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GROUNDWATER MONITORING REPORT

JANUARY-FEBRUARY 2002

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JET PROPULSION LABORATORY
PASADENA, CALIFORNIA

Contract No. N68711-98-D-5537, D.O. No. 0012-01

Naval Facilities Engineering Command
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Project No. 00HW019

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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
ASTM	American Society for Testing and Materials
CCl_4	Carbon Tetrachloride
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
ClO_4^-	Perchlorate
Cr	Chromium
Cr (VI)	Hexavalent Chromium
DQOs	Data Quality Objectives
DTSC	Department of Toxic Substance Control
EPA	Environmental Protection Agency
gpm	Gallons per minute
IAL	Interim Action Level
JPL	Jet Propulsion Laboratory
LDC	Laboratory Data Consultants, Inc.
MCLs	Maximum Contaminant Levels
µg/L	Micrograms per Liter
mg/L	Milligrams per Liter
mL	Milliliter
MS	Matrix Spikes
MSD	Matrix Spike Duplicates
MW	Monitoring Well
NASA	National Aeronautics and Space Administration
OU	Operable Unit
PCE	Tetrachloroethene
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
RWQCB	California Regional Water Quality Control Board
SOTA	SOTA Environmental Technology, Inc.
TCE	Trichloroethene
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds
Westbay	Westbay Instruments, Inc.

EXECUTIVE SUMMARY

Presented in this report are the results of the January-February 2002 groundwater sampling event completed as part of the 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 (at all wells except well MW-7) from January 7 through February 7, 2002. Monitoring well MW-7 was sampled on February 22, 2002.

During the January - February 2002 sampling event, groundwater samples were collected from 23 JPL monitoring wells, both on- and off-facility, and analyzed for volatile organic compounds (VOCs), metals (arsenic, lead, total chromium, and hexavalent chromium), perchlorate, and general water chemistry parameters including major anions/cations, total dissolved solids, and pH. Analyses for 1,4-dioxane and N-nitrosodimethylamine (NDMA) were also performed on six selected samples to evaluate its possible presence in groundwater beneath JPL. MW-2 has not been sampled since it was replaced with well MW-14 as a JPL sampling point.

All data collected were subject to data verification and all laboratory analytical data were validated pursuant to the Navy's Level IV quality assurance requirements. Some of the analytical data were qualified based on data validation reviews, in accordance with applicable U.S. EPA guidelines. No data were rejected for non-compliance with method requirements during the course of validation and no data were qualified as unusable. The analytical results are summarized below.

- Six on-facility wells and three off-facility wells contained concentrations of one or more of four VOCs (carbon tetrachloride, trichloroethene, tetrachloroethene, and 1,1-dichloroethene), that exceeded State or Federal Maximum Contaminant Levels (MCLs) for drinking water. Concentration contour maps generally indicate slow migration of the contaminant plumes over the last year.
- Perchlorate was detected in twelve on-facility wells and four off-facility wells, with concentrations in seven on-facility wells that exceeded the State Interim Action Level (IAL). Perchlorate concentrations in the three most highly contaminated wells have generally increased over the last two years. Concentration contour maps generally indicate slow migration of the contaminant plume over the last year.
- Total chromium was detected in seventeen wells, with concentrations at two on-facility wells that exceeded the State and Federal MCL. Hexavalent chromium was detected in one well. At this time, neither State nor Federal regulatory agencies have established MCLs for hexavalent chromium.
- Trace concentrations of arsenic and/or lead were detected in samples from three on-facility wells and two off-facility wells. No arsenic or lead concentrations were reported above the State or Federal MCLs.
- 1,4-Dioxane was reported at trace concentrations in samples from on-facility wells MW-7, MW-16, MW-13, and MW-24 (Screen-1). At this time, neither State nor Federal MCLs/IALs have been established for 1,4-dioxane.

