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NASA-JPL
SSIC No. 9661

PASADENA
Water&Power

SYNOPSIS OF TECHNICAL MEMORANDUM ON THE PERCHLORATE CONTAMINATION OF THE SUNSET RESERVOIR WELLS

MAY 2012

SYNOPSIS OF THE PWP TECHNICAL MEMORANDUM

Pasadena Water and Power (PWP) has five wells around its Sunset Reservoir, which are contaminated with perchlorate and volatile organic compounds (VOCs) above the Maximum Contaminant Level (MCL), and by law must be treated before they can be used as a drinking water source. PWP and the National Aeronautics and Space Administration (NASA) are disputing the source of contamination in the wells.

On January 31, 2007 NASA prepared a Technical Memorandum (NASA's TM) entitled "Additional Investigation Results". The document concluded that the perchlorate in the Sunset Reservoir Wells does not come from Jet Propulsion Laboratory (JPL) in Pasadena, but is a mix from Chilean nitrate fertilizer and a man-made perchlorate manufactured at the Basic Management Inc. (BMI) Complex in Henderson, Nevada, which entered the Raymond Basin via the Colorado River Aqueduct. NASA has argued that groundwater from the base of the San Gabriel Mountains (SGMs), which includes JPL, is hydraulically contained and cannot migrate south.

PWP's previous evaluation of the data in NASA's TM concluded the opposite: the perchlorate in the Sunset Reservoir Wells is from JPL.

The document below presents additional information confirming that JPL is the source of perchlorate contaminating the Sunset Reservoir Wells.

PWP's evaluation is based on the following four opinions:

OPINION 1 - The source of perchlorate in the Sunset Reservoir groundwater is of recent origin and not from use of Chilean fertilizers for agriculture

According to NASA's TM there are four distinct sources of perchlorate in the Raymond Basin:

1. A source unique to JPL from a perchlorate facility located in Los Angeles, California
2. Colorado River water, contaminated with perchlorate from the BMI Complex in Henderson, Nevada
3. Chilean nitrate fertilizers
4. Road Flares

Chilean nitrate fertilizer cannot be a source of perchlorate in the Sunset Reservoir Wells because:

1. There is no evidence that Chilean fertilizers were ever used in the recharge area of the wells
2. Agriculture in the Pasadena area was discontinued by 1920, and in the La Canada Flintridge (LCF) area discontinued by 1940
3. According to NASA's tritium data the water age of groundwater in the Raymond Basin is post 1952, years after the agriculture in the area was discontinued

4. According to NASA's helium-3 data, groundwater in the Sunset Reservoir Wells is even more recent - between 20 to 30 years old, far too young to have been influenced by any agricultural activities
5. Nitrate data also supports recent water age in the Sunset Reservoir Wells

These results are inconsistent with NASA's hypothesis about the existence of perchlorate in Bangham Well having its origin in Chilean nitrate fertilizers.

OPINION 2 - Perchlorate contamination in the Raymond Basin is from a single industrial source: military grade perchlorate manufactured by Western Electro-Chemical Company (WECCO)

According to NASA's TM Stable Isotope Analysis (SIA) of perchlorate indicates that there were three industrial sources of perchlorate in the Raymond Basin, a "JPL" Source, the BMI Complex in Henderson Nevada, and road flares.

1. All of the perchlorate disposed at the JPL facility is from a single company called WECCO. WECCO owned and operated two perchlorate facilities - one located in Los Angeles California and one located in Henderson Nevada called the BMI Complex. The Los Angeles facility was a small factory that operated only for 2 years between January 1944 and March 1946. The Henderson facility began operation in 1945 and was in operation until 1988. The BMI Complex in Henderson is the same source that contaminated the Colorado River. During the period when perchlorate was being disposed of in open pits at JPL, 1945 – 1960, WECCO was the only manufacturer of perchlorate in the United States. Ninety eight percent of all perchlorate manufactured by WECCO between 1944 and 1960 was manufactured at the Henderson facility and 100% after March of 1946.

2. There is a high variability in NASA's SIA results, particularly the $\delta^{18}O$ that cannot be explained by blending different sources of perchlorate, because there is only one source of perchlorate. The most reasonable explanation for the high variability is due to the natural variability that occurs during the manufacture of perchlorate, during the analysis of perchlorate, and *in situ* biodegradation.

3. There are only two data points linking "road flares" with Las Flores Water Company's Well #2 (LFWC 2), which do not match. It is also unclear where road flare perchlorate would be deposited so that it could influence LFWC 2 and no other well. It seems extremely unlikely that very large quantities of perchlorate from road flares would be deposited in northern Altadena between 1980 and 1990.

All of the industrial perchlorate in the Raymond Basin comes from a single industrial source, WECCO. **It is highly unlikely that all of the perchlorate found on the JPL facility was from the 2% of perchlorate manufactured at the Los Angeles facility between 1944 and 1946.**

OPINION 3 - Perchlorate measured in Sunset Reservoir Wells is from groundwater flowing north to south beneath the JPL facility

NASA has hypothesized that water flowing south from the SGMs, is contained by the pumping operations of various potable water operations and as a result entirely from the LCF area. PWP's evaluation shows there are three water courses influencing groundwater in the Sunset Reservoir Wells:

1. SGM run-off parallel to the Arroyo Seco that doesn't flow under JPL with very low concentrations of nitrate and no measureable perchlorate or carbon tetrachloride (CTC) but very little nitrate
2. SGM run-off that flows beneath JPL with high concentrations of perchlorate and CTC, but very little nitrate
3. Groundwater flow below the LCF area with low concentration, intermittent detections of perchlorate, no CTC, and very high concentrations of nitrate

The blending of groundwater from these three courses is measurable by the nitrate, perchlorate, and CTC concentrations. The amounts of perchlorate found in the Sunset Reservoir Wells are greater than those found in the LCF area, but lower than those found at JPL. The amounts of nitrate found at the Sunset Reservoir Wells are lower than those found in the LCF area, but higher than those found at JPL. Similar results for both nitrate and perchlorate are found in the Patton Well in Pasadena, which also has CTC as well as other VOCs found at both JPL and the Sunset Reservoir Wells. CTC was historically detected in three wells between JPL and the Patton, including the Villa Well.

The nitrate, perchlorate, CTC, and other VOC data indicate that from the groundwater in the Sunset Reservoir Wells is influenced by water from the SGMs, the LCF area, and JPL and that the dominant source of perchlorate and VOCs is JPL.

