Pre-Read Summary for Santee Basin GRRP Modeling

April 16, 2015 IAP Workshop

This document provides a summary of feasibility groundwater flow and travel-time modeling completed for the Santee Basin Groundwater Recharge and Replenishment Project (GRRP). The GRRP is an indirect potable recharge project. The modeling was completed by Daniel B. Stephens & Associates, Inc. (DBS&A), a consulting firm that specializes in managed aquifer recharge and extraction projects. The primary objective of this preliminary modeling effort is to determine if implementation of the GRRP is feasible within the portions of the alluvial aquifer located in Santee, California. The primary sources of information on which the modeling is based are:


DWR well logs supplied by PDMWD


**Determination of Project Area**

Based upon review of the URS (2014) report, and to a lesser extent Bondy and Huntley (2001), it was decided that the feasibility modeling should be conducted for the area that URS refers to as the “Easterly Study Area” in their report, and the adjoining area farther to the east (see Location Map attached). This is the portion of the Santee Aquifer from the vicinity of Magnolia Avenue on the west extending a little over 3 miles to the east to the intersection of Highway 67 and Willow Road. This area was selected because:
1. The aquifer thickness is generally greater in the eastern area than it is in the west, and is believed to be a better location for installation and operation of vertical injection and extraction wells.

2. There is greater thickness of unsaturated zone (zone between the land surface and the water table) in the eastern area than in the western area (about 30 feet in the east compared to about 15 feet in the west).

3. There are large ponds in the former river channel where it was historically dredged in the west; there are less extensive ponds in the east. The ponds could be problematic for some aspects of project implementation because it would be difficult to avoid the comingling of injected water and surface water.

Based on data in URS (2014), the aquifer hydraulic conductivity (K) values in the eastern area appear to be lower than they are to the west. However, hydraulic conductivity was estimated in the eastern area based on slug tests conducted on small-diameter monitor wells, while hydraulic conductivity to the west was estimated using an aquifer test with a pumping well and multiple observation wells. The aquifer test method is a more comprehensive and accurate method for measuring aquifer hydraulic conductivity than is the slug test method. Even if the aquifer hydraulic conductivity is lower to the east (which may not be true for the entire area), it is anticipated that the benefits of the greater aquifer thickness would likely to outweigh the lower aquifer hydraulic conductivity relative to the feasibility of project implementation.

**Analytical Computations**

Prior to constructing the numerical model, a series of analytical computations were completed using the Theis solution, which provides the change in water level through time, at a given distance from a pumping or injection well. The effects of multiple wells operating at the same time, as well as simple boundary conditions can also be considered through superposition. Initial computations were conducted for multiple flow rates and well configurations within the study area. The limited aquifer extent was approximated through the use of two parallel no-flow boundaries. The results of these initial computations are not presented here, but the conclusions of this analysis were:
1. The project appeared to be reasonably feasible such that the completion of more detailed numerical modeling was warranted.
2. A “cross valley” configuration of injection and pumping wells, where injection wells are aligned along one side of the valley and pumping wells along the other side, appeared to be the most effective means of project implementation, particularly with regard to meeting the required residence time for injected water of 4 months.

**Numerical Modeling**
The U.S. Geological Survey (USGS) code MODFLOW-NWT (Niswonger et al., 2011) was used to complete the simulations. The NWT version of the USGS MODFLOW code was applied because it is able to simulate fluctuations of the water table between model layers (i.e. wetting and drying of model cells), which is required to accurately simulate project effects within the study area.

**Model Domain and Grid**
The extent of the numerical model domain (Figure 1) was based on the results of the analytical computations. The base of the model is defined as the contact between the alluvium and the underlying, low-permeability granitic rocks (Figure 1). The model grid ranges in size from 20 feet by 20 feet in the vicinity of the proposed injection and extraction wells, and increases in size to 100 by 100 feet at the edge of the active domain.

There are two model layers. Model layer 1 is representative of the young alluvium, and is assumed to be 50 feet thick based on multiple well logs. Where the aquifer thickness is greater than 50 feet, the additional thickness is represented by model layer 2 and is assumed to be composed of older alluvium, which has a greater proportion of fine grained material (silt and clay) than the younger alluvium. The maximum aquifer thickness, measured as land surface to the base of aquifer, occurs in the San Diego River Valley and is about 185 feet (Figure 1).

**Boundary Conditions**
Model boundary conditions are illustrated on the figures.
• General Head Boundaries (GHBs) are used for groundwater inflow from the northeast and groundwater outflow to the west. These boundaries are set far enough from the pumping and injection such that water level changes are zero or small.

