GROUNDWATER MODEL APPROACH AND METHODOLOGY

Pixley Groundwater Banking Project
Tulare County, California

Hydrology and Water Quality

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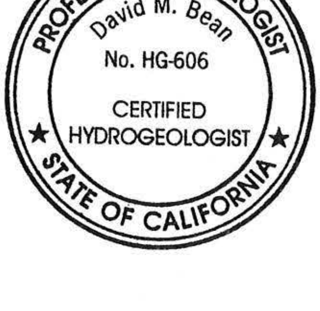

TABLE OF CONTENTS

Page

TABLES

FIGURES

TABLE OF CONTENTS
(Continued)

GROUNDWATER MODEL APPROACH AND METHODOLOGY
Pixley Groundwater Banking Project
Tulare County, California

ABBREVIATIONS

af	Acre-Feet
af/y/a	Acre-Feet per Year per Acre
CEQA	California Environmental Quality Act
CVHM	Central Valley Hydrologic Model
CVP	Central Valley Project
DEID	Delano-Earlimart Irrigation District
EA	Environmental Assessment
ft/d	Feet per Day
GHBs	General Head Boundaries
GUI	Graphic User Interface
GWV	GroundWater Vistas
K_h	Horizontal Hydraulic Conductivity
MNW	MODFLOW Multi-Node Well Package
PID	Pixley Irrigation District
Project	Pixley Groundwater Banking Project
RCH	MODFLOW Recharge Package
S_s	Specific Storage
S_y	Specific Yield
SGMA	California Sustainable Groundwater Management Act
USGS	United States Geological Survey

1.0 PROJECT BACKGROUND

The proposed Pixley Groundwater Banking Project in southern Tulare County, California, in the southeasterly portion of the San Joaquin Valley (Figure 1). The Project will be constructed and operated within the Pixley Irrigation District (PID). The PID covers 69,550 acres and borders the Delano-Earlimart Irrigation District (DEID) which lies to the south. The DEID covers 54,418 acres and spans the Tulare/Kern County line between Highway 43 on the west and Road 184 on the east. The PID is a cross-valley canal contractor and a non-long-term contractor of the Friant Division Central Valley Project (CVP). The PID purchases and delivers as much Class 2 water as possible. DEID has a Friant Division CVP contract for 108,000 acre-feet (af) of Class 1 water and 74,500 af of Class 2 water. However, the actual amount of water supplied to DEID in recent years has been significantly less due to recent hydrology and the implementation of the San Joaquin River Restoration Project.

The long-term average rainfall in the area of the proposed Project area is about 10.3 inches per year and occurs largely during winter and spring months (Figure 2). Therefore, agriculture is almost entirely dependent on irrigation.

1.1 CURRENT MODELING OBJECTIVES

The objectives of the current modeling effort are to:

- evaluate the potential for excessive mounding in groundwater elevations beneath the proposed Project area and potential resulting impacts;
- evaluate the potential for excessive declines in groundwater elevations beneath the study area during periods of recovery and potential resulting impacts; and
- evaluate potential impacts from permanent changes in groundwater storage beneath the study area.

2.0 HYDROGEOLOGIC CONCEPTUAL MODEL

A hydrogeologic conceptual model is a simplified representation of the groundwater flow system, frequently in the form of a block diagram or cross section (Anderson & Woessner, 1991). The nature of the conceptual model determines the dimensions of the numerical model and the design of the grid. The purpose of the conceptual hydrogeologic model is to establish an initial understanding of the groundwater system and organize the associated field data so that the system can be analyzed more effectively. Four steps were completed in developing the conceptual hydrogeologic model for the proposed Project area:

1. Description of the model domain and physiographic features.

2. Delineation of the hydrostratigraphic units.
3. Estimation of the water budget.
4. Approximation of the flow system.

2.1 MODEL DOMAIN AND PHYSIOGRAPHIC FEATURES

The northwestern corner of the proposed Project area is located approximately 3 miles southeast of the unincorporated community of Pixley, while the southwestern corner of the proposed Project area is located approximately 4 miles northeast of the unincorporated community of Earlimart (Figure 1). The model domain, which comprises an area of approximately 400 square miles, extends 7 miles to the east and south, and 10 miles to the north and west from the edge of the proposed Project (Figure 3). Physiographic features of significance include Deer Creek.