OPINION 4 - NASA's SIA and the available general mineral and physical data validate that the major source of perchlorate in the Sunset Reservoir Wells originates from JPL

1. NASA's strontium SIA data shows that the water in the Sunset Reservoir Wells is chemically much more similar to the SGMs water (MW-1 and MW-24) than to Colorado River water or rain water
2. The water in the Sunset Reservoir Wells of Type 1 while waters influenced by the Colorado River water are Type 3 waters

3. Sulfate can be used as marker for the influence of Colorado River water, either alone or in conjunction with strontium SIA. In both cases, the data indicates that there is little or no influence of Colorado River water on the Sunset Reservoir Wells
4. When the perchlorate data is combined with the strontium SIA data, the influence of the three different water courses is made clear and that JPL is the dominant source of perchlorate
5. SIA of water indicates that the water from the SGMs (MW-1), JPL (MW-24), and the Sunset Reservoir Wells is located on the Global Meteoric Water Line (GMWL) indicating little or no blending with Colorado River water.
6. The Type 1 waters are evenly distributed above and below the GMWL, while the Type 3 waters, those influenced by Colorado River water, are all below the GMWL. Type 3 waters are also at the lower left-hand side of the distribution of SIA data while the Type 1 waters are on the upper right-hand side of the distribution. The Sunset Reservoir wells are Type 1 and located in the upper right-hand side of the SIA distribution.
7. When the perchlorate data is combined with the water SIA data, the influence of the three different water courses is made clear and that JPL is the dominant source of perchlorate. This even more clear with the CTC data is also included.

All various markers: carbon tetrachloride, nitrate, perchlorate, chloride, sulfate, strontium, the Stable Isotope Analysis, and the water types indicate that the groundwater in the wells is overwhelmingly local run-off from the SGMs

CONCLUSIONS

Groundwater in the Sunset Reservoir Wells is of recent age 20 to 30 years old and agricultural activities ceased 90 years ago so Chilean nitrate fertilizer, even if it had ever been used, could not be a source of perchlorate in these wells. There are three water courses that influence the Sunset Reservoir wells: (1) the flow from the LCF area, northwest of JPL, influenced by infiltration and injection of substantial amounts of Colorado River water, with high concentrations of nitrate and low concentrations of perchlorate and no CTC, (2) the flow originating from the SGMs north of JPL with low concentrations of nitrate and no measurable amounts of perchlorate and CTC, and (3) the flow that passes under JPL and accumulates both high concentrations of perchlorate and CTC, but has low concentrations of nitrate. Both the JPL and LCF area water courses contain perchlorate that came from the same industrial source, military grade perchlorate manufactured by WECCO in Henderson Nevada. SIA of strontium and water, general mineral and physical characteristics, and all available data clearly indicates the vast majority of perchlorate and VOCs found in the Sunset Reservoir Wells is from JPL.

PWP RECOMMENDATION

The five Sunset Reservoir Wells should be included in the JPL Superfund Site without any further investigations.

City of Pasadena
100 NORTH GARFIELD AVENUE
P.O. BOX 7115, PASADENA, CA 91109-7215

OFFICE OF THE CITY ATTORNEY
ROOM 228, CITY HALL
(626) 744-4141
FAX (626) 744-4190

January 13, 2004

Via Federal Express

OSJA Claims
ATTN: Torts, Bldg. 275
1336 Plummer St.
Monterey, CA 93944-3327

Re: Federal Tort Claims Act
City of Pasadena's Claim

Dear Sir or Madam:

The City of Pasadena ("City") hereby submits the enclosed Claim in the amount of $2,045,992.13. This Claim consists of this letter, the attached executed Standard Form 95 ("SF 95"), a more detailed description of the City's Claim and resulting costs (Attachment A to the SF 95), and supporting exhibits. As the City Attorney, I am duly authorized by the City to sign the Claim, as set forth in the attached statement of authorization.

This Claim is submitted under the Federal Tort Claims Act ("FTCA"), 28 U.S.C. §§ 2671-2680, 28 C.F.R. §§ 14.1-14.11, and Department of Army Regulation 27-20, Chapter 4. The City's Claim is for injury, damages, and loss of property caused by the negligence, wrongful acts, and omissions of the United States, acting through the Department of the Army ("Army"), in its contamination of groundwater in and around the Jet Propulsion Laboratory ("JPL") with perchlorate and other emerging chemicals, from which the City obtains a water supply. Damages beyond those included in this Claim are not foreseeable based on information and facts currently known to the City. The City reserves its right to amend this Claim upon the discovery of evidence or additional facts relating to the amount of damages.

The City is a public water purveyor, regulated by the California Public Utility District and the California Department of Health Services. The City's water supply system is comprised of sixteen wells, eighteen booster stations, and two reservoirs connected via an underground pipeline distribution system. Water produced from the wells is stored in one of two reservoirs prior to distribution.

The City's public drinking water wells are down gradient of JPL, which is operated by the California Institute of Technology ("Caltech"). Caltech began operating JPL as early as 1936 as

a research laboratory for the Army, focusing on jet propulsion and liquid rocket propellants. The Army contracted with Caltech to study jet propulsion from 1940 through 1958. The Army provided the funding for the first permanent structures on the land that became JPL. Beginning in 1945, the Army purchased the majority of the parcels that comprise JPL. In 1959, NASA took over ownership of JPL from the Army Air Corp, but Caltech remained under contract with the Army until 1961 when NASA entered its own contract. During the Army's tenure, hazardous wastes were disposed of in cesspools and directly in the channel of the Arroyo Seco, overlying the groundwater basin from which the City derives the majority of its public drinking water supply. Contaminants, including perchlorate, have been and continue to be released into the groundwater, polluting the City's drinking water supply.

Perchlorate is an inorganic chemical used in solid rocket and missile propellants, like those used in studies at JPL. Perchlorate is highly mobile in water, and can persist in groundwater for decades. Perchlorate poses human health risks to the developing nervous system and in the form of thyroid tumors.

On January 18, 2002, EPA released a draft revised risk assessment for perchlorate, concluding that the health risks associated with perchlorate were greater than previously determined. In response, also on January 18, 2002, DHS lowered its action level for perchlorate from 18 ppb to 4 ppb.

Under the new action level, eight of the City's thirteen active drinking supply wells became inoperable—three in the Monk Hill Subarea, and five in the Pasadena Subarea. As a result, the City has incurred substantial costs, set forth in the attached SF 95, due to perchlorate contamination in its wells. Based on the foregoing contamination, the City's claims against the Army include, but are not limited to negligence, nuisance, and trespass.

As a result of the shutdown of wells, the City has incurred and continues to incur significant costs due to the perchlorate contamination from JPL, including consulting fees, monitoring and evaluation costs, and water transfer and replacement costs. As of June 30, 2003, these costs amount to $2,045,992.13.

The City has been pursuing negotiations with NASA to work toward a settlement of its claims. ~~The City prefers to resolve this matter out of court. To achieve a comprehensive settlement of~~ the claims arising out of contamination from JPL, the Army's participation in a settlement is necessary. To that end, I look forward to hearing from you shortly.

