Hydrologic Model Analysis of Basin Management Plan Alternatives Revised July 2013

Prepared for:

Pajaro Valley Water Management Agency

July 2013

Prepared by:
# TABLE OF CONTENTS

Abbreviations .................................................................................................................. iii

Executive Summary ........................................................................................................ 1

Section 1 Introduction ..................................................................................................... 1

Section 2 Purpose and Scope .......................................................................................... 3

Section 3 Project Setting .................................................................................................. 5
  3.1 Project Location ........................................................................................................ 5
  3.2 Hydrogeology ........................................................................................................... 7
  3.3 Existing Water Supply Infrastructure ........................................................................ 7

Section 4 Hydrologic Model Description ....................................................................... 11

Section 5 Model Simulation Descriptions ....................................................................... 19
  5.1 Baseline Simulation ................................................................................................. 19
  5.2 Selected Alternative Simulation ............................................................................. 21
    5.2.1 Project Descriptions ......................................................................................... 21
    5.2.2 Model Assumptions ......................................................................................... 21
    5.2.3 Model Setup .................................................................................................... 22

Section 6 Model Results .................................................................................................. 25
  6.1 Model Analysis Approach ....................................................................................... 25
  6.2 Current Conditions ................................................................................................... 28
  6.3 Selected Alternative Simulation Results ................................................................... 28
  6.4 Comparison of Baseline and Selected Alternative Simulations ............................. 28
  6.5 Simulated Options on the Selected Alternative ....................................................... 37
    6.5.1 Selected Alternative Option 1 ........................................................................... 37
    6.5.2 Selected Alternative Option 2 ........................................................................... 37
    6.5.3 Selected Alternative Option 3 ........................................................................... 37
    6.5.4 Results from Selected Alternative Option Simulations .................................... 38

Section 7 Conclusions and Recommendations ............................................................... 39

Section 8 References ....................................................................................................... 41
LIST OF FIGURES

Figure 1: Pajaro Valley Location and Features .................................................................6
Figure 2: Harkins Slough Recharge Project Facilities .......................................................9
Figure 3: Extent of Model Area .........................................................................................12
Figure 4: Hydrostratigraphic Outcrops in the Model Domain (from Hanson et al., in review) .........................................................................................................................14
Figure 5: Cross Sections Showing Hydrostratigraphic Units and Associated Model Layers (from Hanson et al., in review) .................................................................15
Figure 6: Example Simulated Ocean Level Rise ..............................................................17
Figure 7: Baseline Simulation Rainfall at Watsonville .....................................................20
Figure 8: Coastal Model Cells Used for Estimating Seawater Intrusion ......................27
Figure 9: Extent of Simulated Seawater Intrusion – Alluvial Aquifer .........................30
Figure 10: Extent of Simulated Seawater Intrusion – Upper Aromas Aquifer ............31
Figure 11: Extent of Simulated Seawater Intrusion – Lower Aromas Aquifer ............32
Figure 12: Average Water Level Change Due to Implementing Selected Alternative – Alluvial Aquifer ...........................................................................................................34
Figure 13: Average Water Level Change Due to Implementing Selected Alternative – Upper Aromas Aquifer ..........................................................................................35
Figure 14: Average Water Level Change Due to Implementing Selected Alternative – Lower Aromas Aquifer ..........................................................................................36

LIST OF TABLES

Table 1: Correspondence between Hydrostratigraphic Units and Model Layers 13
Table 2: Selected Alternative Option Results ..................................................................38
ABBREVIATIONS

afy........................................Acre-feet per year
BMP........................................Basin Management Plan
CDS ........................................Coastal Distribution System
DWR........................................California Department of Water Resources
ESA.........................................Environmental Science Associates
PVHM .......................................Pajaro Valley Hydrologic Model
PVWMA .................................Pajaro Valley Water Management Agency
USGS ...............................U.S. Geological Survey
EXECUTIVE SUMMARY

The Pajaro Valley Water Management Agency (PVWMA), in coordination with an Ad Hoc BMP Committee that represents a broad group of local stakeholders, is updating the Basin Management Plan (BMP) to address the Valley’s groundwater overdraft. This BMP is intended to identify and analyze a range of feasible water supply and water management projects that could help reduce the Valley’s overdraft. The result of the BMP will be a set of technically and financially feasible projects and management practices that, when combined, ensure sufficient water supplies for present and projected needs in the Pajaro Valley.

Analyzing and comparing various alternative projects and practices considered during the BMP process requires a standardized tool that estimates the effectiveness of each scenario. The PVWMA’s existing, calibrated, hydrologic model was selected as the tool for analyzing and comparing the various projects. The model is used to simulate combinations of projects, and analyze them against two criteria: effectiveness at reducing seawater intrusion; and effectiveness at reducing overdraft.