• Recharge from precipitation and all other potential sources (e.g. landscape irrigation) was assumed to be 0.85 inches per year. This recharge rate is applied across the entire active model domain, with the exception of the San Diego River channel and floodplain, where recharge is assumed to be zero due to the dense vegetation and the fact that the water table is close to land surface.

• Multiple ponds that exist in the San Diego River channel are simulated using the MODFLOW Lake package. Evaporation from the pond surfaces is prescribed to occur at the average annual rate of 57 inches per year, consistent with average potential evapotranspiration in Bondy and Huntley (2001). These ponds are also simulated to receive the annual average precipitation of 12 inches per year. The pond depths are assumed to be 50 feet, consistent with model layer 1. The pond depths are variable through the study area (two measurements show them to be 33 to 54 feet in depth); in a future version of the model the pond depths could be simulated in greater detail using an additional model layer.

• All other model boundaries (bottom and sides) are assumed to be no flow.

Model Scenarios
Two basic model scenarios were run - low permeability (Low K) and high permeability (High K). The Low K scenario is based on the average hydraulic conductivity of the slug tests completed for small diameter monitor wells P-1 through P-3 (URS, 2014), which is 22 feet per day (ft/d). This value was implemented in the model by assigning 36 ft/d to Layer 1, and 18 ft/d to layer 2, based on the observation that the younger alluvium appears to have higher hydraulic conductivity than the older alluvium. For the High K scenario a hydraulic conductivity of 73 ft/d was used for both model layers based on the results of the aquifer test conducted for well URS-MW-1a, about 2,400 feet west of the model domain. A vertical to horizontal anisotropy factor of 10 was assumed for all model runs (i.e. the vertical hydraulic conductivity is 10 times less than the horizontal hydraulic conductivity). In addition, a specific yield and specific storage of 0.15 and $1 \times 10^{-5}$ ft$^{-1}$, respectively, were assumed for all simulations.
Simulated water levels for the High K and Low K scenarios are provided in Figures 2a and 2b, respectively. Although the groundwater model was not calibrated, the simulation results match the observed water level data reasonably well (Figure 2c). A summary of the simulation mass balance, for the case of no project pumping or injection, is provided below.

Table 1 - Simulated mass balance (values in acre-feet per year).

<table>
<thead>
<tr>
<th>Source</th>
<th>Low K Scenario</th>
<th>High K Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underflow from the northeast</td>
<td>38.6</td>
<td>176.9</td>
</tr>
<tr>
<td>Recharge</td>
<td>146.6</td>
<td>146.6</td>
</tr>
<tr>
<td>Seepage from the ponds</td>
<td>163.5</td>
<td>362.5</td>
</tr>
<tr>
<td><strong>Total Inflow</strong></td>
<td><strong>348.7</strong></td>
<td><strong>686.0</strong></td>
</tr>
<tr>
<td>Underflow to the west</td>
<td>104.7</td>
<td>243.4</td>
</tr>
<tr>
<td>Seepage into the ponds</td>
<td>244.1</td>
<td>443.5</td>
</tr>
<tr>
<td><strong>Total Outflow</strong></td>
<td><strong>348.8</strong></td>
<td><strong>686.9</strong></td>
</tr>
</tbody>
</table>

**Summary of Results**

Several predictive simulations were conducted for the Low K and High K scenarios. In each scenario, the goal was to determine the feasibility of achieving full project implementation, defined as 1.7 MGD of injection and commensurate pumping during the summer, and 2.8 MGD of injection and commensurate pumping during the winter, which is an average annual flow rate of 2.2 MGD. Each period (summer and winter) is assumed to be 6 months in duration.

We assumed, as an approximate design criteria, that the water table should remain 10 feet or greater below land surface. This constraint will need to be confirmed or adjusted by a registered geotechnical engineer.

For the Low K scenario, project implementation with varied seasonal injection rates (1.7 MGD summer and 2.8 MGD winter) is highly unlikely. The simulation shows flooded cells around a few of the injection wells which means that groundwater is expected to rise above the ground surface (Figure 3). However, the project is potentially feasible under the scenario of a uniform injection and extraction rate of 1.7 MGD (Figures 4a through 4c). Figure 4b shows that the water table would be between 5 and 10 feet below land surface at 6 of the 14 injection wells, a condition that may be alleviated considering that:
1) there are likely some higher permeability zones within the aquifer, and
2) there are some additional options for increasing the spacing between injection wells.

The minimum simulated travel time for the Low K scenario between an injection well and a pumping well is 184 days, or about 6 months (Figure 4c) for the case of uniform injection and extraction of 1.7 MGD.

