PRELIMINARY WATER SUPPLY ANALYSIS

Prepared by Mike Conway,
John Fio, and Steve Deverel, PG

SUMMARY OF INITIAL REVIEW

Staff is supportive of projects that use degraded water supplies. The Buena Vista Water Storage District (BVWSD) service area is known to be impacted by shallow saline ground water. Removal of water within the district that has limited use, or may improve crop productivity, would be supported by staff for use in power plant cooling.

Staff was unable to obtain geologic reports that were prepared for Buena Water Storage District (BVWSD) specifically to evaluate the impact of the proposed water supply. Staff Data Request 103, dated October 12, 2009, states, “Please provide a copy of the completed document, or most recent draft, of the following report: “An Evaluation of the Geology, Hydrology, Well Placements and Potential Impacts of the Buena Vista Water Storage District’s proposed Brackish Groundwater Remediation Project”, prepared by Sierra Scientific Services, Bakersfield, California, dated 2009.” BVWSD has indicated in their Final Environmental Impact Report for the Brackish Groundwater Remediation Program that this and other supporting reports provide the scientific basis for development of the proposed water supply through the BGRP. The Kern Water Bank Authority, Sierra Club, and the California Department of Water Resources have also independently inquired about this report as well and have not received a copy that we are aware of. Without these reports staff could not evaluate how BVWSD and the applicant analyzed the potential impacts and feasibility of the proposed water supply. Since these reports were not made available staff has had to undertake an independent assessment.

Based on a preliminary assessment of the proposed Hydrogen Energy California (HECA) project, the California Energy Commission (Energy Commission) staff finds that development of the project’s proposed industrial water supply could result in the following:

1. ***The project pumping could result in well interference and lower water levels in neighboring wells.***

   The applicant utilized a three-dimensional numerical groundwater-flow model and superposition to simulate the proposed well field and quantify water level drawdown due to project pumping. The applicant’s model simulated drawdown values at select well locations that range from -0.7 to 12.0 feet; drawdown less than zero indicate that as a result of simulated recharge water levels increase during the 25-year simulation period. However, staff believes the model incorrectly includes simulated recharge, ignores potentially relevant boundaries, and may use inappropriate parameter values. Staff modifications to correct and test the model increased simulated drawdown. A worst-case simulation showed that drawdowns range between 5.1 and 34.2 feet.

   Staff employed a significance threshold of 15-feet for well interference. Simulated drawdown by the applicant’s model did not exceed the threshold at any well locations considered. However, simulated drawdown by the modified model (no-flow boundary added and no recharge) exceeded the threshold at one location. Additional model tests conducted by staff indicate the drawdown threshold was exceeded at one location using the above staff-modified model with reduced storativity (0.007), and the threshold was exceeded at 13 well locations using the staff-modified model with reduced storativity and increased anisotropy.

2. ***The proposed industrial supply wells may induce the inflow of relatively poor quality groundwater into a zone of relatively higher water quality within the water-supply aquifer beneath the Buttonwillow Service Area.***

   Staff cannot verify that the project's proposed well configuration protects water quality beneath the Buttonwillow Service Area. The proposed industrial supply wells may induce the inflow of relatively poor quality groundwater into a zone of relatively higher water quality within the water-supply aquifer beneath the Buttonwillow Service Area. The depth to the base of freshwater beneath the well field is about 700 feet, and up-coning of the underlying salt water is a potentially important factor affecting inflow of salt into the pumped zone. The applicant's model indicates a substantial proportion of extracted groundwater (58-percent) likely would originate at depths below the proposed extraction wells. The staff-modified model with reduced storativity and increased anisotropy (15-percent) simulates a lesser proportion. For example, assuming a minimum salinity for brackish groundwater of 2,000 mg/L, the staff-modified groundwater-flow model results suggest the salt load may increase by almost 13,000 US tons per year, and potentially increase TDS concentrations and shift the water from a calcium-sulfate to sodium-chloride dominated water.

3. ***The project's pumping could exacerbate overdraft in the Kern County subbasin.***

   Observed water levels in wells spanning the period 1974-2001 show a statistically significant upward trend at the 95 percent confidence level. The significant upward trends range from 0.28 feet per year (ft/yr) to 1.27 ft/yr. The average trend suggests the annual increase in groundwater storage beneath Buena Vista Water Storage District's Buttonwillow Service Area ranged from about 4,600 to 6,100 AF/yr (assumed specific yield values ranging from 0.15 to 0.20, respectively). The geometric mean storativity from local aquifer test results (0.007) is substantially lower than the applicant's assumed specific yield, and estimated groundwater storage changes may be considerably less than 4,600 to 6,100 AF/yr. The planned well field extraction rate (7,500 AF/yr) therefore likely will exceed the annual storage increase characterized by historical water level trends.

4. ***The project pumping could reverse local water level increases and increase the threat to the California Aqueduct from subsidence.***

If the proposed well field extraction indeed exacerbates overdraft in the Kern County subbasin, staff's analysis indicates it could also exacerbate subsidence in areas near the California Aqueduct. There is no historical evidence for subsidence in the Buttonwillow Service Area or immediate vicinity of the proposed well field. However, the Buttonwillow Service Area is located adjacent to two major historic subsiding areas in the southern San Joaquin Valley. Observed Buttonwillow Service Area groundwater level data indicate water levels have increased on average since 1970, however if pumping causes these trends to reverse and water levels decline below historical lows it could increase the risk of land surface subsidence.

5. ***The project use of the proposed water supply may not be consistent with Energy Commission and other state water policies.***

   Staff conducted several methods of analysis to estimate the expected TDS concentrations in water produced by extraction wells operating in the proposed well field. The results indicated an expected concentration range from 945 mg/L to 3,730 mg/L. This range in concentrations suggests water of sufficient quality for other beneficial uses may be produced during pumping from the proposed well field.

   Staff notes that the proposed power plant uses water at an extremely high rate and primarily for evaporative cooling. Staff also cannot verify that the proposed groundwater for use is the worst water quality available, or that the use satisfies state and Energy Commission policies regarding the use and conservation of water resources. Staff is therefore unable to verify that the proposed groundwater pumping for industrial cooling is reasonable.

