Scenario modeling in the Pajaro Valley Aquifer utilizing WEAP

Zineb Babi, Jose Luis Rodriguez, April Jean Tafoya Grade: 10/10

Abstract:

The Pajaro Valley aquifer, located in the Monterey Bay in the central coast of California, struggles to supply for all of its water demands as the population grows and agricultural production water demands increase. The main areas depending on this aquifer can be summarized as the city of Watsonville, rural areas, and agricultural areas. Not only is water supply an issue in this region. Due to its proximity to the ocean, the Pajaro valley aquifer faces saline water intrusion as the water table level drops below the sea level. The Pajaro Valley Water Management Agency (PVWMA) has been addressing these issues during the last decade. Water efficiency and conservation policies have been implemented in the region to try to mitigates the negatives effects of pumping to much water from the aquifer . Other efforts to try to meet water demands include the conjunctive use of the available surface water with the groundwater source. We will use the Water Evaluation and Planning (WEAP) software to simulate the current conditions of the system, and to create scenarios to test current and proposed policies and see how they would respond under different stress circumstances. Our simulation covers a 30-year period from 2000 to 2030 and will include artificial-recharge projects proposed by PVWMA and its performances under dryer-than-usual-year conditions.

After running the proposed scenarios it becomes evident that current water use trends will lead to complete contamination by saline water in the aquifer and important unmet water demands in the region. Furthermore, our simulation shows that even conjunctive use projects will work fine under normal climate conditions, but are likely to fail if a long-enough dry period takes place.

Introduction:

The Pajaro Valley is located in central California, hosting the city of Watsonville on the coast of Monterey Bay. The Pajaro Basin supplies one of the most productive agriculture valleys in the United States with fresh water, attained through groundwater pumping. The basin is under direct threat of saltwater intrusion due to continued overdraft of groundwater. Subsidence and chloride contamination of groundwater wells up to 3 miles inland has already occurred; further fresh water contamination, compromising both drinking and agricultural water supplies, is unavoidable at the current groundwater pumping rates and allocation plans. In addition to experiencing saltwater intrusion, population growth is expected to continue in the area which will increase the water demand in the already overdrafted Basin. In addition, this region of California has experienced severe drought in the past, and forecasted climate change scenarios are predicting less precipitation and potential drought like conditions for the region. Pajaro Valley Water Management Agency (PVWMA) has taken steps towards mitigation with several suggestions, including water conservation, limits in groundwater pumping, extraction from the Pajaro River, and three groundwater recharge projects (1).

Objective:

The main objective of this project is to build a simulation model using SEI's Water Evaluation and Planning (WEAP) program, with available water use, aquifer storage, precipitation, and Pajaro River flow data to simulate an approximation of the surface and groundwater inputs and demands in the area (2). We will run time-stepped scenarios for a 30 year water plan with the following scenarios to determine if an optimal solution, in which groundwater overdraft ceases while meeting all urban, agricultural and rural demands, exists within the proposed plans:

- ***Scenario 1. Linear population growth, no water conservation policy, no extraction from the river, no limitation in groundwater pumping.***

- ***Scenario 2. Linear population growth, water conservation, diversion from the river, limitation in groundwater pumping.***

- ***Scenario 3. Linear population growth, water conservation, diversion from the river, limitation of groundwater pumping, variation in precipitation representing a dry period from 2014 to 2030.***

- ***Scenario 4. Linear population growth, water conservation, extraction from the river, limitation of groundwater pumping, variation in precipitation representing a dry-year cycle experienced in the region. This scenario includes the addition of three proposed recharge projects; Harkins Slough Recharge Facilities, Watsonville Slough, and College Lake.***

Hypothesis:

Utilizing the available data and WEAP, we will be able to discretize the system to analyze how it would respond to the proposed scenarios. We hypothesize that maintaining the current groundwater storage is essential to mitigating further seawater intrusion. We think that a combination of groundwater pumping, river extraction, conservation efforts, and recharge projects will be necessary to meet demands and prevent further overdraft of the aquifer, especially in dry years.

