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Subject: Raymond Basin Assessment

1. Purpose and Scope

Pasadena Water and Power ("PWP") is currently engaged in the significant challenge of staving off the potential of critical water supply shortfalls, ensuring continued water reliability, and implementing long-term solutions to address water quality issues in the Raymond Basin.

The Raymond Basin Assessment (RBA) presented here is based on review of information, data, historical documents, discussions with Pasadena Water and Power (PWP), and others with knowledge of the Raymond Basin. Much information exists describing the Raymond Basin and the longstanding effects over time and little will be repeated in the RBA. This document, the RBA, is intended to provide a perspective on water resource stewardship in the Raymond Basin aimed at forwarding PWP's interest in protection and recovery of the Raymond Basin.

The purpose of the RBA is to provide an initial effort comprised of reviewing the Raymond Basin and management to identify current status and understanding. The RBA is intended to evaluate whether over-all management of the Raymond Basin has been effective over time, including Pasadena's involvement. The purpose also includes consideration of strategic options for Pasadena to consider in working towards improving the Raymond Basin. The findings and recommendations described here are based on an evaluation of limited time availability and resources, and represent an initial effort for implementation.

CONCLUSION

The Raymond Basin is not managed in a sustainable manner as evidenced by the decrease in basin groundwater levels over the last 118 years, and is under threat of spreading contamination.

PWP and RBMB must change its course and take action to prevent permanent failure of the basin.

2. Raymond Basin Adjudication

In the 1940s the Raymond Basin was the subject of adjudication, a legal agreement or decision that defines the rights of water pumpers in a basin. The adjudication focused on water right entitlements. The adjudication did not focus on management efforts that would allow for a sustainable operation of the basin that would balance extractions from the basin with natural replenishment supplemented by imported supplies. The original judgment established a safe yield for the basin of 21,900 acre-feet per year and divided the water rights among sixteen users. In 1955 the judgment was modified, resulting in a decreed safe yield of 30,622 acre-feet per year. Justification for this increase is not clear in the documents. A 1974 modification of the judgment allows basin parties the right to spread canyon diversions and recapture a percentage of the spread water. In 1984 the judgment was restated and modified with no change in the decreed rights. The Raymond Basin decreed rights and storage accounts are shown in Table 1.

Table 1. Raymond Basin Decreed Rights and Long-Term Storage

Area	(Acre-Feet Per Year)	Pasadena Subarea Long-Term Storage as of 6/30/2018, Acre-Feet
Monk Hill Subarea		
La Canada Irrigation District	100	999.3
Las Flores Water Company	249	457.2
Lincoln Avenue Water Company	567	1,254.8
Pasadena, City of	4,464	13,398.8
Pasadena Cemetery Association	91	184.3
Rubio Canon Land & Water Assn.	1,221	1,077.0
Valley Water Company	797	525.4
Subtotal:	**7,489**	**17,897**
Pasadena Subarea		
Alhambra, City of	1,031	3,543.1
Arcadia, City of	2,118	891.0
California-American Water Company	2,299	1,510.6
East Pasadena Water Company	515	317.4
H.E. Huntington Library & Art Gallery	372	434.1
Kinneloa Irrigation District	516	790.0
Pasadena, City of	8,343	9,968.8
San Gabriel County Water District	1,091	2,825.0
Sunny Slope Water Company	1,558	2,427.9
Subtotal:	**17,843**	**22,708**
Western Unit Total:	**25,332**	**40,605**
City of Pasadena Total:	12,807	--
Santa Anita Subarea		
Arcadia, City of	3,526	--
Sierra Madre, City Of	1,764	--
Subtotal	**5,290**	--
Raymond Basin Total	**30,622**	--

3. Groundwater Levels

The Raymond Basin contains alluvium consisting of sands, gravels, and other porous materials of large depth through which groundwater percolates, with total volume estimated at 820,000 acre-feet (Geoscience, 2004). The Pasadena subarea groundwater elevation decreased approximately 100 feet between 1980 and 2008 (Stetson, 2017), and has decreased approximately 275 feet since 1910. Additionally, studies indicate that groundwater levels had generally declined in the Pasadena subarea since the Judgement was entered and had not recovered, even during sustained wet periods. (Stetson, 2017)