   Alternative water supplies have not been adequately evaluated by the applicant. In staff Data Request 97 dated October 12, 2009, staff initially introduced this issue. Staff issued 11 Data Requests on November 12, 2010, again inquiring about water supply and alternatives. In a staff Issues ID Report from July 10, 2012 staff reiterated that water supply alternatives that appear to be feasible are sources of shallow, degraded groundwater to the north of the proposed well field, other well field construction and pumping configurations, or surplus water from the Elk Hills oil field operation. These or other alternatives should be evaluated in detail to ensure there is no other environmentally desirable or economically feasible supply.

PROPOSED PROJECT

SETTING AND EXISTING CONDITIONS

The proposed Hydrogen Energy California (HECA) project would be constructed on a 453-acre site located seven miles west of Bakersfield and a mile and half northwest of Tupman, western Kern County. The site is contained within Section 10 of Township 30 South, Range 24 East. The site is also just north of the West Side/Outlet Canal, the Kern River Flood Control Channel, and the California Aqueduct. Agriculture is the primary land use at the site and local vicinity; onions, cotton, and alfalfa are currently being cultivated on the proposed project site. The project site is approximately 285 feet above mean sea level (amsl) (HECA 2012b).

The proposed project would require extensive construction and groundwater pumping in close proximity to the California Aqueduct. The proposed power plant would be built within 0.5 miles of the aqueduct and the proposed groundwater supply would be pumped within approximately 2 miles of the aqueduct. The California Aqueduct is a significant conveyance component of the State Water Project (SWP) managed by the California Department of Water Resources, which begins at the Sacramento-San Joaquin River Delta and continues south through the Central Valley, over the Tehachapi Mountains, and into southern California. The State Water Project provides a water supply for up to 23 million Californians and up to 755,000 acres of irrigated agriculture and is a vital water supply for many southern Californians. This analysis pays particular attention to impacts to the California Aqueduct (HECA 2012b).

The HECA project would be built along the west side of the San Joaquin Valley river basin, contained between the Coast Ranges to the west, the Emigdio and Tehachapi Mountains to the south, and the Sierra Nevada to the east. The proposed site is approximately two miles north of the Elk Hills oil field, the location of proposed carbon dioxide injection related to the project. The Elk Hills form the surface expression of an anticline composed of gravel and mudstone (HECA 2012b).

The site is located within the Kern County groundwater basin. The subbasin covers almost 2,000,000 acres within Kern County. Within the Kern County subbasin further hydrogeologic subunits are defined; the proposed process water supply would be drawn from and used within the Buttonwillow subbasin. Two main water units exist within the Kern County subbasin, the Plio-Pleistocene Tulare Formation and the overlying Pleistocene alluvium/stream deposits. The site is located along the course of the old Kern River. The site is uniquely situated along the axis of the Kern County subbasin and is underlain by 600-700 feet of interbedded alluvial deposits (BVW 2010a).

Surface water flow is northward from the terminal drainage basin. The proposed project site is north of both the Kern and Buena Vista lakebeds and is in the Tulare Hydrologic Unit. Surface water in the southern portion of the subbasin discharges toward the north, toward Goose Lake lakebeds via various drainage canals.

The Central Valley climate is semi-arid, creating hot dry summers and mild winters. Average daily summer temperatures recorded between 1937 and 2006 range between the 70s and 80s, while average daily winter temperatures range between the 40s and 50s. Average annual precipitation during the same period was 6.23 inches (HECA 2012b).

Local Water Management

Both the proposed power plant and proposed water supply wells are located within the Buena Vista Water Storage District (BVWSD) service area. The district contains two sub-service areas within it, the Buttonwillow Service area which is approximately 46,600 acres and the Maples Service Area which is approximately 5,000 acres. Approximately 45,000 acres of the district is developed and 35,000 acres of district land are farmed annually for field and row crops. **SOIL&WATER Figure 1** shows the location of the service areas (FEIR 2009). The project site is within the Buttonwillow Service Area.

BVWSD manages supply and demand within the district which has been recorded during the period 1970 through 2007 (BVW 2010a). The district relies on groundwater and various surface water deliveries to supply its customers. The district's most significant supply is provided by a Kern River entitlement dating back to 1888, known as the Miller-Haggen Agreement. As a second-point interest (State Water Rights Board Decision D 1196 defines First, Second, and Lower Service Areas, or interests) to the Kern River water supply, the BVWSD is entitled to about 158,000 AF/y. The district also has a contract with the Kern County Water Agency (KCWA) to receive 21,300 AF/y from the State Water Project (SWP). In years when it is available the district also has a surplus entitlement of 3,750 AF/y. The district also receives Central Valley Project water from the Friant-Kern Canal water to supplement its entitlements (BVW 2010a).

KCWA is one of 29 SWP contractors. The KCWA was created in 1961 by the State Legislature and is the designated SWP contracting entity for local water district's in Kern County. KCWA is involved with various banking and recovery operations and also provides some flood control services. KCWA has contracts with 13 member agencies including Belridge Water Storage District, Berrenda Mesa Water Storage District, BVWSD, Cawelo Water District, Henry Miller Water District, Kern Delta Water District, Lost Hills Water District, Rosedale-Rio Bravo Water Storage District, Semitropic Water Storage District, Tehachapi-Cummings County Water District, Tejon-Castaic Water District, West Kern Water District, and Wheeler Ridge-Maricopa Water Storage District (KCWA 2010). The BVWSD is bounded by and operates in conjunction with these numerous water district's and agencies in the southern San Joaquin Valley as shown in **SOIL&WATER Figure 1**. The BVWSD is able to exchange its Kern River entitlements for other KCWA members' SWP water, due to the BVWSD's close proximity to the California Aqueduct (BVW 2010a).The BVWSD receives its SWP water from five turnouts along the California Aqueduct. The turnouts provide a direct, gravity-fed connection to the district's distribution system.

The Belridge Water Storage District (BWSD) is located immediately west of BVWSD's Buttonwillow Service Area. The 92,000 acre district has 121,508 acre-feet of SWP firm entitlement. The district is highly invested in pumping water from the California Aqueduct; aqueduct water is pumped from a canal altitude of 300 feet amsl uphill to an elevation of 500' amsl using up to 14,000 horsepower. The BWSD also participates in banking projects within Kern County, but extracts very little groundwater from beneath its district boundaries (BVW 2010a).