Data Sources:

Data for our project will be provided by the Pajaro Valley Water Management Agency and Dr. Samuel Sandoval-Solis. We will use water demand data from 1990 to 2012, as well as aquifer recharge and river headflow data from 1999 to 2012.

Methods and Assumptions:

Linear Population Growth

Population data was available from 1860-2010 which generated a power trend with the regression formula:

$$y = (2.6401*10-175)*Year54.292$$

A closer look at population data shows Watson is experiencing a fixed increase in population which has been the trend since approximately the 1970's. Incorporating partial data (1970-2010), a linear trend is observed with the regression formula:

$$y = 939.82*Year - 1837306.8$$

Considering the coefficient of determination (R^2), the second regression produces a more robust model of observed outcomes, with an R^2 value of 0.9915, versus 0.9704 produced by the first regression. The second regression, incorporating partial data, will be used to project future population.

Scenario 1.

This scenario is the baseline scenario.

Scenario 2.

Water conservation is implemented by a city wide policy called the Five!Five! Plan, in which the goal is to reduce urban water use 20% by 2030 in 5 year/5% increments, starting in year 2015. A limitation in groundwater pumping for the city of Watsonville was also implemented; all pumping is monitored and 85% of demand will be supplied from groundwater while 15% is supplied from the Pajaro River. Agricultural and rural areas are also to reduce use their water use by 10% and 15% respectively through conservation and efficiency policies. In addition, agricultural areas have also been limited to 95% of their demand supplied from the aquifer, with the remaining demand supplied from the water treatment plant.

Scenario 3.

Scenario 2, with the addition of reductions in the precipitation and natural recharge values. Our model does not have precipitation input, but this reduction can be represented in headflow and natural recharge values which would be directly affected by precipitation. We simulated dryer than normal time period by using a stochastic model to simulate synthetic precipitation within the 10 percentile of the precipitation range.

Scenario 4.

Scenario 3, with the addition of the three proposed recharge projects. These recharge projects will deliver water to agricultural users in an attempt to meet demands during drier years, while avoiding further aquifer overdraft. They are represented in WEAP with a single transmission link per recharge project supplying the acre-footage of water mentioned above.

Calculations/Results:

Scenario 1. – Results

Under the current water allocation plan, or the baseline scenario, in the year 2020 Watsonville urban, rural and agricultural areas will begin to experience water shortages which will continue, to a varying degree on almost an annual basis (Figure 1). Aquifer storage will deplete severely, and seawater will replace all freshwater aquifer storage, permanently contaminating the aquifer (Figure 2).