- NDMA was not detected in any of the groundwater samples collected above the laboratory reporting limit (0.002 μg/L). The current drinking water IAL for NDMA is 18 μg/l. No State or Federal MCLs have been established for NDMA.
- Results from major anion and cation analyses (water chemistry) were used to identify the general water types beneath JPL. General water chemistry analyses indicate an adequately defined and relatively stable groundwater chemistry beneath JPL. This finding is generally consistent with previously-reported data.

Groundwater gradients and flow directions before and after sampling activities were consistent with previous observations. Moderate increases in hydraulic head were measured in shallow wells and Westbay well screens in Aquifer Layers 1, 2, and 4, while significant increases were measured in Aquifer Layer 3 well screens. The water level fluctuations are likely due to several hydrologic phenomena operating simultaneously including, but not limited to, groundwater recharge, pumpage, and/or artificial recharge.

1.0 INTRODUCTION

This report summarizes the results from the January-February 2002 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. 0012-09. 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.

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.

During the January-February 2002 event, SOTA personnel collected samples from 23 on-facility and off-facility JPL monitoring wells. In addition, the water-level elevation at each well was measured on January 7 and 8, 2002 (prior to sampling), and on February 7, 2002 (after sampling) to evaluate groundwater flow directions and gradients. Water levels were not measured at MW-7 before or after sampling activities due to wellhead access restrictions.

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 January 9 through February 6, 2002. Monitoring well MW-7, where a pilot test by others has been in progress by others, was sampled on February 22, 2002. Samples from each well were collected and analyzed during this event in accordance with the sampling program that was approved by the Environmental Protection Agency (EPA), Department of Toxic Substance Control (DTSC), and California Regional Water Quality Control Board (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 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 (Ebasco, 1993a), which was approved by the regulatory agencies. The following analyses were performed on the samples collected at JPL:

JANUARY - FEBRUARY 2002 GROUNDWATER SAMPLE ANALYSES

Analysis	Well (Screen)	EPA Method
Volatile Organic Compounds (VOCs)	All*	524.2
Perchlorate (ClO_4^-)	All*	314.0
Total Chromium (Cr)	All*	200.8
Hexavalent Chromium [Cr(VI)]	All*	7196
Total Lead (Pb)	All*	200.8
Total Arsenic (As)	All*	200.9
Total Dissolved Solids (TDS)	All*	160.1
pH	All*	150.1
Major Cations and Major Anions	All*	Various
1,4-Dioxane	MW-4 (Screen 2), MW-7, MW-13, MW-16, MW-17 (Screen 3), MW-24 (Screen 1)	8270
N-Nitrosodimethylamine (NDMA)	MW-4 (Screen 2), MW-7, MW-13, MW-16, MW-17 (Screen 3), MW-24 (Screen 1)	1625M

Note: * MW-18 (Screen 1) was not sampled due to a dry screen.

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 analyses. 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 to collect 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, including 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® pumps, a pump controller, and a 220-volt generator. All of the dedicated Grundfos Redi-Flo2® pump systems were previously decontaminated prior to their permanent installation. Details of the decontamination procedures for the Grundfos Redi-Flo2® 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 gpm) 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 in accordance with Federal, State, and local regulations.
>
> Temperature, pH, electrical conductivity, and turbidity of the water removed from each well were monitored during purging. Pursuant to the approved work plan (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 without overflowing, 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 according to the manufacturer's specifications at the beginning of each sampling day.

A groundwater sample was collected from shallow well MW-7 on February 22, 2002. The sampling procedure for this well was generally the same as for the other shallow wells, with the following exceptions:

1) A 3-½” diameter submersible pump was installed at well MW-7 for use with pilot testing that was conducted by others. This pump was used for purging and sampling at MW-7.
2) Due to the pilot system installation, the wellhead at MW-7 was not accessible for water level measurements. Based on previous measurements, the water level in the well was estimated to calculate the appropriate volume of water that needed to be purged prior to sampling.

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. To ensure proper use, field personnel using this equipment were trained by Westbay personnel. 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®) and distilled water, followed by a solution of an acidic detergent (Citranox®) 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® and distilled water through them, followed by forcing several volumes of a solution of Citranox® and distilled water. 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 was not 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 source blanks. Laboratory QA/QC samples were used by the laboratory according to analytical method requirements.

