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Technical Memorandum

Aquifer Testing and Groundwater Injection Modeling for Lincoln Avenue Water Company Wells National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California

Final April 10, 2006

This technical memorandum presents the results of an aquifer test conducted during shutdown of the Lincoln Avenue Water Company (LAWC) production wells. This test was conducted as part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Program at NASA's Jet Propulsion Laboratory (JPL). Groundwater extraction and treatment by LAWC is being performed as a Removal Action under the CERCLA Program[1].

The objective of this investigation was to better understand the effects of groundwater extraction from the LAWC production wells on local aquifer conditions. During the aquifer test, the effect of pumping on local groundwater flow conditions was observed in a JPL multi-port monitoring well, MW-17, which is located 399 ft upgradient (northwest) of LAWC Well No. 3 (LAWC#3) and 1,470 ft upgradient of LAWC#5 (Figure 1).

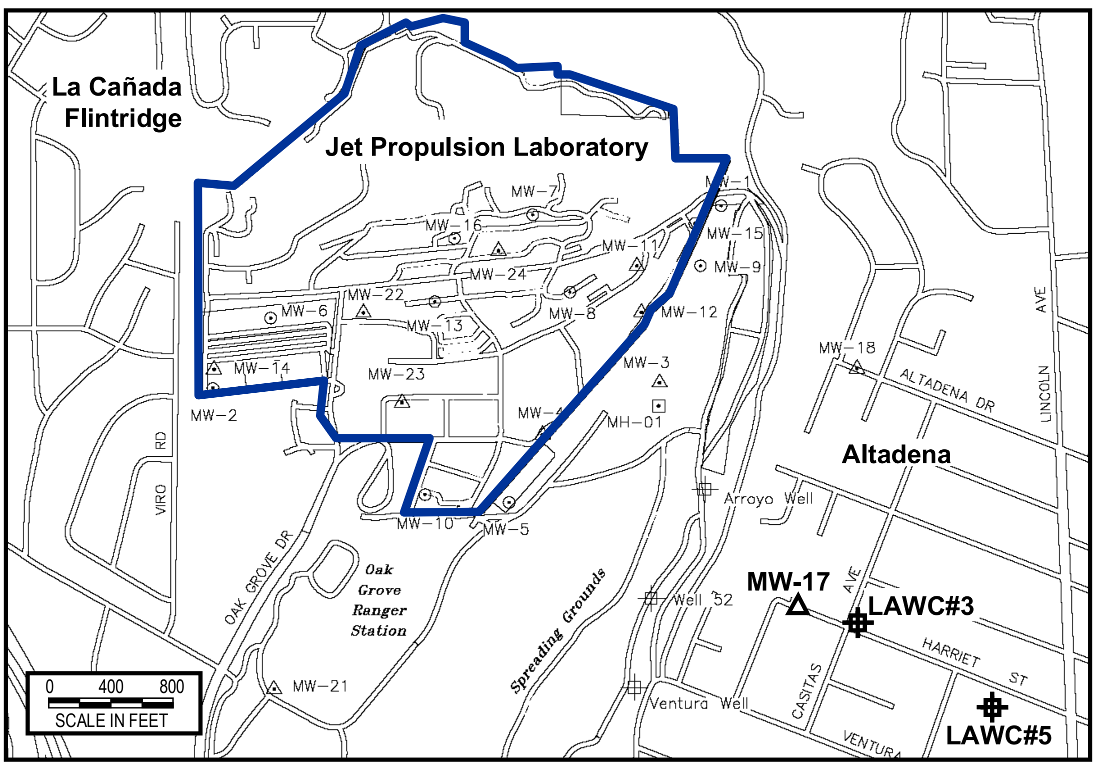

Figure 1. Location of JPL, MW-17, LAWC#3, and LAWC#5

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[1] NASA. 2004. Action Memorandum For the Lincoln Avenue Water Company (LAWC), Altadena, Calfifornia Associated with the Groundwater Cleanup at the National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California. August.

Also, this technical memorandum summarizes additional groundwater modeling performed by Battelle associated with the proposed injection of imported water into LAWC#5. Injection of water into LAWC#5 has been proposed by LAWC as part of their operations and is not associated with NASA's CERCLA Program.

AQUIFER TEST TIMELINE

November 9: The MOSDAX groundwater monitoring assembly was installed in MW-17. The assembly consisted of five pressure transducers and a data logger, specifically designed for a Westbay™ multi-port well. Each transducer was programmed to collect pressure readings at 30 minute intervals for the duration of the investigation.

November 15: LAWC#5 was taken off line due to mechanical reasons.

November 16: Aquifer testing was initiated by shutting down LAWC#3. Prior to shutdown, the depth to groundwater was measured manually in LAWC#3 and LAWC#5 and a transducer was installed in LAWC #3. Manual groundwater-level elevation measurements were collected in LAWC#5 for five hours after the shutdown of LAWC #3, with the frequency of measurements decreasing with time.

November 17: The depth to groundwater was measured manually in LAWC#5 prior to restarting LAWC#3 at a rate of approximately 1,050 gallons per minute (gpm). Three hours after restarting LAWC#3, LAWC#5 was restarted at a rate of approximately 1,150 gpm. Manual groundwater-level elevation measurements were collected in LAWC#5 for the three hours after LAWC#3 was restarted.