Sincerely yours,

Michele Beal Bagneris
City Attorney
City of Pasadena

cc: Scott D. Rasmussen, Esq., Assistant City Attorney
James J. Dragna, Esq., Bingham McCutchen, LLP
Enclosures

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

22 October 2007

Mr. Steve Slaten
NASA Management Office – JPL
M/S 180-801
4800 Oak Grove Drive
Pasadena, CA 91109

Dear Mr. Slaten:

Enclosed are the comments of the U.S. Environmental Protection Agency to the National Aeronautics and Space Administration (NASA), Jet Propulsion Laboratory (JPL) - EPA ID #CA9800013030, Technical Memorandum: Additional Investigation Results.

If you have any questions please give me a call at (415) 972-3032.

Sincerely,

Lewis Mitani
Remedial Project Manager

Enclosure

cc: Mr. Michael Iskarous, CAL-EPA
Mr. Mohammad Zaidi, LA RWQCB
Mr. Bill Mabey, TLI

REVIEW OF TECHNICAL MEMORANDUM: ADDITIONAL INVESTIGATION RESULTS JANUARY 2007

GENERAL COMMENTS

The Technical Memorandum: Additional Investigation Results (TM/AIR) presents four lines of evidence that the perchlorate in groundwater in the downgradient Sunset Reservoir is not derived from the JPL site. The four lines of evidence are presented as follows:

- ✓ Groundwater Modeling
- ✓ Groundwater Geochemistry
- ✓ Groundwater Chemical Concentration Data
- ✓ Perchlorate Isotope Data

Together, the lines of evidence are interpreted in the TM/AIR to demonstrate that the perchlorate found in the downgradient wells does not originate from the JPL site. However, it is also important to recognize that none of the lines of evidence identify a specific, or even a major, source of perchlorate to these supply wells. The several lines of evidence do show an obvious complex pattern of the mixing of waters in the basin from both natural and anthropogenic sources. The following comments on the TM/AIR are provided to assist in ongoing discussions of whether JPL may have contributed perchlorate to the Sunset wells.

COMMENTS ON GROUNDWATER MODELING

1. The TM/AIR does not specifically discuss why the results of this groundwater modeling effort differ from information presented in the Final Operable Unit 3 Remedial Investigation RI Addendum Work Plan, Battelle 2004 (OU 3 RI Addendum WP). The OU 3 RI Addendum WP indicate that the Coupled Flow and Energy Solute Transport model was used to simulate groundwater flow in the Raymond Basin and that potential groundwater migration pathways and particle tracking from near the Arroyo Seco Spreading Grounds was performed for the period from 1989 to 2023. The simulation results found a flow path from the Arroyo Seco Spreading basins and the unsewered La Canada-Flintridge area towards the City of Pasadena production wells located near the Sunset Reservoir. However, the Tech Memo states that particle tracking indicates that groundwater originating to the west of JPL in La Canada Flintridge flows south of the JPL facility and then heads toward the Sunset Reservoir Wells. It is unclear why these two model results would differ and the Tech Memo does not provide an explanation. Please explain why these two models differ in their results.

2. As a general observation, it is unclear from the TM/AIR whether the model has been applied in a way that is specific enough to address the objective of an almost absolute capture of perchlorate originating from the JPL site. The objective(s) and the assumptions of the model used to predict capture are not described. For example, if the model

objective and assumptions were to predict the capture zones of the future pumping, it is not appropriate to make conclusions about the past capture zones of the same wells, especially if the pumping history of the wells is different. Please describe the model objective(s) and model assumptions regarding the pumping history, scale of the model, and the geohydrologic and other features that support an adequate capture zone analysis has been conducted. The comments below address some of these issues.

3. The RBMB model is a two layer regional model, and the JPL model is a more localized site model consisting of four layers. Figures 2, 3, and 4 show particle tracking simulation results. Considering the existence of the vertical hydraulic gradient, the particle paths would look different for each layer. The composite paths shown in Figures 2, 3, and 4 are then not sufficient to describe the three-dimensional nature of the particle paths. Please show the information for each layer rather than as a composite. Please show the particle paths in cross-section as well as forward paths originating at JPL.

4. A closer view of Figures 3 and 4 does not support the TM/AIR conclusion that the flow fields of the RBMB and JPL Models are "very similar." Considering the size of the grids, the number of layers, etc., it is not surprising that the results of the two models would be different. It is important to realize that we are not looking at the whole model domain, but rather a small (JPL) area within the large model domain. Please elaborate on how the two models can be regarded as similar when the grid sizes and layers are different.

5. The JPL model uses the average extraction rates observed between 1960 and 2000. The production wells "Arroyo Well" and "Well 52" are listed as the most important wells. However, these two wells were not operating for five years (1985-1990). It is not clear whether there are other periods when the wells were not operational, but the five-year period was mentioned as the "longest period" when the wells (and two other wells) were not pumping. Please also explain the basis for the statement that "...the chemicals would have been drawn back upon reinitiating operation of these wells..." (Page 11, first paragraph.) Each production well has a stagnation point downgradient from the well. If the well is shut down for some duration and the contaminant passes the stagnation point, restarting the well (assuming the same pumping rate and the same regional flow) will not recapture the escaped contaminant.

6. The TM/AIR does not adequately discuss the perchlorate detections in MW-25 in the context of why these additional monitoring wells were proposed in the OU 3 RI Addendum Work Plan. The OU 3 RI Addendum proposed installing MW-25 and MW026 to verify the location of the leading edge of the JPL perchlorate plume and discusses that these monitoring wells were specifically located between MW-20 and the Sunset Reservoir Wells to verify that the leading edge of the plume had traveled beyond the MW-20 location. Subsequently, the purpose of the TM/AIR appears to have changed from specifically verifying the location of the leading edge of the plume to a discussion of other perchlorate sources. Please discuss if the leading edge of the perchlorate plume was established.

7. The TM/AIR does not discuss the potential impact of the top of bedrock and its relationship to the perchlorate detections in MW-25 as well as the Sunset Reservoir wells. Perchlorate is detected at depth at the MW-25 location consistent with depths to bedrock in MW-19. Please provide a discussion of the potential for perchlorate to enter bedrock and then migrate toward the Sunset Reservoir Wells.

8. The assumption that groundwater contamination is contained by wells in the Monk Hill Subarea appears to be based on recent and current groundwater extraction rates and information rather than on historical conditions. In addition, although the text indicates that there were no periods "since the early 1940s of sustained shutdown of all of these Monk Hill Subarea wells," shutdown or intermittent operation of one or more wells may have allowed migration of perchlorate beyond the Monk Hill Subarea. In addition, it is likely that these water supply wells extracted water from the deeper portions of the aquifer, so perchlorate contamination may have migrated in the shallower layers. Further, historical pumping rates may have been less than current pumping rates; Table 2-1 of the OU 3 RI Addendum WP indicates that the maximum extraction rate in several of the wells occurred in the 1960s, 1990s or in 2000. Since many of the wells apparently pumped at lower rates in the 1940s and 1950s, it is likely that "containment" of the perchlorate plume was not achieved. Statements about containment of the perchlorate plume should either be deleted from the text or modified to specify the period of years to which the conclusion applies. In addition, historical low extraction rates could be used in the model to evaluate the potential that perchlorate migrated beyond the Monk Hill Subarea.