For the High K scenario, the full project implementation using seasonally varied injection rates (1.7 MGD summer and 2.8 MGD winter) appears to be feasible (Figures 5a through 5c). Figure 5b illustrates that the simulated water table is greater than 15 feet below land surface for this scenario at all injection wells. The minimum simulated travel time for this scenario between an injection well and a pumping well is 142 days, or about 4.7 months (Figure 5c).

**Recommendations**

Based on this initial numerical modeling investigation, implementation of the GRRP appears to be feasible. The completed model can serve as the basis for additional simulations of alternatives and as a framework for moving forward. The District should proceed with additional investigations recommended below.

**Aquifer Testing** - The predictive simulations illustrate that a good understanding of aquifer properties (hydraulic conductivity of the recent and old alluvium and aquifer thickness) in the project area is critical to successful project planning and implementation. An aquifer characterization field program (including pumping tests) should be planned and implemented for the project area.

We also recommend that water levels at available monitor wells be monitored on a regular basis to determine changes due to seasonal and climatic effects. Measurements should be collected at least quarterly. Alternatively pressure transducers, which can be set at a predetermined interval such as hourly or daily, can also be used. Regular measurement of one or more selected pond levels would also be beneficial.
Groundwater Flow Modeling - The groundwater flow model should be updated to account for the additional aquifer characterization information when it becomes available. Other recommendations include:

- The next version of the model should be constructed to account for seasonal effects and more complete simulation of surface water-groundwater interaction within the San Diego River Valley. For example, a third model layer would be needed to better simulate some of the ponds within the San Diego River channel.
- Additional, relevant information within and adjacent to the model domain should be collected and considered for implementation into the next version of the model. For example, the estimated or metered (if available) pumping for the Willowbrook Country Club golf course should be implemented in the model.

References
Legend

NAME

Ray Stoyer Water Recycling Facility

Original Area of Study by BOR

Current Area of Study

Location Map: Santee Basin Groundwater Recharge and Replenishment Project
Figure 1

PADRE DAM MWD SANTTEE BASIN MODELING
Base of Aquifer

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4/9/2015
JN WR12.0249

Explanation
- 312 Base of aquifer (ft msl)
- Bondy and Huntley (2001) well
- URS well
- DWR well
- Base of aquifer elevation contour (ft msl)
- NoFlow

NoFlow

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PRELIMINARY SUBJECT TO REVISION
Simulation Results for Current Conditions for Low K Scenario

Daniel B. Stephens & Associates, Inc.
4/10/2015

PRELIMINARY SUBJECT TO REVISION
Simulation Results for Current Conditions for High K Scenario

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4/10/2015
JN WR12.0249

Explanation
- URS well
- Recently surveyed well
- Simulated head (ft msl)
- Dry cell
- Flooded cell

Model Boundary
- General head
- Lake
- No flow
Comparison of Simulated and Observed Water Levels

(a) Low K

(b) High K
Simulated Change in Water Level for Low K Scenario for Full Injection (1.7 MGD Summer, 2.8 MGD Winter) After 5 Years

Pumping and injection rates posted for each well represent summer (top) and winter (bottom) values.
Figure 4a

PADRE DAM MWD SANTEE BASIN MODELING

Simulated Change in Water Level for Low K Scenario for Reduced Injection (1.7 MGD All Year) After 50 Years

Explanation
- Pumping well (gpm)
- Injection well (gpm)
- Simulated change in water level (ft)

Model Boundary
- General head
- Lakes
- No flow

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JN WR12.0249
Figure 4b
PADRE DAM MWD Santee Basin Modeling
Simulated Depth to Water Below Land Surface for Low K Scenario for Reduced Injection (1.7 MGD All Year) After 50 Years

- Pumping well (gpm)
- Injection well (gpm)
- Simulated depth to water (ft)
- Dry cell

Model Boundary
- General head
- Lake
- No flow
Simulated Particle Traces for Low K Scenario for Reduced Injection (1.7 MGD All Year) After 50 Years

Yellow particle trace represents shortest time for an injection particle to reach a pumping well (184 days).
Simulated Change in Water Level for High K Scenario for Full Injection (1.7 MGD Summer, 2.8 MGD Winter) After 10 Years

Pumping and injection rates for each well represent summer (top) and winter (bottom) values.
Figure 5b
PADRE DAM MWD SANTEE BASIN MODELING

Simulated Depth to Water for High K Scenario for Full Injection (1.7 MGD Summer, 2.8 MGD Winter) After 10 Years

Pumping and injection rates for each well represent summer (top) and winter (bottom) values.
Simulated Particle Traces for High K Scenario for Full Injection (1.7 MGD Summer, 2.8 MGD Winter) After 10 Years

Yellow particle trace represents shortest time for an injection particle to reach a pumping well (142 days).