NASA's Comments on the Technical Memorandum Entitled,
***NASA/JPL Perchlorate Contamination of Ground Water in the Raymond Basin*[1]**

Introduction:

We have been working collaboratively with the City of Pasadena and their consultants since 2004 in an effort to collect data[2] and maintain an open technical discussion regarding the presence of perchlorate in the City's Sunset Reservoir area wells. This effort has included installation of two new monitoring wells, groundwater modeling, analysis of groundwater monitoring well data dating back to the early 1990s, analysis of production well water quality data dating back to 1940, and a perchlorate isotope study. To be as comprehensive as possible, NASA's analysis used four distinct lines of scientific evidence, which were evaluated individually and collectively. The result of NASA's analysis completed in 2007 was the conclusion that the perchlorate in the Sunset wells had not originated from JPL, but was likely a mix of naturally occurring perchlorate and at least one other synthetic source.[3]

Since finalizing our findings in January 2007, an ongoing effort has been made to respond to comments from the City of Pasadena, U.S. Environmental Protection Agency (EPA), and the Department of Toxic Substances Control (DTSC). NASA submitted responses to all comments received on the January 2007 technical memorandum in December 2008.[4] After responding to all comments, NASA again concluded that the perchlorate in the Sunset wells had not originated from JPL.

Some of the comments received on NASA's technical memorandum had to do with groundwater modeling, which is one of the four lines of scientific evidence used for our analysis. On March 6, 2009, a teleconference was conducted with groundwater modeling experts to sort out the various assumptions being made and different interpretations. Following the teleconference, Pasadena contracted Geoscience Support Services, Inc. to conduct additional modeling and evaluate the other lines of evidence presented by NASA in the Additional Investigation technical memorandum[3] and the associated responses to comments.[4] Their findings were documented in a technical memorandum,[1] dated October 28, 2009.

NASA has many questions regarding the assumptions used by Geoscience. *Overall, the findings presented in the October 28, 2009 technical memorandum from Geoscience Support Services, Inc. are not substantiated by available data and do not consider all available data in an integrated manner.*

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[1] Geoscience Support Services, Inc. and Williams-McCaron, Inc. 2009. *NASA/JPL Perchlorate Contamination of Ground Water in the Raymond Basin*. Prepared for the City of Pasadena Water and Power. October.
[2] NASA. 2004. *Operable Unit 3 Remedial Investigation (RI) Addendum Work Plan (Pasadena Sampling Plan [PSP]-2004-1)*. Prepared by Battelle for the National Aeronautics and Space Administration. November.
[3] NASA. 2007. *Technical Memorandum, Additional Investigation Results, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California*. Prepared by Battelle for the National Aeronautics and Space Administration. January.
[4] NASA. 2008. *Responses to Comments on the Additional Investigation Results, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California*. Prepared by Battelle for the National Aeronautics and Space Administration. December.

Throughout the process, NASA's approach to understanding groundwater conditions and the source of perchlorate in the Sunset Wells has been to evaluate all of the available data in an integrated manner. Groundwater modeling results – NASA's and Pasadena's included – must be evaluated in the context of all available site-related data. NASA evaluated four lines of evidence, representing all of the available data, to establish a conceptual site model for the study area and achieve the objectives of the study. The four lines of evidence included groundwater modeling data, groundwater geochemical data, chemical concentration data collected as part of the JPL groundwater monitoring program, and perchlorate isotope analysis data. Each of the four lines of evidence provide important information and need to be evaluated together to fully develop and understand the site conceptual model regarding the complexities of underground conditions and the presence of perchlorate in local groundwater.

NASA has reviewed the technical memorandum prepared by Geoscience Support Services in October 2009 and provides the following general comments and data requests. NASA believes that the data requests associated with Findings 1 through 3 need to be provided prior to any meeting between the modeling experts. General comments and data requests are organized by the findings presented in the Executive Summary of the memorandum.[1]

GEOSCIENCE Finding 1: *Forward particle tracking suggests that the JPL source area is the origin of perchlorate at the Sunset Reservoir area wells (P-COP, P-SUN, P-BAN, P-GAR, and P-VIL).*

- We disagree with this finding, and it is not supported by information presented in the report. No particles were released near the JPL source area wells (MW-7, MW-16, and MW-24). Modeling results show that the particles released closest to the JPL source area (to the southwest near MW-13) and within the JPL Facility boundary appear to all be contained by Well 52 and Ventura Well, and do not migrate downgradient to the Sunset Reservoir wells (this is consistent with the JPL Groundwater Model).
- We strongly disagree with the estimated extent of perchlorate (in 1981). The extent of perchlorate is based on an average migration rate of 0.83 ft/day and ignores plume containment/capture by the Monk Hill production wells. Plume containment/capture cannot be ignored when evaluating migration of chemicals originating from JPL because Monk Hill Subarea production wells have been operating since the early 1900s. In addition, the estimated extent of perchlorate (in 1981) includes MW-19, which is not accurate based on groundwater modeling, the absence of carbon tetrachloride, tritium data, and groundwater geochemistry.[3,4] Lastly, the estimated extent of perchlorate cannot be verified with historical chemical concentration data (no perchlorate data exist prior to 1997), and the 1981 estimated extent of perchlorate contradicts available monitoring data which indicate that the current extent of the JPL perchlorate plume is just beyond MW-20 (see Figure 29 in Geoscience Technical Memorandum).
- **Data Request:** NASA modeling experts request that Geoscience clarify where particles were released in Figure 31.[1] It appears that some particles were released from the Arroyo Seco in between Well 52 and Ventura Well.
- **Data Request:** We request that Geoscience explain the rationale behind the hydraulic conductivity values used in the RBMB model for the Monk Hill Subarea in the vicinity of and