The existing model was developed by the U. S. Geological Survey (USGS) for PVWMA (Hanson et al., 2008; Hanson et al., 2010). The model simulates groundwater flow in Pajaro Valley with the commonly used and widely accepted MODFLOW2005 model (Harbaugh, 2005). The model incorporates the most recent version of the USGS Farm Process program (Schmid and Hanson, 2009) which allows detailed and realistic simulations of agricultural pumping and water transfers.

After developing and analyzing a number of scenarios, PVWMA staff and Ad Hoc BMP Committee agreed upon a selected alternative comprising the following projects and management practices:

- Improving agricultural irrigation efficiency by 10%, representing a reduction in groundwater pumping of approximately 5,000 acre-feet per year (afy), distributed evenly throughout the valley.
- Delivering 8,600 acre-feet of water per year to the existing Coastal Distribution System. This comprises:
  - 4,000 acre-feet of recycled water per year,
  - 2,400 acre-feet of water from College Lake per year,
• 1,000 acre-feet of water from the Harkins Slough recharge project per year, and
• 1,200 acre-feet of water from the North Dunes recharge project per year.
• Recharging 500 acre-feet of captured Pajaro River flow per year near Murphy’s Crossing.

This selected alternative is simulated with the model and compared to a baseline scenario. The baseline scenario simulates groundwater conditions under the assumption that current land use, potable water demand and water delivery practices are maintained for the next 34 years.

Results of the simulations show that implementing the selected alternative will eliminate overdraft in the most productive aquifers in Pajaro Valley, and will reduce seawater intrusion by more than 90% in these aquifers. Further refinement of the selected alternative using the model is not warranted because the current results are within the model’s uncertainty. We suggest that the selected alternative be implemented as proposed, and modifications be made based on groundwater monitoring results.
SECTION 1
INTRODUCTION

Pajaro Valley is one of the most productive agricultural regions in the United States. Over the past several decades, however, groundwater pumping for agricultural and potable uses has led to overdraft of the aquifers beneath the Valley. Groundwater overdraft occurs when the long-term pumping rate consistently exceeds the long-term rate of aquifer replenishment. The overdraft in the Pajaro Valley is most notable under the City of Watsonville, where groundwater elevations are currently below sea level; the depressed water level creates a gradient that in combination with continued coastal pumping attracts the inland migration of sea water.

The Basin Management Plan (BMP) is being updated by the Pajaro Valley Water Management Agency (PVWMA), in coordination with an Ad Hoc BMP Committee that represents a broad group of local stakeholders. This updated BMP will identify and analyze a broad range of feasible water supply and water management projects to reduce the Valley’s overdraft. The result of the BMP will be a set of technically and financially feasible projects and practices that, taken together, ensure sufficient water supplies for present and projected needs in the Pajaro Valley.

Part of the BMP analysis relied on testing the effects of various projects and management practices with PVWMA’s existing hydrologic model. This report presents the model background, assumptions, and results that support the selected BMP alternative.
SECTION 2
PURPOSE AND SCOPE

Analyzing and comparing various project scenarios and management practices considered during the BMP process requires a standardized tool that estimates the effectiveness of each alternative. The PVWMA’s existing calibrated groundwater model was selected as the tool for analyzing and comparing the various projects and practices.

The Ad Hoc BMP Committee is interested in addressing two related and equally important groundwater concerns: halting seawater intrusion and stopping ongoing overdraft. For the selected alternative to be effective, it must address both of the following issues.

1. **Effectiveness at reducing seawater intrusion** - Seawater intrusion occurs when groundwater elevations in an aquifer that is connected to the ocean drop too close to sea level. The low groundwater elevations permit salt water from the ocean to flow inland, through the aquifer. Because this salt water is unsuitable for most agricultural or municipal uses, wells impacted by seawater intrusion are unusable.

   Seawater intrusion has been observed along much of coastal Pajaro Valley. Halting seawater intrusion in order to maintain high quality groundwater for beneficial uses is a primary objective of the BMP.

2. **Effectiveness at reducing overdraft** - In the current model, overdraft is defined separately from seawater intrusion. Overdraft in this instance is defined as a net loss in the amount of groundwater stored in the Pajaro Valley aquifers. Under this definition, continued overdraft results in lower groundwater elevations. This leads to higher pumping costs, can eventually result in insufficient groundwater to meet demands, and contributes to the inland migration of seawater. Halting overdraft in a primary objective of the BMP.