Deer Creek is a natural drainage channel that has the potential to convey and recharge water within the PID service area. Deer Creek flows from east to west through southern PID and through the center of the proposed Project area. Historic records indicate that the PID diverted an average annual amount of 10,300 af from Deer Creek from 1994 to 2006. However, 4 of those 13 years provided no diverted water from Deer Creek (P&P, 2008).

The topography of southern Tulare County rises moderately from about 200 feet above mean sea level west of the proposed Project area at the western edge of the county (approximately 17 miles to the west) to approximately 650-feet above mean sea level at the toe of the Sierra Nevada foothills approximately 11 miles to the east. Ground surface elevations within the model domain range from about 215 to 615 feet above mean sea level.

2.2 HYDROSTRATIGRAPHY

The proposed Project area is located within the Great Valley geomorphic province, which is a large, elongate, northwest-trending trough extending more than 430 miles. Sedimentation within the valley consists of several thousand feet of marine and non-marine sedimentary rock derived from Mesozoic through recent age erosion of the Coast Ranges and the Sierra Nevada Mountains (Tulare County, 2012). The proposed Project area is underlain by part of the Great Valley Sequence, primarily younger unconsolidated Quaternary age alluvial fan deposits.

An evaluation of the Project hydrogeologic setting is presented in part H2 of this appendix. It entailed a review of over 450 water well drillers reports and oil and gas electric logs, plus nine geotechnical borings at the Project site to investigate the upper 100 feet of sediments. Two regional and two site-specific geologic cross sections were constructed to characterize the occurrence of aquifer materials and their stratigraphic relationships. The regional cross sections delineate the edge of the Corcoran Clay west of the Project site and the nature and distribution of aquifer units that are targets of water supply wells in the groundwater basin underlying PID. Aquifer materials exhibit variable continuity and are interbedded with finer-grained materials including clay beds.

The conceptualization of the aquifer system in the Project area is of a single aquifer system with no continuous clay or other fine-grained sediments separating shallow unconfined from deeper confined systems. From its configuration, the aquifer system is expected to be leaky, but with impedance to vertical flow of varying degrees. Direct recharge would move vertically and horizontally and accrue to groundwater storage in the manner that streamflow from Deer Creek and irrigation conveyances recharge the underlying aquifer system under existing conditions. This conceptualization is reflected in numerical model constructed for the analysis of Project impacts to groundwater resources.

2.3 WATER BUDGET

The water budget describes the inflow and outflow to and from the hydrogeologic system. Inflow and outflow can occur from the natural hydraulic boundaries of the system such as precipitation, streams, and lakes or from physical boundaries, such as bedrock, faults or man-made sources like canals, spreading works, water supply wells, and applied water for irrigation. Water balances provide monthly summaries of deliveries, pumping, and recharge water within the proposed Project area. These flows were allocated to model specific boundaries, sources, and sinks as described in the following subsections.

2.3.1 Physical and Hydraulic Boundaries

As shown on the Alquist-Priolo Earthquake Fault Zone map, there are no known earthquake faults within the proposed project area that could act as physical boundary. Additionally, the continental sediments that form the aquifer system at the proposed Project area are between 3,000 and 4,000 feet thick (Williamson et al., 1989).

Aquitard – Sedimentary layers with permeability's so low that they cannot transfer useful amounts of water act as physical boundaries. The Corcoran Clay, which acts as an aquitard over large areas of the Central Valley, has been identified at a depth of 200 feet approximately 2 miles southwest of the proposed Project. Model layers and parameters reflect the presence of the Corcoran Clay outside the Project area.

Bedrock – Compared to the alluvial fans in the valley, the bedrock Sierra Nevada foothills yield little groundwater and essentially form a no-flow boundary. The model domain does not contain any areas where bedrock is at or near the ground surface.

Faults – No known active faults are found within the proposed Project area or within the model domain.

Regional Aquifer System – The regional aquifer system of the proposed Project location is the most significant hydraulic boundary within the model domain. Groundwater pumping and recharge activities outside of the proposed Project area have a direct influence on groundwater levels beneath the proposed Project area.

2.3.2 Sources and Sinks

Several groundwater sources (additions to) and sinks (losses from) influence groundwater levels beneath the proposed Project area. These are described in the following paragraphs.

Sources

Aerial Recharge: Direct aerial recharge from precipitation is a minor source of groundwater recharge within the model domain (DWR, 2012). Rainfall occurs seasonally, primarily during the winter months between November and March. Annual rainfall ranges between 3.71 to 21.32 inches per year and averages 10.3 inches per year (Figure 2).