Duplicate samples for VOCs, metals, and perchlorate (ClO_4^-) analyses were collected from shallow groundwater monitoring wells MW-15 and MW-16, and deep multi-port monitoring wells MW-4 (Screen 3), MW-12 (Screen 2), MW-18 (Screen 3), MW-19 (Screen 3), MW-23 (Screen 3), and MW-24 (Screen 5). Duplicate samples for NDMA and 1,4-dioxane analyses were collected from shallow groundwater monitoring well MW-16.

Matrix-Spike (MS) and Matrix-Spike Duplicate (MSD) samples were collected for 10% of samples that were analyzed for VOCs, perchlorate, NDMA, 1,4-dioxane, 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 that was passed through the sampling equipment after the equipment was decontaminated. Equipment blanks were analyzed for the same constituents as the groundwater samples, except for cations and anions, total dissolved solids, and pH, to identify potential cross contamination due to inadequate decontamination. Because only dedicated sampling equipment was used, equipment blanks were not collected during sampling of the shallow wells.

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. Trip blanks were used to identify potential cross contamination of groundwater samples during transport.

During this sampling event, one source blank was collected on January 9^{th}. The source blank was used to evaluate whether the source water or sample containers may have affected the analytical results. The source blanks, consisting of sample bottles filled with distilled water, were analyzed for VOCs.

3.0 ANALYTICAL RESULTS

The groundwater samples collected during this sampling event were analyzed for the following:

- Volatile Organic Compounds
- Total Chromium (Cr)
- Hexavalent Chromium [Cr(VI)]
- Total Lead (Pb)
- Total Arsenic (As)
- Total Dissolved Solids (TDS)
- pH
- Major Cations and Major Anions
- Perchlorate ($ClO4^-$)

Groundwater samples collected from six locations [MW-4 (Screen 2), MW-7, MW-13, MW-16, MW-17 (Screen 3), and MW-24 (Screen 1)] during the January-February 2002 sampling event were also analyzed for 1,4-dioxane and NDMA. 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.

The aquifer beneath JPL was divided into four aquifer layers based primarily on correlations interpreted from lithologic cross sections (Foster Wheeler, 2000). Table 3-2 provides a list of the JPL Westbay monitoring well screens and their corresponding aquifer layers. Concentrations of carbon tetrachloride (CCl_4), trichloroethene (TCE), tetrachloroethene (PCE), and ClO_4^- reported during this event are presented for each aquifer layer in Figures 3-1 through 3-12.

3.1 Volatile Organic Compounds

Groundwater samples collected during the January-February 2002 sampling event were analyzed for over 60 different VOCs in accordance with EPA Method 524.2. Results of the analyses for VOCs in the January-February 2002 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 four VOCs [carbon tetrachloride, TCE, PCE, and 1,1-DCE] were found in one or more wells at concentrations that exceeded State and/or Federal MCLs. The concentrations of carbon tetrachloride, TCE, and PCE detected in each aquifer layer were contoured on site maps to show the spatial distribution of each constituent (Figures 3-1 through 3-9). The analytical results for compounds that exceeded MCLs are discussed below.

- Concentrations of carbon tetrachloride in excess of the State MCL (0.5 µg/L) were reported in samples from seven on-facility wells (MW-3, MW-7, MW-8, MW-12, MW-13, MW-16, and MW-24) and two off-facility wells (MW-17 Screen 3 and MW-18 Screen 4). The Federal MCL (5.0 µg/L) was exceeded in all of these wells, except MW-8, MW-12, MW-17 and MW-18. The highest concentrations of carbon tetrachloride were reported in well MW-7 (135 µg/l) and well MW-24 (24.2 µg/l).