The model is used to simulate combinations of projects, or alternatives, rather than individual projects. This approach is adopted because individual projects may either enhance or reduce the effectiveness of other projects. Simulating groups of projects as single alternatives accommodates any symbiotic or antagonistic effects between projects.
SECTION 3
PROJECT SETTING

3.1 PROJECT LOCATION

Pajaro Valley is a coastal valley that straddles southern Santa Cruz County and northern Monterey County (Figure 1). The Valley covers approximately 160 square miles. The Valley is bordered on the northeast by the coastal Santa Cruz Mountains and on the southwest by the Pacific Ocean. The northern boundary of the valley is generally considered to be the drainage divide between the Aptos Creek watershed and the Pajaro River watershed. The southern boundary of the valley is generally considered to be the drainage divide between Elkhorn Slough and Morro Coho Slough (Johnson et al. 1988). California’s Department of Water Resources Bulletin 118-2003 identifies the Pajaro Valley as Basin 3.2 in the Central Coast Hydrologic Region (California DWR, 2003).

The primary surface water feature in the Pajaro Valley is the Pajaro River and its tributaries. The main stem of the Pajaro River enters the Pajaro Valley through the Chittenden Gap in the Santa Cruz Mountains. Corralitos Creek is the largest tributary to the Pajaro River in the Pajaro Valley. The flow in Corralitos Creek is approximately one-tenth the flow in the main stem of the Pajaro River (Johnson et al. 1988).

The City of Watsonville is the largest urban area in the valley; and is located near the middle of the valley. Additional unincorporated communities in the valley include Freedom, Pajaro, Salsipuedes, Corralitos, Aromas, Las Lomas, Pajaro Dunes, and La Selva Beach. Moss Landing is on the southern edge of the valley, and is sometimes included as part of the valley.
Figure 1: Pajaro Valley Location and Features
3.2 Hydrogeology

The hydrogeology of Pajaro Valley has been described in numerous reports including those by Green (1970), Muir (1972), Muir (1974), Dupré, (1975), and Johnson et al. (1988), among others.

Pajaro Valley area is underlain by a basement of Cretaceous granitic rocks. Overlying these consolidated, poorly permeable rocks are a series of westward-dipping, sediments of late Tertiary and Quaternary age. These sediments include the poorly consolidated Mio-Pliocene Purisima Formation, the Pleistocene Aromas Red Sands, and Holocene terrace deposits, unconsolidated alluvium, dune deposits, and younger marine sediments.

The Purisima Formation underlies the valley at depths ranging from at or near land surface along the northern and eastern boundaries, to as much as 800 or 900 feet near the mouth of the Pajaro River (Johnson et al. 1988). The Purisima Formation consists of layered sandy silts and silts deposited in near shore and far shore marine deposits. It is generally screened only by deeper wells in the Pajaro Valley, and provides limited amounts of water to the Valley.

The Aromas Red Sands are between 100 and 900 feet thick in Pajaro Valley. The sands consist of both older fluvial deposits and younger eolian deposits. The Aromas Red Sands are described as well sorted brown to red sands with interbeds of clay and poorly sorted gravels (Hanson et al., 2008; Hanson et al., 2010). The Aromas Red Sands provide a significant amount of the groundwater pumped by wells in Pajaro Valley.

The terrace deposits, unconsolidated alluvium, dune deposits, and younger marine sediments blanket the Aromas Red Sands to depths of 245 feet in most of the Pajaro Valley. The alluvium is described as a highly variable mixture of unconsolidated gravel, silt, and sand with lenses of clay and silty clay. Terrace deposits consist of moderately to poorly sorted silt, sand, silty clay, and gravel; while dune deposits consist of fine-to medium-grained quartz sand (Johnson et al., 1988). Relatively little water is pumped from these units.

3.3 Existing Water Supply Infrastructure

In 2002, the PVWMA Board of Directors adopted a BMP designed to balance water supply and demand through the acquisition of supplemental water and
conservation practices. A number of the projects and programs outlined in the previous BMP have been implemented. Existing projects that are particularly relevant to the current modeling effort include:

1. **The existing Coastal Distribution System (CDS)** - The CDS is an underground pipeline used to deliver supplemental water supplies, including recycled water, to farms in coastal Santa Cruz and northern Monterey Counties. Water delivered through the CDS replaces pumped groundwater from coastal wells, thus reducing seawater intrusion. In this sense, delivered water allows “in-lieu recharge” to the aquifers.