November 18: The transducer in LAWC #3 was removed from the well.

November 22: A manual groundwater-level reading was collected in LAWC#5, and the MOSDAX string was removed from MW-17. Data from the datalogger were downloaded for analysis.

AQUIFER TEST RESULTS

The observed groundwater-level fluctuations in MW-17 are summarized in Table 1 and are shown graphically in Figure 2. Data collected from MW-17 indicated that operation of LAWC#3 has the greatest effect on groundwater levels in Screen 2 and Screen 3. This effect was expected, as these two screens correlate most closely with the screen depth of LAWC#3. Although the effects of the pumping changes in the LAWC wells is observed in Screen 1 and Screen 5, it is considerably less than that observed in Screens 2 and 3. The transducer in Screen 4 malfunctioned during the test, so no data are available for this screen.

These groundwater-level data indicate a maximum rise of 8 ft in Screen 3 after cessation of pumping, and a maximum drawdown of roughly 7 ft in Screen 3 after pumping was resumed. Changes in groundwater elevations in MW-17 as a result of cessation of pumping in the LAWC wells were observed rapidly, within 10 minutes of the pumping modification. Changes in groundwater elevations in MW-17 as a result of restarting pumping in the LAWC wells were

Table 1. Summary of Groundwater-Level Changes in MW-17

Screen	Maximum Groundwater-Level Fluctuation (ft)			
	LAWC #5 Shutdown	LAWC #3 Shutdown[(1)]	LAWC #3 Startup	LAWC #5 Startup[(2)]
1	0.14	1.09	-0.44	-0.37
2	2.63	4.06	-4.10	-0.63
3	4.96	8.00	-7.04	-1.06
5	-0.02	1.52	0.14	-0.18

(1) LAWC#3 shutdown refers to having both wells off line; LAWC#5 was shut down 13 hours earlier.
(2) LAWC#5 startup refers to having both wells on line; LAWC#3 was started 3 hours earlier. The fluctuation is indicative of a 24 hour period after both wells were in operation.

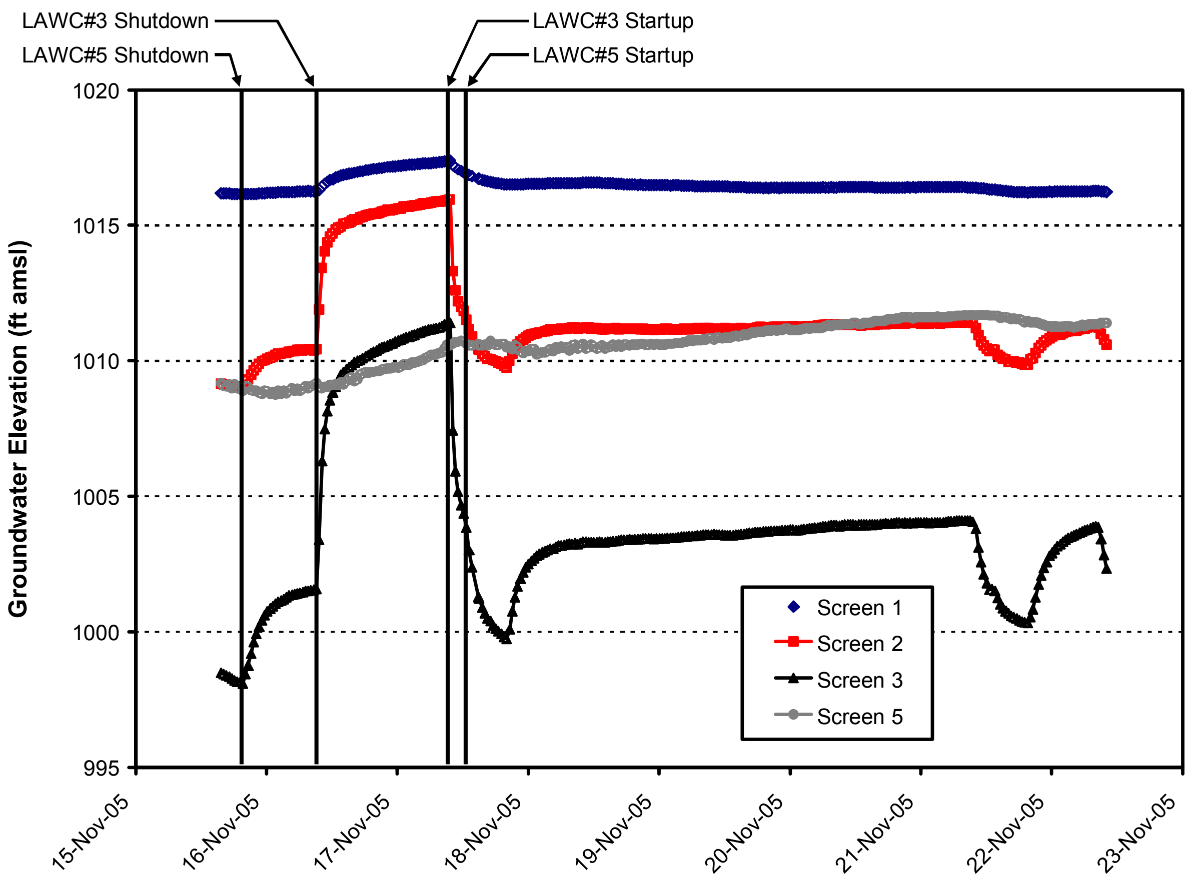

Figure 2. Graph of Groundwater-Level Elevation Data in MW-17 During Aquifer Test

observed within 30 minutes of the pumping modification. It should be noted that some noticeable groundwater fluctuations were observed in MW-17 after completing the LAWC aquifer test (see Figure 2). The cause of these fluctuations is uncertain, but it is possible they are the result of pumping rate changes in the LAWC wells.