- Trichloroethene was detected in fourteen on-facility wells and four off-facility wells. Reported TCE concentrations exceeded the State and Federal MCL (5.0 µg/L) in three on-facility wells (MW-7, MW-13, and MW-24) and one off-facility well (MW-17 Screens 4 and 5). The highest concentrations of TCE were reported in samples from on-facility wells MW-7 (15.4 µg/L) and MW-13 (12.5 µg/L).

- Tetrachloroethene was detected in nine on-facility wells and in all five off-facility wells. The State and Federal MCL (5.0 µg/L) was exceeded only in off-facility well MW-21 (9.9 µg/L in Screen 4 and 19.2 µg/l in Screen 5) and on-facility well MW-7 (17.1 µg/L).

- 1,1-Dichloroethene was detected in five on-facility wells (MW-6, MW-7, MW-13, MW-16, and MW-24 Screen 1), with one concentration reported at the State MCL of 6.0 µg/L (MW-7) and the remaining concentrations reported between 0.7 and 1.3 µg/L.

A summary of the VOC results compiled from the long-term sampling events that have been completed to date is provided in Table 3-4. Nine chemicals have been most commonly reported with concentrations above the laboratory detection limits [CCl_4, TCE, PCE, 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethene (1,1-DCE), Freon 113, Chloroform, and ClO_4^-)]. The concentrations of these compounds versus time were plotted, if at any time they exceeded their respective MCL in the period from August/September 1996 through January-February 2002. The plots are presented in Figures 3-13 through 3-54.

Additional data regarding VOC concentrations in samples collected from the 15 municipal production wells in the vicinity of JPL was obtained from the California Department of Health Services Drinking Water Program. The most recently available analytical results were compiled for samples collected from municipal and private drinking water wells owned and operated by the City of Pasadena, La Canada Irrigation District, Lincoln Ave. Water Company, Valley Water Company, Rubio Canon Land & Water Company, and Las Flores Water Company. The drinking water data are summarized in Table 3-5 and presented in the concentration contour maps for carbon tetrachloride, PCE, and TCE in Figures 3-1 through 3-9.

The most recent samples from seven drinking water wells exceeded the State MCLs for carbon tetrachloride, TCE, or PCE. Carbon tetrachloride was detected in two City of Pasadena wells - the Arroyo Well and Well #52 (10.1 µg/L and 2.3 µg/L, respectively), both exceeding the State MCL (0.5 µg/L). TCE was detected in all of the City of Pasadena, Lincoln Ave. Water Co., and Valley Water Co. wells, but only reported above the MCL (5.0 µg/L) at Lincoln Ave. Water Co. Well #3 (5.4 µg/L). PCE was detected in nine of the 15 municipal wells, exceeding the MCL (5.0 µg/L) at Valley Water Co. Well #1 (7 µg/L), Well #2 (11 µg/L), and Well #4 (5.4 µg/L), as well as Las Flores Water Co. Well #2 (13 µg/L).

3.2 Perchlorate

Perchlorate (ClO_4^-) analyses were conducted on groundwater samples from the January-February 2002 event using ion chromatography (EPA 314.0, modified) and the results are summarized in Table 3-3. No MCLs have been established for perchlorate, although the California Department of Health Services has established an IAL of 18 μg/L. Perchlorate was detected in twelve on-facility wells and four off-facility wells. Perchlorate concentrations in seven on-facility wells exceeded the IAL (MW-3, MW-5, MW-7, MW-8, MW-13, MW-16, and MW-24).

The highest levels of perchlorate were reported in samples from MW-7 (4090 μg/l), MW-16 (2070 μg/l), and MW-24 (1460 μg/l in Screen 1). Perchlorate concentrations in these farthest upgradient wells have generally increased over the last two years, which suggests that the source is nearby or to the north. Perchlorate concentrations have been contoured in Figures 3-10, 3-11, and 3-12 for aquifer layers 1, 2, and 3, respectively.