The primary groundwater movement in the Western Unit is from the north and west of Monk Hill, through the Pasadena Subarea to the south and east towards the Raymond Fault. The barrier in the alluvium caused by the Raymond Fault zone mostly impedes the sub-surface movement of water from the Raymond Basin to the Main San Gabriel Basin. However, it is estimated that about 6,000-10,000 acre-feet per year "spills" from the Raymond Basin into the Main San Gabriel Basin, mostly along the eastern side of the fault. (Geoscience, 2004) (Zampiello 2018). Over time, Main San Gabriel Basin management has led to a reduction of groundwater levels in the Main San Gabriel Basin, increasing the spillage. A 10,000 acre-feet spill into Main San Gabriel Basin represents approximately one third of the total Raymond Basin adjudicated rights. This water is lost from the basin every year, severely impacting basin health and sustainability. It appears as if nothing has been done in the Raymond Basin to reduce or prevent this loss.

Simulation water level modeling was completed by Stetson for the Woodbury Well, owned and operated by the City of Pasadena (Board R. B., Unknown). This well was designated by the RBMB as the key well for determining the groundwater level of the Pasadena Subarea. Figure 1 illustrates simulated water levels at Woodbury Well for three scenarios. The black line going back to 1911 is the historic measurement. In Scenario 1 (red line), the groundwater production and water use in the Pasadena subarea remain at the 2005-2006 levels (28,243 and 57,737 acre-feet per year respectively) for the following 20 years under average hydrologic conditions. In Scenario 2 (green line), the groundwater production in the Pasadena subarea was reduced 50% from the 2005-2006 levels and remains at that level (14,121 acre-feet per year) for the following 20 years. Scenario 3 (magenta line) is similar to Scenario 2 except the groundwater production in the Pasadena was kept at the 1944 rights starting in 1954-1955 (15,412 acre-feet per year).