9. There are only a few wells in the area between JPL and the Sunset Reservoir Area, so this area cannot be considered well characterized and the potential for preferential migration pathways should be considered. Preferential migration pathways or channels are common in the depositional environments that resulted in the subsurface lithology between JPL and the Sunset Reservoir Area. These preferential migration pathways may have facilitated perchlorate migration to the Sunset Reservoir Area. The text should be revised to acknowledge this possibility.

10. The following statements in the TM/AIR are of concern for the accuracy of the results of the model, and should be addressed in any future modeling efforts.

    - Page 6, paragraph 2: "... vertical hydraulic head differences with depth are observed... this indicates that the aquifer does not exhibit truly unconfined conditions..." Please recognize that the existence of the vertical hydraulic gradient alone does not indicate whether the aquifer is confined or unconfined.

    - Page 6, paragraph 5: "...groundwater elevations have fluctuated up to 75 ft each year beneath JPL..." Such large water table fluctuations indicate strong transient conditions at the site. Any steady-state model that represents some "average conditions" in the future would be less reliable because of the fluctuations.

- Page 7, paragraph 1: "...as part of the steady-state model development, a transient model was constructed using data from 1996-2000." If the water levels at the Site fluctuated up to 75 ft, it needs to be clarified how the transient model calibration is similar to the steady-state model calibration.

COMMENTS ON GROUNDWATER GEOCHEMISTRY

1. This section provides a thorough discussion of the groundwater types, water imports, likely anthropogenic sources of constituents - including perchlorate - to groundwater, and an interpretation of how the general water quality has been impacted by such sources. While the section does present information suggesting that significant amounts of perchlorate in imported water reasonably were introduced into the Raymond basin by the Metropolitan Water District (MWD) distribution system, there is no information that assists in evaluating the respective contributions of perchlorate from various sources (MWD, JPL, fertilizer applications, etc.)

COMMENTS ON GROUNDWATER CHEMICAL CONCENTRATION DATA

1. The analysis that carbon tetrachloride is a reliable tracer for perchlorate originating from JPL is not a valid assumption for several reasons. One reason is that monitoring data indicate that the groundwater concentrations of perchlorate are typically higher than the carbon tetrachloride concentrations, and therefore simple dilution due only to advective flow and dispersion should result in carbon tetrachloride reaching non-detectable concentrations before perchlorate would similarly become nondetect.

2. The use of carbon tetrachloride (an organic compound) as a reliable tracer is also difficult to support because it can undergo transformation reactions whereas perchlorate (an inorganic ion) is more stable. As a measure of the ease of reduction of carbon tetrachloride, its reduction/oxidation half-reaction potential is relatively high, between that of denitrification (nitrate reduction to nitrogen) and reduction of tetrachloroethene (PCE, to trichloroethene.) Furthermore, the environmental literature has several citations of transformations of carbon tetrachloride by microbial processes and chemical processes (abiotic reactions); the latter processes are a result of residual effects of microbial processes that create chemical conditions (mineral surfaces, sulfides) where carbon tetrachloride is subsequently transformed (reduction reactions.) In the expected predominate aerobic subsurface it is expected that such reducing conditions will be present but sporadic, and probably due to localized leaching of constituents with infiltrating surface waters (maintenance, landscaping, irrigation, etc.); the sporadic presence and very low concentrations of such reactant systems and possible transformation products obviously makes the identifications of such adventitious processes almost impossible.

3. In summary, it is plausible to qualitatively consider carbon tetrachloride as a tracer for perchlorate originating from the JPL site as long as both constituents are detected in the groundwater sampling program, but the absence of carbon tetrachloride in a groundwater

sample cannot be the basis for the conclusion that perchlorate in the sample is not from the JPL site.

COMMENTS ON PERCHLORATE ISOTOPE DATA

1. The conclusion that the isotopic signature of perchlorate samples collected from the downgradient wells is different from the signature of perchlorate at the JPL site and therefore that JPL is not a source of perchlorate does not adequately take into consideration that the measurements on the downgradient water samples are possibly a composite from several sources of perchlorate to the Raymond basin. The TM/AIR does make a persuasive case that several sources are reasonably suspect, and that there may be other sources of perchlorate that cannot be identified. The complexity of the multiple sources, as well as the unknown contribution of these sources, does not eliminate JPL as one possible contributor of perchlorate to the downgradient wells based on the isotopic data alone.

   Review of the perchlorate isotope data indicate several uncertainties that confound an interpretation of the data that could be applied in source allocation. As discussed in the TM/AIR, the most reasonable suspected sources of perchlorate to the downgradient wells are the JPL, Colorado River water, and fertilizer perchlorate (dark blue diamonds in yellow shaded area, light blue circles, and orange squares, respectively, on Figures 16 and 17.) However, there is significant scatter of the isotopic signatures of samples from each suspected source which has been attributed to different batches of the source perchlorate. Additionally, the perchlorate samples from the multilevel well MW-25, show no clear trends that can be interpreted as hydrostratigraphic zones that have been impacted by discrete sources. For example, the isotopic signature of the shallowest sample (MW-25-1) most closely resembles the JPL source perchlorate, which would be expected to be at greater depths from a further upgradient source. Additionally, the isotopic signatures of the samples from the intermediate depths, MW-25-2 and MW-25-3, appear to resemble the Colorado River water samples in the $^{37}Cl/^{18}O$ plot (Figure 16), but the same two samples are the most anomalous in the $^{17}O/^{18}O$ plot.

   While, the perchlorate isotope data does not support a conclusion the perchlorate in the downgradient wells is solely due to JPL as the source. The data also does not eliminate JPL as a contributing source of perchlorate to the downgradient wells in an obviously complex geohydrologic system with several possible sources of perchlorate.

Linda S. Adams
Secretary for
Environmental Protection

Department of Toxic Substances Control

Maureen F. Gorsen, Director
9211 Oakdale Avenue
Chatsworth, CA 91311

Arnold Schwarzenegger
Governor

May 21, 2008

Mr. Steve Slaten
NASA Remedial Project Manager
NASA Management Office
4800 Oak Grove Drive
Pasadena, California 91109

REVIEW OF NASA, JANUARY 31, 2007 TECHNICAL MEMORANDUM, ADDITIONAL INVESTIGATION RESULTS, JET PROPULSION LABORATORY, 4800 OAK GROVE DRIVE, PASADENA, CALIFORNIA 91109

Dear Mr. Slaten:

The Department of Toxic Substance Control (DTSC) has reviewed the January 31, 2007 Technical Memorandum, Additional Investigation Results, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California. Enclosed, please find DTSC's comments on the Technical Memorandum.

