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Results of Additional Studies

NASA is committed to communicating with the public about the Groundwater Cleanup Project at the Jet Propulsion Laboratory (JPL). This information sheet describes the results of several integrated studies we recently completed.

NASA is making significant progress with cleanup efforts at the Jet Propulsion Laboratory (JPL). We recently completed soil cleanup, and we are in the process of expanding the capacity of our source area (onsite) groundwater treatment facility. We continue to fund the treatment system for two Lincoln Avenue Water Company drinking water wells and to work with the City of Pasadena to fund its construction and operation of a new groundwater treatment facility in northern Pasadena. Cleanup efforts also include completing an in-depth site investigation required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Beginning in 1992, NASA conducted several investigations to determine the type and extent of chemicals originating from historic waste practices at JPL.

There have been detections of perchlorate at various wells located in the Raymond Basin aquifer, including wells near the Sunset Reservoir. These findings prompted NASA to conduct further study in the area to:

Understand the downgradient (southern) extent of chemicals that originate from JPL, and

Determine if the occurrence of perchlorate in the Sunset Reservoir area was associated with migration from the JPL facility.

Four analytical tools were used: Groundwater Modeling, Groundwater Geochemistry, Groundwater Chemical Data and Perchlorate Isotope Analysis. When evaluated together, these studies provide an understanding of the complexities of underground conditions and the existence of perchlorate in groundwater in the Raymond Basin.

NASA has collected data from monitoring wells (referred to here as MW) since the mid-1990s. In 2004, two new multi-port wells were installed and added to NASA's quarterly groundwater monitoring program to help understand the extent of chemicals from JPL. Multi-port wells allow sampling of groundwater from up to five different depths. The new wells, MW-25 and MW-26, are located between what was formerly the southernmost NASA monitoring well (MW-20), and the Sunset Reservoir area.

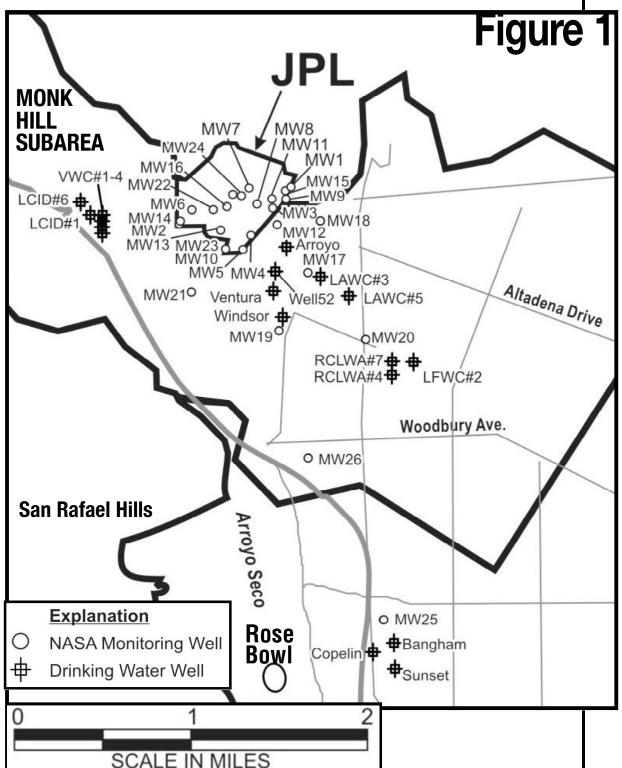


Figure 1 **shows the locations of monitoring wells installed as part of NASA's CERCLA program. Also shown are the locations of several water supply production wells in the Monk Hill Subarea of the Raymond Basin and wells near the Sunset Reservoir area.**