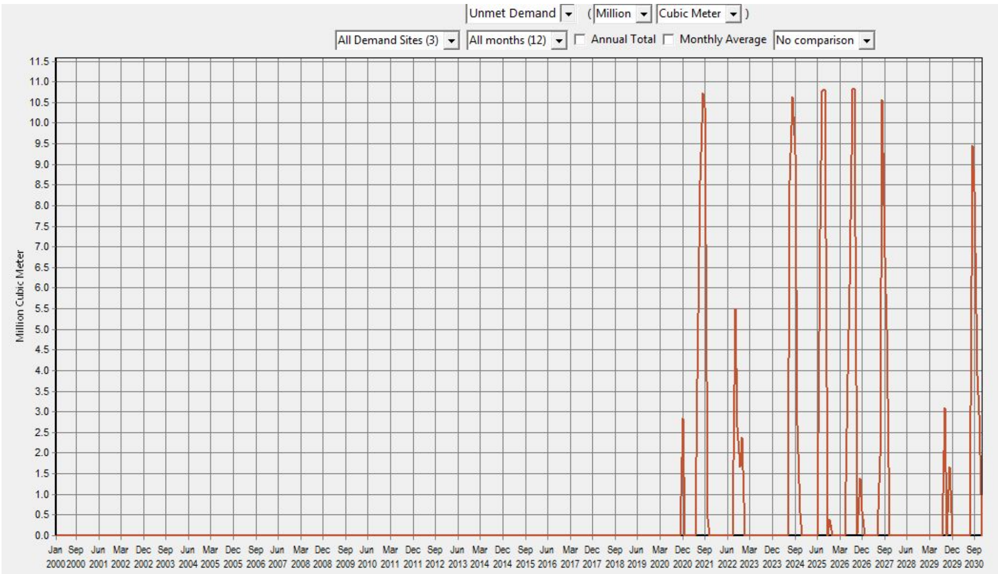

Figure 1. Unmet demands of the baseline scenario.

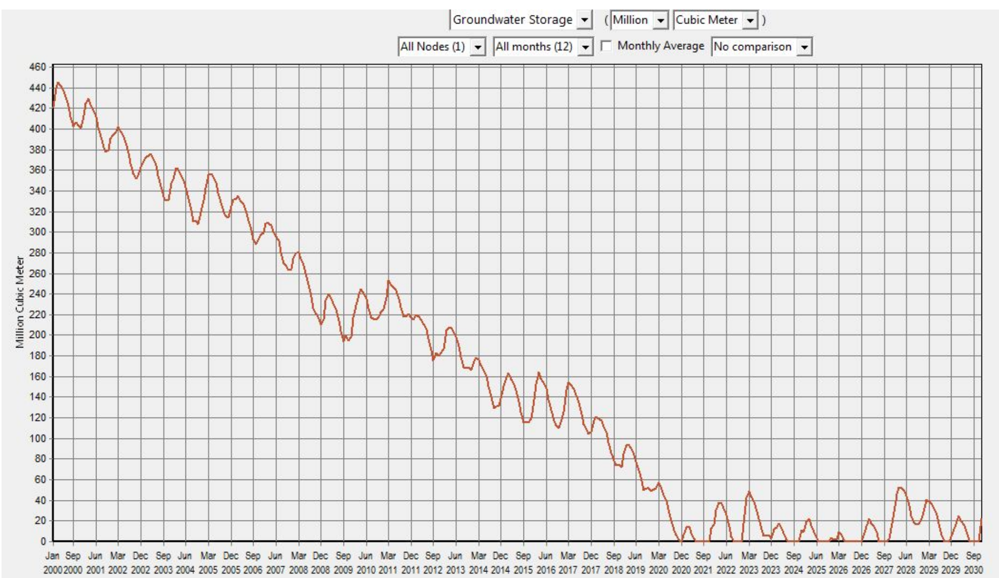

Figure 2. Aquifer storage of baseline scenario.

Scenario 2. - Results

When water conservation is implemented, an increase in groundwater recharge begins from the baseline scenario, by 2030, when conservation is in full effect (20% less use of water in Watsonville)

there is an increase of 73 million cubic meters from the baseline scenario. Because of conservation, limitation and diversion from the river, aquifer overdraft was avoided (Figure 3). However, since the water table keeps dropping, the intrusion of saline water into the aquifer is still significant.
In this scenario, groundwater limitations created many unmet demands within the city of Watsonville, even with conservation efforts (Figure 4). These unmet demands occurred annually, concentrated in the summer months. Agriculture also experienced unmet demands, although with less frequency and magnitude than the city of Watsonville (Figure 5). An interesting note is that the agricultural unmet demands increased in magnitude when conservation efforts were put in place; this can only be due to less water entering return flow from Watsonville to the water treatment plant which then supplies agriculture.