2. **The existing Recycled Water Project** - The PVWMA partnered with the City of Watsonville to build a water recycling plant that delivers up to 4,000 acre-feet per year of blended, recycled water through the CDS. The plant came on line in 2009. In 2011, the plant provided 1,980 acre-feet of water to the CDS. This recycled water was mixed with 520 acre-feet of blend water.

3. **The existing Harkins Slough Recharge Project** - The Harkins Slough Recharge project seasonally stores wet weather flows from Harkins Slough in the shallow aquifers near the coast (Figure 2). Stored water is pumped from a series of wells and delivered to coastal farms through the CDS. In 2011, the Harkins Slough Project delivered 250 acre-feet of water to the CDS.
Figure 2: Harkins Slough Recharge Project Facilities
This page left intentionally blank
SECTION 4
HYDROLOGIC MODEL DESCRIPTION

Modeling of the projects and programs considered for the BMP was completed using the Pajaro Valley Hydrologic Model (PVHM). This model was developed by the U. S. Geological Survey (USGS) for PVWMA (Hanson et al., 2008; Hanson et al., 2010). The model simulates groundwater flow in the Pajaro Valley with the commonly used and widely accepted MODFLOW2005 model (Harbaugh, 2005). The model incorporates the most recent version of the USGS’s Farm Process program (Schmid and Hanson, 2009) which allows detailed and realistic simulations of agricultural pumping based on simulated crop demand and non-routed deliveries from Agency water supply facilities.

The model simulates the hydrology of sediments both onshore beneath the Pajaro Valley, and offshore beneath the Pacific Ocean (Figure 3). The model consists of 150 rows and 150 columns, each cell representing a 250 meter by 250 meter area.
Figure 3: Extent of Model Area
The model comprises six layers. The layers are generally based on the hydrostratigraphic units described in Section 3, with some modifications. The alluvium, dune deposits, and terrace deposits are divided into an upper productive layer and a lower confining bed. The Aromas Aquifer is divided into an upper unit, a middle confining unit, and a lower unit. The Purisima Formation is not subdivided. Incorporating these modifications, the relationship between the identified hydrostratigraphic units and the six layers of the groundwater model are shown on Table 1.

Table 1: Correspondence between Hydrostratigraphic Units and Model Layers

<table>
<thead>
<tr>
<th>Model Layer</th>
<th>Hydrostratigraphic Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alluvium, dune sands, and terrace deposits</td>
</tr>
<tr>
<td>2</td>
<td>Confining layer below the alluvium</td>
</tr>
<tr>
<td>3</td>
<td>Upper Aromas Red Sands</td>
</tr>
<tr>
<td>4</td>
<td>Aromas Red Sands confining layer</td>
</tr>
<tr>
<td>5</td>
<td>Lower Aromas Red Sands</td>
</tr>
<tr>
<td>6</td>
<td>Purisima Formation</td>
</tr>
</tbody>
</table>

A surficial geologic map showing the interpreted outcrop pattern of the hydrostratigraphic units in the modeled area is shown on Figure 4. Two example cross sections showing how the model layers correspond to various hydrostratigraphic units are shown on Figure 5.
Figure 4: Hydrostratigraphic Outcrops in the Model Domain (from Hanson et al., in review)
The model used for simulating BMP projects and programs simulates a 34 year period, starting in 2010. The 34 years of hydrology were based on weather conditions between 1976 and 2009, inclusive. Model stress periods are monthly: the model changes pumping and rainfall every month. Model time steps are semi-monthly; the model calculates groundwater elevations in the aquifers twice per month.
One modification was made to the USGS model to simulate future conditions: reasonably foreseeable sea level rise is incorporated into the model. Rising sea levels were incorporated at all offshore model boundaries. The rate of sea level rise is based on the Intergovernmental Panel on Climate Change’s A2 scenario. Between 2000 and 2050, sea levels in Monterey Bay are expected to rise an average of 14 inches (USGS & ESA-PWA, personal communication). The USGS provided model input files that reflect these expected rates of sea level rise (Hanson, personal communication). An example of the simulated ocean level rise is shown on Figure 6. This figure shows simulated ocean pressures at the ocean floor adjacent to Zmudowski State Beach. A trend line, shown in red, shows that the average ocean level rises a bit more than 0.5 feet over the 34 year simulation.
Figure 6: Example Simulated Ocean Level Rise
SECTION 5
MODEL SIMULATION DESCRIPTIONS

The Ad Hoc BMP Committee along with PVWMA staff and the project team developed and analyzed a number of BMP projects and project combinations, or scenarios, that address part or all of the Pajaro Valley groundwater issues. A subset of promising project combinations was simulated with the hydrologic model. Including baseline simulations, 14 combinations of BMP project configurations and basin conditions were selected for simulation, primarily based on questions and feedback from the Ad Hoc BMP Committee. The result of these efforts was to narrow the number of BMP project combinations (scenarios) that could be analyzed in more detail for presentation and consideration by the committee.