Additional data regarding perchlorate concentrations in samples collected from the fifteen municipal production wells in the vicinity of JPL was obtained from the California Department of Health Services Drinking Water Program. The most recently available analytical results were compiled for samples collected from municipal and private drinking water wells owned and operated by the City of Pasadena, La Canada Irrigation District, Lincoln Ave. Water Company, Valley Water Company, Rubio Canon Land & Water Company, and Las Flores Water Company. The drinking water data are summarized in Table 3-5 and presented in the concentration contour maps in Figures 3-10 through 3-12. Although perchlorate exceeded the IAL (18 μg/L) only at City of Pasadena Well #52 (23.25 μg/L), it was detected in ten of the fifteen wells.

3.3 Metals

Groundwater samples collected during the January-February 2002 event were analyzed for the following metals: arsenic, lead, total chromium, and hexavalent chromium. The results of the metals analyses are presented in Table 3-6, and are summarized below.

- Arsenic was detected in four on-facility wells (MW-3, MW-5, MW-12 Screens 2 and 5, and MW-23 Screens 1 and 5) and off-facility well MW-17 Screens 3 and 4, with concentrations ranging from 0.0014 mg/L to 0.0047 mg/L. None of the reported concentrations exceeded the State and Federal MCL of 0.05 mg/L.

- Lead was detected in two samples that were collected during the January-February 2001 event (MW-12 Screen 5 and MW-17 Screen 5, with concentrations of 0.0011 mg/L and 0.0028 mg/L, respectively). Neither of the reported concentrations exceeded the State MCL (0.05 mg/L) or the Federal MCL (0.1 mg/L).

- Total chromium was detected in seventeen wells in fourteen on-facility wells and three off-facility wells (MW-18, MW-19, and MW-21). Total chromium concentrations in on-facility wells MW-6 (0.20 mg/L) and MW-13 (0.12 mg/L) exceeded both State and Federal MCLs (0.05 and 0.10 mg/L, respectively).

- Hexavalent chromium was detected in one on-facility well, MW-13, at a concentration of 0.034 mg/L. At this time, neither State nor Federal regulatory agencies have established MCLs for hexavalent chromium.

Table 3-7 presents a summary of metals data from all quarterly sampling events completed to date during the long-term monitoring program.

3.4 1,4-Dioxane and NDMA

During the January-February 2002 event, groundwater samples were collected from six locations [MW-4 (Screen 2), MW-7, MW-13, MW-16, MW-17 (Screen 3), and MW-24 (Screen 1)] and analyzed for 1,4-dioxane and NDMA. Samples from these six wells have historically contained the highest-reported concentrations of VOCs at JPL. 1,4-Dioxane was analyzed using EPA Method 8270, and NDMA was analyzed using EPA Method 1625 (modified).

NDMA was not reported in any of the groundwater samples collected above the laboratory reporting limit (0.002 μg/L). No State or Federal MCLs have been established for NDMA, although the current drinking water IAL for NDMA is 0.02 μg/L.

1,4-dioxane was detected in four of the six wells analyzed: MW-7 (5 μg/L), MW-13 (4 μg/L), MW-16 (10 μg/L) and MW-24 Screen 1 (3 μg/L). No detectable concentrations of 1,4-dioxane were reported in samples collected from MW-4 (Screen 2) or MW-17 (Screen 3). The method detection limit for 1,4-dioxane was 1 μg/L. At this time, neither State nor Federal MCLs or IALs have been established for 1,4-dioxane.

3.5 Quality Assurance/Quality Control

Review of the QA/QC data provided with the laboratory analytical results indicates that all of the analytical results obtained from January-February 2002 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 general accordance with Quality Assurance Project Plan (QAPP) (Ebasco, 1993c). The field QA/QC samples included duplicate samples, equipment rinsate blanks, trip blanks, and a source blank.

Duplicate samples were used to evaluate the precision of the laboratory analyses. Duplicate samples for VOCs, metals, and perchlorate (ClO_4^-) analyses were collected from shallow groundwater monitoring wells MW-15 and MW-16, and deep multi-port monitoring wells MW-4 (Screen 3), MW-12 (Screen 2), MW-18 (Screen 3), MW-19 (Screen 3), MW-23 (Screen 3), and MW-24 (Screen 5). Duplicate samples for NDMA and 1,4-dioxane analyses were collected from shallow groundwater monitoring well MW-16. All of the analytical results for the duplicate samples were comparable to the results of the original groundwater samples (Table 3-3 and Table 3-6).