Hydraulic conductivity values were estimated from the drawdown and recovery data using a software program called AQTESOLV[2]. The hydraulic conductivity estimates ranged from 17 to 25 ft/d. These values are similar to those estimated during the large scale pumping test conducted by CH2M-Hill in 2002 and presented in the *JPL Groundwater Modeling Report*[3].

Groundwater levels in LAWC#5 showed an increase in elevation of nearly 2 ft within five hours and 4.8 ft within 24 hours after LAWC 3 was taken off line. After LAWC#3 was restarted, groundwater levels in LAWC #5 showed an initial increase in elevation of 0.26 ft within seven minutes, after which they decreased in elevation by slightly more than 1 ft within three hours. Hydraulic conductivity values were estimated from the drawdown and recovery data in LAWC#5 using AQTESOLV™ and ranged from 4.3 to 10 ft/d.

LAWC GROUNDWATER INJECTION MODELING

Groundwater modeling simulations were performed to investigate the effects of injection of imported water into LAWC#5 on chemical migration in the vicinity of the LAWC wells. The JPL groundwater flow model[3] was used to perform the simulations, and particle tracking was used to estimate capture zones for select production wells. The calibrated steady-state groundwater flow model was developed by NASA as part of the JPL CERCLA Program to evaluate treatment alternatives and groundwater flow in the Monk Hill Subarea. The model consists of four layers, corresponding to the four hydrostratigraphic units defined in the Remedial Investigation (RI) Report[4]. The division of the aquifer into these four layers was based upon the presence of relatively thin, silt-rich layers that inhibit vertical groundwater flow and differences in hydraulic head measurements observed during aquifer testing. As part of the steady-state model development, a transient model was prepared using data from 1996 to 2000. Results from the transient model calibration indicated the calibrated flow field in the steady state groundwater flow model is similar to that generated under transient conditions and appropriate for use in predictive simulations[3]. A summary of model input parameters is presented in Table 2.

Table 2. Groundwater Flow and Transport Simulation Parameters in Model Area of Interest

Parameter	Layer			
	1[(a)]	**2**	**3**	**4**
Hydrostratigraphic Unit	1	2	3	4
Horizontal Hydraulic Conductivity (ft/d)	22-28	28	28	1-22
Vertical Hydraulic Conductivity (ft/d)	0.92	0.062-0.62	0.11	0.008
Porosity	0.30	0.30	0.30	0.30

(a) Recharge rate: 0.74 ft/yr

[2] Gerraghty and Miller. 1991. AQTESOLV™ Aquifer Test Design and Analysis Computer Software, Version 1.1. Gerraghty and Miller, Inc. Modeling Group. Reston, VA.
[3] NASA. 2003. JPL Groundwater Modeling Report. December.
[4] Foster Wheeler Environmental Corporation. 1999. *Final Remedial Investigation Report for Operable Units 1 and 3: On-Site and Off-Site Groundwater*. Prepared for the National Aeronautics and Space Administration Jet Propulsion Laboratory. August.

Three simulations were performed using the JPL groundwater flow model:

- *Baseline*: The baseline simulation corresponds to operations over the past 1 ½ years and assumes 1,000 gpm extraction from LAWC#3 and 500 gpm extraction from LAWC#5. Since this is a steady-state model and LAWC#5 is not operated continuously, 500 gpm was assumed to represent the average flow rate from LAWC#5 over the past 1 ½ years of operation. Extraction rates from Rubio Cañon Land and Water Association (RCLWA), Las Flores Water Company (LFWC), and City of Pasadena wells were not varied during these simulations. The total extraction rate from RCLWC wells was assumed to be 835 gpm and the total extraction from the LFWC Well was assumed to be 212 gpm. It was also assumed that the City of Pasadena Monk Hill wells were not operating.

  Figure 3 shows the capture zones associated with LAWC#3 and LAWC#5 as well as RCLWA and LFWC production wells. The capture zones were developed based on forward and reverse particle tracking simulations and were designed to approximate a 20-year capture zone. Figure 4 shows the flow paths of particles that were released along a line extending from MW-8 to MW-10 (monitoring wells located inside the JPL property boundary) and forward tracked downgradient. Figures 3 and 4 show that under baseline conditions groundwater originating from JPL is effectively contained.