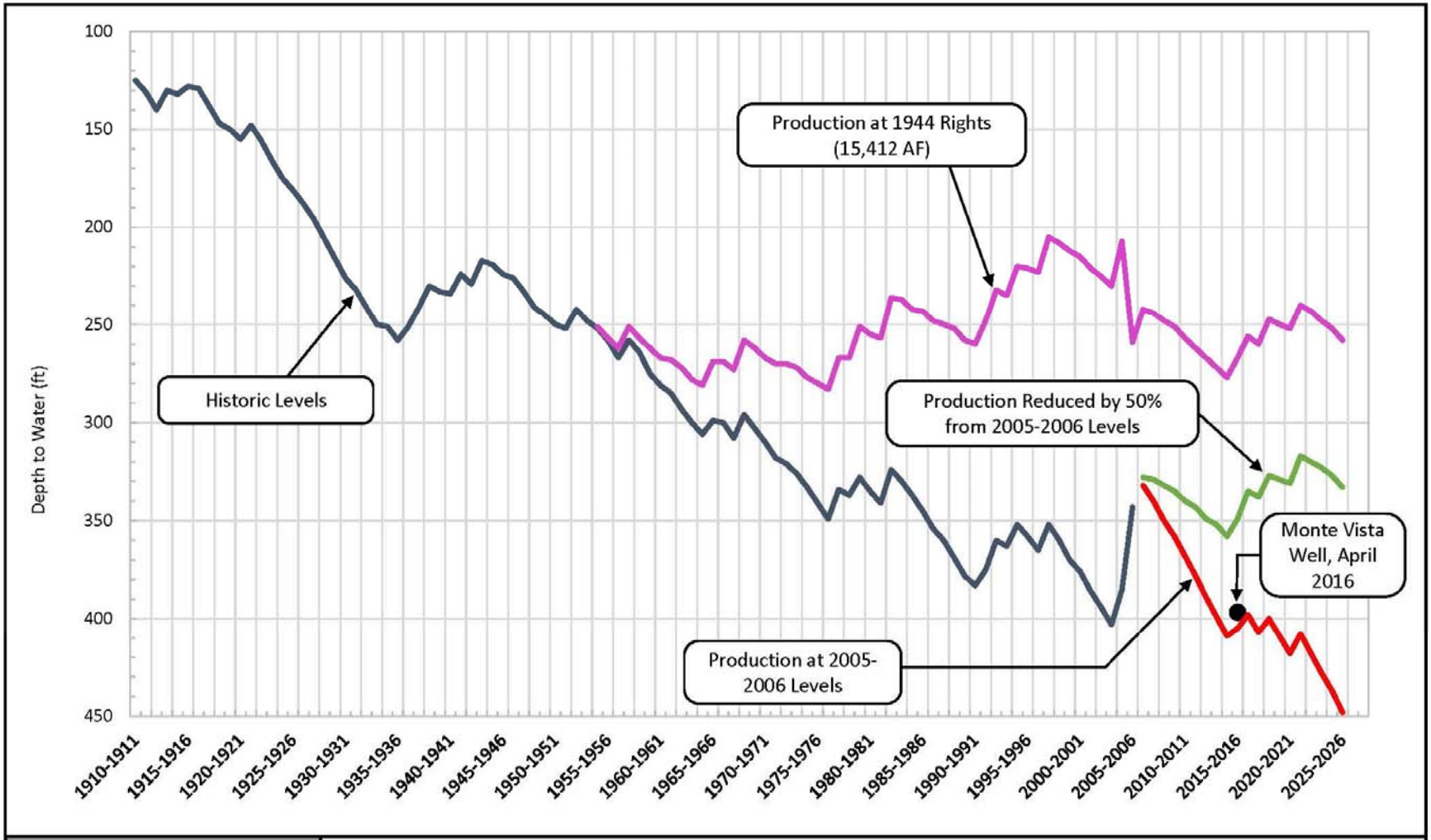

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Figure 1 - Historic and Projected Pasadena Subarea Levels

Source: RMBM, Draft Oppurtunities to Enhance Groundwater Levels in Pasadena Subarea, unknown date

As shown in Figure 1 under Scenario 1, the simulation indicated that the water level at Woodbury Well would continue to decline from approximately 330 feet to 450 feet (about 120 feet). Under Scenario 2, results indicate that the water level at Woodbury Well appears to stabilize although it declines about 10 feet. Under Scenario 3, results indicate that the water level at Woodbury Well stabilizes at about 250 feet since 1954-1955.

Informed with the data shown in Figure 1 and concerned over basin contamination, the RBMB developed an approach to both recover groundwater levels and mitigate groundwater contamination. In 2009, the Pasadena subarea subcommittee adopted Resolution No. 42-0109 entitled, "Resolution of the Board of Directors of the Raymond Basin Management Board Adopting a Cooperative Pumping Reduction Plan for the Parties with Water Rights in the Pasadena Subarea" (Reduction Plan). This Reduction Plan called for the water agencies and pumpers involved to voluntarily agree to incrementally decrease pumping in the Pasadena subarea by six percent each year for five years for a maximum of 30 percent reduction. The initial goal of the Reduction Plan is to increase groundwater levels to 50 feet above the conditions as of July 1, 2009.

The groundwater level, as measured at the Monte Vista Well, decreased by about 13 feet from 2009 to 2017 (Stetson, 2017).[1] The Reduction Plan didn't produce anticipated results (i.e. increase groundwater levels). In addition, the actual volumes pumped didn't significantly change – it was just a "paper" reduction. The Reduction Plan restriction primarily placed a limitation on the use of 1955 Decreed Rights, but allowed producers to continue to produce groundwater against their Long Term Storage. Consequently, it is likely actual production would have been the same whether or not the Reduction Plan was enacted. (Stetson, 2017)

The amount of long-term storage available in the Pasadena subarea is 22,708 acre-feet. (Board R. B., 2018) Although the ability to add to the long-term storage account is no longer available, the remaining long-term storage account could provide decades of "make up" water. In other words, the actual volume of water pumped from the basin may not decrease by 30 percent for decades, resulting in the continual lowering of groundwater levels.