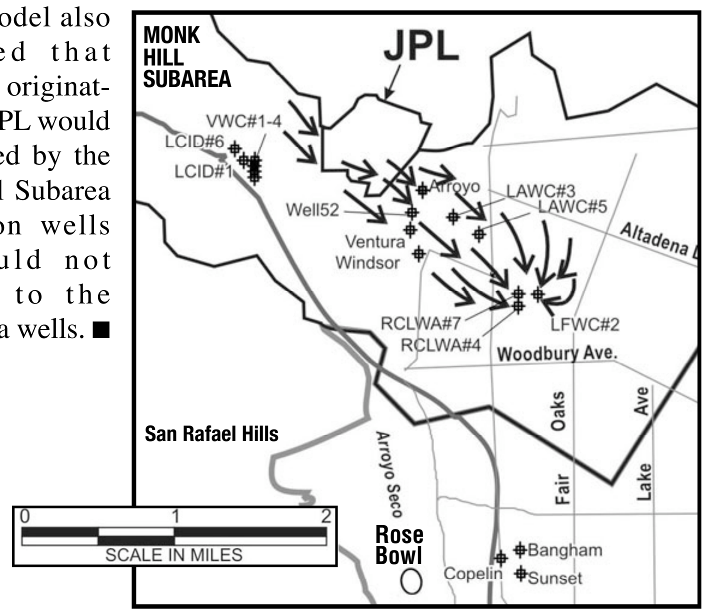
NASA conducted additional studies according to the workplan approved by the U.S. Environmental Protection Agency, California Department of Toxic Substances Control, and the Regional Water Quality Control Board. The Department of Health Services and the City of Pasadena provided input on the plan. ■

Groundwater Modeling

Computer modeling was used to estimate groundwater flow direction and velocity and to understand how chemicals from JPL move over time. Part of this analysis included asking how water production (drinking water) wells affect groundwater movement while the wells are operating and during periods when they are not. When a production well is extracting water during operation, the pumping action will draw groundwater flow toward the well, creating an area called a capture zone.

Particle tracking simulations were performed using a model that NASA developed initially to evaluate groundwater treatment alternatives and groundwater flow in the Monk Hill Subarea. In this study, normal seasonal variations were accounted for and average water extraction rates from 1960 to 2000 were used. Particle tracking works by releasing a computer-generated (imaginary) particle at a specific location and following its path in the aquifer. Modeling showed that particles originating from the JPL facility would be captured by wells in the Monk Hill Subarea, primarily by Arroyo Well, Well 52, and the Lincoln Avenue Water Company (LAWC) Well 3. [See Figure 2] In addition, there did not appear to be any times since the 1940s when Monk Hill Subarea production wells experienced widespread or complete shutdown. Any chemicals that escaped containment while some wells were closed likely would have been captured by other production wells in the Monk Hill Subarea that were in operation during that time.

Computer models are only representative of actual conditions. As with any scientific study, the ability to replicate an experiment and get similar results increases confidence in the methods used. NASA also evaluated a groundwater flow model that was developed independently by the Raymond Basin Management Board (RBMB) to evaluate potential changes to groundwater levels and movement throughout the Raymond Basin, including the Monk Hill Subarea. Results from the RBMB model also indicated that chemicals originating from JPL would be captured by the Monk Hill Subarea production wells and would not migrate to the Sunset area wells. ■



Computer modeling shows that production well pumping action draws groundwater flow toward the well creating an area called a capture zone. Chemicals originating from JPL would be captured by wells in the Monk Hill Subarea and would not migrate to the Sunset area wells.

Groundwater Geochemistry

Groundwater chemistry data are used primarily to evaluate drinking water quality. Because the groundwater in the Raymond Basin has been used as a source of drinking water for more than 100 years, chemical analyses data are available from production wells dating back to the early 1900s.

Historical records show that connection to the Metropolitan Water District (MWD) aqueduct tunnel at Sunset Reservoir was completed in 1941, and delivery of Colorado River water began in June of that year. Geochemistry data show a significant change in the concentration of various dissolved chemicals in the Raymond Basin associated with imported water.

More than 1 million acre-feet of Colorado River water have been imported by the Metropolitan Water District (MWD) to the Raymond Basin since the 1940s to supplement local drinking water supplies. More than 30% of the water used in the Raymond Basin between 1952 and 2002 was from the Colorado River. An estimated 25% of imported water has made its way to the Raymond Basin aquifer via irrigation, leaking pipes, unsewered areas, and direct injection.

