells. The highest concentrations of carbon tetrachloride were found in on-facility wells MW-13, MW-16, MW-24 (Screens 1 and 2), MW-12 (Screens 3 and 4) and MW-3 (Screen 3).

TCE concentrations exceeded the State and Federal MCL (5.0 µg/L) in three on-facility wells, and two off-facility wells (Table 3-3, Figures 3-4, 3-5, and 3-6). The highest levels of TCE were found in on-facility wells MW-10, MW-13, and off-facility wells MW-17 (Screens 4 and 5), MW-21 (Screen 1).

PCE was detected at low levels in several on-facility and off-facility wells (Table 3-3, Figures 3-7, 3-8, and 3-9). The State and Federal MCL (5.0 µg/L) was exceeded only in off-facility well MW-21 (Screens 4 and 5).

Additional data was obtained from the California Department of Health Services for the nearby municipal production wells owned and operated by the City of Pasadena and other water purveyors. One detection reported from Lincoln Avenue Water Company Well #5 (5.1 µg/L) exceeded the State MCL for TCE. This additional data was used to contour carbon tetrachloride, PCE, and TCE in Figures 3-1 through 3-9.

### **3.2 Perchlorate Results**

Perchlorate ( $\text{ClO}_4^-$ ) analyses were conducted on groundwater samples from the July 2001 event using ion chromatography (EPA 314.0, modified) and the results are included in Table 3-3. No MCLs for perchlorate have been established by regulators to date. However, the California Department of Health Services has established an Interim Action Level (IAL) of 18 µg/L for perchlorate. Perchlorate was detected in a total of 10 wells (Table 3-3), with concentrations in seven of the 10 wells exceeding the IAL (18 µg/L). Perchlorate concentrations are contoured in Figures 3-10, 3-11, and 3-12 for aquifer layers 1, 2, and 3, respectively. The highest perchlorate levels were observed on-facility in wells MW-13, MW-16, and MW-24 (Screens 1 and 2).

Additional data was obtained from the California Department of Health Services for the nearby municipal production wells. Only the sample from City of Pasadena Well #52 exceeded the IAL of 18 µg/L. The City of Pasadena Ventura well was sampled for perchlorate on July 25, 2001 and reported concentrations of 6.02 µg/L. The City of Pasadena Well #52 was sampled for perchlorate on July 11, 2001 and reported concentrations of 33.28 µg/L. The City of Pasadena Windsor well was sampled for perchlorate on July 11, 2001 and reported concentrations of 5.91 µg/L. This additional data was used to contour perchlorate in Figures 3-11 and 3-12.

### **3.3 Metals Results**

Groundwater samples were analyzed for the following metals: total chromium and hexavalent chromium. The results of the metals analyses are presented in Table 3-5, and are summarized below.

Total chromium was detected in nine wells with one detection exceeding both the State and Federal MCLs (0.05 and 0.10 mg/L, respectively). Hexavalent chromium was not detected in any of the samples collected during the July 2001 event. At this time, neither State nor Federal regulatory agencies have established MCLs for hexavalent chromium.

Table 3-6 presents a summary of metals data from all sampling events completed to date during the long-term monitoring program.

### **3.4 Quality Assurance/Quality Control Results**

Review of the QA/QC data provided with the laboratory analytical results indicates that all of the analytical results obtained from July 2001 samples are acceptable for their intended use of characterizing aquifer quality. Surrogate compound, matrix and blank spike, and method blank results were used by the laboratory to determine the accuracy and precision of the analytical techniques with respect to the JPL groundwater matrix, and to identify anomalous results due to laboratory contamination or instrument malfunction.

In addition to laboratory QA/QC samples, SOTA personnel collected QA/QC samples in the field in accordance with Quality Assurance Project Plan (QAPP) (Ebasco, 1993c). These samples included duplicate samples, equipment blanks, trip blanks, and a field blank.

Duplicate samples were used to evaluate the precision of the laboratory analyses. Duplicate samples for VOCs, metals, and perchlorate ( $\text{ClO}_4^-$ ) analyses were collected from shallow groundwater monitoring wells MW-5, MW-10, MW-16 and deep multi-port monitoring wells MW-14 (Screen 2), MW-19 (Screen 2), and MW-24 (Screen 3). All of the analytical results for the duplicate samples were comparable to the results of the original groundwater samples (Table 3-3 and Table 3-5).