- *Injection Simulation No. 1*: The first injection simulation assumed that LAWC#3 will continue to operate at 1,000 gpm and LAWC#5 would inject water an annual rate of approximately 250 gpm. Assumed extraction rates for RCLWA, LFWC, and City of Pasadena remained unchanged from the baseline simulation. Figure 5 shows the approximate 20-year capture zones for Injection Simulation No. 1, and Figure 6 shows the of particles released in the vicinity of JPL and forward tracked downgradient using 20 year time markers. Under this scenario, containment is maintained by the Monk Hill Subarea wells. In addition, it does not appear that water injected at LAWC#5 would be captured by LAWC#3 (i.e., no apparent short-circuiting, which would result in significantly decreased containment).

- *Injection Simulation No. 2*: The second injection simulation assumed that LAWC#3 is not operating, LAWC#5 is injecting water at a rate of 250 gpm, and that there is no change to the operating assumptions for the RCLWA, LFWC, and City of Pasadena wells. Figure 7 shows the approximate 20-year capture zones for select extraction wells for the second simulation, and Figure 8 shows the flow paths of particles released within the JPL property and forward tracked downgradient using 20 year time markers. Under this scenario, containment is significantly affected, with a significant portion of particles bypassing the Monk Hill Subarea wells.

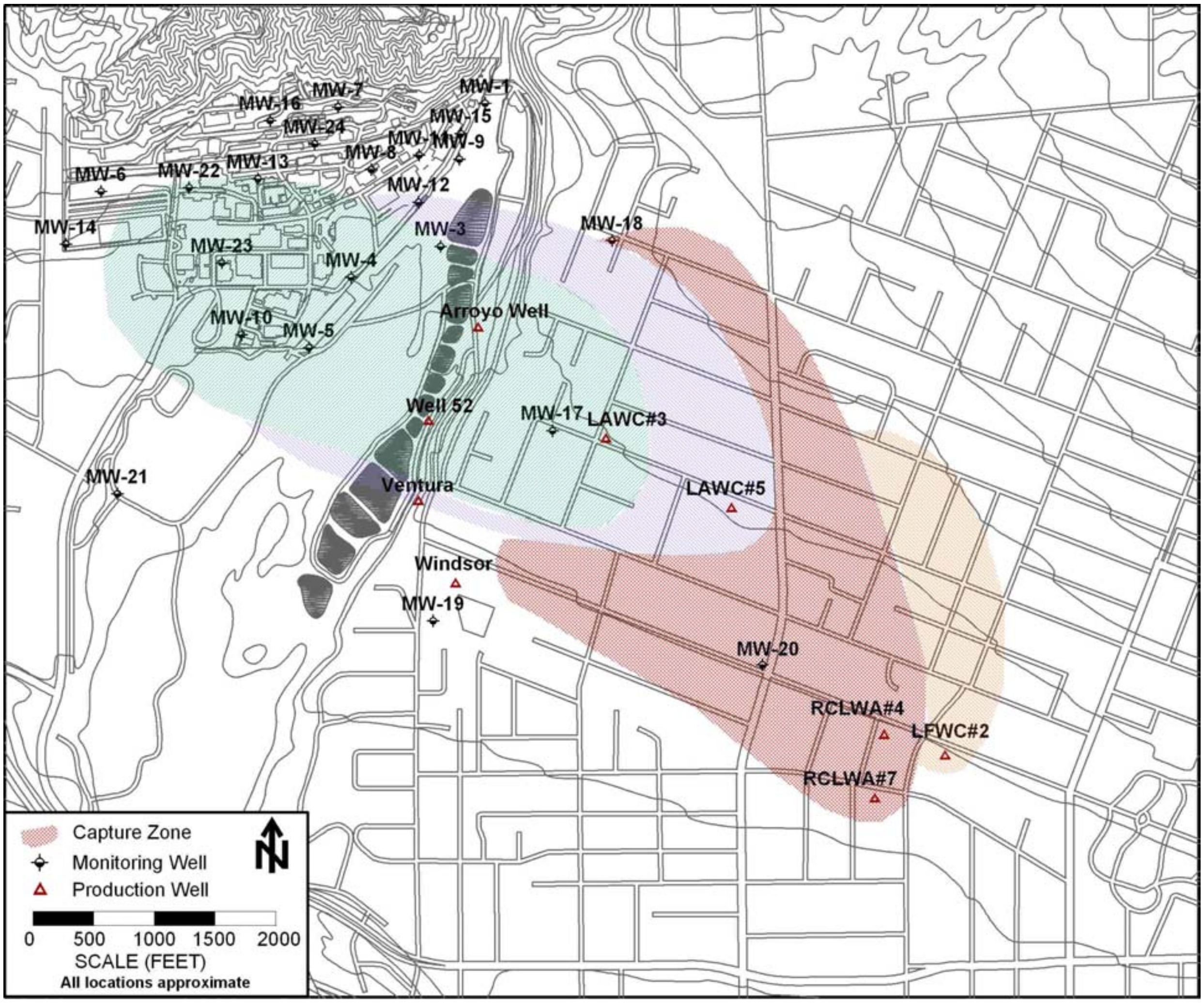

Figure 3. Baseline Scenario – Approximate 20-Year Capture Zones (1,000 gpm Extraction from LAWC#3, 500 gpm Extraction from LAWC#5, 835 gpm from RCLWA Wells, and 212 gpm from LFWC)

RECOMMENDATIONS

The aquifer test yielded hydraulic conductivity values similar to or slightly less those determined by CH2M-Hill during the 2002 pumping test[5]. However, no change to the conceptual site model and the JPL Groundwater Model is proposed since lower hydraulic conductivity values would result in larger capture zones and slower groundwater migration rates.