Equipment rinsate blanks were collected each day non-dedicated sampling equipment was used. The equipment rinsate blanks, consisting of distilled water run through the sampling equipment after decontamination, were analyzed for all contaminants of concern to monitor possible cross-contamination of samples due to inadequate decontamination. Methylene chloride, chloroform, and/or MTBE were detected in three equipment rinsate blanks (ER-1, ER-7, and ER-12) at trace concentrations (i.e., at or near the practical quantitation limit). Based on the results of the trip blanks and source blank discussed below, the detections of methylene chloride and chloroform are considered likely due to cross-contamination of samples in the laboratory.

A laboratory-prepared trip blank, consisting of reagent-grade water placed in VOA vials and transported with the sample bottles to the field, was submitted to the laboratory with each daily shipment of groundwater samples. Trip blanks were used to help identify cross-contamination of groundwater samples during transport and/or deficiencies in the laboratory bottle cleaning and sample handling procedures. Methylene chloride was detected in most of the trip blanks and chloroform was detected in one trip blank at trace concentrations (i.e., 2µg/L).

One source blank was collected during this sampling event, consisting of sample bottles filled with the distilled water used for decontamination and equipment rinsate blanks. The source blank was used to evaluate the influence of ambient conditions or sample containers on the analytical results. No contaminants were detected in the source blank.

4.0 GENERAL WATER CHEMISTRY

As part of this groundwater monitoring event, groundwater samples were analyzed for major cations and anions in an effort to further understand the natural water chemistry of the groundwater beneath and adjacent to JPL. All groundwater samples collected during the January/February 2001 event were analyzed for major cations (Ca^{2+}, Fe^{2+}, Mg^{2+}, Na^{+}, and K^{+}), major anions (Cl^{-}, SO_4^{2-}, NO_3^{-}, CO_3^{2-} and HCO_3^{-}), pH, alkalinity, and total dissolved solids (TDS). The water chemistry results for this quarterly sampling event are summarized in Table 4-1.

4.1 Analytical Results

To illustrate the relative proportions of the major cations and anions in each groundwater sample, the water chemistry results from the January-February 2002 event have been plotted as Stiff diagrams (Figures 4-1, 4-2, and 4-3). Based on previous review of the water chemistry data, groundwater at JPL has been divided into three general types, based on the predominant cation and anion, and the occurrence of other ions. These general water types include:

Type 1. Calcium-bicarbonate groundwater. Groundwater with Ca^{2+} as the dominant cation and HCO_3^{-} as the dominant anion.

Type 2. Sodium-bicarbonate groundwater. Groundwater with Na^{+} as the dominant cation and HCO_3^{-} as the dominant anion.

Type 3. Calcium-bicarbonate/chloride/sulfate groundwater. Groundwater with Ca^{2+} as the dominant cation and HCO_3^{-} as the dominant anion, but with relatively elevated Cl^{-}, and SO_4^{2-} concentrations.

In addition to the general water types, the previous analytical data suggest that these water types mix or blend with one another, creating “intermediate” water types. For example, water Types 1 and 2 can mix to create a 1+2 or a 2+1 type, where the first number indicates the general water type that is predominant in the mixture. The Stiff diagrams presented in Figures 4-1 through 4-3 contain some graphical representations of these “intermediate” water types.

Water Type 1, the calcium-bicarbonate water type, was again found to be the most common water type at JPL during the January-February 2001 sampling event. In general, it was found at relatively shallow depths in wells located around the Arroyo Seco. Water Type 2, the sodium-bicarbonate water type (including associated blends) was typically found in the deeper well screens of both the on-site and off-site multi-port wells. Type 3 groundwater, the calcium-bicarbonate/chloride/sulfate water type, was prevalent in the shallower screens of the monitoring wells located upgradient and to the south of the JPL facility. A list of water types and JPL monitoring wells in which they occur is provided in Table 4-2.