Streams and Rivers: Recharge from streams and rivers is not a major source of groundwater recharge within the model domain. Historic records indicate that Deer Creek can be a source of recharge within the model domain. However, due to the highly transient nature of flows through the creek, groundwater recharge from Deer Creek was not incorporated into the model.

Water Conveyance: Canals and pipeline distribution systems are not a major source of groundwater recharge within the model domain. Although about 17 miles of the Friant-Kern Canal lies within the model domain, groundwater recharge from the canal is assumed to be minimal since it is concrete lined in this part of its alignment.

Recharge Basins: Recharge basins are a major source of groundwater recharge within the model domain. The model simulated 800 acres of direct recharge consistent with Project design of 500 to 800 acres for recharge basins. The proposed Project provides for an annual "put" amount of up to 30,000 af. The hydrology used to determine how often banking partners would be "putting" water into the bank was based upon DEID's surface water availability under their Friant Division CVP contract surplus to in-District water demands over a base period of 1983 to 2003 (P&P, 2008).

Applied Water: Applied water recharge rates are highly variable, depending on the crop type and availability of surface water. Deep percolation from application of irrigation water is a major source of groundwater recharge within the model domain. The overall irrigation efficiency, or amount of applied water that reaches the root zone of the plant, for DEID and PID was estimated to range between 75 and 80 percent based on estimated acreage of flood irrigated row crop and drip irrigation permanent crops (CSUF, 1988; P&P, 2008). The remaining 20 to 25 percent of applied water was assumed to be return flow that percolates into the groundwater aquifer.

Sinks

Evapotranspiration: Evaporation and/or evapotranspiration of groundwater that are applied for irrigation purposes, are a minor source of groundwater discharge within the model domain. Evaporation from bare soil can be a significant sink in areas where the water table is near the ground surface (less than 5 feet below ground surface). However, groundwater is first encountered at significant depth (greater than 100 feet) beneath most of the model domain, resulting in little or no direct evaporation of groundwater. Evapotranspiration by agricultural crops of applied water (accounted for externally) can be significant throughout the model domain. However, direct evapotranspiration of groundwater is not a significant sink.

Water Supply Wells: Groundwater pumping by water supply wells is a major source of groundwater discharge within the model domain. It was assumed that most of the groundwater pumping within the district service areas and surrounding area is utilized for agricultural purposes. It was further assumed that groundwater would be pumped to supplement surface water supplies when surface deliveries were less than the crop consumptive demand. The resulting product was then simulated utilizing hypothetical, analytical wells centered in one square mile blocks proximal to sections (Figure 4).

2.4 FLOW SYSTEM

The hydrogeologic and water budget information described previously have been used to conceptualize the movement of groundwater through the model domain. The conceptual groundwater flow system is summarized as follows.

The available data indicate groundwater flow is generally from southeast to northwest. Groundwater recharge is seasonal, primarily from the streams draining the foothills and entering the basin (P&P, 2008). Agricultural return flow from applied water, while not significant beneath any one parcel, is a significant source of groundwater recharge across the model domain. Groundwater pumping to supplement surface water deliveries (or where surface water is unavailable) is the primary sink within the model domain.

3.0 MODEL SELECTION

In order to meet the model objectives discussed in Section 1.1, the groundwater flow model code must meet the following criteria:

- be able to simulate three-dimensional groundwater flow within the model domain;
- be well documented and verified against analytical solutions for specific flow scenarios;
- be accepted by regulatory agencies;
- be readily understandable and usable by others for simulation of future groundwater conditions; and
- have a readily available technical support structure.

The model code MODFLOW2005 (Harbaugh, 2005) meets these criteria and was used to develop the site model.

MODFLOW2005 is a modular, finite-difference computer code developed by the United States Geological Survey (USGS) to simulate three-dimensional groundwater flow. The use of MODFLOW2005 is well documented in technical literature and is the de facto standard for groundwater flow modeling worldwide. MODFLOW2005 solves the partial-differential equations that describe three-dimensional groundwater flow by approximating the solution through the finite-difference method, wherein the continuous groundwater flow system is replaced by a finite set of discrete points in time and space. This process leads to a system of linear algebraic equations, which are solved by the computer program to yield values of potentiometric head and groundwater flow velocity at specific locations and at specific points in time (Harbaugh, 2005).