The West Kern Water District (WKWD) serves a population of approximately 25,000 people within a 250 square mile area located along the western border of Kern County. The WKWD supplies its customers with groundwater pumped from eight wells within the district. Current water demand is approximately 20,000 AF/y (BVW 2010a).

The Semitropic Water Storage District (SWSD) is located immediately east of the BVWSD. SWSD serves 300 customers located within 220,000 acres. The district also offers groundwater banking and storage services for various water districts in Kern

County, Southern California, and the Bay Area. SWSD currently banks 700,000 acre-feet of water and has a capacity to bank 2.15 million acre-feet of water (SWSD 2010).

The Rosedale-Rio Bravo Water Storage District (RRBWSD) is located immediately southeast of the BVWSD. The RRBWSD spans approximately 43,000 acres and serves approximately 33,400 acres of cropland and 6,000 acres of urban area (USBR 2009).

The Kern Water Bank Authority (KWBA) owns about 20,500 acres located along the Kern River and directly southeast of the BVWSD. Similar to the BVWSD, the KWBA receives its water supply from the Kern River, the Friant-Kern Canal, and the California Aqueduct. The KWBA includes 80 supply wells which have the capacity to recover 240,000 AF/y. The primary purpose of the water bank is to recharge, store, and recover water for the benefit of those participating in the program. The KWBA is a Joint Powers Authority, formed in 1995. Participants in the management of the water bank include Dudley Ridge Water District, Kern County Water Agency, Improvement District 4, Semitropic Water Storage District, Tejon-Castaic Water District, Westside Mutual Water Company, and Wheeler Ridge-Maricopa Water Storage District (KWB 2010).

Kern Water Bank (KWB) facilities are also located southeast of BVWSD. The KWB was formed in 1995 to manage banking facilities previously operated by DWR. The KWB has the capacity to store up to 1,000,000 acre-feet and extract up to 240,000 acre-feet per year. The facilities are jointly managed by Dudley Ridge Water District, KCWA (Improvement District 4), SWSD, Tejon-Castaic Water District, Westside Mutual Water Company, and Wheeler Ridge-Maricopa Water Storage District (BVW 2010a).

Water purveyors in the Kern County subbasin are engaged in joint groundwater management agreements. The interconnectivity of hydrogeological subunits within the greater Kern County subbasin requires a joint interest in protecting the shared groundwater resource. For instance, the Memorandum of Understanding (MOU) Regarding Operation and Monitoring of the BVWSD Groundwater Banking Program (2002) reflects the interest of many of the local water districts to safely manage groundwater in the Kern County subbasin. The districts that are party to the MOU include: BVWSD, Semitropic Water Storage District, Henry Miller Water District, Kern County Water Agency, Kern Delta Water District, Kern Water Bank Authority, Rosedale-Rio Bravo Water Storage District, and West Kern Water District. This agreement is hereafter referred to as MOU #1 (BVW 2010a).

Staff is aware of another agreement titled Memorandum of Understanding Regarding Operation and Monitoring of the Semitropic Groundwater Banking Project, signed September 14, 1994. The agreement was entered into by the following: Semitropic Improvement District of Semitropic Water Storage District, North Kern Water Storage District, Shafter Wasco Irrigation District, Southern San Joaquin Municipal Utility District, Shafter Wasco Irrigation District, Southern San Joaquin Municipal Utility District, Buena Vista Water Storage District, and Rosedale-Rio Bravo Water Storage District. This agreement is hereafter referred to as MOU #2 (BVW 2010a).

BVWSD is also engaged in two banking and recovery programs with their immediate neighbors. In 1983 BVWSD entered an agreement with the West Kern Water District and in 2002 with the Rosedale-Rio Bravo Water Storage District.

PROJECT DESCRIPTION

The proposed project would use a blend of petroleum coke and coal to produce hydrogen, which would then be used to fuel a combined cycle turbine. This 405-gross-megawatt (MW) plant would provide 300 MW of baseload power to the grid. The Gasification Block would capture 90 percent of raw syngas carbon, which would be transported to the Elk Hills 5 miles to the south, via pipeline, where it would be used to facilitate carbon dioxide enhanced oil recovery (CO_2-EOR).

Process water would be supplied by the Buena Vista Water Storage District (BVWSD) and would be delivered from a new well field that would be installed 15 miles northwest of the project site. The summary of Proposed Water Transfer Terms (HECA 2012b, Appendix N) shows BVWSD would supply HECA with up to 7,500 acre-feet per year (AF/y) of water with a concentration of total dissolved solids (TDS) ranging from 1,000 to 4,000 mg/L. The use of this water supply would allow the BVWSD implement one of the primary components of their Brackish Groundwater Remediation Plan (HECA 2012b). HECA will fund development of this component of BVWSD's program and turn it over to BVWSD to own and operate.

Water for construction and potable uses would be supplied by the WKWD located south of the project. Seven miles of pipeline would be constructed to deliver water from the district. Horizontal directional drilling (HDD) would be necessary to route the pipeline beneath the Outlet Canal, the Kern River Flood Control Channel (KRFCC), and the California Aqueduct (HECA 2012b).
Construction of the power plant would begin in June 2013 and be complete in February 2017. The project would begin commercial operation in September 2017 (HECA 2012b).

Project Water Supply

Potable water needs during operation would be supplied by groundwater from WKWD. Average potable water use would be approximately 1,800 gallons per day (gpd), but could be as high as 2,750 gpd. The average potable water demand would be equal to 2.0 AF/y. The project would provide potable water for up to 200 full-time employees (HECA 2012b).

Construction water would also be supplied by WKWD. Average construction water use would be approximately 5,340 gpd and maximum use would be approximately 12,000 gpd. Total use over the 42 months of construction would be about 46 AF, about 13 AF/y (HECA 2012b).

Buena Vista Water Storage District, Industrial Supply

The proposed project would use an annual average of about 6.6 million gallons of groundwater per day and up to 7.4 million gallons per day (gpd) in summer for industrial purposes. This is equivalent to an average water use of 7,420 acre-feet per year (AF/y). BVWSD would supply up to 7,500 AF/y to the HECA as detailed in the will-serve letter (HECA 2012b). About 0.5 million gpd of the supply would be necessary to create high-quality demineralized water for a gasifier and boiler make-up water. All of the proposed industrial supply water would be supplied by the BVWSD and treated as necessary by the HECA project.