Information available in 2009 when the resolution was adopted to curtail pumping by 30% clearly showed that the curtailment would not obtain stated goals (i.e., 50 feet increase in ground water levels). Modeling information shown in Figure 1 indicated that

[1] Although Woodbury Well was designated as the key well for determining the groundwater level of the Pasadena Subarea, data was not collected and the Monte Vista Well was instead used to determine static water elevation for the Pasadena Subarea.

a minimum curtailment of about 50% would be required to maintain groundwater levels over time and therefore a curtailment of larger than 50% would be required to increase groundwater levels by 50 feet. Even with this data, the RBMB selected to only reduce pumping by 30 percent, and then allowed use of carryover storage, nullifying any potential for positive basin impacts.

4. Contamination of the Basin

The National Aeronautics and Space Administration (NASA) is responsible for remediation of contaminates originating from the Jet Propulsion Laboratory (JPL) site, as required under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA). See Figure 2 below depicting the contamination zone. The cleanup effort includes treatment of groundwater extracted from drinking water production wells in the Monk Hill subarea containing site-related chemicals of interest, which include volatile organic compounds (VOCs) and perchlorate. Contaminated wells are located in both the Monk Hill subarea and the Pasadena subarea down gradient of the JPL facility, however, NASA has not accepted responsibility for groundwater

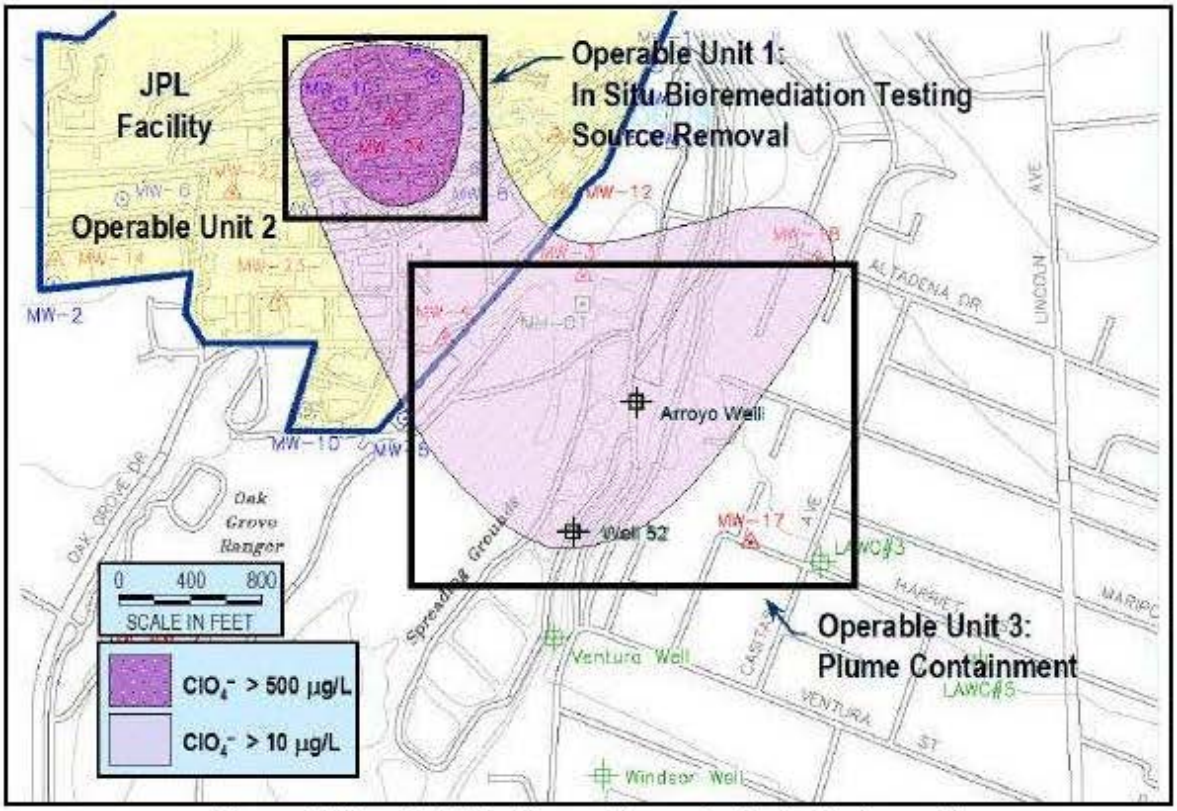

Figure 2 - Map of JPL Perchlorate Contamination in the Arroyo Seco (Brick, 2018)