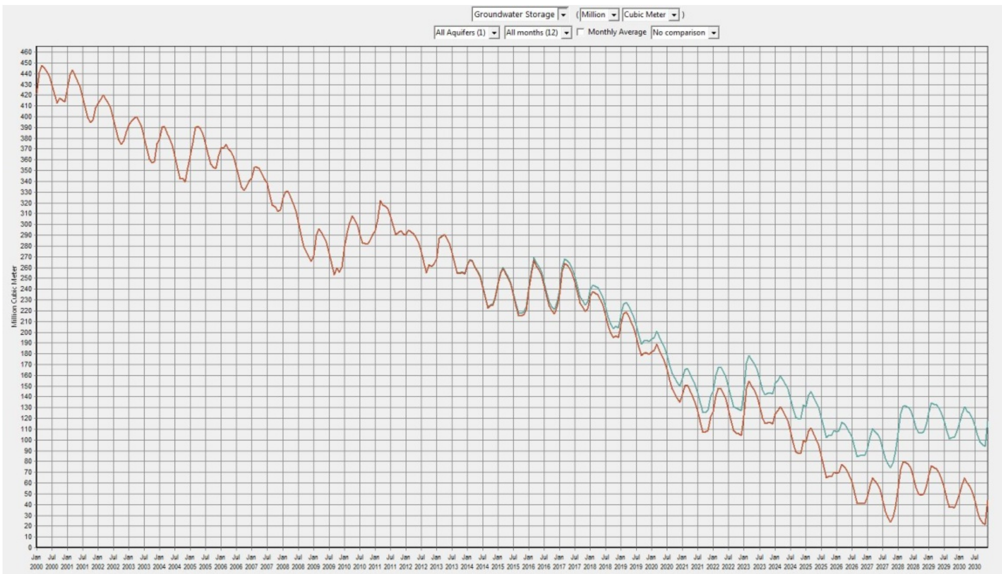

Figure 3. Aquifer storage in scenario 2 (green= implemented changes; red = baseline).

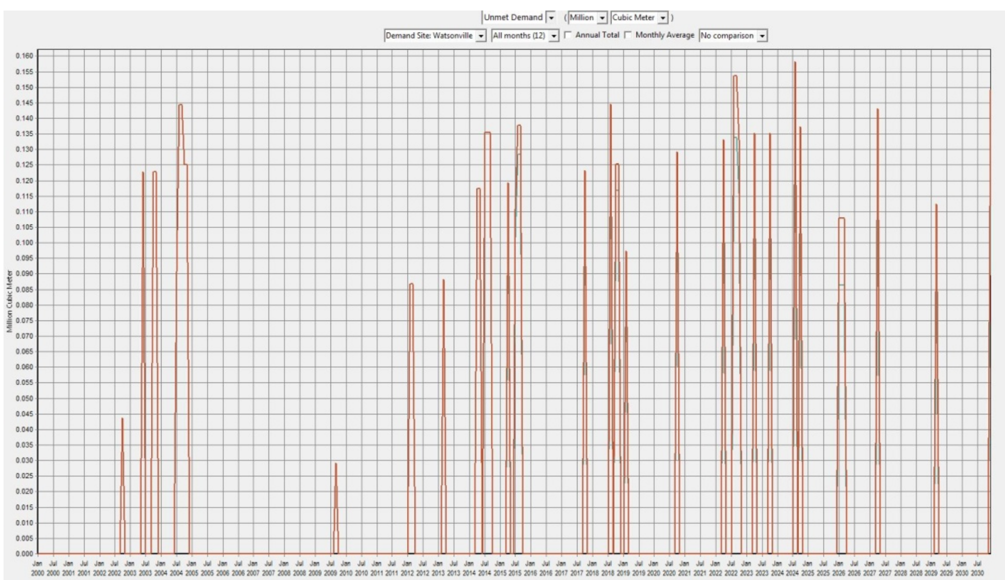

Figure 4. Watsonville unmet demands in scenario 2 (green= implemented changes; red = baseline).