In addition, groundwater modeling indicates that if LAWC#3 is operating, injection of imported water at LAWC#5 will not adversely impact the CERCLA cleanup in OU-3.

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

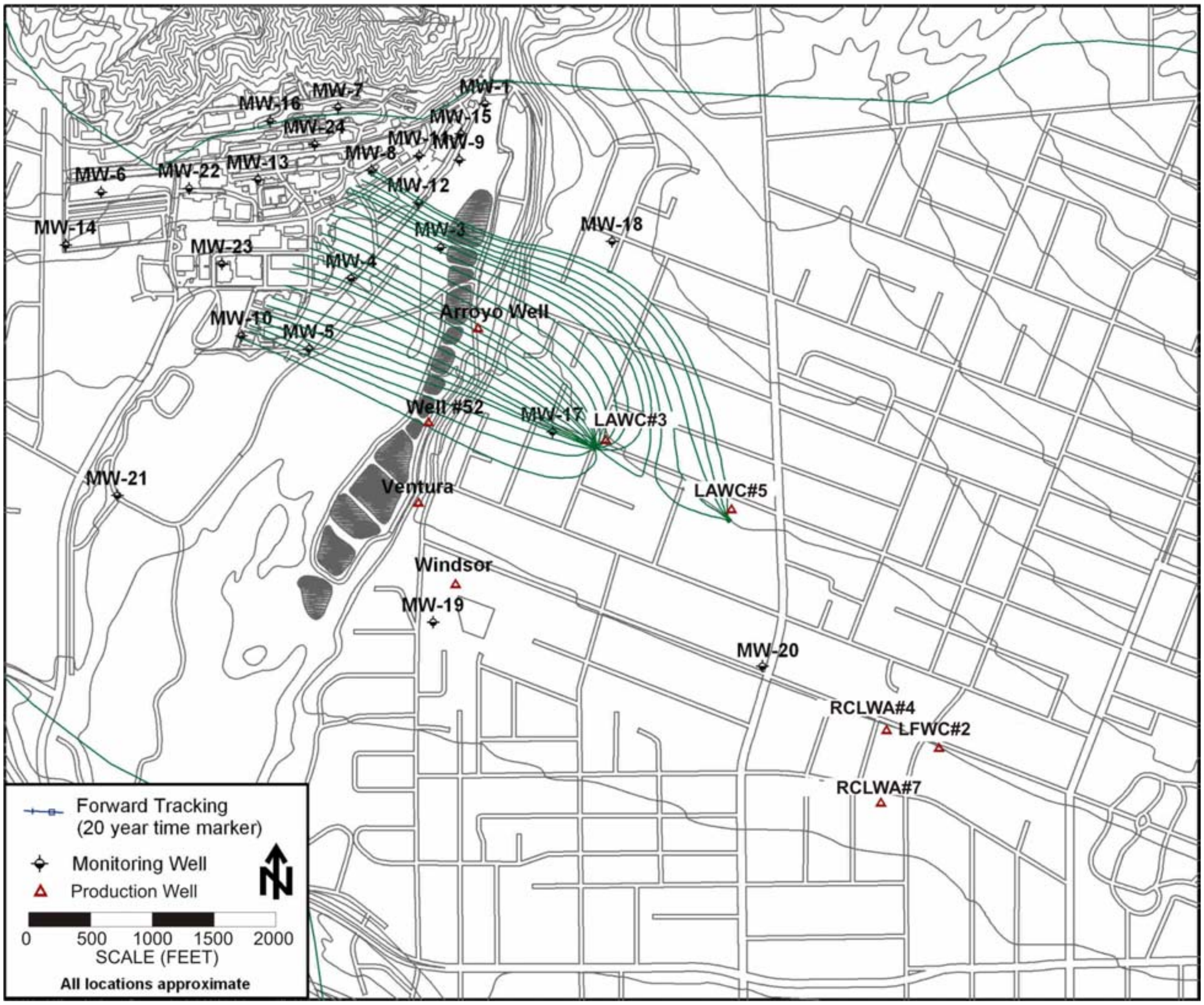