If you have any questions, please contact Mr. Michel Iskarous, Project Manager, at (818) 717-6547 e-mail miskarou@dtsc.ca.gov or me, at (818) 717-6539 e-mail joborne@dtsc.ca.gov.

Sincerely,

Juli Oborne
Unit Chief
Brownfields and Environmental Restoration Program – Chatsworth Office

Enclosure

cc: Ms. Judy Huang
Remedial Project Manager
U.S. Environmental Protection Agency (EPA) Region 9
75 Hawthorne Street (SFD-8-3)
San Francisco, California 94105

cc: Mr. Mohammed Zaidi
Regional Water Quality Control Board, Los Angeles Region
320 West 4th Street
Los Angeles, California 90013

Mr. Gary Takara
Pasadena Water And Power
150 S. Los Robles Ave, Suite 200
Pasadena, California 91101

Linda S. Adams
Secretary for
Environmental
Protection

Department of Toxic Substances Control

Maureen F. Gorsen, Director
9211 Oakdale Ave
Chatsworth, California 91311

Arnold Schwarzenegger
Governor

MEMORANDUM

TO: Mr. Michel Iskarous, Project Manager
Site Mitigation and Brownfields Unit,
Chatsworth Office

FROM: Alice Campbell, PG, CEG, CHg
Senior Engineering Geologist
Chatsworth Geological Services Unit

CONCUR: Craig Christmann, PG
Senior Engineering Geologist
Chatsworth Geological Services Unit

DATE: May 13, 2008

SUBJECT: Review of NASA, January 31, 2007 Technical Memorandum, Additional Investigation Results, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California 91109

PCA: 11065 Site Code: 300318-00 Log No. 73154

Introduction:

At your request, the Chatsworth Geological Services Unit (GSU) prepared this memorandum to provide comments on the Additional Investigation Results Report (AIR) cited above. The AIR describes the results of work done to first, evaluate the downgradient extent of contaminants originating form the JPL facility, and second, determine whether the occurrence of perchlorate at the Sunset Reservoir originated at JPL. This work is being undertaken under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) program at JPL. The investigation included re-analysis of existing data, collection of new isotope data, the installation of two new multiport wells, and preparation of well logs and construction documentation. Our review was performed to assess the results of the additional investigation.

GSU reviewed the AIR, and has the following comments:

1. Page 6. Background. The background lacks a description of the depositional environment of the alluvium of the Monk Hill basin. The depositional environment determines large-scale features of the groundwater system that may affect contaminant migration. Most of the alluvium near JPL was deposited by the Arroyo Seco, which is one of the largest local drainages. The landform is an alluvial fan, characterized by about 10% coarse channel deposits and 90% flood and overbank deposits, which may develop flat soil horizons. The stream channels have a permeability contrast with the materials they incise, and this stream fabric imparts a strong lateral anisotropy to groundwater flow. Other features of the alluvium include detrital charcoal, which is deposited after brushfires. This naturally occurring organic carbon also affects contaminant transport. The section should include a discussion of the geologic factors that affect groundwater flow.

2. Page 6, second bullet. Vertical hydraulic gradients are caused by pumping, and not by the degree of confinement. It is usual in most alluvial basins for the degree of confinement to gradually increase with depth. In the Coastal Plain, the four main divisions of the alluvium correlate with climate changes related to Sierra glaciations, and it would not be surprising to find much the same sequence in the smaller basins. The section should be revised to remove the relation of unconfined conditions to vertical gradient. In an alluvial fan environment, new channels characteristically cut across soil horizons, so the assumption that these layers are intact is not supported.

3. Inspection of topography reveals a slightly more complex situation than described. The base of the San Gabriel Mountains has several fans centered on prominent drainages. In the Monk Hill basin, Flint Ridge blocks southern continuation of the fans, so the drainage upon the fans is shunted east to join the Arroyo. Because of the structure of the fans, water moving in buried channels tends to follow the same general pattern. It is more correct to say that groundwater gradients are more easterly, because of pumping. The actual particle flow direction is determined by the vector sum of the gradient vector and the anisotropy vector. Pumpage is not the most significant determinant of groundwater flow. The most important factor is topography, and water in the basin does flow from higher to lower elevations. The second most important factor is anisotropy, because it is an aquifer property, and pumping vectors are third, because they are superimposed on the other two factors. The section should be revised.

4. Water resources models typically neglect the effects of lateral anisotropy, because bulk flow volumes are little affected. However, for contaminant transport problems, anisotropy cannot be neglected, because the issue is determining actual flow paths, not bulk movement. Thus, the RBMP model is not useful to predict contaminant flow unless it incorporates horizontal anisotropy. Inspection of the particle tracks indicates it does not account for the north-south channel deposits of the Arroyo Seco, which indicates that the aquifer has been assumed to be laterally isotropic. This is not consistent with the depositonal environment.

5. The methods used to calibrate the RBMP model are not described, nor are the actual values given of conductivity, vertical anisotropy, or recharge used in its calibration. No water balance is provided. It is not stated whether automated parameter estimation was used. Since any one calibration is not unique, there is a range of values and combinations of parameters that will all calibrate the model, yet some are more unlikely than others. The uncertainty of the calibration is not given. Likewise, no information on the JPL model is given other than results. The results of the particle tracing indicate that both models assume laterally isotropic conditions. Basically the models assume the basins are uniform layers of sand and silts/clays. The real basins, however, were laid down by streams flowing mainly north to southwards, and these stream channels create preferential southward flow pathways. The largest and most prominent of these is the Arroyo Seco. Any model that does not show the slightest deviation in particle tracks while crossing the Arroyo sediments at right angles is not a believable model.

6. The northern boundary of the model is stated as the San Gabriel mountains. The mountains are bounded by the Sierra Madre Fault, a thrust fault that moves bedrock over alluvium. The geometry of the fault indicates that substantial alluvium extends beneath the fault to the north. It is not clear whether this alluvium was included in the model.

7. The water balance for the model needs to be shown, along with interlayer water balances. Constant head boundaries have unlimited capacity to remove water from the basin, and errors in subsurface outflow are often calibrated out by increasing both recharge and conductivity. General head boundaries, which limit outflow to the aquifer conductance and gradient, are a better choice. Since a very large combination of flows and conductances can match the same gradient, inspection of outflow volumes is needed to identify whether reasonable outflow volumes are being produced by the boundary. Constant head boundaries are more appropriate to fully penetrating streams and lakes, and are not good choices for subsurface outflow.

8. Results of Groundwater Modeling. The flow fields of the two models are similar because they both assume the basins are laterally homogenous and isotropic, which is obvious from the way the streamlines cross one major stream course after another without deflection. Neither model appears to incorporate anisotropy, a key feature of the aquifer that governs particle flows. The models do not accurately model contaminant flow, only bulk flow. They are water resource models, not contaminant flow models. The particle tracks illustrate the gradient, but do not and cannot illustrate contaminant flow. The maps lack a north arrow and scale.

