Responses to Comments from the California Department of Toxic Substances Control (DTSC)
Revised Draft Optimization Work Plan, NASA Jet Propulsion Laboratory, Pasadena, CA

Comments Dated March 18, 2014 from Alice Campbell

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1	6	2.1.1	Bridle trail, not bridal trail.	The spelling error has been corrected.
2	-	-	The calculation of capture by the groundwater model includes uncertainty, particularly uncertainty associated with the distribution of hydraulic continuity and the volume and location of recharge from stream infiltration. The southern part of the groundwater model incorrectly portrays the Monk Hill 'dike'. The model treats the aquifer as continuous across Monk Hill, while in reality Monk Hill is actually a buried outlier of the San Rafael Hills. The model also treats the aquifer as horizontally isotropic, and does not spell out the buried river channel which drains the upper Monk Hill basin and turns south east of Monk Hill. Particles are shown originating against the northern no-flow boundary (the Sierra Madre Fault), but the origin of this water is not clear. Mountain-front recharge between canyon mouths is likely to be minimal. Instead, most groundwater originates as recharge in the Devil's Gate reservoir, and the remainder originates at the mouths of major canyons. The pattern shown on the model is very unlikely based on topography. Comparing the particle tracks with actual contour maps of zone three from groundwater monitoring wells, there are major differences that are missed by the model. In particular, the buried ridge connecting Monk Hill with the San Rafael hills causes the Rubio Canyon wells to have much higher drawdown due to the effects of the barrier, and thus much greater capture for their size. While models may be convenient, they should be verified against	We appreciate your comments, and agree that groundwater flow at JPL is complex. We also recognize that groundwater models, or any model, has a certain degree of uncertainty; thus, it is important to be clear about the purpose of any such model and the assumptions used. The JPL Groundwater Model was developed and refined to evaluate plume containment in the Monk Hill Subarea. As part of model development, a large scale pumping test was performed and is documented as Appendix A in the JPL Modeling Report.[1] This test was completed to evaluate hydraulic properties of the hydrogeologic units in the vicinity of JPL. Analysis of the test data provided estimates of horizontal and vertical hydraulic conductivity, transmissivity, and storativity of the hydrogeologic units included in the JPL Model. Based on the effort to develop and validate the JPL Groundwater Model, NASA believes the model provides an understanding of groundwater flow and plume containment in the Monk Hill Subarea appropriate to support locating additional extractions wells near JPL.

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

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			actual monitoring data, and the discrepancies fixed.	
3	-	-	The model does not include the irrigation well at Mountain View Cemetery, which also makes the flow lines at the northeast edge unlikely. Groundwater that escapes east of MW-18 may be captured by the Mountain View Cemetery Well. The model should include pumping by all known wells, not just the municipal wells.	We agree that it is important for the model to account for pumping by all known wells, and in fact, the JPL Groundwater Model does include/account for pumping from the irrigation well at Mountain View Cemetery (i.e., Park 2-3).[1]
4	-	-	The time series charts for perchlorate and VOCs show instances of abrupt temporary decreases in concentration, generally after wet years. Four of these dropouts are generally visible for most wells downgradient of the Arroyo. The dropouts appear to be mountain-front recharge which fast-tracks into the municipal production zone. Two cross sections showing contours on hydraulic head in a vertical slice were prepared (Figures 1 and 2, attached), which show that the municipal extraction wells are inducing downward gradients and temporarily rearranging the flow system to pull clean water from a temporary recharge mound down to the production zone. When the mound dissipates, the flow system switches back to its dry-season pattern. This kind of detail is being missed by the model. Another observation from the time series charts is that the RCLWC wells show evidence of rapid switching between two different water compositions, likely being caused by changes in nearby pumpage. This indicates that the plume is narrow and the well sits along the edge of the plume, and small gradient changes are sufficient to tip the plume towards or away from the wells. The two types of behavior are consistent with a fluvial system with narrow, long bands	DTSC makes a number of good and interesting points regarding just how much a conceptual model can take into consideration. We agree that the hydrogeology is complex and that temporal variations exist relative to infiltration, pumping, and seasonal flow patterns. Also, we concur with your observations that perchlorate and VOCs concentrations seem to correlate with recharge. Some of the detail you note is missing from the model we are able to discern from over 20 years of monitoring data we have collected from the JPL monitoring well network. The groundwater monitoring data adds to our understanding of the chemical plumes originating from JPL. In particular, carbon tetrachloride appears to be unique to JPL in the Monk Hill Subarea. The time series data for carbon tetrachloride support the groundwater modeling results and confirm our understanding capture zones within the Monk Hill Subarea. We agree that our generalized conceptual site model may not capture some micro-scale details of plume movement within the aquifer. When considering historical concentration trends and the macro-scale movement of groundwater in the Monk Hill Subarea, NASA believes the conceptual model for groundwater