3.1 CODE ASSUMPTIONS AND LIMITATIONS

There are certain model code assumptions and limitations that constrain the accuracy of the model simulations. The assumptions and limitations that may affect the site models are briefly discussed below, including comments relative to the respective characteristics' presence in, or relevance to, the Project study area, if known.

- **Unsaturated flow:** Unsaturated flow is not simulated. MODFLOW2005 simulates flow in the saturated portion of porous media only. The flow of water through the approximate 200 to 300 foot thick vadose beneath the recharge basins will be primarily in the vertical direction, with some lateral spreading in fine grained materials within the vadose zone. However, no laterally extensive fine grained units have been identified in the vadose zone beneath the proposed basins.

- **Rewetting:** Rewetting of dry model cells is assumed to be from the bottom and side of adjacent cells. While rewetting from the bottom only maybe more computationally efficient, it can lead to simulation error in areas of steep groundwater gradients.

- **Recharge Simulation:** Recharge was assumed to occur at the water table of the upper-most active model layer and not at the ground surface. While this is physically unrealistic, it is a necessary assumption given that MODFLOW2005 does not simulate unsaturated flow.

3.2 GRAPHIC PRE/POST-PROCESSOR

To facilitate the preparation and evaluation of each model simulation, Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler) utilized the graphics pre/post-processor GWVistas™ Version 6.78. (GWV) by Environmental Simulations, Inc. (ESI, 2012). GWV is a Windows® program that utilizes a graphic user interface (GUI) to build and modify a database of model parameters. The model grid, hydraulic properties, and boundary conditions are input using the GUI and then GWV creates the necessary MODFLOW data input files. The input files generated by GWV are generic (standard) MODFLOW files compatible with USGS MODFLOW-88/96, MODFLOW2000 and/or MODFLOW2005. Amec Foster Wheeler also utilized some in-house utilities and Microsoft EXCEL spreadsheets to generate standard MODFLOW data input files for selected simulations and for post-processing simulation results.

GWV comes supplied with MF2005Win32, a Windows® based version of MODFLOW2005 compiled by Environmental Solutions, Inc. MF2005Win32 is a standard version of MODFLOW2005 optimized to run under the Windows® environment. This version of MODFLOW2005 was utilized for the modeling effort.

GWV was also utilized to post-process the model simulations. GWV can display the simulated head results as plan views and cross sections. In plan view, the contour intervals and labels specified by the user and dry cells are denoted by a different color. In cross-section view, the water table surface is also plotted. Most outputs to the screen can be saved in a number of formats (DXF, WMF, PCX, SURFER, etc.) for utilization in other graphics programs.

4.0 MODEL DESIGN

A simplified numerical groundwater model was prepared for the proposed Project area and vicinity to do a comparative evaluation of potential impacts from the water banking storage and recovery operations. The comparative evaluation is considered appropriate for identifying potential impacts to groundwater as required by California Environmental Quality Act (CEQA). The following sections describe the numerical groundwater flow model for the proposed Project area.

4.1 MODEL DOMAIN/GRID

The model domain is centered on the proposed water banking site and simulates groundwater flow upgradient and downgradient of the Project location so that the model boundaries do not unduly affect the simulation results beneath the Project (Figure 3). The model domain, which comprises an approximate 400 square mile area (256,000 acres), extends approximately 2.5 miles north of the unincorporated community of Tipton at the north to 3.3 miles north of the City of Delano on the south. The eastern model boundary extends 0.25 miles east of the unincorporated community of Terra Bella, and the western model boundary extends 6.5 miles west of the unincorporated community of Pixley.

The model grid is oriented approximately 0.75 degrees east of north to align the model grid with the Township/Range/Section grid system, thereby creating 16 cells per section, using the State Plane Coordinate System, California Zone 4, North American Datum 1983. The model grid consists of 50,464 cells with a uniform cell size of approximately 1,320 feet by 1,320 feet (1/4 mile square). The complete model grid consists of 76 rows, 83 columns, and 8 layers.

4.2 MODEL LAYERS

The purpose of model layers is to represent the hydraulic influence of stratigraphy at a scale appropriate to the study objectives. It is understood that stratigraphic variations occur at scales that are both smaller and larger than that characterized for this model. The conceptual and numerical models of the proposed Project area and vicinity were developed based on consideration of several types of hydrostratigraphic information, including literature sources, lithologic and geophysical logs, cross sections, and monitoring well perforation intervals in sub-areas of the proposed Project area (see part H2 of this appendix). In addition, the model layering scheme in the USGS Central Valley Hydrologic Model (CVHM) was adopted for layers below the Corcoran Clay (Faunt, 2009). The layers are summarized in the following table.