contamination in the Pasadena subarea. (Brick, 2018) PWP staff has indicated that sampling in wells to the south and east have elevated plume contaminates, indicating the contamination continues to spread outside the capture area. There are contamination sites that are currently not managed that appear to be migrating downgradient into the central portion of the Pasadena subarea, where Pasadena's Woodbury and Monte Vista wells are located, by 2024. (Geoscience, 2004) JPL and NASA's cleanup efforts of the managed areas are important. However, plume movement outside of the existing managed area is a direct threat to the long-term sustainability of the basin and needs to be addressed.

5. Hydrologic Modeling

A Raymond Basin groundwater model has been developed by Geoscience. It uses MODFLOW modeling software. The MODFLOW computer code is a block-centered, three-dimensional, finite-difference groundwater model widely used. MODFLOW was developed by the U.S. Geological Survey for the purpose of modeling groundwater flow.

The Geoscience 2004 report, "Raymond Basin Ground Water Flow Model Predictive Simulations", provides a description of how the Raymond Basin model was developed. The discussion of model development is sound and should provide an adequate tool to examine the Raymond Basin. However, in the 2004 Geoscience report, the projected 2017 groundwater levels, under baseline conditions, were predicted to rise throughout the entire basin. While the basin essentially operated under baseline conditions through 2017, there was actually a decrease in groundwater levels throughout the basin. This is presumably at least partially due the drought conditions experienced in the basin during these years. However, it is unknown how much of the incorrect projection might be attributable to modeling development or calibration.

6. Basin Management

The most noteworthy finding is the seemingly lack of urgency regarding the basin's state of health and implementing effective management actions. There appears to be ample data and basin information to identify the deteriorating state of the basin, and many available project options to reduce declining groundwater levels in the Pasadena subarea. However, only limited efforts have been implemented. Actions that have been taken over time (such as the 30% reduction in decreed rights pumping) have failed to increase or even maintain groundwater levels in the Pasadena subarea. It does not appear that the RBMB fully evaluated the 30% reduction plan prior to implementation as review of information suggests that a 30% evaluation was not completed. A 50% reduction was studied that indicated a 50% reduction would maintain groundwater levels.

Additionally, the over-arching RBMB goals and objectives are unclear. It appears the current goal for the Pasadena subarea is to raise the groundwater levels 50 feet above the 2009 conditions. Why is this a goal? How is that goal tied to reaching basin sustainability? What is basin sustainability? There does not appear to be an over-arching policy that could answer these questions. In addition, there is no urgency or effective practices in place to even meet the stated goal of 50 feet above 2009 conditions.

The structure of the RBMB was determined by the Court. It appears that the approval structure of the RBMB minimizes the ability for PWP to prioritize the Pasadena subarea making significant and meaningful projects difficult to carry out. It also appears that the City of Pasadena has not been proactive or assertive in an effort to improve basin management and sustainability.

The RBMB structure does not address the myriad of interlinking urban issues that impact water quality and quantity. For instance multiple entities have authority over land use, stormwater, well construction/ abandonment, hazardous cleanup, and many other factors. At a minimum, the RBMB should be involved in all these issues to ensure groundwater protection.

There have been discussions regarding combining management of the Raymond Basin with the management of the Main San Gabriel Basin. The RBMB should fully investigate and understand the advantages and disadvantages of this possibility and assure that one basin isn't being favored over the other.

7. Sustainable Groundwater Management Act (SGMA)

Adjudicated basins are largely exempt under the Sustainable Groundwater Management Act (SGMA). As such, SGMA does not require sustainability management of adjudicated basins. The Raymond Basin adjudication focuses on the water rights interests of the parties and not sustainability management of the basin. Discussions with California Department of Water Resources (DWR) SGMA staff indicate that the State of California (State) is aware that adjudicated basins including Raymond Basin, are not operated under a sustainably management approach that would meet the requirements of SGMA.