The projected annual use by the HECA project is presented in **SOIL&WATER Table 1** below.

SOIL&WATER Table 1: Expected Industrial Use

	Supplier	Average Use Rate (gpd)	Average Use Rate (AF/y)	Maximum Use Rate (gpd)
Industrial Water (total)	BVWSD	6,624,000	7,420	7,416,000

Source: HECA 2012b

Beneath the proposed well field, TDS concentrations in well water samples range from 1,000 to 4,000 mg/L. The TDS concentrations in groundwater reportedly decrease toward the east, where groundwater for agricultural supply increases. West of the proposed well field, groundwater is believed to be relatively high in salinity and of low quality due to the influence of alluvium originating from the Coast Range marine rocks. The BVWSD therefore envisions extraction wells located near the western district boundary to intercept the high TDS groundwater originating in the Coast Range alluvium while inducing the westward migration of relatively low TDS groundwater from the east. The desired outcome of well field operation is therefore an overall improvement in groundwater quality beneath BVWSD areas located east of the well field.

BVWSD does not currently have the capacity for the proposed groundwater pumping or conveyance facilities necessary to implement the BGRP and would construct pumping and conveyance facilities specifically for HECA. No other potential users of this supply are identified in BVWSD's Final Environmental Impact Report (FEIR) for the BGRP (BVW 2010a). The purpose of the BGRP program would be to remediate shallow perched and brackish groundwater that has adversely impacted plant growth and crop yield within the district. The program would seek to operate two strategic pump zones called Target Area A (north of 7th Standard Road) and Target Area B (mostly south of 7th Standard Road), as shown on **SOIL&WATER Figure 2**. The portion of the district south of 7th Standard Road is underlain by groundwater having total dissolved solids (TDS) concentrations ranging from 300 to 1,000 mg/L (Target Area A), whereas areas to the north are underlain by ground water with concentrations ranging from 1,000 to 4,000 mg/L (Target Area B). Combined extraction of the BGRP could total up to 12,000 AFY (BVW 2010a).

The BGRP Target Area A would include 40 shallow, low flow extraction wells in a grid pattern in the northern half of the district where water stands at two to ten feet below the ground surface. The goal in this target area is to lower the water table and improve cropland productivity. The FEIR identifies no potential users for this water. This water is identified as having TDS concentrations between 1,000 and 5,000 mg/L (BVW 2010a).

Though not a proposed source of groundwater for HECA, Target Area A is described as a source of brackish water that may supply up to 4,500 AF/y to the BGRP.

The HECA project would receive water from Target Area B. Target Area B is located along the west-central edge of the district. Up to ten wells are planned designed to extract groundwater from between 200 to 700 feet below the ground surface (the zone of brackish water with TDS concentrations between 700 and 4,000 mg/L). The water quality produced by the extraction wells is expected to be a mix of relatively high TDS water originating west of the well field and low TDS water originating east of the well field. The strategic locations of the proposed wells are intended to reduce the lateral recharge from the west (BVW 2010a).

STAFF ANALYSIS OF INDUSTRIAL WATER SUPPLY

Applicant Groundwater-Flow Model Construction

The applicant utilized a three-dimensional numerical groundwater-flow model to simulate well interference (drawdown) and delineate the pumping Zone of Influence (ZOI). The model is based on MODFLOW (McDonald&Harbaugh1988); MODFLOW is a widely accepted model code that has been verified to produce numerically stable solutions (Anderson&Woessner1991).

Numerical groundwater-flow modeling involves first developing a conceptual model of the physical system and then applying a mathematical model to quantitatively represent it. The conceptual model is a clear, qualitative description of the natural system and its operation including water sources (recharge), flow directions, and groundwater sinks (discharge). The mathematical model utilizes equations to simulate the physical processes described by the conceptual model. The potential complexity of processes and variety of boundary conditions typically require numerical procedures to determine an approximate solution to the mathematical groundwater-flow equations.

In applying models to real world groundwater-flow systems, errors can potentially arise from the following sources:

- Numerical deficiencies from errors associated with the equation solvers. These errors introduce problems with computational accuracy and precision.
- Conceptual deficiencies (i.e., erroneous basin geometry, incorrect boundary conditions, neglecting important processes, including inappropriate processes, and so forth).
- Inadequate representation of water transmitting and storage properties (parameterization) and incorrectly specified stresses (the magnitude, timing, and spatial distribution of water inflow [recharge] and outflow [pumpage]).

The most common modeling errors are attributed to conceptual deficiencies and inadequate/poorly defined parameterization and stresses. Key model assumptions and construction specifics are listed below, followed by modifications staff deemed necessary to improve the model's representation of the real-world groundwater system.

- The model simulates a 25-year period. Each year is comprised of two stress periods. One stress period is 75 days in length, and simulates the two and one-half month period that recharge occurs due to seepage from irrigation ditches and the canal system, and the second stress period is 290 days in length to simulate the remainder of the year when recharge does not occur. Pumpage is simulated during both stress periods to represent continuous pumpage 365 days of the year. These stress periods sufficiently represent temporal changes in water use within the model area as a result of the proposed project. However, staff disagreed with simulating recharge in this model application and provide their reasons in the section "Applicant's Modeling Approach."
- The model represents a 10,000 square mile area, which is considerably larger than the proposed project area and intended to minimize boundary effects on the simulation results. Head-dependent flow conditions specified at its boundaries are employed to further minimize boundary effects and approximate an aquifer of infinite extent. Staff concluded this approach is too generalized for this application, and the results likely minimize water level changes due to project pumping. Staff recommended changes to the model are discussed below in "Staff Recommended Changes to Model Construction."
- The model is a rectangular grid appropriately utilizing cell sizes that range from 20 x 20 feet in the vicinity of the proposed pumping wells to 2,500 x 2,500 feet at the most distant model boundaries. By definition, the simulated groundwater level changes in each model cell represent the average groundwater level change within the area represented by the cell.
- In the vertical direction, three model layers appropriately represent the aquifer. The simulated water table and pumping wells are located in layer 1 (270 feet thick saturated interval), and deeper aquifer conditions are represented by layer 2 (300 feet thick saturated interval) and layer 3 (2,000 feet thick saturated interval).
- The modeled hydraulic conductivity value is 42.8 ft/d and reasonably close to the median effective conductivity value of 47.6 ft/d determined from 7 aquifer tests reported by URS (2010a). Horizontal hydraulic conductivity is therefore likely appropriately specified in the model. The modeled vertical conductivity is assumed to be 30 times smaller than the horizontal conductivity. No measured vertical conductivity values are available from which to confirm this value, but a previous San Joaquin Valley modeling effort suggested the vertical conductivity may be lower than represented in the model. Staff recommended a more complete assessment to include potential uncertainty in model results due to the assumed vertical conductivity. The recommended analysis is discussed below in the subsequent section "Staff Recommended Changes to Model Construction."
- The modeled specific yield and specific storage values are 0.18 and $5.5x10^{-5}$ per ft, respectively. However, aquifer test results reported by URS (2010a) indicate a geometric mean storativity of 0.007. The actual water level decrease due to simulated pumpage from the model layer 1 depth interval may therefore be substantially greater than modeled. Staff recommended a more complete assessment to include potential uncertainty due to the specified storage