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			of behavior are consistent with a fluvial system with narrow, long bands of interconnected channel gravels within a finer flood-and overbank matrix. The active flow zone can switch in response to changes in saturated thickness, pumping patterns, and temporary recharge mounds. The conceptual model for the model does not include this level of detail.	near JPL is sufficiently understood to proceed with installation of new wells.
5	-	-	As a check on the model, groundwater contour maps for zone 3 should be prepared for a number of years including the wet year 2009, when the basin was low, and 2011, when the basin was high. The elevation of groundwater is important because the sides of the basin are not vertical, so there are boundary effects, particularly along the southern margin along the Bunker Hill 'dike', which is inaccurately portrayed in the model. The zone 3 contours for 2011 show that there is southeast flow from MW-18 towards the municipal wells. The 2013 contours show that Rubio and Las Flores wells capture virtually all the water from the Arroyo. The actual data bring into question the idea of needing a more northerly well.	NASA believes that the data from the JPL Groundwater Model and MW-18 support the potential value of a new extraction well located north of the Arroyo Well. The installation of a new production well adds value because it can intercept chemicals migrating north of the Arroyo Well and treat the extracted water at MHTS. If the plume reaches the RCLWA and Las Flores wells, then additional treatment will be required.
6	-	-	New MHTS well location. The location of the well is based on the idea that water will be extracted from the same zone as the zone extracted by PWP's Arroyo well. This assumption seems to be based on the idea that the sediments were deposited from north to south, since if they were deposited from east to west one would not expect to intercept the same channel when moving north. However, the sediments *were* deposited from west to east, so there is less reason to expect to intercept the same channel zone when moving northwards, particularly because alluvial fans from the	NASA acknowledges variations in the aquifer, including anisotropic conditions, have the potential to impact flow. Our studies show that groundwater movement and flow direction near JPL is dominated by pumping. Data from our groundwater monitoring network support this observation. NASA chose the new MHTS well location based on elevated chemical concentrations in nearby JPL multi-port monitoring wells MW-3, MW-4, MW-11, MW-12, and MW-18, as well as PWP's Arroyo well. Based on the