Figure 4. Baseline Simulation Forward Particle Tracking from JPL

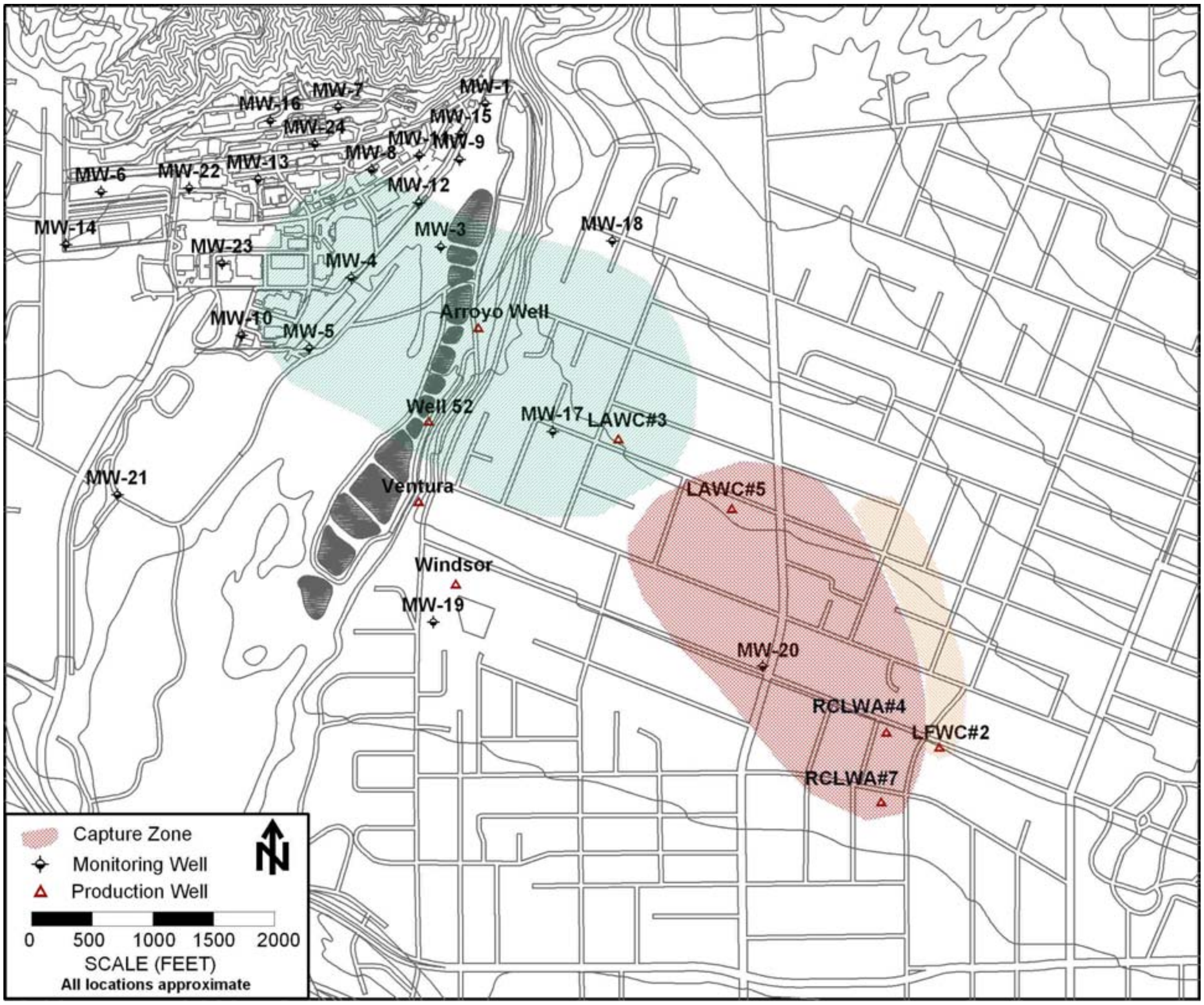

Figure 5. Injection Simulation No. 1 – Approximate 20-Year Capture Zones (1,000 gpm Extraction from LAWC#3, 250 gpm Injection to LAWC#5, 835 gpm from RCLWA Wells, and 212 gpm from LFWC)