parameter. The recommended analysis is discussed below in the subsequent section "Staff Recommended Changes to Model Construction."

- The model simulations are assumed to converge when the residuals in hydraulic head and volumetric fluxes meet the user's specified criteria. The recommended error criterion for groundwater levels should be one to two orders of magnitude smaller than the accuracy level desired, and the error in the water balance is ideally less than 0.1 percent (Anderson&Woessner1991). The model simulations reviewed by staff appropriately employed a water level closure criterion of 0.01-foot and resulted in typical mass balance errors less than 0.01 percent.
- Groundwater pumpage is the sole discharge simulated from the aquifer. The model appropriately simulates a continuous annual pumping rate of 7,500 AF/yr distributed evenly between three wells. All of the pumpage occurs in model layer 1.
- Recharge is the primary simulated inflow to the aquifer. Recharge is simulated to "off-set project pumping", and 7,500 AF/yr of recharge is simulated as occurring within 18,750 acres around the extraction wells. The simulated recharge is assumed to occur during a 75-day period each year. Staff disagreed with the need to simulate recharge in this model application, and the recommended changes to simulated recharge are discussed below in the subsequent section "Review of Applicant's Modeling Approach."

Staff Recommended Changes to Model Construction

Staff disagreed with several of the hydrologic conditions and assumptions utilized to construct the groundwater-flow model as follows:

- The model domain ignores the contact between water-bearing alluvium and the essentially non-water bearing marine rocks of the Coast Ranges. The contact between alluvium and rock is located approximately six miles west of the proposed well field. Accordingly, a zero- or no-flow boundary is needed approximately 6 miles west of the well field.
- Hydrogeologic subbasin boundaries are reportedly located about 5 to almost 17 miles north and south of the proposed well field, respectively. These boundaries are defined by structural highs due to folding or faulting, and may isolate, at least partially, the hydrogeologic subbasin in which the simulated well field is located (the Buttonwillow subbasin) from other parts of the southern San Joaquin Valley groundwater basin (URS2009). Hence, the three remaining model boundaries could conceivably also be re-located and changed to no-flow boundaries to correspond to the Buttonwillow subbasin boundaries.
- Specific yield is a measure of the volume of water drained from saturated unconfined aquifer material under the force of gravity per unit surface area and unit change in water table elevation. The pumped aquifer is simulated by the applicant as unconfined and employs a modeled specific yield of 0.18. URS (2010a) aquifer tests suggest however that the pumped aquifer is not unconfined but rather may be semi-confined. The aquifer test results reported by URS (2010a) indicate a geometric mean storativity of 0.007. Storativity is a measure of the volume of water released by compression of the aquifer structure and expansion of the water in response to the decline in pressure in a confined or

semi-confined aquifer. The storativity of 0.007 is about 25 times smaller than the modeled specific yield 0.18. The URS (2010a) aquifer tests were conducted on wells screened at depths corresponding to model layer 1 and the upper portion of layer 2, and the storativity should therefore be utilized to represent storage properties of the pumped aquifer.

- The model assumes vertical conductivity is 30 times smaller than horizontal conductivity, which may be too low relative to actual conditions. URS (2009) tested model sensitivity to vertical conductivity and reported that the extent of simulated drawdown increases as the vertical conductivity decreases. Aquifer testing and model calibration results reported by Belitz and others (1993) for Coast Range and Sierran alluvium suggest that intermittent clay deposits can reduce modeled vertical conductivity relative to horizontal conductivity by a factor of more than 1,000. Staff recommends revising the anisotropy in the model to 1,000.

Review of Applicant's Modeling Approach

The applicant appropriately employed "superposition" to simulate the proposed well field operation. Superposition solves a complex problem using an incremental and additive approach. The principal constraint to using superposition is that the mathematical equation describing the groundwater problem – both within the model domain and the boundary conditions – must be linear.[1] In this application, the complex problem is the prediction of groundwater level changes in the basin, and superposition is employed to determine the incremental drawdown due solely to pumping for proposed power plant water use.

In practice, in a superposition model the specified initial head distribution and boundary conditions are defined in terms of relative changes rather than actual observed values. Initial heads within the model domain are specified as all being equal. Fixed-head boundaries use water levels specified equal to initial groundwater levels so that the initial hydraulic gradient along the boundary is zero. Constant-flux boundaries are specified as no-flow (zero-flux) boundaries corresponding to no net change in flow. Specified pumpage represents the incremental increase in the pumping rate relative to existing or background pumpage, and specified recharge represents the incremental increase in recharge relative to existing or background recharge rates.

In applying superposition to analyze the proposed well field, the applicant simulated a pumping rate of 7,500 AF/yr. The simulated pumping rate represents an incremental increase in groundwater extraction above background groundwater production within the Buttonwillow Service Area. Similarly, the applicant simulated a recharge rate of 7,500 AF/y to represent an incremental increase in recharge within the Buttonwillow Service Area. The simulated water levels and fluxes therefore represent the incremental

[1] Some of the mathematical equations that describe groundwater flow are linear – others are not. The equations utilized to describe unconfined groundwater-flow are not linear, but when the saturated interval is thick relative to the water level changes considered it is common practice to assume the unconfined system behaves approximately linearly. As a rule of thumb, superposition can be applied if the basin-wide drawdown of the unconfined aquifer is 10 percent or less of the saturated interval (Reilly&Others1987).

changes in groundwater conditions resulting from these increases in pumping and recharge. The model results are relative to background groundwater conditions, and actual changes would be the combined sum of the incremental changes due to the project and background conditions.