9. It is unlikely that the pumping in the Monk Hill basin contains JPL's contaminants, because water would be forced to move upstructure and across grain to get to the wells. Real water follows the path of least resistance, and the actual flow paths tend to follow the structure of the fans. In anisotropic media, true particle paths diverge from hydraulic head maps because of the sideways component of conductivity. One characteristic of anisotropic aquifers is that contaminant plumes follow the topography, not the groundwater gradient.

10. Figures 2 and 3. Over much of these two maps, particle tracks cross topography at high angles. Under these scenarios, there is no real flow of water to the Arroyo Seco near the Rose Bowl. There is no outflow to the southwest near South Pasadena either, yet Arroyo sediments clearly underlie the 110 freeway alignment. There are no groundwater monitroing wells within the Arroyo south of Devil's Gate which forms a significant data gap. Recent personal communications with the L.A. Department of Public Works indicate perchlorate was detected during dewatering near the 110 freeway, down the Arroyo Seco Channel.

11. The rate of groundwater movement is not well supported, because the model uses boundaries liable to cause conductance errors. The models do not prove that contaminants were contained in the Monk Hill basin, only that there was a flattened gradient.

12. Groundwater Geochemistry. Page 11. last bullet (artificial recharge). Who made the estimate? Was it verified? Has this percentage been constant over time? The Calif Dept of Water Resources observes that the use of dishwashers and automatic washers has changed the proportion of water used inside and outside the home. The introduction of low-flow toilets has also skewed proportions. Because this recharge is a significant portion of the basin's water, errors in this value will propagate as conductivity errors in the model. Changes in the percentage of sewered areas also change areal recharge. It is also not clear whether the proportion of delivered water to sewer flows were checked over time, which can lead to errors in estimating recharge.

13. Page 14, last bullet. The evidence for ion exchange is that sodium shows a wide range, and increases as calcium and magnesium decrease, generally by twice the amount, since sodium is monovalent and calcium and magnesium are divalent. The lower left triangle on the Piper shows that both type 1 and type 2 waters are softened by ion exchange, and type 3 is not. Type 2 water appears to be simply a softened version of type 1 native water. There appear to be two types of type 3 water, particularly evident in the left lower triangle as two distinct bands. These appear to be mixtures of type 2 and type 3 waters. No stability calculations are presented, but it is likely that type 3 waters are nearly saturated with respect to calcium sulfate, and precipitation of calcium sulfate can skew the proportion of calcium to magnesium. Some analyses seem to have unusually high magnesium proportions, which suggest some calcium has been precipitated.

14. There are alternative ways of interpreting the Piper diagram if precipitation has occurred. It is not obvious that ion exchange has been properly accounted for in the analysis. What is shown as a mixing line in the lower triangle is obviously an ion exchange line.

15. Another factor not included in the analysis is the impact of percolated wastewater and sulfate/nitrate reduction. Sulfate reduction causes a shift in the proportion of sulfate to bicarbonate that looks like a mixing line, but is actually a removal line. Water mixed with wastewater is often softened and loses much of its sulfate. These reactions, however, are not really mixing phenomena. In any case, saturation indices need to be checked before mixing is invoked to explain the data. Yet another factor is whether some native water derived from metasediments near Flintridge also have high sulfate. An analysis of nitrate would be instructive, particularly if young waters low in sulfate but high in chloride are also low in nitrate. This would suggest denitrification in addition to sulfate reduction.

16. Aerobic conditions are assumed, yet much of the chemistry suggests local anaerobic conditions.

17. While figures 7 and 8 may suggest recharge along the western corridor, the particle tracking maps certainly do not, and in fact, the conspicuous absence of a groundwater mound associated with the golf course is a strong argument for anisotropic conditions beneath the Arroyo.

18. Figure 8 also shows that sulfate migrates southerly along the Arroyo and its buried earlier channels. Note the similarity of the Ventura to the Copelin wells, and the Arroyo to the Sunset wells. The chemistry appears to track the geologic structure.

19. Figure 9 only reinforces the impression that groundwater moves down the Arroyo. The conspicuous data gap in the Arroyo only serves to suggest that more data would probably show that sulfate is high near the Rose Bowl, and that in fact, despite the direction of the gradient, contaminant transport is respecting the geology.

20. Page 19. A table with estimated pounds of perchlorate by source, and levels achieved by different dilutions, would be welcome here. Using the perchlorate levels in Las Vegas wash to imply high levels in Colorado River water is not justified, and would in any case have a high degree of uncertainty. While the resultant wide distribution of perchlorate would create a kind of background perchlorate smog in the basin, local sources greater than background can be easily distinguished.

21. Isotope data. The chart shows just as much mixing of type 3 water as it does of types 1 and 2 waters. This graph suggests that the deep water is not necessarily old, unmixed water, but is just ion-exchanged native water, possibly with some sulfate reduction.

22. The strontium isotope analysis also suggests that type 3 water is actually two different types, and that type 1 water can be turned into type 2 water by ion exchange. This was actually also shown on the Piper diagrams, but was misinterpreted.

23. Tritium samples. Although the data are not shown, it is likely that most of the type 2 water is young, not old, which suggest that the old, deep water is simply in a part of the aquifer that cannot be mobilized by wells. Often this happens in anisotropic aquifers where wells are at right angles to the stream fabric, and whose actual source of water is upstream and downstream, not across the stream fabric.

24. Carbon tetrachloride. Contrary to the statement in the report, PCE and TCE make excellent tracers when their molar ratios, not their absolute levels, are compared. Comparing and contrasting molar ratios is very successfully used to differentiate different solvent sources. The presence of PCE and TCE at the Sunset wells, despite the assertion that the Monk Hill pumping depression prevents JPL's plumes from migrating south, is a logical inconsistency.

25. While carbon tetrachloride has not been detected in the Sunset wells, onsite monitoring data indicates it is breaking down to chloroform, despite assertions that it is not biodegrading. MW-3 screen 2 shows both carbon tetrachloride and chloroform, its first daughter product. It also contains methylene chloride, another daughter product. While many people assume methylene chloride is a laboratory contaminant, in the presence of carbon tetrachloride and chloroform,

this is not justified. Sorption on natural carbon is also a possible process attenuating carbon tetrachloride, but the presence of daughter products is a stronger argument that it is degraded before reaching the Sunset wells. The data contradicts the statement that biodegradation is not occurring. It also suggests that water is not, in fact, flowing backwards towards Monk Hill.

26. The model cannot be used to predict the extent of carbon tetrachloride, since it incorrectly predicts the distribution of sulfate and perchlorate.

27. Perchlorate Isotope analysis. The isotope analysis shows that the perchlorate at the Sunset wells is a mixture of two sources, JPL and Las Vegas. This is what would be expected from spreading imported water in the vicinity of the JPL plume, which migrates down buried stream channels to the Sunset Reservoir area. MW-25 is the only well with a convincing difference from a mixture of JPL and Las Vegas perchlorate, which suggests fertilizer as a source.