TABLE 1:

Model Layers

Layer	Top Elevation (MSL Feet)	Bottom Elevation (MSL Feet)	Thickness (Feet)	Kh Layer Range (feet/day)	Kz Layer Range (feet/day)
Layer 1	340	60	280	1.4000 – 141.3	0.7411 – 0.9984
Layer 2	60	-220	280	4.0000 – 99.92	0.7380 – 0.8998
Layer 3	-220	-295	75	0.1155 – 59.52	0.1440 – 0.7610
Layer 4	-295	-370	75	0.1155 – 59.52	0.1440 – 0.7610
Layer 5	-370	-570	200	0.1155 – 59.52	0.3413 – 0.7610
Layer 6	-570	-770	200	0.7960 – 63.55	0.1000 – 0.7763
Layer 7	-770	-970	200	0.7960 – 63.36	0.1000 – 0.7760
Layer 8	-970	-1170	200	0.7960 – 65.21	0.1000 – 0.7796
Total			**1510**		

Notes:
1. MSL: Mean Sea Level

4.3 HYDRAULIC PARAMETERS

The hydrostratigraphic heterogeneity of the aquifer system has been simulated in the numerical model at a scale appropriate for the modeling objectives. Given the lack of specific hydrogeologic data for the model domain, the hydraulic properties assigned to model layers were extracted from the CVHM and modified with site specific data for the Project area. As such, the model contains no more complexity than is justified by the available data, the model objectives, and the model results to date.

Hydraulic conductivity ranged from 0.1155 to 141.3 feet per day (ft/d) with approximately 50 percent of the values falling between 5 and 20 ft/d. Vertical hydraulic conductivity ranged from 0.1000 to 0.9984 ft/d with approximately 50 percent of the values falling between 0.04 and 0.09 ft/d. Specific storage ranged between 1.7E-05 and 2.5E-02 with 89 percent of the values falling between 1.7E-05 and 6.7E-03. Specific yield and porosity values were fixed at 0.105 and 0.15, respectively.

4.3.1 Hydraulic Conductivity

The horizontal hydraulic conductivity (K_h) for the model were extracted from the CVHM and modified with site specific data including the results of aquifer pumping tests and lithologic boring descriptions within the Project area. A total of 2,327 hydraulic conductivity values were utilized in the model.

4.3.2 Storage

The specific storage (S_s) values for the model were extracted from the CVHM and modified with site specific data including the results of aquifer pumping tests. The layers above the Corcoran Clay have heterogeneous S_s parameters while the layers below the Corcoran Clay have uniform S_s parameters. A total of 421 S_s parameters were utilized in the model.

4.3.3 Specific Yield

A specific yield (S_y) value of 0.105 was assigned uniformly to all zones. This value is within the published range of values for the clayey to sandy sediment types beneath the proposed Project area and vicinity (Spitz and Moreno, 1996).

4.3.4 Porosity

The porosity value was assumed to be 0.15 for all zones. These values are within the published range of values for the sediment types beneath the proposed Project area (Spitz and Moreno, 1996).

4.4 BOUNDARY CONDITIONS

There are no significant hydraulic boundaries within the model domain.

4.4.1 General Head Boundaries

General head boundaries (GHBs) were assigned to all model layers at the northern and southern edges of the model domain to represent the regional aquifer system beyond the model domain. GHBs were not assigned to the east and west edges of the model as groundwater flow is generally perpendicular to these edges. Specified heads for the GHBs were interpolated from a spring 2007 potentiometric surface map, which shows a southeast to northwest flow, and long-term hydrographs that exhibit a regional decline between 1.5 and 4.5 feet per year.

The model boundary condition represents recent and current conditions of overdraft in the study area. It is recognized that future groundwater management under the 2014 California Sustainable Groundwater Management Act (SGMA) requires that certain prioritized groundwater basins in the state must achieve and maintain sustainability according to a timeline specified in the legislation. The Tule Basin is a high priority basin identified as being under conditions of critical overdraft and as such must meet a timeline for sustainability within 20 years of implementing a Groundwater Sustainability Plan in 2020. For CEQA purposes, findings from the subject modeling would apply for either continued overdraft or stabilization of groundwater levels under SGMA.