Project-related pumpage will be exported 15 miles southeast of the well field and consumed at the proposed project site. Hence, the superposition model appropriately simulates a 7,500 AF/y pumping rate to represent the incremental increase in groundwater consumption above typical annual well use within the Buttonwillow Service Area. Simulated recharge (7,500 AF/y) represents an incremental increase in recharge above typical annual applied water and seepage losses in the Buttonwillow Service Area. However, this incremental increase in recharge requires a corresponding increase in applied water and/or seepage losses from drainage ditches and canals downstream from the well field. The applicant's analysis does not consider potential downstream impacts resulting from the reduction in ditch and canal flows. Accordingly, unless there is a 7,500 AF/y reduction in annual water consumption, or a similar decrease in annual drainage discharge considered in the analysis, the simulated recharge rate requires a corresponding increase in annual Buttonwillow Service Area water supply. The source of the "new" water was not identified as part of the project description, and therefore Staff concluded recharge is incorrectly specified in the model.

Model Results

Well Interference

Consumptive use of water from wells within a groundwater basin may contribute to lower water levels at other well locations (well interference). The groundwater-flow model was employed to simulate the water level drawdown at existing wells due to pumping from the proposed well field.

Well interference is considered significant if water level changes in and around an existing well appreciably affects its ability to meet its intended use. Reductions in well yield can occur as the static or pumping water levels decrease. The maximum theoretical well yield can be defined as the maximum pumping rate supplied by a well without lowering the water level below the pump intake (Freeze&Cherry1979). Typically, pump intakes are located near the top of the screened interval because it is desirable to keep the well screen submerged as this minimizes chemical clogging and physical deterioration of the well screen (Driscoll1995).

SOIL&WATER Table 2 summarizes available well completion data from well driller reports (well logs) and water level data records obtained from the California Department of Water Resources. On average, wells are almost 450 feet deep and the top of the well screens are located almost 200 feet below land surface. See **SOIL&WATER Figure 3** for general locations of wells.

SOIL&WATER Table 2. Available well completion data from well driller reports (well logs) and water level data records.

Map number	Well Depth	Top of perforation	Bottom of perforation	Water level (amsl)	Date

	feet below land surface				
1	450	240	450	--	--
2	340	276	340	--	--
3	256			--	--
4	204	168	204	--	--
5	553	203	553	--	--
6	460	200	460	--	--
7	201	174	198	--	--
8	300	120	300	--	--
9	400	175	400	--	--
10	340	78	340	--	--
11	515	275	515	--	--
12	620	410	610	--	--
13	532	312	532	--	--
14	455	414	455	--	--
15	300	108	300	--	--
16	600	150	600	--	--
17	335	150	335	--	--
18	300	90	294	--	--
19				224	2/8/1961
20	274			228	2/8/1961
21	402			223	2/8/1961
22				222	2/8/1961
23	725			141	2/8/1961
24				221	2/8/1961
25				225	2/8/1961
26				224	2/8/1961
27	400			221	2/8/1961
28	515	212	515	215	2/8/1961
29	526			215	2/8/1961
30				222	2/8/1961
31	516			216	2/8/1961
32				219	2/8/1961
33	433			221	2/9/1961
34	800			197	2/9/1961
35	600			214	2/9/1961
36	700			168	2/9/1961
37	525			177	2/9/1961
38				223	2/9/1961
39	606	150	606	226	2/9/1961
40	304			219	2/9/1961
41	402			197	2/9/1961
42				202	2/18/1961
43	291			169	2/18/1961
44	324	102	318	213	2/18/1961
45	446			206	2/18/1961
46	402			206	2/18/1961
47	670			211	2/18/1961
48				221	2/18/1961
49	450	150	450	242	5/5/1986
50	364			211	9/23/2002
51				208	9/23/2002
52				243	9/1/2006

Map number	Well Depth	Top of perforation	Bottom of perforation	Water level (amsl)	Date
	feet below land surface				
53				234	1/7/2008
54				235	8/26/2008
55				214	8/26/2008
56				232	8/3/2009
57				234	8/3/2009
58				222	8/3/2009
59				237	9/1/2009
60				236	9/1/2009
61				235	9/1/2009
62				243	9/1/2009
Average	446	198	418	207	
Median	440	174	450	206	

Average and median water levels calculated from 2009-2010 data only.
Map number refers to **SOIL&WATER Figure 3**.

Drawdown Impacts

The BVWSD is party to a collective Memorandum of Understanding on the operation and monitoring of the Semitropic Water Storage District Groundwater Banking Project. One objective of the project is to mitigate or eliminate short-term and long-term impacts from complex water banking, extraction, and transfer programs. This includes insuring the project does not adversely impact water levels, water quality, or land subsidence. The agreement specifies that withdrawals shall not cause average groundwater levels to decrease 15-feet or more below average groundwater levels in the absence of the banking project. Because this threshold was developed among local water management entities, staff applied 15 feet as the significance threshold for well interference due to proposed groundwater use by the power plant.

Staff utilized the applicant's model to simulate projected water level changes owing to 25-years of project pumping. Simulated drawdown contours resulting from use of the applicant's model are mapped in **SOIL&WATER Figure 4**, and simulated drawdown at select well locations is summarized in **SOIL&WATER Table 3** (see **SOIL&WATER Figure 3** for well locations corresponding to the map numbers listed in **SOIL&WATER Table 3**). The simulated drawdown values using the applicant's model ranged from -0.7 to 12.0 feet; drawdown less than zero indicate that as a result of simulated recharge the model predicts water levels will increase during the 25-year simulation period.

SOIL&WATER Table 3 drawdown at select well locations simulated by applicant's model and three modified models.