## **4.0 DATA VERIFICATION AND VALIDATION**

The purpose of data verification and validation is to assure that the data collected meet the DQOs outlined in the Quality Assurance Project Plan of the Groundwater Monitoring Plan and that the data are of sufficient quality for use in meeting the objectives outlined in the Groundwater Monitoring Plan (Ebasco, 1993c).

### **4.1 Data Verification**

All data collected were subjected to data verification. In general, verification identifies non-technical errors in the data package that can be corrected (e.g., typographical errors). Data verification included proofreading and editing hard-copy data reports to assure that data correctly represent the analytical measurement. Data verification also included verifying that the sample identifiers on laboratory reports (hard copy) match those on the chain-of-custody record.

### **4.2 Data Validation**

Data validation was performed by an independent subcontractor, Laboratory Data Consultants, Inc., Carlsbad, CA (LDC). One hundred percent of all data analyzed by a fixed-base analytical laboratory (APCL) were validated. One hundred percent of the data were subjected to Level IV quality assurance requirements of the Navy (Navy, 1996 and Navy, 1999).

Data validation is a systematic process used to interpret, define, and document analytical data quality and determine if the data quality is sufficient to support the intended use(s) of the data. Validation of a data package includes a reconstruction of sample preparation and analysis activities from the raw data and reconciliation of the raw data with the reduced results, identification of data anomalies, and qualification of data to identify data usability limitations. The data were further evaluated to help ensure suitability and usability for the purpose of the groundwater monitoring report.

### **4.3 Data Validation Qualifiers**

Analytical data were qualified based on data validation reviews. For chemical data, qualifiers were assigned in accordance with the applicable U.S. EPA National Functional Guidelines for Data Validation (EPA, 1994a and 1994b). Data may be rejected for non-compliance with method requirements during the course of validation. Data may also be qualified as unusable in dilutions and reanalysis to yield only one complete set of data for a given sample and eliminate redundant data. The intent of the latter classification is to guide data users in choosing the best set of sample analytical results when reanalysis and/or dilutions exist. Individual laboratory data flags can be found in Appendix D.

## 5.0 WATER-LEVEL MEASUREMENTS

Water-level measurements were recorded before the sampling event on July 2-3, 2001, and after the sampling event on August 1, 2001, to evaluate groundwater flow directions and gradients beneath and adjacent to JPL. Water levels in the shallow wells were measured using a Solinst® water level meter. In the deep multi-port wells, the hydraulic head at each sampling port was measured with a Westbay pressure-transducer probe.

Water table elevation measurements taken before sampling are provided in Table 5-1 and have been contoured in Figure 5-1. Water-table elevation measurements taken after sampling are provided in Table 5-2 and have been contoured in Figure 5-2. The hydraulic heads measured at each deep multi-port well screen before and after sampling are presented graphically in Figures 5-3 and 5-4, respectively. The pressure-profile records for the deep wells are included in Appendix B.

As indicated by Figures 5-1 and 5-2, the estimated groundwater flow direction both before and after sampling was primarily to the south through JPL and then turned east across the Arroyo and plain in the vicinity of nearby municipal production wells. Groundwater gradients ranged from about 0.14 feet per foot near MW-9, at the northern end of the Arroyo, to roughly 0.008 feet per foot across the arroyo and plain.

## **6.0 CONCLUSIONS AND RECOMMENDATIONS**

The following conclusions are based upon interpretation of analytical data and field measurements collected during the July 2001 event of the JPL Monitoring Program:

- The chemical plumes beneath JPL are adequately defined and relatively stable.
- The estimated groundwater flow direction was observed to be primarily to the south and east across JPL with an eastward flow direction in the plain near the City of Pasadena municipal production wells. This observation is generally consistent with previously reported data (Foster Wheeler, 2000).

Based on the results of the JPL Monitoring Program, an evaluation of the groundwater monitoring program should be conducted to update the program, which may include a reduction in the frequency of analyte monitoring as well as the number of analytes reported.

## 7.0 REFERENCES

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