5.1 BASELINE SIMULATION

The baseline simulation provides a benchmark to which all scenarios can be compared against. The baseline simulation estimates the hydrologic conditions if current irrigation and water delivery practices are extended into the future.

Assumptions in the baseline simulation include the following:

- The simulation includes 34 years of hydrology. The 34 years of hydrology were based on weather conditions between 1976 and 2009, inclusive. The simulated hydrology was inverted for this simulation: the hydrology of the first year of the baseline simulation reproduces the 2009 hydrology; the hydrology of the last year of the baseline simulation reproduces the 1976 hydrology. This approach is illustrated in Figure 7. This figure shows the first four years of rainfall simulated in Watsonville for the baseline simulation.
- Crop distribution is maintained at 2009 levels.
- Municipal pumping is maintained at 2009 levels.
- Irrigation efficiency is maintained at 2009 levels.
- Deliveries through the CDS are maintained at 2011 levels. These deliveries include 1,980 acre-feet of recycled water, 520 acre-feet of blend water, and 250 acre-feet of Harkins Slough water.
Figure 7: Baseline Simulation Rainfall at Watsonville
5.2 SELECTED ALTERNATIVE SIMULATION

5.2.1 PROJECT DESCRIPTIONS

The selected alternative simulation includes the following projects and management practices.

- A 10% improvement in agricultural irrigation efficiency, distributed evenly throughout the valley, representing a reduction in groundwater pumping of approximately 5,000 afy.
- Delivering 8,600 acre-feet of water per year to the CDS. This comprises:
  - 4,000 acre-feet of recycled water per year,
  - 2,400 acre-feet of water from College Lake per year,
  - 1,000 acre-feet of water from the Harkins Slough recharge project per year, and
  - 1,200 acre-feet of water from the North Dunes recharge project per year.
- Recharging 500 acre-feet of captured Pajaro River flow per year near Murphy Crossing (Figure 1).

5.2.2 MODEL ASSUMPTIONS

Assumptions in the selected alternative simulation included the following:

- The simulation includes 34 years of hydrology. The 34 years of hydrology were based on weather conditions between 1976 and 2009, inclusive, which includes the drought of 1976-1977. The simulated hydrology was inverted for this simulation: the hydrology of the first year of the baseline simulation reproduces the 2009 hydrology; the hydrology of the last year of the baseline simulation reproduces the 1976 hydrology.
- Crop distribution is maintained at 2009 levels.
- Municipal pumping is maintained at 2009 levels.
- Irrigation efficiency is improved by 10%, distributed evenly across the basin, representing a reduction in groundwater pumping of approximately 5,000 afy.
- The CDS supplies 8,600 acre-feet of water annually to coastal farms that are currently capable of receiving delivered water. This delivered water is used by farms preferentially, before pumping groundwater.
- The Harkins Slough recharge project and the North Dunes recharge project are not explicitly simulated, but rather the desired amount of
water provided by these projects is included in the total available supplemental supply. These projects were simulated this way in order to ensure the desired yield was achieved each year, regardless of streamflow and weather conditions.

- No blending water from the City of Watsonville or PVWMA blend wells is needed in this scenario because the water supply projects mentioned above meet the demand target.

5.2.3 Model Setup

The model assumptions listed in Section 5.2.2 are implemented in the model through a series of model changes. Improvements in irrigation efficiency are implemented in the model by manipulating each water balance subregion’s (also referred to as each virtual farm’s) irrigation efficiency. Agricultural pumping reported by the model averages 53,470 acre-feet per year over the 34 year period of simulation. The average virtual farm irrigation efficiency in the original model is 75%, meaning that the average consumptive use in the original model is 40,100 acre-feet per year. Reducing the total amount of water pumped by 10%, to 48,120 acre-feet per year, results in an average irrigation efficiency of 83%. Therefore, all virtual farm irrigation efficiencies were initially multiplied by 1.11 to obtain the new irrigation efficiencies. Model results showed that this change did not result in the necessary reduction in agricultural pumping. Iterative model simulations were run to establish the final irrigation efficiency of 85% that resulted in a 10% (or approximately 5,000 acre-foot) reduction in groundwater pumping.

The 8,600 acre-feet per year of CDS deliveries were initially distributed monthly based on average historical monthly deliveries. Initial simulations revealed that this approach resulted in less than 8,600 acre-feet of water being delivered to farms in the CDS area. The model input was iteratively adjusted until model results indicated that the CDS delivered an average annual volume of 8,600 acre-feet per year for the 34-year simulation.