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			San Gabriel mountains would have prevented the river from moving closer towards the foot of the mountains. Base on topography, the courser channel deposits would tend to occupy a more southerly position in the old valley. The head contours on the cross section suggest that there are not really course channel deposits north of MW-13.	available groundwater data collected as part of the JPL groundwater monitoring program and NASA's understanding of capture zones of the MHTS and LAWC wells, we believe that a new well located north of the Arroyo Well would provide containment of groundwater migrating north of the Arroyo Well and toward MW-18. We believe that this well provides value by removing chemical mass and treating extracted water with the MHTS instead of allowing downgradient migration towards other extraction wells.
7	-	-	The capacity of the proposed Lincoln Avenue well appears higher than the water company's water rights to pump. As such, a smaller well may be advisable. Pumping a large well at say 1600 gpm half time is hydroeologically equivalent to pumping an 800 gpm well full time, so there is no benefit in having a large-capacity well at a location without water rights to pump the maximum amount. A high rate will increase capture, but there are institutional limits to the pumping rate. The institutional constraints should be described and their effects on the well's size explained.	We agree with DTSC that LAWC 's ability to pump is constrained by water rights. By partnering with LAWC as part of the CERCLA cleanup process, NASA must balance the cleanup objectives with LAWC's water purveyance objectives. According to LAWC, they need the flexibility to treat up to 2,000 gpm to meet seasonal demands. In addition, the average annual groundwater production from LAWC#3 and LAWC#5 between 2001 and 2012 was 1,696 acre feet, with a peak annual production of 2,759 acre feet in 2007. These production volumes were achieved through cooperation between LAWC and other local water purveyors. LAWC expects this cooperation to continue.
8	-	-	Casing material. While stainless screen is undoubtedly a fine product, the existing municipal wells have plain steel casing, and many are basically one hundred years old. Stainless screen would appear unnecessary.	Stainless steel screen was selected for the new extraction wells for several reasons: 1. Well screen life expectancy = 75 years (as opposed to 25 and 40 years, for low carbon steel [LCS] and HLSA, respectively). Life expectancy is especially important at LAWC due to the limited available property for future well installation locations. 2. Decreased well maintenance/cleaning costs over the life span of the well as compared to LCS and

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				HSLA well screens. 3. Less rapid decrease in well efficiency as compared to LCS and HSLA well screens. Well efficiency is directly related to energy and maintenance costs. Below are two useful case studies regarding well materials: • Roscoe Moss Company Technical Memorandum 004-2 "Case Study Increased Well Efficiency, Extended Lifetime and Reduced Maintenance through Selection of Stainless Steel Casing and Well Screen – Sun City and Sun City West, Arizona" • Roscoe Moss Company Technical Memorandum 005-02 "The Cost-Benefit of Upgrading from Low Carbon Steel for Water Well Casing and Well Screen"
9	32	3.2.5 and Appendix F	Gravel pack. Cleaner sands and gravels leave little work for a gravel pack to do, and the thicker a gravel pack is, the harder the gravel pack is to develop. A naturally developed well with a thinner pack would not produce excessive fines if the screen intervals are chosen carefully and finer zones cased off. Most of the existing muni wells have interrupted screens for this reason. Production wells have different design criteria than monitoring wells, and avoiding the production of fines is a higher priority in municipal wells than in monitoring wells. The long screen interval shown will not produce any more water than an interrupted screen, because 90% of the water in the well comes from the coarsest 10% of the screen. The old Roscoe Moss cable tool	We agree with many of the points made in your comment, and we acknowledge that we should have been more clear about the screen design. We do not intend to install a continuous screen across both impermeable and permeable zones within the aquifer. Our plan is to install a segmented screen similar to existing municipal production wells. To clarify our intentions, the following sentence has been added to Section 3.2.5: "Well screen will be placed as shown in the well construction diagrams provided in Appendix F. Final well screen locations may be modified based on borehole logging, sieve analysis, and geophysical data. Blank casing may be installed in between screened sections based on the occurrence of fine-grained