28. The aquifer is very likely to contain detrital charcoal, and in substantial amounts. This substrate makes a very good locus for biodegradation, and may account for the degradation of carbon tetrachloride. Perchlorate is chemically similar to nitrate and sulfate, and is likely degraded under reducing conditions that may be widely scattered within the aquifer. The investigation did not consider the presence of detrital charcoal as a factor. Chemical evidence of reduction is generally a better indicator of reducing conditions than ORP or DO measurements, which can be contaminated by exposure to atmospheric oxygen by a deteriorated well seal. The functional genomics analysis does not take microenvironments into account.

29. The Sunset wells are down-structure from JPL. The fact that they are cross-gradient is nullified by the anisotropy of the aquifer. The isotope data shows that at least some of the perchlorate in the Sunset wells originated at JPL.

Conclusions and Recommendations

1. Neither groundwater model presented in the report incorporated lateral anisotropy, yet geologic evidence suggests that it is present. Since anisotropy does not affect bulk flow, the models may be used for water management, but neither model should be relied on to calculate particle flow paths.

2. The geochemical analysis misinterpreted some of the ion exchange data, and cannot be relied on to conclusively show differences between water at individual wells.

3. Monitoring data show that carbon tetrachloride is degrading in the aquifer.

4. The hydrogeology and structure of the alluvium provide a pathway from JPL to the vicinity of the Sunset wells.

5. The sulfate data indicate that sulfate moves down the Arroyo despite the groundwater gradient.

6. The perchlorate isotope data shows that some of the perchlorate at the Sunset wells matches the source at JPL.

7. Other data indicates that there is perchlorate in the lower Arroyo Seco along a flow path not predicted by the modeling, but consistent with and predicted by the geology.

Questions regarding this memo should be directed to Ms. Alice Campbell by contacting her at 818-717 -6623 or acampbel@dtsc.ca.gov.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

February 4, 2010

Steve Slaten
NASA Groundwater Program Manager
NASA Management Office
4800 Oak Grove Drive
Pasadena, California 91109

Subject: EPA Review of NASA JPL's Response to Pasadena Water and Power's report titled: *NASA/JPL Perchlorate Contamination of Ground Water in the Raymond* Basin prepared by Geoscience Support Services, Inc. and Williams-McCaron Inc.

Dear Steve:

Thank you for providing the US EPA with a copy of NASA's responses regarding the report, *NASA/JPL Perchlorate Contamination of Ground Water in the Raymond Basin*; prepared by Geoscience Support Services, Inc, and Williams-McCaron, Inc. for the City of Pasadena Water and Power (PWP). This report will be henceforth referred to as the 2009 Geosciences Report. EPA regards these responses from NASA/JPL as constructive steps to resolve the differences between PWP and NASA/JPL in their efforts to determine the extent to which perchlorate has migrated from the JPL Superfund site to the water supply wells used by PWP. At this time, the EPA sees two major areas of discussion:

Groundwater Modeling Results: NASA/JPL's responses to Geoscience Findings 1 through 3 (corresponding to three summary statements in Section 1.3.1 of the 2009 Geosciences Report) and the expected subsequent responses from PWP/Geosciences will be constructive for all parties to understand how the models and modeling results are practically different. As we have discussed, EPA does not have a working knowledge of the details of the respective models used by NASA/JPL and PWP/Geosciences, but EPA expects that such written exchanges between the two parties can resolve some differing interpretations, and the two parties along with EPA can then focus on the outstanding differences that may remain during the planned meeting in the next few months.

Interpretation of Perchlorate Isotope and Degradation Information: NASA/JPL's responses to Geoscience Findings 4 to 9 correspond to six summary statements in Sections 1.3.2 through 1.3.4 of the 2009 Geosciences Report. EPA's review of the NASA/JPL responses and the 2009 Geosciences Report finds Geoscience's interpretation of the isotope data related to source attribution and perchlorate degradation is qualitatively plausible, but it lacks any quantitative evidence that JPL is a major source of the perchlorate present in the PWP water supply wells. Importantly, the existence of geochemical conditions that indicate the potential for biotransformation of perchlorate does not necessarily demonstrate that biotransformation has indeed occurred. The

isotopic information developed by JPL indicating other sources of perchlorate are also reasonably present in the basin further confounds Geoscience's conclusion that the JPL Superfund site is the only source of perchlorate in the downgradient supply wells. If possible, these interpretations should be reviewed by the principal analysts during the upcoming meeting because EPA believes they are too complex to be resolved in a teleconference.

EPA encourages further written exchanges regarding clarifications and interpretations of site conditions by NASA/JPL and the PWP consultants, and the unresolved interpretations and conclusions will then be the basis for the agenda in the upcoming meeting.

If you have any questions or comments, please do not hesitate to call me at (415) 972-3681 or e-mail me at huang.judy@epa.gov.

Sincerely,

Judy C. Huang
Remedial Project Manager

cc:
Ms. Merrilee Fellows
NASA Manager for Community Involvement
NASA Management Office
4800 Oak Grove Drive
Pasadena, California 91109

Mr. Michael Isakarous
Remedial Program Manager
Department of Toxic Substances Control (DTSC) Southern California Cleanup
Operations, Chatsworth Office
9211 Oakdale Avenue
Chatsworth, California 91311-6505

Mr. Mohammad Zaidi
Remediation Program Manager
Regional Water Quality Control Board (RWQCB), Los Angeles Region
320 West 4th Street
Los Angeles, California 90013

Ms. Roumiana Voutchkova
Engineer
Pasadena Water and Power
150 S. Los Robles Ave., Suite 200
Pasadena, CA 91101