4.5 Sources and Sinks

As described in Section 2.3.2, there are a number of groundwater sources and sinks within the model domain. Most of the source and sinks are variable over time during the simulation period.

4.5.1 Net Recharge

The Recharge (RCH) Package of MODFLOW2005 allows for the specification of temporally and spatially variable data arrays. Multiple data arrays are permitted but require extensive re-writing of the master control files. To accommodate simulation of multiple source terms within the proposed Project area model, GWV was used to prepare separate data arrays for recharge basins and applied water. Although these data arrays could be combined within a MODFLOW2005 simulation, it was determined that the separate arrays could be input into a spreadsheet and combined into a single Net-RCH array. Combining the recharge data arrays using a spreadsheet allowed for the rapid re-generation of the Net-RCH input file and simplified generation of the MODFLOW2005 data sets.

4.5.2 Agricultural Pumping

The primary sink in the model is agricultural pumping to meet crop consumptive demand. Annual crop consumptive demand in the area has been estimated to be approximately 2.541 acre feet per year per acre (af/y/a) (P&P, 2008). Assuming an irrigation efficiency of 75 percent, the total crop demand is approximately 3.4 af/y/a. Actual historical pumping records for most wells within the study area are not available. Therefore, it was assumed that groundwater would be pumped to supplement surface water supplies when deliveries were less than the total crop consumptive demand or where/when surface water deliveries were not available.

A spreadsheet that included surface water deliveries was prepared to estimate agricultural pumping demand in each section. Monthly agricultural pumping was then estimated for hypothetical agricultural wells centered in one square mile blocks (proximal to sections). The difference between agricultural demand and available surface water supply was assumed to be provided by pumping wells. The spreadsheet was used to prepare a file of monthly demand by well for import into GWV. Combining the various data arrays using a spreadsheet allowed for the rapid re-generation of the well input file and simplified generation of the MODFLOW2005 data sets.

5.0 PREDICTIVE SIMULATIONS

A 40-year predictive model was prepared (using 240 bi-monthly [~60 day] stress periods) to evaluate potential impacts of the proposed water banking facility on groundwater conditions beneath and in the vicinity of the proposed Project area. A Base Case scenario representative of a No Project Alternative was prepared assuming that agricultural demand, and surface water deliveries for Pixley and Delano-Earlimart Irrigation Districts, would remain consistent with historic records. Also, a potential water banking scenario was prepared using historic hydrology, to simulate periods of recharge and recovery during the 40 year predictive model.

5.1 THE BASE CASE SCENARIO

The Base Case scenario groundwater flow model simulates a future 40-year period during which current conditions of agricultural land use continues, and in which the proposed water bank does not exist. The Base Case scenario assumes that the DEID will continue to receive surface water supplies (supplemented as needed with pumping), while the PID continues to rely on groundwater pumping alone. Surface water supplies and agricultural pumping are simulated on a seasonal basis. The GHBs were set to continue the observed 1.5 to 4.5 feet per year regional decline in the water (see Section 4.4.1). The forecast simulation results were evaluated using three hypothetical observation wells arrayed in a general southeast to northwest direction aligned with groundwater flow (Figure 4). Observation Well 1 is located approximately 3 miles north of the proposed Project area within PID boundary. Observation Well 2 is located at the proposed Project area. Observation Well 3 is located approximately 3 miles south of the proposed Project area within the DEID boundary.

5.1.1 The Base Case Scenario Results

As noted above, the Base Case scenario simulation results were evaluated using three hypothetical observation wells (Figure 4). In the northern third of the model domain, Observation Well 1 exhibited an approximate 87-foot decrease in head over the 40-year period (Figure 5). At the site of the proposed Project area, Observation Well 2 had a 71.6 foot decrease in head over the 40 year period (Figure 6). In the southern third of the model domain, Observation Well 3 had a 40.4 foot decrease in head over the 40 year period (Figure 7). The Base Case scenario reasonably simulates the expected change in groundwater levels from continued agricultural practices in the area, including the limitation of surface water delivers to PID and the continued application of DEID’s surface water allotment. These conditions reflect assumed continued overdraft in the basin.