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			wells never bothered perforating in silts and clays, and their design has stood for a hundred years, and the wells have acceptable efficiencies. A well screen that avoids fines does not need a compromise gravel pack that may be less permeable than the coarser part of formation. Recall that water flows in the path of least resistance (and so does the plume). If the point of the design is to capture the plume, the plume will be in the coarsest materials the screen intercepts. The fine layers leak vertically into the coarse zones because of the local induced seepage stress across the layers, so the coarse zones transmit water horizontally from the fine zones proportionately to the area in contact and the difference in conductivity. The water isn't coming in from the area screened across the fines for both reasons: the zone mainly drains by leakance, and because fine zones don't (actually, can't) develop compared with coarse zones. The well casing design should be reconsidered.	zones." The following note has been added to the well construction diagrams in Appendix F. "Note: Final well screen locations may be modified based on borehole logging, sieve analysis, and geophysical data. Blank casing may be installed in between screened sections based on the occurrence of fine-grained zones." We agree that the Roscoe Moss cable tool wells have stood the test of time. Based on recent communication with Roscoe Moss, the down-hole perforator used to perforate cable tool wells is no longer available for use because gravel envelope production wells have become the norm.
10	-	-	Reverse rotary. Were other drilling methods considered for the LAWC well? In particular, was direct air rotary or air rotary/casing hammer considered? Air rotary is faster than mud rotary. It does not inject mud into the formation, so development is far simpler and faster, and produces less fluid.	Following the March 11, 2014 RPM Meeting, and in response to the comments raised by DTSC, Tidewater conducted additional research into potential drilling methods. This research included correspondence with Roscoe Moss, Layne Christensen, Southwest Pump and Drilling, Raymond Basin Management Board (RBMB), and two California-registered Professional Hydrogeologists with extensive production well drilling experience. These sources confirmed that reverse

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				circulation rotary method is the most appropriate method for installing the extractions wells and that air rotary casing hammer (ARCH) cannot be used to drill the proposed wells due to their depth and diameter.
11	32	3.2.5 and Appendix F	Gravel pack. A gravel pack's function is to prevent migration of fines into the well. In coarse material with few fines, the gravel pack could actually restrict flow in the coarser units because it is designed to hold back fines in the finer units. A better solution is to avoid casing in fine-grained units and have a course gravel pack. A similar solution is to eliminate the gravel pack and screen only the coarse units. The well efficiency will improve and there will be no noticeable reduction in flow because fines don't contribute water anyway. In coarse, clean sands and gravels the gravel pack has little purpose and it might be possible to eliminate it and design a naturally developed well. This might make air rotary and a smaller borehole feasible. The well design should be considered in more detail.	Please see response to Comment No. 9.
12	-	-	Well development. Well development depends on setting up a steep hydraulic gradient that washes fines through the gravel pack into the well. However, the differing hydraulic conductivity of the layers in the screen will ensure that most of the development will work on the most highly conductive layers and leave mud in the less conductive layers. One way to circumvent the physics is to use a single or double packer to isolate sections of the screen. This concentrates development pumping forces to a small area of the screen and promotes development of the finer zones in the parts of the screen not adjacent to the	This point was raised at the March 11, 2014 RPM Meeting by DTSC. We agree with DTSC on the importance of well development, understanding that an underdeveloped well leads to decreased specific capacity which equates to higher operating costs. Therefore, Tidewater conducted additional research into well development methods including the use of straddle packers. Correspondence with Layne Christensen and Southwest Pump and Drilling, and review of technical literature and reference books indicate that the use of straddle packers for large diameter production wells is not common practice. Our

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			highest conductivity zone. Packers should be investigated as an additional development tool to cut costs and reduce the volume of water needing disposal.	project team has extensive experience in the development of injection and extraction wells, as well as rehabilitation of injection and production wells. Industry standard methods will be used for well development to ensure pumping of sand-free water at the maximum specific capacity. These include mechanical methods (i.e., bailing, brushing, swabbing with surge block or dual-swab, surging, airlift pumping, and pumping with a test pump), and chemical treatment utilizing mud dispersants, as required. During development, sand content, turbidity, specific capacity will be monitored to ensure proper development.
13	32	3.2.5	The well bid package should have a specification for borehole straightness and plumbness. Straightness and plumbness are crucial if a turbine pump is to be placed in the well.	We concur with DTSC on the need for a specification for borehole straightness and plumbness. Therefore, the following sentences has been included in Section 3.2.5 of the optimization work plan: "At 100 foot intervals, the driller will check plumbness and alignment of the borehole. The drilling contractor will be required to meet alignment tolerances specified in ANSI/AWWA Standard A100-06." American Water Works Association. 2007. ANSI/AWWA A100-06 Standard for Water Wells. Section 4.7 Well Construction; § 4.7.9 Plumbness and Alignment, pg 22. December. The following subsection was added to the geophysical logging section: "This method determines borehole alignment by calculating well attitude by sensing azimuth and