Map number	Applicant's model	Modified model BC and recharge	Modified model with reduced storativity	Modified model with reduced storativity and vertical conductivity
	simulated drawdown, in feet			
1	3.1	4.1	5.6	11.3

Map number	Applicant's model	Modified model BC and recharge	Modified model with reduced storativity	Modified model with reduced storativity and vertical conductivity
	simulated drawdown, in feet			
2	0.9	4.1	5.5	11.3
3	-0.4	4.7	6.1	13.1
4	0.1	2.4	3.9	5.4
5	-0.4	3.9	5.3	10.7
6	6.8	15.8	17.3	34.2
7	-0.7	7.7	9.1	21.3
8	0.1	12.0	13.5	29.7
9	1.0	7.6	9.1	21.0
10	-0.6	6.8	8.3	19.0
11	-0.2	5.4	6.9	15.3
12	-0.1	3.6	5.1	8.8
13	5.5	5.3	6.8	15.0
14	0.1	4.6	6.1	12.9
15	0.7	4.2	5.6	11.4
16	0.9	4.3	5.8	11.9
17	0.5	4.0	5.5	10.9
18	0.3	3.9	5.4	10.5
19	12.0	3.1	4.5	7.6
20	8.1	4.4	5.8	12.3
21	3.9	4.4	5.8	12.2
22	2.1	3.9	5.3	10.4
23	1.3	2.2	3.5	5.1
24	-0.6	2.6	3.9	6.1
25	-0.3	3.2	4.6	8.0
26	-0.5	3.2	4.6	8.1
27	-0.5	3.2	4.6	8.1
28	-0.4	4.0	5.4	10.8
29	-0.5	5.3	6.7	15.1
30	-0.1	3.0	4.4	7.4
31	-0.1	3.4	4.9	8.9
32	2.9	3.3	4.7	8.4
33	0.3	2.5	3.9	5.9
34	0.3	2.6	4.0	6.1
35	0.7	2.7	4.1	6.2
36	0.2	2.8	4.2	6.7
37	0.1	3.5	4.9	8.9
38	0.7	3.3	4.7	8.3
39	-0.4	6.6	8.1	18.6
40	-0.4	10.7	12.2	27.4
41	-0.2	2.3	3.6	5.1
42	2.8	2.4	3.8	5.6
43	0.2	4.0	5.4	10.9
44	0.7	4.4	5.9	12.1
45	2.6	2.3	3.7	5.4
46	-0.2	2.3	3.7	5.3
47	-0.1	2.6	4.0	6.0

Map number	Applicant's model	Modified model BC and recharge	Modified model with reduced storativity	Modified model with reduced storativity and vertical conductivity
	simulated drawdown, in feet			
48	0.5	2.4	3.8	5.5
49	-0.4	6.7	8.2	19.0
50	3.8	4.0	5.5	11.0
51	-0.4	9.3	10.8	24.9
52	0.5	3.8	5.2	10.0
53	1.5	4.5	5.9	12.5
54	0.8	4.6	6.1	12.9
55	0.4	4.6	6.1	12.9
56	0.1	4.0	5.5	10.9
57	-0.3	3.7	5.1	9.6
58	-0.3	6.1	7.6	17.3
59	0.6	3.4	4.8	8.6
60	0.6	3.2	4.7	8.1
61	-0.5	3.3	4.7	8.2
62	0.5	4.0	5.5	10.8
Maximum	12.0	15.8	17.3	34.2
Minimum	-0.7	2.2	3.5	5.1

The simulated drawdown contours from staff's modified model (no-flow boundary added and no recharge) are shown in **SOIL&WATER Figure 5.** The results indicate greater drawdown over a generally larger area than simulated by the applicant's model. The simulated drawdown in the staff modified model ranged from 2.2 to 15.8 feet, representing an average increase of more than 3 feet relative to the applicant's model. The maximum drawdown (15.8 feet) exceeds the well interference threshold by almost 1 foot at one well (the well is located within the boundaries of the proposed well field area and identified by Map ID 6 in **SOIL&WATER Figure 3**).

Simulated drawdown in **SOIL&WATER Table 3** represents the water level changes due solely to project well field operation. Actual water level changes and volumetric fluxes will be the net result of multiple recharge and discharge processes occurring in the basin and can therefore be quite different from the model results. For example, the simulated drawdown in the well identified by Map ID 50 is 3.8 feet, indicating that 25-years after well field start-up the water level in this well will be 3.8 feet lower than without the well field (no project conditions).

Staff performed additional model testing which showed simulated drawdown extracted by the proposed well field are sensitive to assumed aquifer conditions. Utilizing the reported representative storativity (0.007) increased the magnitude and extent of simulated drawdown (**SOIL&WATER Figure 6**), and on average simulated drawdown increased by almost five feet relative to the applicant's model results (**SOIL&WATER Table 3**). The maximum simulated drawdown increased from 12.0 to 17.3 feet, but the 15-feet threshold was exceeded at only one location.

Increasing the simulated anisotropy from 30 to 1,000 further increased the magnitude and extent of simulated drawdown (**SOIL&WATER Figure 7)**. On average, simulated drawdown increased by almost 11 feet relative to the applicant's model (**SOIL&WATER Table 3**). The maximum simulated drawdown increased from 12.0 to 34.2 feet, and the 15-feet threshold was exceeded at 13 locations (an increase of 12 wells).

Groundwater Quality Impacts

There is no specific provision in the MOU between BVWSD and Semi-Tropic Water Storage District for what constitutes a water quality impact. Staff used the RWQCB Basin Plan beneficial uses for groundwater designated in this area and considered whether the pumping would degrade water quality such that it could not be used for the identified beneficial uses. The suitability of water for use as irrigation water becomes marginal where TDS reaches concentrations of 2,000 ppm. As described by Dr. L.D. Doneen in 1954 (Doneen, 1954), reiterated by DWR in various Water Quality Investigations, and promulgated in the Water Control Plan for the Tulare Lake Basin (RWQCB, 2004) water that exceeds electrical conductivity levels of 3,000 micromhos per centimeter and TDS levels of 2,000 mg/L has limited suitability for irrigation use (**SOIL&WATER Table 4**).

SOIL&WATER Table 4: Irrigation Water Suitabilities

Irrigation use	Electrical Conductivity (mhos/cm @ 25˚C)	TDS (mg/L)
Suitable/Class I	0 - 1,500	< 700
Marginal/Class II	1,500 - 3,000	700 - 2,000
Inferior/Class III	> 3,000	> 2,000

Source: Doneen, 1954; Tulare Lake Basin Plan, RWQCB, 2004

The HECA project proposes to receive groundwater from BGRP Target Area B. The water underlying Target Area B contains TDS at concentrations between 1,000 mg/L and 4,000 mg/L. The will-serve letter signed by Hydrogen Energy and BVWSD states that the water supply for HECA would vary between 1,000 mg/L to 4,000 mg/L, with an average of 2,000 mg/L. This water is described by BVWSD as having few uses and also as being the cause of low crop yield and low crop quality within the district. However, specific studies of crops of pistachios from western San Joaquin Valley indicate no adverse impacts to crop or yield at salinities greater than 3,000 mg/L TDS (Fergusson et al., 2002). This same claim is made by HECA intervenor and residents, Association of Irritated Residents (AIR), that states the water proposed for use by the project is suitable for pistachios (AIRe). They believe groundwater of this quality should be protected for such agricultural use.