The sources of water delivered by the CDS are not explicitly simulated.

- College Lake is not simulated in the original USGS developed model, therefore the 2,400 acre-feet of water College Lake supplies to the CDS were introduced as a source of water from outside the model.

- Annual yield from the Harkins Slough recharge project in the original USGS developed model is dependent on rainfall and groundwater
elevation. The selected alternative required that the Harkins Slough recharge project consistently deliver 1,000 afy regardless of rainfall and groundwater elevation. Therefore, the simulated Harkins Slough project was deactivated in the selected alternative model. The 1,000 acre-feet of water from the Harkins Slough project was introduced as a source of water from outside the model.

- Similar to the Harkins Slough recharge project, the selected alternative required that the Watsonville Slough/North Dunes recharge project consistently deliver 1,200 acre-feet of water per year regardless of rainfall and groundwater elevation. Therefore, the 1,200 acre-feet of water from the Watsonville Slough/North Dunes recharge project was also introduced as a source of water from outside the model.
SECTION 6
MODEL RESULTS

6.1 MODEL ANALYSIS APPROACH

Model results are used to assess the selected alternative using two criteria: effectiveness at reducing seawater intrusion and effectiveness at reducing overdraft.

Seawater intrusion is estimated from the model’s simulated groundwater flows. Each model cell along the Pajaro Valley coastline is analyzed for seawater intrusion (Figure 8). The flow direction, averaged over the 34 year simulation is calculated for each coastal model cell. If the average flow direction is towards land rather than towards the ocean, the model cell is counted as a cell that contributes to seawater intrusion. All ocean inflows and outflows are summed for the cells that contribute to seawater intrusion, resulting in a total average seawater intrusion rate. Seawater intrusion is only calculated for the Alluvial Aquifer, Upper Aromas Aquifer, and Lower Aromas Aquifer. These aquifers provide most of the water that is pumped from Pajaro Valley, and therefore are of the most concern for seawater intrusion.

Seawater intrusion also occurs in the Purisima Aquifer, the confining layer below the Alluvial Aquifer, and the Aromas Red Sands confining layer. Because the confining layers consist of low permeability materials such as clay and silt, the amount of groundwater pumping and subsequent seawater intrusion in these layers is small. Therefore, halting seawater intrusion in the confining layers is of limited benefit considering the potential costs involved. Quantifying and halting seawater intrusion in the Purisima Aquifer is not addressed for the following reasons:

- There are limited groundwater data from the Purisima Aquifer in Pajaro Valley. Groundwater elevation data are sparse and there is no current estimate of seawater intrusion.
- The limited data from the Purisima Aquifer means that the groundwater model is less reliable for the Purisima Aquifer than for the Alluvial or Aromas Aquifers.
- Relatively few wells in Pajaro Valley pump from the Purisima Aquifer, particularly near the coast. Therefore any seawater intrusion that might
be occurring in the Purisima Aquifer has little impact on the Valley’s water supply.

- Conditions in the Purisima Aquifer in the groundwater model are highly controlled by conditions north and south of Pajaro Valley; where the BMP has no influence.

Overdraft is defined in this project as a net loss in the amount of groundwater stored in the Pajaro Valley aquifers. Overdraft can be estimated by the change in storage term produced by MODFLOW2005 for all onshore model cells. Some modifications to the change in storage term are necessary, however, to allow comparisons between scenarios. Overdraft is only calculated for the Alluvial Aquifer, Upper Aromas and Lower Aromas Aquifers.

The approaches to estimating both seawater intrusion and overdraft from the existing groundwater model were devised and refined exclusively for this project. Because the PVHM does not directly provide these values, there is some potential uncertainty in estimating both seawater intrusion and overdraft. Therefore, the model results should be used as guidance to determine the effect of various projects, but not as estimates of absolute results. Verification of the success of each project will come from ongoing and future monitoring.
Figure 8: Coastal Model Cells Used for Estimating Seawater Intrusion
6.2 CURRENT CONDITIONS

Model results from the baseline simulation show that the current conditions include the following:

- Seawater intrusion in the Alluvial Aquifer, the Upper Aromas Aquifer, and the Lower Aromas Aquifer (the aquifers of interest) is currently 1,900 afy.
- Overdraft in the Alluvial Aquifer, the Upper Aromas Aquifer, and the Lower Aromas Aquifer (the aquifers of interest) is currently 1,400 afy.

Note that all rates are rounded to the nearest 50 acre-feet per year.