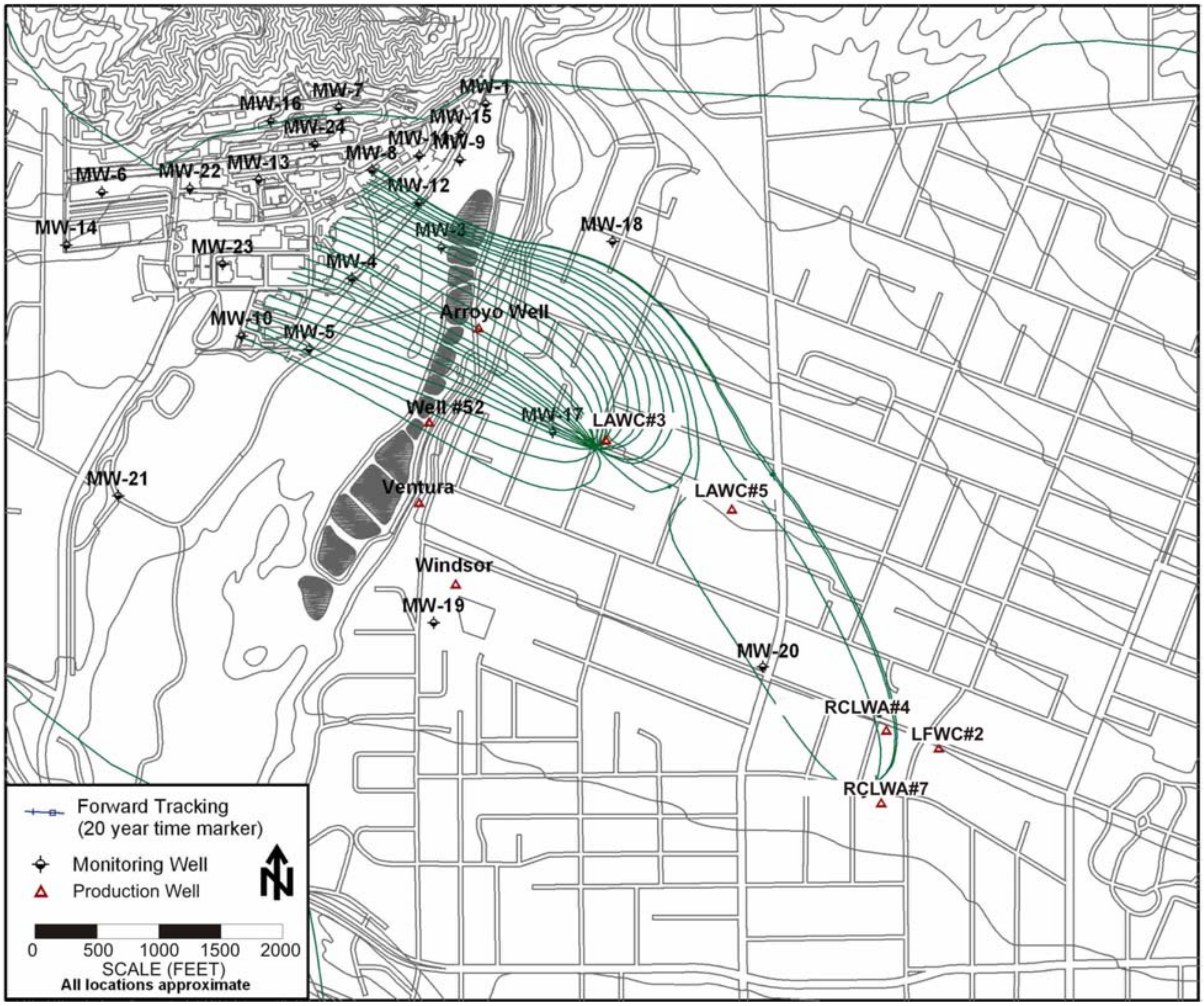

Figure 6. Injection Simulation No. 1 Forward Particle Tracking from JPL

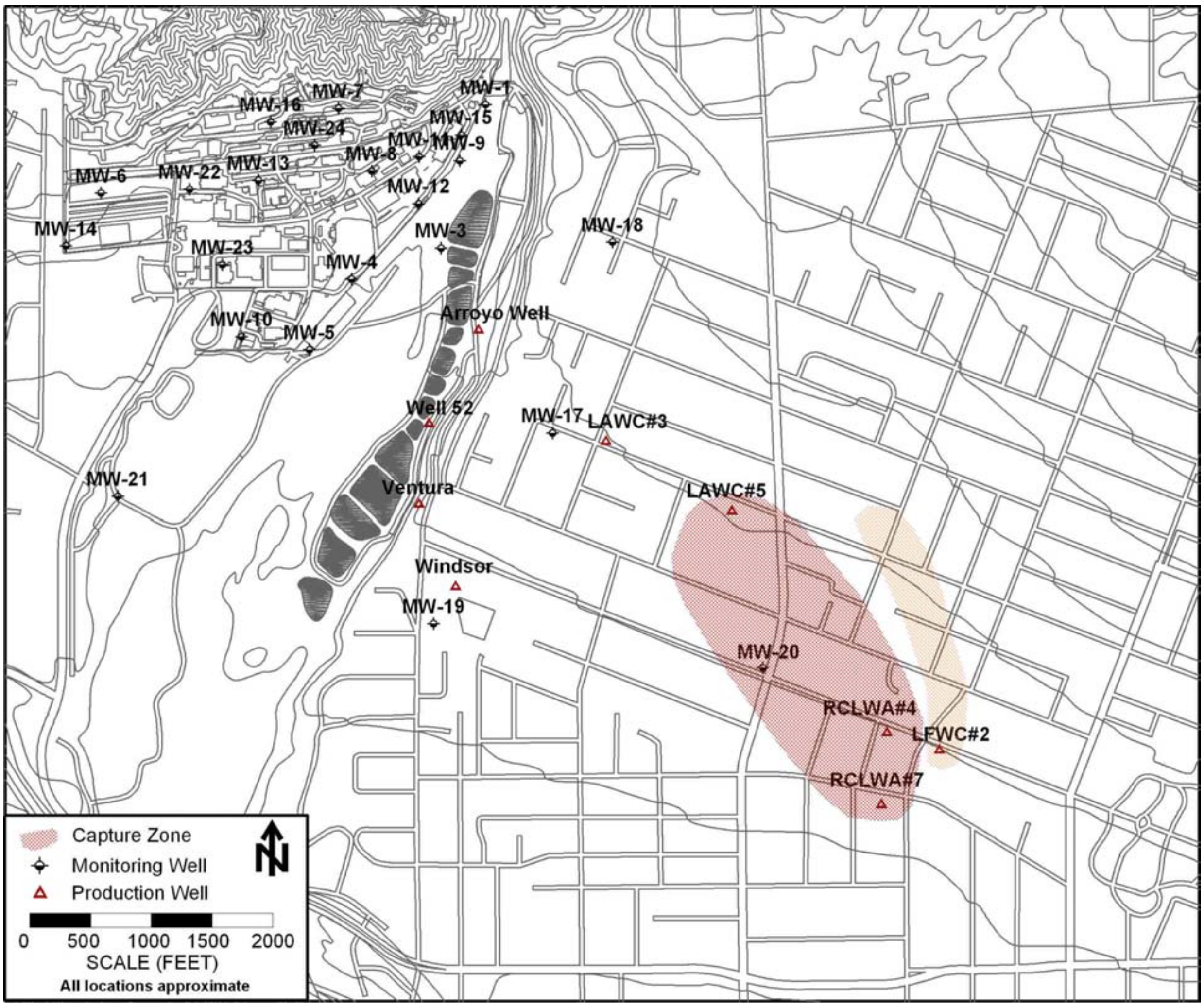

Figure 7. Injection Simulation No. 2 – Approximate 20-Year Capture