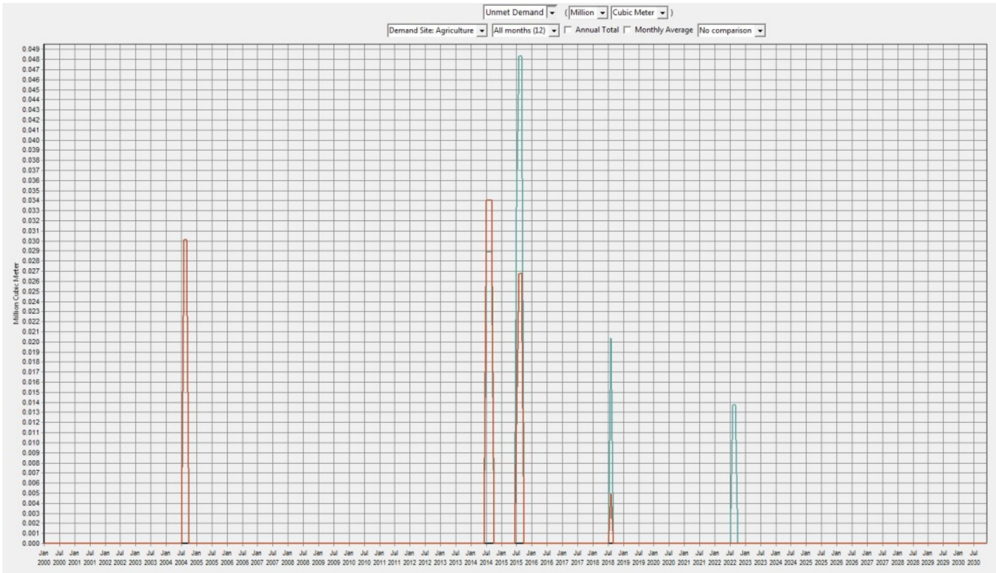

Figure 5. Agriculture unmet demands in scenario 2 (green= implemented changes; red = baseline).

Scenario 3. - Results

With simulated reduction in natural recharge and headflow, we see overdraft in the aquifer beginning in September, 2022 (Figure 6). The aquifer struggles to recover throughout the simulated dry years, until 2028, when we finally see a slight recovery from overdraft. In this basin, however, if saltwater intrusion replaced the freshwater storage, recovery will likely not return the aquifer to the freshwater state. Unmet demands increase for both the city of Watsonville and agriculture in the simulated dry years (Figure 7; Figure 8). In this scenario, the rural users have unmet demands as well, this was not seen in the previous scenario.

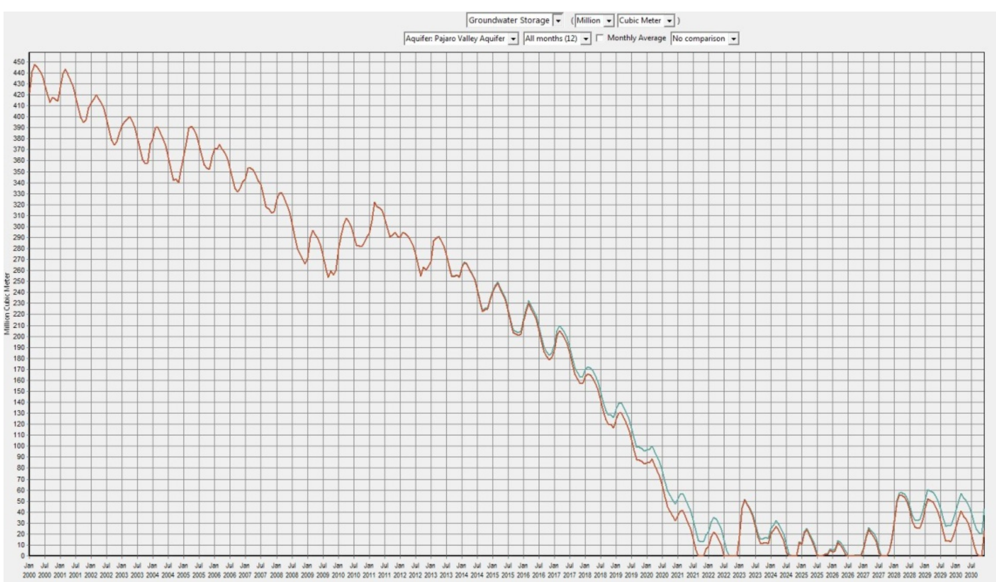

Figure 6. Aquifer storage in scenario 2 (green= implemented changes; red = baseline).