downgradient of the JPL Facility. Based on an evaluation of transmissivity and layer thickness maps, it appears that the hydraulic conductivity values used by Geoscience are roughly double those measured during the JPL large-scale pumping test.[5]

- **Data Request:** To help estimate how far perchlorate traveled from the JPL source area and to understand plume capture it is necessary to have forward particle tracking results for particles released near the JPL source area wells (i.e., MW-7, MW-16, and MW-24), and from the JPL facility boundary. These data will help us understand flow paths and capture of chemicals originating from JPL beginning in 1981 (almost 30 years ago) and provide results that can be compared to the JPL model. Prior to 1981, historical data show that there was significant pumping from the Monk Hill production wells during the 1960s and 1970s.[4] In particular, the Arroyo Well was utilized heavily in the 1960s and 1970s. This well has a major impact on JPL plume containment and is the nearest Monk Hill production well to the JPL Facility. NASA can have Battelle conduct this forward particle tracking if the City of Pasadena provides the RBMB model or the City of Pasadena can have Geoscience conduct this forward particle tracking. We consider this a key piece of data that will help resolve the current differences in technical understanding of the groundwater flow.

GEOSCIENCE Finding 2: *Backward particle tracking suggests that the JPL source area is the origin of perchlorate at the Sunset Reservoir area wells (P-COP, P-SUN, P-BAN, P-GAR, and P-VIL).*

- We disagree with this finding, and it is not supported by information presented in the report. None of the particles backtracked from the Sunset, Copelin, and Bangham wells intersect the JPL Facility boundary. They appear to terminate to the south and west of the JPL Facility, as previously determined.[4] In addition, none of the particles backtracked from the Garfield and Villa wells intersect the JPL source area. It is also noteworthy that Garfield and Villa have historically contained the lowest levels of perchlorate among the five Sunset Reservoir area wells (currently around 4 to 5 µg/L) and the perchlorate isotope results for Garfield well were much different than those from JPL (much heavier $\delta^{18}O$ value and a significant contribution of natural/fertilizer perchlorate).[3]
- **Data Request:** Similar to forward particle tracking from the JPL Facility, backward particle tracking from the production wells in the Monk Hill Subarea provide key data that will help resolve the current differences in technical understanding of the groundwater flow. Backward tracking from the production wells and forward tracking from the JPL Facility need to be evaluated together to understand plume containment/capture. Please provide individual well backward particle tracking results for particles released from Arroyo Well, Well 52, Ventura Well, Windsor Well, LAWC#3, LAWC#5, LFWC#2, RCLWA#4, and RCLWA#7. Alternatively, NASA can have Battelle conduct this backward particle tracking if the City of Pasadena provides the model.
- **Data Request:** Please provide backward particle tracking results from MW-19. The JPL model and the previous version of the RBMB model (as well as chemical data, water geochemistry, and tritium data) showed that MW-19 contains groundwater originating in La Cañada-Flintridge

[5] NASA. 2003. *JPL Groundwater Modeling Report*. December.

traveling a path to the south of the JPL Facility. It is necessary to compare previous model results to the revised RBMB model results, as this is critical to our understanding of plume extent, groundwater migration, and the interpretation of perchlorate isotope data (recall that MW-19 isotope results and the Sunset Well isotope results are very similar).

- The reported migration timeframes and rates associated with the backward (and forward) particle tracking from the Sunset Reservoir area wells are not consistent with migration rate estimates (i.e., 0.83 ft/day) within the known JPL plume (Figure 29 and Section 3.2).
- **Data Request:** Please provide individual well backward particle tracking results for particles released from the Sunset Reservoir area wells. Individual well data may help us better evaluate the findings.

GEOSCIENCE Finding 3: *Backward particle tracking suggests that the JPL source area is the origin of perchlorate in the deep screen intervals of JPL MW-20.*

- We have stated previously that this is our understanding.[3,4] However, forward and backward tracking Figures 31 and 32 do not indicate particles near MW-20 travel to the Sunset Reservoir area wells. The JPL groundwater model indicates that MW-20 is in the capture zone of RCLWA wells.
- **Data Request:** Please provide forward particle tracking results for particles released from MW-20 to help understand if MW-20 is in the capture zone of RCLWA wells. These data are important to understand the potential of chemicals in MW-20 to migrate past the RCLWA wells.