5.2 GROUNDWATER BANKING OPERATIONAL SCENARIO

The Base Scenario was modified to simulate a potential water banking operational scenario. The potential water banking scenario uses the same model grid, boundary conditions, and hydraulic parameters as the Base Case scenario. Agricultural water demand is assumed to also remain the same for the water banking scenario. The proposed Project would operate on the operational rule that recharge to the basins would occur before any recovery, and that there would be a 10-percent “leave behind” of all water contributed to the proposed water bank. As such, a cap of 90 percent was placed on the amount of water that could be recovered following recharge periods.

The following table shows recharge, recovery, and leave-behind quantities for the Groundwater Banking Operational Scenario. The hydrologic year is based on estimated deliveries over a 30-year base period for San Joaquin River hydrology using estimates described in Section 2.2 of the Environmental Assessment (EA) whereby DEID and other potentially participating CVP Friant Districts would contribute recharge water to the Project during water years when the total available water supply exceeds the contracted irrigation demand within the participant's respective service areas. Hydrologic Years 1 through 10 are repeated to provide the 40-year simulation scenario.

Model Year	Hydrologic Year	Delivery to Bank	Take	Leave Behind	Bank Balance
2015	0	-	-	-	-
2016	1	30,000	0	3,000	27,000
2017	2	30,000	0	3,000	54,000
2018	3	0	30,000	0	24,000
2019	4	0	24,000	0	0
2020	5	30,000	0	3,000	27,000
2021	6	30,000	0	3,000	54,000
2022	7	30,000	0	3,000	81,000
2023	8	2,483	0	248	83,235
2024	9	7,517	0	752	90,000
2025	10	0	0	0	90,000
2026	11	0	0	0	90,000
2027	12	0	23,075	0	66,925
2028	13	25,083	0	2,508	89,500
2029	14	0	30,000	0	59,500
2030	15	0	30,000	0	29,500
2031	16	0	29,500	0	0
2032	17	0	0	0	0
2033	18	0	0	0	0
2034	19	0	0	0	0
2035	20	30,000	0	3,000	27,000
2036	21	0	27,000	0	0
2037	22	30,000	0	3,000	27,000
2038	23	30,000	0	3,000	54,000
2039	24	30,000	0	3,000	81,000
2040	25	10,000	0	1,000	90,000

Model Year	Hydrologic Year	Delivery to Bank	Take	Leave Behind	Bank Balance
2041	26	0	0	0	90,000
2042	27	0	0	0	90,000
2043	28	0	30,000	0	60,000
2044	29	0	30,000	0	30,000
2045	30	3,575	0	358	33,217
2046	31	30,000	0	3,000	60,217
2047	32	30,000	0	3,000	87,217
2048	33	0	30,000	0	57,217
2049	34	0	24,000	0	33,217
2050	35	30,000	0	3,000	60,217
2051	36	30,000	0	3,000	87,217
2052	37	3,092	0	309	90,000
2053	38	0	0	0	90,000
2054	39	0	0	0	90,000
2055	40	0	0	0	90,000
			307,575	44,175	

The water banking scenario was compared with the Base Case scenario using hydrographs and potentiometric surface maps. Simulated hydrographs (Figures 5 through 10) compare the simulated heads of the Base Case to both water banking operational scenario at each of the three hypothetical monitoring wells for model layers 1 and 5. To more easily quantify the net effects of the water banking scenarios on groundwater levels beneath the proposed Project area, the difference between the two sets of simulated potentiometric surface maps were calculated for the stress period where the greatest differences in heads were observed (Figures 11 through 15). These figures show the net change in groundwater levels in 10-foot intervals. The results of the predictive water banking operational scenario is described below.

5.2.1 90K Limit Scenario Results

The proposed water banking scenario represents the proposed Project using historical hydrology and a 90,000 af limitation on the amount of water that can be stored at the Project. There are several cycles of recharge and recovery during the 40-year simulation (see previous table). The largest recharge mound (over 60 feet at its peak) occurs in July 2050. This groundwater mound extends nearly 2 miles to the north and west of the proposed Project (Figures 11 and 12). Due to the depth of the water table, mounding does not pose a hazard to adjacent lands or crops.

The largest recovery related drawdown (cone of depression) is about 30 feet in June 2030. This recovery depression extends beyond the proposed Project over a mile to the north and less than a mile to the west (Figure 13 and 14). As indicated in Section 4.5.2, the head (or drawdown) calculated by MODFLOW represents the average head (or drawdown) within the 40-acre model cell. This potential impact would be addressed through a set of potential mitigation measures to ensure that local groundwater users are not adversely affected during the recovery periods of the water bank operation.

6.0 REFERENCES

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