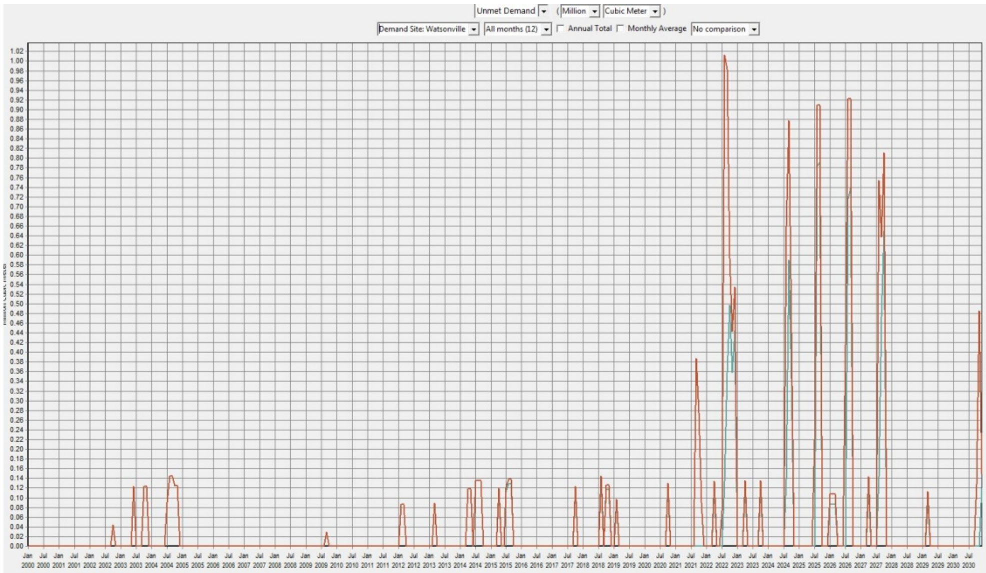

Figure 7. Watsonville unmet demands in scenario 3 (green= implemented changes; red = baseline).

Figure 8. Agricultural unmet demands in scenario 3 (green= implemented changes; red = baseline).

Scenario 4. - Results

With the implementation of these water recharge projects, unmet demands for agricultural areas are completely mitigated. However, the city of Watsonville continues to have unmet demands (Figure 9; Figure 10). Aquifer storage, however, remains above 100 million m^3, regardless of the simulated dry years (Figure 11).