4.2 Quality Assurance/Quality Control

To evaluate the general quality of the water chemistry data, two independent geochemical quality control checks of the analytical results from the January-February 2002 samples were performed. These checks included calculation of total ion-charge balances, and comparison of errors in the measured TDS values or the presence of other cations/anions. The results of these checks for the January-February 2002 water-chemistry results are presented in Table 4-3.

Charge balances are expressed as the percent difference between the sum of the equivalent weights of all of the anions and cations analyzed (Freeze and Cherry, 1979). The ideal range for charge balances is ±5 percent, although charge balance errors up to ±10 percent are considered acceptable. The charge balances for 22 of the 73 samples analyzed for major anions and cations during the January-February 2002 sampling event are within the ideal range (±5 percent) for all wells. Forty-five of the samples had charge balances between 5 and 10 percent, and six samples had a charge balance over 10 percent. This indicates that 92% of the results are acceptable for their intended use.

The TDS results were used to verify that all of the important water chemistry constituents were analyzed by comparing the measured laboratory TDS value to a calculated TDS value (calculated as the sum of the major anion and cation concentrations) for each sample. Under ideal conditions, the ratio of the measured to calculated TDS values should range from 0.8 to 1.2 (Oppenheimer and Eaton, 1986). The ratio of measured to calculated TDS values for the January-February 2002 water chemistry results fell within the ideal range (0.8 to 1.2) for 50 of the 73 sets of water chemistry analyses performed (Table 4-3). The TDS ratios for the remaining 23 sets of data fell slightly outside this ideal range, which suggests possible minor analytical errors and/or the presence of other cations/anions. However, all of the data are considered suitable for their intended use of identifying differences in water chemistry across the site.

5.0 DATA VERIFICATION AND VALIDATION

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

5.1 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) matched those on the chain-of-custody record.

5.2 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). The data were further evaluated to help ensure suitability and usability for the purpose of the groundwater monitoring report.

Data validation is a systematic process that is used to interpret, define, and document analytical data quality and determine whether the data quality is sufficient to support the intended use(s) of the data. Validation of a data package includes reconstruction of sample preparation, analysis of the raw data, reconciliation of the raw data with the reduced results, identification of data anomalies, and qualification of data to identify data usability limitations.

5.3 Data Validation Qualifiers

Analytical data were qualified based on data validation reviews. For chemical data, qualifiers were assigned in accordance with the applicable USEPA National Functional Guidelines for Data Validation (EPA, 1994a and 1994b). Individual laboratory data flags can be found in Appendix D. No data were rejected for non-compliance with method requirements during the course of validation.

6.0 WATER LEVEL MEASUREMENTS

Water level measurements were recorded before the sampling event on January 7 and 8, 2002, and after the sampling event on February 7, 2002, 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 6-1 and have been contoured in Figure 6-1. Water table elevation measurements taken after sampling are provided in Table 6-2 and have been contoured in Figure 6-2. The hydraulic heads measured at each deep multi-port well screen before and after sampling are presented graphically in Figure 6-3. The pressure-profile records for the deep wells are included in Appendix B.

Water levels in the shallow wells rose from roughly 0.7 to 9.9 feet during the January - February 2002 event, rising an average of about 6 feet. This increase was similar to the increases measured in Westbay wells screened in Aquifer Layer 1, which averaged about 7.8 feet and ranged from roughly 3.1 to 12.6 feet. Hydraulic head elevations in Westbay wells screened in Aquifer Layer 2 ranged from almost 5 feet to over 33 feet with an average increase of about 15 feet, while those screened in Aquifer Layer 3 ranged from about 7 feet to 140 feet and averaged over 54 feet. The most notable increases in hydraulic head measured during the January - February 2002 event, as shown in Figure 6-3, were seen in Aquifer Layer 3 screens in wells MW-3, MW-11, MW-12, MW-17, and MW-19. The only well screen in Aquifer Layer 4 (MW-20 Screen 5) rose 9.42 feet during this event.