GEOSCIENCE Finding 4: *Available ground water quality data show that reducing conditions, which are necessary for perchlorate biodegradation, occur extensively in the JPL and Sunset Reservoir areas.*

- We disagree. This finding is based on field-measured redox potentials (ORP) and total iron concentrations. Field measurements of ORP are well-known to be unreliable[6] and need to be evaluated along with other available data. Total iron concentrations cannot be used to evaluate redox conditions in the aquifer because it is not known whether it is particulate (ferric) or dissolved (ferrous). The presence of dissolved iron (ferrous) would indicate reducing conditions.
- Only a small percentage of JPL study area groundwater measurements showed dissolved oxygen (DO) < 1 mg/L (< 5% of the data). Also, less than 16% of the ORP data are below 0 mV. Therefore, conditions under which perchlorate biodegradation could occur are not common in the JPL study area.
- Perchlorate biodegradation occurs only when bacteria that produce the chlorite dismutase (*cld*) enzyme are present, and requires the presence of the *cld* mRNA to indicate activity of the *cld* gene. Tests for the *cld* mRNA were negative in seven of nine groundwater samples tested. Positives were found only in MW-1 and MW-24-1. MW-1 does not contain measurable perchlorate and is located near the mouth of the Arroyo Seco. MW-24-1 is in the source area where biological treatment and biological treatability studies have been performed.

[6] Lindberg and Runnells. *Science*. vol. 225, no. 4665, p. 925-927.

- A review of groundwater monitoring results shows a lack of TCE degradation daughter products within the JPL plume. This provides further evidence that reducing conditions are not widespread in the study area.

GEOSCIENCE Finding 5: *Based on sampling of seven wells in the Raymond Basin, two wells (MW-20 and MW-25) show direct evidence of perchlorate degradation.*

- We disagree. A number of assumptions are required before these data can be interpreted as evidence for biodegradation, including that nitrate and perchlorate concentrations are consistent along the vertical profile of the aquifer (which is not the case). For example, the highest levels of perchlorate observed in MW-20 have been in the deeper zones (screens 4 and 5).[3,4] Similar results are observed throughout the JPL monitoring network, which is why there are multiple sampling intervals in many of the wells and why the JPL groundwater model includes four distinct layers.

GEOSCIENCE Finding 6: *Perchlorate in the Colorado River undergoes seasonal biodegradation in Lake Mathews.*

- The interpretation as biodegradation ignores other possible physical and biological causes of change in the depth profile. There is stratification in reservoirs and the deeper water is likely not representative of the water that eventually is transported to Southern California. Also, biodegradation occurring in bottom sediments (e.g., nitrate in river and lake bottom sediments) can occur without isotopic fractionation because perchlorate diffusing into bottom sediments is completely degraded.[7]
- There is a strong correlation between DO concentration and temperature of Lake Mathews water (based on data from Volume 2 of the Geoscience report). This may indicate that the low-T, low-DO, low perchlorate bottom water is actually groundwater that is entering the bottom of Lake Mathews.

GEOSCIENCE Finding 7: *Perchlorate in the Sunset Reservoir area wells is synthetic in origin.*

- This statement ignores the $\Delta^{17}O$ data that indicate the apparent presence of 13 to 20% perchlorate derived from a natural source (Chilean nitrate fertilizer) in Bangham well and Garfield well. In addition, the likely presence of some indigenous natural perchlorate, such as that documented from West Texas, New Mexico, and the Mojave Desert, is ignored.[8] The perchlorate in the Sunset well does appear to be synthetic in origin based on the perchlorate isotope data.
- Existing perchlorate isotopic data indicate substantial contribution of perchlorate from a probable agricultural source (Chilean nitrate fertilizer) and at least one non-JPL synthetic source in Sunset Reservoir wells.[3]

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[7] Brandes and Devol. 1997. *Geochimica Cosmochimica Acta*, vol. 61, no. 9, p. 1793-1801.
[8] Sturchio et al. 2009. *Environmental Science and Technology,* vol. 43, no. 18 p. 6934-6938.

GEOSCIENCE Finding 8: *Perchlorate measured in the Sunset Reservoir area wells is consistent with JPL-source perchlorate, which has undergone limited biodegradation.*

- We disagree. None of the Sunset Reservoir wells' (Sunset, Bangham, Garfield) perchlorate isotopic composition can be modeled simply as residual perchlorate from biodegradation of any JPL wells' perchlorate isotopic composition. We recommend that the Geoscience geochemist who supported this work discuss the results with Dr. Sturchio.
- It is recommended that we have our statistician discuss the statistical evaluation and results with the Geoscience statistician.

GEOSCIENCE Finding 9: *Perchlorate isotope ratios in imported water are shifted as a result of biodegradation in Lake Mathews.*

- This statement relies on a theory that perchlorate biodegradation in Lake Mathews has affected the isotopic composition of perchlorate in imported water. No isotopic data are provided to substantiate this theory.
- See comments associated with Finding 6.

Again, to move the process forward, NASA believes that the data requests associated with Findings 1 through 3 need to be provided prior to any meeting between the modeling experts from Geoscience, EPA, and Battelle. Other discussions associated with geochemical interpretations, perchlorate isotopes, and statistical evaluations can occur via teleconference while additional modeling results are prepared.