City of Pasadena Sunset Wells Contamination

June 14, 2011

No.	NASA's Claim	City of Pasadena's Position Including Geoscience's Findings	EPA Comments	DTSC Comments
		1. Groundwater Modeling		
1	Both NASA's and Raymond Basin's groundwater models indicate that perchlorate from JPL would be contained by the production wells in the Monk Hill Subarea and will not migrate to the Sunset wells.	NASA's Technical Memo (TM) used future pumping instead of historical pumping to make conclusions regarding moving of contaminated groundwater; particle tracking using historical data show groundwater path way from JPL to Sunset wells. The southern limit of JPL's plume has not been adequately characterized.	The area between JPL and Sunset wells is not well characterized with only a few wells. The TM should acknowledge that preferential migration pathway may have facilitated perchlorate migration to the Sunset area. TM doesn't adequately discuss the perchlorate detection in one monitoring well between JPL and the Sunset wells.	Neither groundwater model incorporated lateral anisotropy, yet geologic evidence suggests that it is present. The two models should be used for water management, but not to calculate particle flow path. The 2 models do not prove that contaminants were contained in the Monk Hill basin.
2	Historical pumping records indicate that since the early 1940s there were no sustained shutdown of all Monk Hill wells , which would have allowed chemicals to migrate out of the Monk Hill subarea.	Assumptions for all Monk Hill wells continuously pumping are not supported by historical pumping records. Four of the highest capacity Monk Hill wells belong to Pasadena and have been off service for extended periods.	JPL's model uses average pumping rates between 1960-2000. Two important production wells were off for 5 years (1985-1990). Each well has a stagnation point down gradient of the well. If the well is off for some time and the contaminant passes the stagnation point restarting the well will not recapture the escaped contaminant, as NASA TM claims.	There is a significant data gap in Arroyo area. Per recent communications with L A Department of Public Works perchlorate was detected during dewatering near the 110 freeway, down the Arroyo Seco Channel. This is not predicted by modeling, but consistent with and predicted by the geology.
		2. Groundwater Geochemistry		
1	Groundwater cations and anions data in Raymond Basin are available since 1900s. Based on the data 3 separate water types were determined in Monk Hill area. Mixing of imported water and native groundwater is observed and supported by the groundwater, strontium, and tritium isotope analysis.	NASA does not adequately characterize the anions and cations of MWD water or take into account the blend of waters from Colorado River and State Water Project. Anions and cations in Valley Water Company wells contradict NASA's water types. The tritium isotopes contradict classification by other methods.	While presented information suggest that significant amount of perchlorate were introduced in Raymond Basin by MWD, there is no information that assists in evaluating the contributions of perchlorate from MWD, JPL, fertilizers, etc.	The geochemical analysis misinterpreted some data, and cannot be relied on to conclusively show differences between water at individual wells.
2	Groundwater geochemistry from Sunset wells indicates an influence by the Colorado River water and Colorado River is a potential source of perchlorate in groundwater near the Sunset wells	The claims of imported water impacts on ambient water quality are not supported by data. NASA's findings that Colorado River is responsible for Sunset wells perchlorate is flawed, as the concentration in groundwater are at least an order of magnitude higher than in Colorado River water perchlorate levels.		NASA's TM assumed aerobic conditions, yet much of the chemistry suggests local anaerobic conditions.
		3. Groundwater Chemical Concentrations		
1	Carbon tetrachloride (CTC) is a reliable tracer of perchlorate originating from JPL. Groundwater monitoring data delineates the extent of CTC from JPL as approximately 1 mile south of the facility. Perchlorate and CTC were used at JPL at the same time, and based on hydrogeology both chemicals would follow similar flow paths. There is no detections of CTC in the Sunset wells. The absence of CTC supports an origin of perchlorate in Sunset wells not associated with JPL.	NASA's conclusions regarding the association of CTC and perchlorate are not supported by data, and do not take into account the different fate and transport of the two chemicals. CTC is subject to retardation, reductive dechlorination in the presence of free sulfide and ferrous ions, and dispersivity that will slow its transport. The association of perchlorate and CTC is less reliable the further from JPL. Concentrations of CTC are too low to be a reliable tracer for contaminant plume.	CTC is not a reliable tracer of perchlorate for several reasons: simple dilution due to advective flow and dispersion will reduce it to non-detectable concentrations. CTC can also undergo transformation reactions, whereas perchlorate is more stable. The environmental literature has citations of transformations of CTC by microbial and chemical processes. The absence of CTC in a groundwater cannot be the basis for the conclusion that perchlorate in the Sunset wells is not from the JPL.	NASA's model cannot be used to predict the extent of CTC, since it incorrectly predicts the distribution of sulfate and perchlorate. Contrary to the report PCE and TCE make excellent tracers. The presence of PCE and TCE at the Sunset wells, despite the assertion that the Monk Hill pumping depression prevents JPL's plume from migrating south, is a logical inconsistency. While CTC has not been detected in Sunset wells, data shows that CTC is breaking down to chloroform, despite assertions that it is not biodegrading.

No.	NASA's Claim	City of Pasadena's Position Including Geoscience's Findings	EPA Comments	DTSC Comments
		4. Perchlorate Isotopes		
1	JPL perchlorate isotopic signature is distinct within the Raymond Basin.	NASA did not measure isotopic source of perchlorate (1) in the JPL area, and (2) in imported MWD water	Review of data indicate several uncertainties that confound an interpretation of the data that could be applied in source allocation.	The Sunset wells are downstream from JPL. The isotope data shows that at least some of the perchlorate in the Sunset wells originated from JPL.
2	There is no evidence of perchlorate degradation in Raymond Basin groundwater.	The water quality data presented by NASA provides evidence that perchlorate biodegradation is occurring.	The conclusion that the isotopic signature of perchlorate samples collected from Sunset wells is different from the JPL perchlorate and therefore that JPL is not the source of perchlorate does not adequately take into account consideration that Sunset perchlorate is possibly a composite from several sources of perchlorate in the Raymond Basin.	The Isotope analysis shows that the perchlorate at the Sunset wells is a mixture of two sources - JPL and Las Vegas [Colorado River].
3	Perchlorate in Sunset area appears to be influenced by at least two non-JPL sources.	This isotopes method has only been used for distinguishing between natural and man-made perchlorate. The presence of biodegradation makes distinguishing different man-made perchlorate sources more complex.		
		Conclusions		
1	The perchlorate detected in the Sunset wells is of a different origin than that used at, and originating from JPL.	Geoscience's findings do not support NASA's conclusion that the perchlorate in Sunset area is different than that originating from JPL.	While, the perchlorate isotope data does not support a conclusion the perchlorate in the down gradient Sunset wells is solely due to JPL as a source, data does not eliminate JPL as a contributor to perchlorate contamination with possible several sources of perchlorate.	It is unlikely that pumping in Monk Hill subarea contained JPL's contaminants. The hydrogeology and structure of the alluvium provide pathway from JPL to the vicinity of the Sunset wells.
2	Groundwater modeling, geochemistry, chemical concentrations, and perchlorate isotopes taken together lead to the conclusion that the chemicals from JPL are contained in the Monk Hill subarea.	The groundwater flow in Raymond Basin is from north/west to south/east. JPL is located on the north/west of Pasadena. The highest concentrations of perchlorate in the Raymond Basin is in the groundwater beneath JPL. Sunset wells are about 3 miles downstream of JPL.		

Abbreviations and Notes:

JPL: Jet Propulsion Laboratory is a CERCLA site, due to the waste disposal during the 1940s and 1950s. JPL is a known source of perchlorate contamination in the Raymond Basin.
MWD: Metropolitan Water District of Southern California
DTSC: California Department of Toxic Substances Control
Raymond Basin is the adjudicated groundwater basin beneath the City of Pasadena
Geoscience Support Services Inc. is a Southern California engineering company contracted by Raymond Basin to perform groundwater studies, and City of Pasadena to evaluate NASA's TM
Monk Hill subarea - a subbasin in the Raymond Basin in the immediate vicinity of JPL
Sunset area - a subbasin of the Raymond Basin south of the Monk Hill subarea