6.3 SELECTED ALTERNATIVE SIMULATION RESULTS

Model results from the selected alternative simulation show that if current irrigation and water delivery practices were to continue, the following would be expected:

- Seawater intrusion in the Alluvial Aquifer, Upper Aromas Aquifer, and Lower Aromas Aquifer would continue at a rate of 200 afy. Almost all of this would be in the Lower Aromas Aquifer. This represents a 90% reduction in seawater intrusion.
- Overdraft in the Alluvial Aquifer, Upper Aromas Aquifer, and Lower Aromas Aquifer would be eliminated. On average, groundwater elevations in all three aquifers would rise under the selected alternative.

6.4 COMPARISON OF BASELINE AND SELECTED ALTERNATIVE SIMULATIONS

The baseline simulation and the selected alternative simulation can be compared graphically. Figure 9 through Figure 11 compare areas of seawater intrusion under baseline (current) conditions and after the selected alternative is implemented. Although the overall reduction in seawater intrusion is 90%, the amount of reduction varies by aquifer. Locations of existing seawater intrusion are shown in dark red on the left side of each figure. Locations of seawater intrusion after implementing the selected alternative are shown on the right side of each figure. The percentage reduction in seawater intrusion is indicated by the color of the intrusion area. Red indicates no reduction in seawater intrusion.
White indicates 99%+ reduction in seawater intrusion. Areas with 100% reduction in seawater intrusion are removed from the right side graphic in each figure.

Figure 9 shows areas of seawater intrusion in the Alluvial Aquifer, Figure 10 shows areas of seawater intrusion in the Upper Aromas Aquifer, and Figure 11 shows areas of seawater intrusion in the Lower Aromas Aquifer.

Figure 9 shows that under current conditions seawater intrusion occurs along most of the coast in the Alluvial Aquifer, but occurs in only limited and isolated areas under the selected alternative. Seawater intrusion denoted by the light red areas at the southern end of the coast in the selected alternative is an artifact of the model boundary condition; the model will always show seawater intrusion in this area because of the low groundwater elevations in neighboring Salinas Valley. Implementing the selected alternative reduces seawater intrusion in the Alluvial Aquifer by 94%.

Figure 10 shows that under current conditions seawater intrusion occurs along most of the coast in the Upper Aromas Aquifer, but occurs in only limited and isolated areas under the selected alternative. As with the Alluvial Aquifer, seawater intrusion denoted by the light red areas at the southern end of the coast in the selected alternative is an artifact of the model boundary condition; the model will always show seawater intrusion in this area because of the low groundwater elevations in neighboring Salinas Valley. Implementing the selected alternative reduces seawater intrusion in the Upper Aromas Aquifer by 96%.

Figure 11 shows that under both current conditions and the selected alternative, seawater intrusion occurs in the Lower Aromas Aquifer along most of the coast. This seawater intrusion appears to be driven by deep inland pumping. The wells that appear to drive the Lower Aromas Aquifer intrusion are not influenced by the proposed CDS deliveries. Implementing the selected alternative reduces seawater intrusion in the Lower Aromas Aquifer by 66%.
Figure 9: Extent of Simulated Seawater Intrusion – Alluvial Aquifer
Figure 10: Extent of Simulated Seawater Intrusion – Upper Aromas Aquifer

1. This figure shows simulated location and relative degree of existing seawater intrusion and seawater intrusion after implementation of the selected alternative for one of three different aquifers.
2. The aggregated reduction in seawater intrusion for the three aquifers is 90%.
Figure 11: Extent of Simulated Seawater Intrusion – Lower Aromas Aquifer

1. This figure shows simulated location and relative degree of existing seawater intrusion and seawater intrusion after implementation of the selected alternative for one of three different aquifers.
2. The aggregate reduction in seawater intrusion for the three aquifers is 90%.
Maps showing average expected groundwater level rises resulting from the selected alternative are shown in Figure 12 through Figure 14. Groundwater level rise is shown for the three aquifers of interest. These figures show that groundwater levels generally rise throughout the basin. As expected, the greatest groundwater elevation rise is beneath the CDS, where the most pumping reduction occurs.