To understand the impact of imported Colorado River water on groundwater, we looked specifically at the ion concentration data. (An ion is an atom or group of atoms that has a positive or negative charge as a result of having lost or gained one or more electrons.) These data were collected both from local drinking water wells and NASA's groundwater monitoring program. Plotting this data (called Piper diagrams) assists in visualizing the geochemical variations in the water. These analyses confirmed that three distinct water types are found in the Raymond Basin aquifer.

Type 1 water is characterized by its trace amounts of dissolved calcium and bicarbonate ions. It originates as rainwater runoff from the San Gabriel Mountains and filters through the earth into the Raymond Basin. Type 1 water is native groundwater found at shallower depths.

Type 2 water is characterized by its trace amounts of dissolved sodium and bicarbonate ions and is found in deeper portions of the aquifer. Type 2 water is native groundwater that has been in contact with minerals in the subsurface.

Type 3 water is created by mixing of imported Colorado River water with native water. This results in water becoming relatively enriched in sulfate and chloride ions. Type 3 water consistently has higher levels of total dissolved solids (TDS) than either of the other two water types. Geochemical data confirm that Type 3 water did not exist in the Raymond Basin prior to the introduction of Colorado River water in the 1940s and 1950s.

The influence of imported water on the Raymond Basin is important because Colorado River water is known to contain perchlorate and sulfate. Although perchlorate data are not available prior to 1997, we do have sulfate data, which serves as a tracer for the influence of imported water. Chemically, perchlorate acts like sulfate in groundwater. Sulfate is a very stable compound and does not biodegrade under the conditions found in the Raymond Basin. Elevated sulfate levels in groundwater show the impact that Colorado River water has had since being introduced to the area in the 1940s. It appears that the change in water quality is a result of imported Colorado River water mixing with native groundwater – shifting it from Type 1 (native, shallow) to Type 3 (Colorado River water introduced into the aquifer).

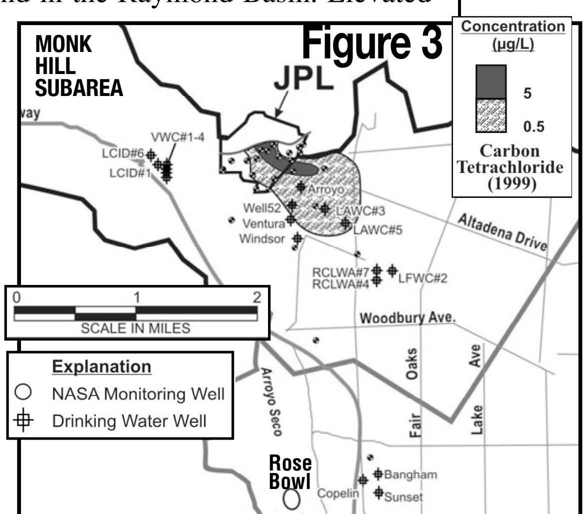
Geochemistry data show how the Raymond Basin, including the Sunset area wells has been impacted by Colorado River water. These data alone do not show whether there are additional sources or how much of the perchlorate in the Sunset area wells is from the Colorado River water. ■

Groundwater Chemical Data

The third analytical tool used by NASA was evaluating groundwater chemical data. Groundwater samples are regularly collected from production wells, which supply public drinking water. These samples are analyzed for chemicals specified by federal and state law and regulations. In addition, NASA has collected thousands of groundwater samples on a quarterly basis for more than a decade from more than 20 monitoring wells, both on- and off-facility at JPL. These samples are routinely analyzed for chemicals historically used at the facility including volatile organic compounds (VOCs), certain metals and perchlorate. These data were used to understand the extent of chemicals originating from JPL.