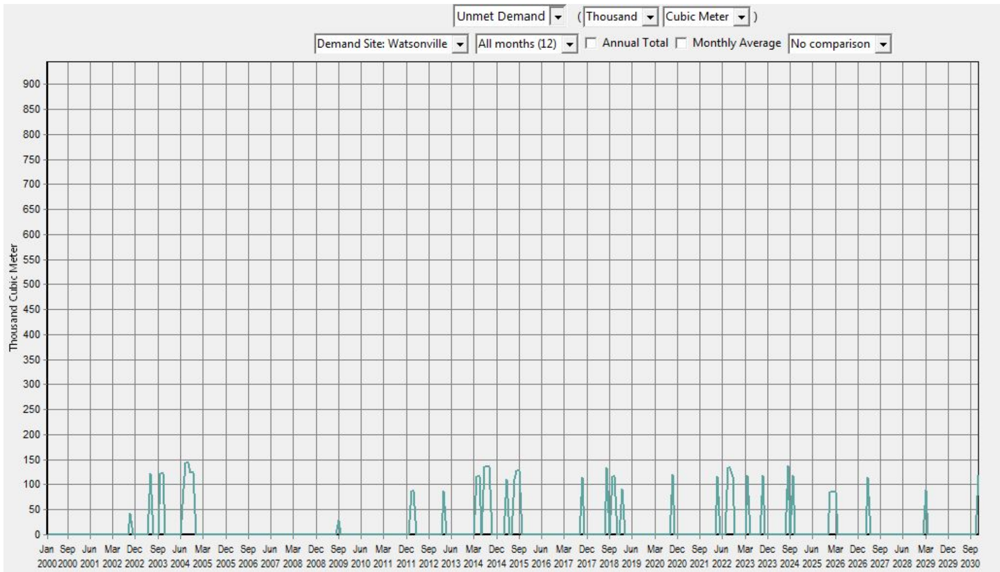

Figure 9. Watsonville unmet demands in scenario 4 (green= implemented changes; red = baseline).

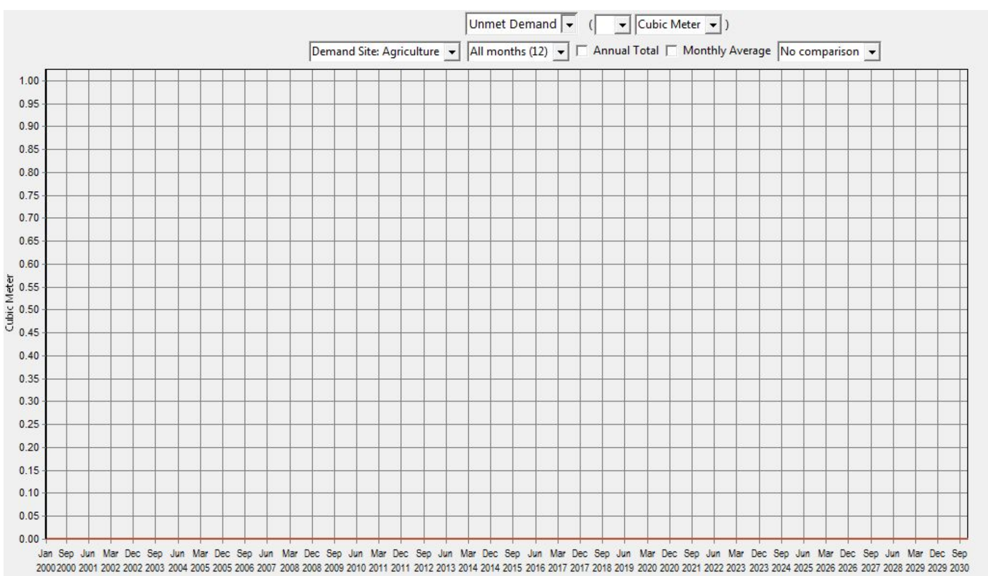

Figure 10. Agriculture unmet demands in scenario 4 (green= implemented changes; red = baseline).