Three smaller groundwater mounds are observed along the mountain front at the northeast side of the basin in the Lower Aromas Aquifer. The southernmost of these three mounds partially results from recharge of water near Murphy’s crossing. Based on our current understanding of the groundwater model, we believe Figure 12 through Figure 14 likely underestimate some of the expected groundwater level rises. Therefore, the selected alternative will likely result in a greater benefit than that shown on these figures.
Figure 12: Average Water Level Change Due to Implementing Selected Alternative – Alluvial Aquifer
Figure 13: Average Water Level Change Due to Implementing Selected Alternative – Upper Aromas Aquifer
Figure 14: Average Water Level Change Due to Implementing Selected Alternative – Lower Aromas Aquifer
6.5 SIMULATED OPTIONS ON THE SELECTED ALTERNATIVE

Three options on the selected alternative were simulated with the PVHM model for comparison purposes. The three options included the following assumptions:

6.5.1 SELECTED ALTERNATIVE OPTION 1

This option is identical to the selected alternative, with the following modifications:

- The 500 acre-feet per year of recharge near Murphy’s Crossing is removed from the alternative.
- The Watsonville Slough/North Dunes project is removed from the alternative.
- The College Lake project is removed from this alternative.
- Blend water for the CDS is derived from wells near the City of Watsonville.
- The total amount of water delivered to the CDS under Option 1 is 6,200 acre-feet per year.

6.5.2 SELECTED ALTERNATIVE OPTION 2

This option is identical to the selected alternative, with the following modifications:

- The 500 acre-feet per year of recharge near Murphy’s Crossing is removed from the alternative.
- The Watsonville Slough/North Dunes project is removed from the alternative.
- The total amount of water delivered to the CDS under Option 2 is 7,400 acre-feet per year.

6.5.3 SELECTED ALTERNATIVE OPTION 3

This option is identical to the selected alternative, with the following modifications:

- The 500 acre-feet per year of recharge near Murphy’s Crossing is removed from the alternative.
6.5.4 Results from Selected Alternative Option Simulations

Table 2 summarizes the results for the selected alternative option simulations. This table shows that the selected alternative is the only option that eliminates overdraft. Additionally the rate of remaining seawater intrusion is lowest in the selected alternative, and is within the likely error of the model.

Table 2: Selected Alternative Option Results

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Simulated Seawater* Intrusion (acre-feet/year)</th>
<th>Simulated Overdraft (acre-feet/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Simulated Seawater* Intrusion (acre-feet/year)</td>
<td>Simulated Overdraft (acre-feet/year)</td>
</tr>
<tr>
<td>Baseline</td>
<td>1,900</td>
<td>1,400</td>
</tr>
<tr>
<td></td>
<td>Acre-Feet % Solved</td>
<td>Acre-Feet % Solved</td>
</tr>
<tr>
<td>Option 1</td>
<td>1,600 15</td>
<td>800 45</td>
</tr>
<tr>
<td>Option 2</td>
<td>650 65</td>
<td>500 65</td>
</tr>
<tr>
<td>Option 2</td>
<td>650 65</td>
<td>500 65</td>
</tr>
<tr>
<td>Option 3</td>
<td>300 85</td>
<td>300 80</td>
</tr>
<tr>
<td>Selected Alternative</td>
<td>200 90</td>
<td>None 100</td>
</tr>
</tbody>
</table>

*In the Alluvium, Upper Aromas & Lower Aromas Aquifers.
SECTION 7
CONCLUSIONS AND RECOMMENDATIONS

The PVHM groundwater model shows that, based on likely future hydrologic conditions, implementing the selected alternative will eliminate overdraft in the most productive aquifers in Pajaro Valley, and will reduce seawater intrusion by 90% in the aquifers of interest. Projects focused on the coastal portions of the Valley predominantly alleviate seawater intrusion; projects focused inland predominantly alleviate overdraft. A combination of demand management (conservation), and coastal and inland projects is the most efficient approach to alleviating both issues.

The existing groundwater model provides guidance for selecting projects that should be implemented through the BMP. However, the model is better suited for comparing relative benefits among alternatives than for providing definitive values of seawater intrusion and overdraft because, as with all groundwater models, there is some error in model accuracy.

We recommend the following:

- Projects in the BMP selected alternative should be implemented in a logical sequence, with ongoing monitoring to assess the effect of each project. Monitoring should include groundwater elevations throughout the basin, and groundwater quality near the coast.

- Validate the extent and rate of seawater intrusion with field monitoring. While the model estimates the extent and rate of seawater intrusion, the model results have not been compared to field data because adequate data do not exist. Additional monitoring and analyses of existing data could provide show where saltwater concentrations are increasing and where they are decreasing in the aquifer. These analyses can be used to verify model results.

- Projects should be modified based on monitoring results. Projects that are more successful than anticipated may reduce the need for later projects. Projects that do not meet expectations may require additional modifications.

- The groundwater model should be continuously updated and improved to reflect the monitoring results. Continuous improvement of the model
will enable more accurate and credible predictions for the effects of future projects or groundwater management activities.
SECTION 8
REFERENCES