Zones (0 gpm Extraction from LAWC#3, 250 gpm Injection to LAWC#5, 835 gpm from RCLWA Wells, and 212 gpm from LFWC)

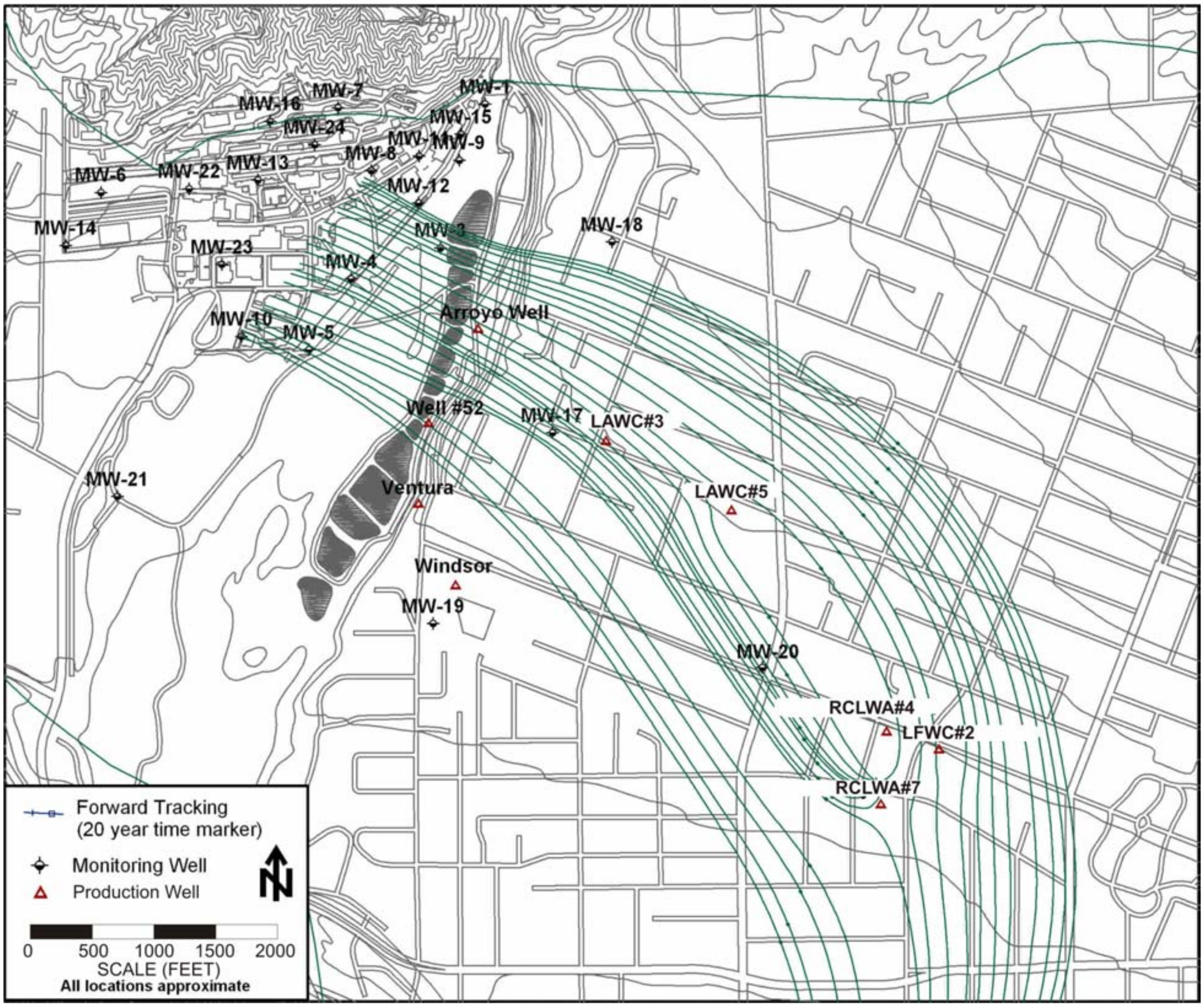

Figure 8. Injection Simulation No. 2 Forward Particle Tracking from JPL