Water level fluctuations can result from a wide variety of hydrologic phenomena; some natural and some induced by man. It is likely that several of these phenomena are operating simultaneously including, but not limited to:

- Groundwater recharge/infiltration to the water table,
- Air entrapment during groundwater recharge,
- Groundwater pumpage, and/or
- Artificial recharge from the spreading grounds.

As depicted in Figures 6-1 and 6-2, the estimated groundwater flow direction both before and after sampling was generally consistent with previous observations. The flow was primarily to the south-southwest through the eastern portion of JPL and to the east-southeast in the southwest portion of JPL, Arroyo, and plain. The estimated groundwater gradients measured both at the beginning and end of the event ranged from about 0.2 feet per foot near MW-9, at the northern end of the Arroyo, to 0.005 feet per foot across the Arroyo and plain.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are based upon interpretation of analytical data and field measurements collected during the January-February 2002 event and previous events of the JPL Monitoring Program:

- The chemical plumes beneath JPL are adequately defined and relatively stable. The concentration contour maps generally indicate slow migration of the contaminant plumes over the last year. Comparison of the results with the previous monitoring events did not reveal any significant increases or decreases in contaminant concentrations, with the exception of perchlorate, discussed below. In summary, the January-February 2002 analytical results indicate the following:

  - Four VOCs (carbon tetrachloride, trichloroethene, tetrachloroethene, and 1,1-dichloroethene) were detected in one or more monitoring wells at concentrations above the State or Federal MCLs for drinking water.
  - Perchlorate concentrations exceeded the State IAL for drinking water in seven on-facility wells. The highest levels of perchlorate were reported in samples from MW-7, MW-16, and MW-24. Perchlorate concentrations have generally risen over the last two years in these three wells, which are the farthest upgradient, suggesting that the source is nearby or to the north.
  - Total chromium was detected in seventeen wells, with concentrations at two on-facility wells exceeding the State and Federal MCL. Hexavalent chromium was detected in one well. At this time, neither State nor Federal regulatory agencies have established MCLs for hexavalent chromium.
  - Very low (trace) concentrations of arsenic and/or lead were detected in samples from three on-facility wells (MW-3, MW-7, and MW-12) and two off-facility wells (MW-17 and MW-23). No arsenic or lead concentrations were reported above the State or Federal MCLs.
  - 1,4-dioxane was detected at trace concentrations in on-facility wells MW-7, MW-16, MW-13, and MW-24 (Screen-1). At this time, neither State nor Federal MCLs or IALs have been established for 1,4-dioxane.
  - NDMA was not detected in any of the groundwater samples collected above the laboratory reporting limit (0.00039 µg/L). The current drinking water IAL for NDMA is 18 µg/l. No State or Federal MCLs have been established for NDMA.

- General water chemistry analyses indicate adequately defined and relatively stable groundwater chemistry beneath JPL, which is generally consistent with previously-reported data (SOTA, 2001 and Foster Wheeler, 2000).

- Moderate increases in hydraulic head were measured during this event in shallow wells and Westbay well screens in Aquifer Layers 1, 2, and 4, while significant increases were measured in most Aquifer Layer 3 well screens. The water level fluctuations are likely due to several hydrologic phenomena operating simultaneously including, but not limited to, groundwater recharge, pumpage, and/or artificial recharge.

- Groundwater gradient maps prepared using the January-February 2002 water level measurements indicate that groundwater gradients and flow directions are generally consistent with previous observations (SOTA, 2001 and Foster Wheeler, 2000).

At the direction of NASA JPL and the Naval Facilities Engineering Command, a reevaluation of the JPL Groundwater Monitoring Program is currently being conducted. It is recommended that the results of the January-February 2002 monitoring event be incorporated into this evaluation to help develop a new work plan for groundwater monitoring activities at JPL.

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