There is interest at the State level to require adjudicated basins to be managed in a sustainable approach. No known actions at the State level have initiated towards this goal at this time. However, it is likely the State will become involved in the current political atmosphere within California water management. It is recommended that sustainability requirements be considered in developing long-term basin goals and objectives in order to maintain local basin management.

8. Conclusions and Recommendations

The Raymond Basin holds over 800,000 acre-feet of water. The Basin's water supply is critical to the continued success of the member communities. It is also the critical local supply during short-term and long-term supply emergencies. In the case of an emergency where Metropolitan Water District supplies are not available such as through drought, regulatory constraints, contamination, or earthquake, the Raymond Basin would be the primary and only local water supply available to meet the City of Pasadena demands. However, current conditions and trends for basin volume and quality threaten its ability to supply water during normal conditions, and during emergencies. Without a healthy, sustainable basin, there may be no groundwater available for supply shortage emergencies.

There are three main threats to the basin that PWP should address with near-term decisions and actions.

1. Contamination. The JPL contamination plumes need to be actively halted, treated, and remediated to prevent irreparable effects to the basin, limiting operational flexibility and water availability. The RBMB and/or Pasadena could assume an increased role in working with JPL, the EPA and others to develop options to address contamination.
2. Basin Management. The basin levels have trended down since the adjudication, yet there appears to be no urgency in responding. The basin management needs to define basin long-term sustainability goals and develop, support, and implement actions to reach sustainability. RBMB should investigate ways to lead, or at least participate in, the many other urban-interface issues that impact basin health, including land use, stormwater, well permitting, hazardous cleanup, etc.
3. SGMA. The State acknowledges that almost none of the adjudicated basins meet SGMA requirements. Given the State's recent actions in water management, it is highly likely the State will at the minimum soon enforce SGMA requirements on adjudicated basins, or even more intrusive, become active regulators of the basin.

PWP is in the unique situation as the basin's biggest user, and therefore at most risk to basin failures. However, PWP's voting power on the RBMB is equal to all users, limiting the ability to control its destiny. Therefore, PWP should take a two-part strategy to improve the basin and its supply reliability:

1. PWP Self Actions

PWP should identify the risks, goals, and management alternatives to directly improve sustainability of the Monk Hill and Pasadena subareas. Implement these actions as the lead, but enjoining partners where possible if the partnerships do not significantly impact the schedule. Specific project actions include:

a. Reduce loss to Main San Gabriel Basin. Obtain a copy of the basin model for use in alternatives analysis. Calibrate model to most recent conditions as required. Model each project and identify their effect on the water lost over the fault and plume movement.
b. One project could be to pump back from the fault line and recharge near the Arroyo Seco spreading grounds and contamination plume.
c. Another project is to add new wells and/or increase pumping from the fault line to feed Pasadena's distribution system. Obtain the system hydraulic model and analyze feasibility, including necessary improvements.
d. Investigate moving Arroyo Seco diversion/recharge away from plume area and downstream to allow full water right diversions. Investigate ability of relocated diversions to support recycled/raw water opportunities.
e. Investigate potential issues in merging the managements of the RBMB with the Main San Gabriel Basin and identify specific policies PWP should pursue on this effort.

2. PWP and RBMB Actions

PWP needs to work within the RBMB in a proactive manner to establish an understanding of basin threats and a sense of urgency in the need to address long-term sustainability. Specific project actions include:

a. Identify and commit to pursuing responsible entities in contamination management and cleanup. RBMB needs to lead this effort and manage contamination cleanup activities to protect the basin.
b. Determine the sustainable yield of the basin.
c. The RBMB should establish an overarching policy on basin sustainability, develop management goals, and actively implement management actions to meet sustainability goals.
d. Development of basin protection policies and guidelines to be adopted by all other land use and regulatory entities in the basin.

Ultimate success of basin management and sustainability will depend on how concisely the issues and alternatives have been set out and how assertively PWP and the RBMB chooses to act upon them.

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