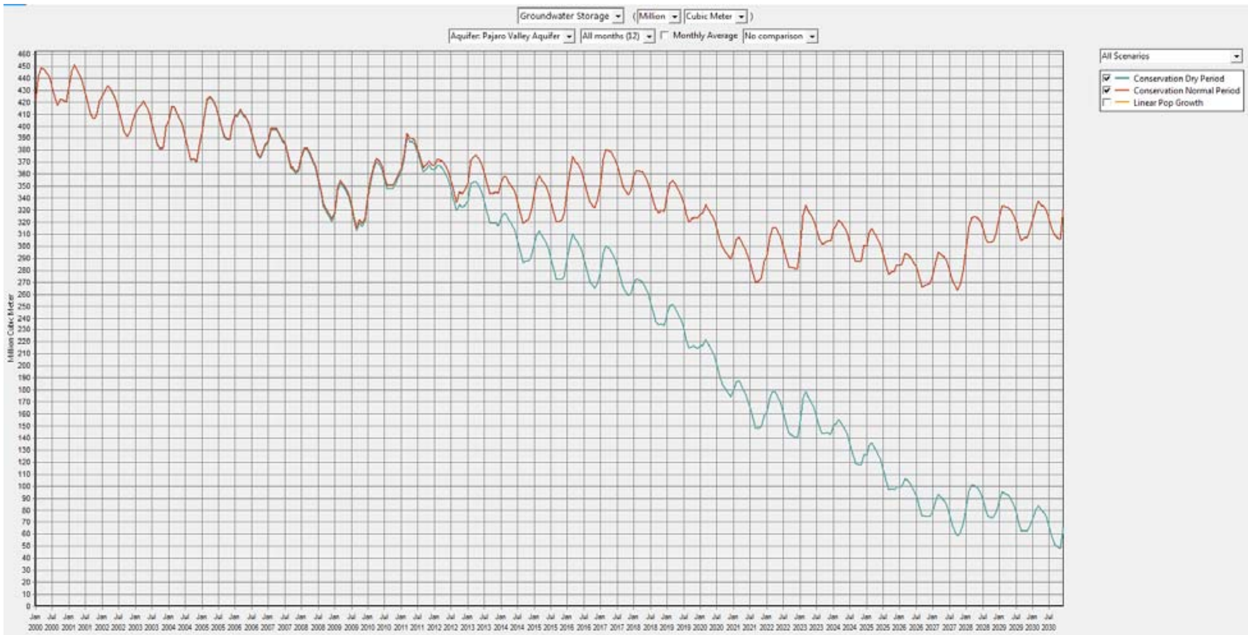

Figure 11. Aquifer storage in scenario 4 (green= conservation under dry conditions; red = conservation under normal conditions).

Conclusions:

Under the current water allocation plan, Watsonville urban and agricultural users will face water shortages in the next decade while the aquifer is continually depleted of freshwater. With conservation efforts and groundwater pumping limitations in place, unmet demands will decrease and aquifer freshwater storage will not deplete completely. Freshwater aquifer storage will, however, drop below 70 million m^3, furthering the process of seawater intrusion.

For long-enough dry periods, conservation efforts and limitations in groundwater pumping will not be enough to mitigate unmet demands for urban, rural and agricultural users. The simulated aquifer storage in scenario 3 faces complete freshwater storage depletion, and possible permanent contamination. It is only with the implementation of the three proposed recharge projects in which the aquifer does not face dire depletion and contamination. With the implementation of the recharge projects, agricultural users will not face unmet demands, and urban users unmet demands decrease, and occur with less frequency as long as the climate conditions do not vary to the point to create a long-enough dry periods. In scenario 4 is easy to see that even with all efforts put in place, prolonged dry periods exerts significant damage to the water levels and quality in the aquifer.

Recommendations:

It is our recommendation to the city of Watsonville and the PVWMA to implement water conservation, perhaps at a greater percentage than the 20% simulated in the scenario. The average demand in urban Watsonville is 132 gpd/person; a 20% reduction would require 105.6 gpd/person, which is still considered a large amount per capita globally. For example, in Australia, where standards for quality of life are comparable to the United States, an average of 83 gpd/person is consumed (3). With a 30% reduction in use for Pajaro Valley users, demand would be 92 gpd/person, still above Australia's demand level. Not only would a more aggressive conservation policy benefit the freshwater aquifer storage, which is likely unreplaceable under geologic conditions, but could be potentially "trend-setting" or "cutting edge," which may attract national recognition for the city.

It is also our recommendation that the city of Watsonville and the PVWMA limit groundwater pumping and complete the three proposed recharge projects. Without implementation of these limits, freshwater aquifer storage will completely decrease; the proposed recharge projects were successful in mitigating most unmet demands, and possibly, with aggressive conservation efforts, unmet demands could be completely mitigated.

Citations

(1) Raskin, P. *Water Evaluation and Planning*. (Stockholm Environmental Institute). at <http://www.weap21.org/index.asp>.

(2) 2012 Basin Management Plan Update, Board Review Draft. (2012).

(3) "Indicator: HS-42 Water Consumption per Capita." *Department of the Environment*. Autraolian Government, n.d. Web. 17 Nov. 2013. <http://www.environment.gov.au/node/22261>.