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				inclination of the measurement sonde. The gyroscopic survey uses high-speed Litton gyros for azimuth and two accelerometers for inclination. The deviation survey uses a magnetometer for azimuth and tiltmeter to determine inclination. Plumbness and alignment of the borehole and well are very important when installing a vertical turbine pump. The log results will be plotted to demonstrate compliance with ANSI/AWWA alignment tolerances described in Section 3.2.5 above." In addition, following the March 11, 2014 RPM Meeting, Tidewater established a subcontract with Tom Regan, a California-licensed professional geologist, hydrogeologist, and engineering geologist. Mr. Reagan is a recognized expert in the water industry and has overseen the installation of over 60 production wells. Mr. Reagan will provide consulting support during installation and development of the proposed new LAWC well.
14	-	-	Welding specifications. It was not clear whether the screens will be welded or threaded. If welded casing is to be used, the welding specifications should be included. In general, two wraps are preferable to one, and the welder should be certified	Well casing and screen joints will be welded by a certified welder. Welding specifications will be added to the well technical specifications.
15	-	Appendix F	Gravel makeup pipe. If a gravel pack is used, will there be a gravel makeup pipe to replace material lost by settlement of the formation or gravel pack?	A gravel fill pipe (or make-up pipe), will be installed during well construction to replace material lost by settlement of the formation or gravel pack. Appendix F has been revised to mention the gravel fill pipe.
16	-	-	The irrigation well at Mountain View cemetery is along the northerly part of the flowpath. This well is not, to our knowledge, ever sampled, since it is not used for	NASA agrees that accumulation of salts (e.g., perchlorate) from irrigation and evapotranspiration can be flushed from soils during wet periods. We also agree

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			drinking water. It should be sampled at least for VOCs. Perchlorate is an issue at an irrigation well, since evapotranspiration concentrates perchlorate and chloride, and the large irrigated area becomes a groundwater recharge source in wet months, and the recharge pulse moves salts from the root zone to groundwater. Some municipal wells in the Central Pasadena area have detected perchlorate, but if irrigation return is the source, additional work would be needed to separate JPL's perchlorate from MWD perchlorate and irrigation return perchlorate. This complicates the plume monitoring effort in the plume front area. DTSC will have additional comments on distinguishing irrigation return from the plume in a future white paper which will also address the water source for the Sunset Reservoir wells.	that this phenomenon is responsible for some of the perchlorate detections in groundwater following heavy rain events. NASA does not have chemical data for the irrigation well at Mountain View Cemetery. NASA looks forward to reviewing your white paper.
			Conclusions	
17	-	-	GSU requests that the MHTS proposed well design include considerations of pumping rights, well drilling method, gravel pack design, construction specifications, and development methods.	Please see responses to Comments No. 7 to 15.
18	-	-	GSU requests that additional groundwater contour maps of the lower and middle zone be done using TIN and the existing JPL water level data, supplemented where municipal where municipal well water levels are available, to compare the configuration of the water surface at several fill stages of the basin, in order to check the particle tracks produced by the model. GSU's analysis, based on the JPL quarterly measurements, differs substantially from the model predictions.	Please see responses to Comments No. 2 to 6.
19	-	-	Similarly, analytical equations can be used to calculate	Please see responses to Comments No. 2 to 6.

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			capture mathematically. Model predictions should be compared with calculations based on actual data, and are not in themselves sufficient to demonstrate capture.	
20	-	-	Additional water quality data may be available from Mountain View Cemetery's irrigation well, but the data must be interpreted carefully as described above. This well should also be used in the model, although adding this well will not fix all the problems with the model.	The Mountain View Cemetery well is accounted for in the JPL Groundwater Model.
21	-	-	GSU has no other comments on the report.	