Carbon tetrachloride is the primary VOC that is associated with past operations at the facility and the JPL cleanup. The only known source of carbon tetrachloride in the Monk Hill Subarea groundwater is from JPL. Carbon tetrachloride, therefore, can be considered a tracer for chemicals originating from JPL. In the wells where carbon tetrachloride is found, perchlorate originating from JPL is also found. A review of more than 10 years of monitoring data shows that carbon tetrachloride has not been detected beyond approximately one mile downgradient from JPL. [See Figure 3] NASA recognizes that, due to its chemical properties, perchlorate could travel faster than carbon tetrachloride in the absence of groundwater pumping. Still, no carbon tetrachloride has been detected outside of the Monk Hill Subarea. This correlates well with our understanding of production well capture zones and provides additional evidence that perchlorate originating from JPL is contained in the Monk Hill Subarea.

Another interesting finding associated with the groundwater chemical data is the elevated levels of perchlorate in MW-21, detected in the late 1990s. [See Figure 1 for well locations] Chemical data from MW-21 detects no carbon tetrachloride. In addition, groundwater modeling shows that MW-21 is in the flowpath between the upgradient area of La Cañada and the capture zone of the downgradient Sunset area wells. The Monk Hill Subarea capture zone is separate. These results provide evidence that elevated levels of perchlorate in MW-21 are from a source of perchlorate not associated with JPL. ■



Carbon tetrachloride is considered a tracer for chemicals originating from JPL, and has not been detected beyond approximately one mile downgradient from JPL.

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Perchlorate Isotope Analysis

Perchlorate in the environment today is widespread. Sources of perchlorate include road flares, fireworks, blasting operations, and other commercial and military products, as well as rocket propellant. A well documented naturally occurring perchlorate is found in nitrate salt deposits of the Atacama Desert in Chile. These deposits have been exported extensively since about 1870 for use as agricultural fertilizer. According to the California Department of Agriculture, more than 477,000 metric tons of Chilean nitrate were used in the state to fertilize crops between 1923 and 1998. Other natural perchlorate has been reported in samples of rain and snow. This naturally occurring perchlorate, as well as the different man-made sources of perchlorate, can be measured and be potentially differentiated by their isotopic "fingerprint".

NASA collected groundwater samples for perchlorate isotope analysis from 13 locations including three of the five Sunset area wells (Sunset, Bangham, Garfield).

Dr. Neil Sturchio, a specialist in the field of isotopic analysis from the independent laboratory of the University of Illinois at Chicago, conducted the analysis for NASA. Specific isotopes of chlorine and oxygen, in the man-made type of perchlorate historically used at the site, were measured and evaluated. These analyses were able to (1) distinguish the JPL perchlorate as having an isotopic fingerprint distinct from other sources in the Raymond Basin and (2) show that the perchlorate found at Sunset wells appears to be from at least two different sources: man-made (e.g., found in imported Colorado River water, fireworks, flares, etc.) and naturally-occurring (e.g., imported in large quantities of fertilizer from Chile). ■

Summary of Results

Groundwater Modeling

Modeling developed by NASA and independently by the RBMB indicate that dissolved chemicals from JPL would be contained by production wells in the Monk Hill Subarea and not migrate to the Sunset area wells.

Groundwater Geochemistry

Imported Colorado River water has changed the geochemistry of groundwater in the Raymond Basin. Imported Colorado River water also is known to contain perchlorate.

Groundwater Chemical Data

Carbon tetrachloride is considered a tracer for chemicals originating from JPL and has not been detected beyond approximately one mile downgradient from JPL, which is consistent with modeling results.

Perchlorate Isotope Data

Perchlorate originating from JPL has a fingerprint that is distinct from the fingerprint of perchlorate present in the Sunset area wells.

Results

The investigation employed the use of four different analytic tools. Taken together, the results of the groundwater modeling, groundwater chemistry, groundwater chemical data and groundwater monitoring, and isotopic analysis, lead to the conclusion that (1) NASA has determined that the chemicals from the JPL facility are captured within the Monk Hill Subarea, and, (2) the perchlorate detected at the Sunset area wells is of a different origin than that used at and originating from JPL.

For More Information

More information about the NASA Groundwater Cleanup Project at JPL is available on our **Web site** http://jplwater.nasa.gov and at the **NASA Information Repositories** located in the Pasadena Central Library, La Cañada Flintridge Public Library or the Altadena Public Library.

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