Staff used a TDS concentration of 2,000 ppm as a threshold for comparison with background or baseline conditions where the primary beneficial use is irrigation. Where project pumping could cause TDS concentrations to exceed 2,000 ppm staff believes there is potential for a significant impact. Where background TDS concentration is greater than 2,000 ppm staff considered whether the groundwater may reasonably be considered a potential drinking water supply that should be protected in accordance with SWRCB Drinking Water Policy. This policy requires, among other things, that a water source with TDS concentrations less than 3,000 ppm should be protected as a potential drinking water supply. Where project pumping would cause TDS concentration increases beyond 2,000 ppm staff concludes this would also be a significant impact for potential use as a drinking water supply. Where background TDS concentrations are greater than 3,000 ppm staff believes that pumping would not impact reasonable beneficial uses.

In the Buttonwillow Service Area, the pumped groundwater zone as indicated by the average depth to water in supply wells is greater than about 200 feet below land surface (**SOIL&WATER Table 2**). Well water sample results and composite 1970-2007 TDS concentrations contours (BVWSD2009) for deep wells are mapped in **SOIL&WATER Figure 8**. Five deep wells have posted values that are greater than the TDS concentrations depicted by the contours. Four of these five wells are located in the central part of the Buttonwillow Service Area or to the east and in the Semitropic Water Storage District. Over half of the remaining wells have posted TDS concentrations that are less than the values depicted by the contours. The remaining posted well concentrations generally agree with the contours. There doesn't appear to be an identifiable spatial pattern in the differences between well concentrations and the reported contours, and the contours may be considered an unbiased but only approximate representation of the spatial variability in groundwater quality.

Well water sample results and summer 2001 TDS concentrations contours (BVWSD2009) for deep wells are mapped in **SOIL&WATER Figure 9**. Most well water samples had TDS concentrations either less than or similar to the TDS concentrations contours. The sample results generally agree with the contours in the area south of Highway 58 where TDS concentrations are relatively low. In the central part of the Buttonwillow Service Area and near the proposed well field, all but two of the well water samples have lower TDS concentrations than indicated by the contour values (the two exceptions are the 4,300 mg/L sample from the well located on the 2,000 mg/L contour, and 1,400 mg/L sample from the well located east of the 1,000 mg/L contour). In the northern part of the Buttonwillow Service area, there appears to be little agreement between well water sample results and TDS concentrations contours.

In the northern part of the Buttonwillow Service Area, shallow “perched”[2] groundwater and elevated TDS concentrations have reportedly adversely impacted plant growth and crop yields. **SOIL&WATER Figure 10** shows 2008 TDS concentrations contours reported by BVWSD (2009) and the results from shallow well-water samples collected in the northerly area. The posted well sample results are generally higher than the TDS concentrations depicted by the contours. One exception is the DWR data value of 537 mg/L from a well of unknown depth located near the intersection of I-5 and Highway 46. In the southern half of the area represented by the contours, the posted values are either consistent or lower than the contours. The three lower posted values are located between the West Side and Main Drain canals and range from 389 to 828 mg/L, whereas the contours indicate concentrations range from between 2,000 and 4,000

[2] A perched water-table is a special case of an unconfined aquifer whereby the perched groundwater is separated from the underlying main groundwater system by low permeability strata and an underlying unsaturated zone. In the Buttonwillow Service Area, it is uncertain whether an unsaturated zone exists between the shallow water table and main (pumped) groundwater zone.

mg/L. Two of the three samples (389 and 828 mg/L) are from wells of unknown depth, and therefore may represent deep groundwater. These samples were collected and analyzed more than 50-years ago (DWR1961), and present-day TDS concentrations at these locations may be different than at the time of sampling.

In 1986, the USGS collected TDS and stable isotope data (deuterium and oxygen-18) which indicated greater TDS concentrations in the northern area likely reflect concentration increases due to evaporation from the shallow water table. The evaporation process adds kinetic separation to the deuterium and oxygen-18 species causing increased enrichment resulting in a characteristic evaporative trend line. **SOIL&WATER Figure 11** shows the deuterium and oxygen-18 compositions (expressed in the "δ" notation) for the 1986 USGS sample locations shown in **SOIL&WATER Figure 12** (the deep well samples plotted in **SOIL&WATER Figure 11** were discussed previously under the heading "TDS Concentrations in the "Deep" Pumped Groundwater Zone"). The shallow well data points plot on an evaporative trend line with a shallower slope than the meteoric water line discussed in Craig (1961), and the posted TDS concentrations indicate the more isotopically enriched Buttonwillow Service Area water samples generally have the greater TDS concentrations.

The evaporative trend line is described by the equation $\delta D = 4.6 \times \delta^{18}O - 31.5$ and is comparable with previous isotope studies from the San Joaquin Valley (Deverel& Fujii1988; Deverel&Gallanthine1989) and other arid areas (e.g. Gat&Isaar1974; Fontes&Gonfiantini1967). **SOIL&WATER Figure 13** shows that correlation between TDS concentrations and isotope composition ($\delta^{18}O$) and calculations indicate the correlation is statistically significantly ($r^2 = 0.47$, $p < 0.05$). Deverel&Fujii1988 and Deverel&Gallanthine1989 found similar correlations between groundwater salinity and isotopic enrichment in the San Joaquin Valley.

Evaporation from the water table is likely ongoing in parts of the Buttonwillow Service Area where shallow groundwater conditions are prevalent. Moreover, the shallow geologic deposits in the area are fine-grained and hydraulic conductivity is low. In the area where the depth to groundwater is ten feet or less, the soils range in texture from clay to clay loam (USDANRDC2008). These soil textures are similar to shallow groundwater areas in the San Joaquin Valley described by Fio&Deverel1991 and Deverel&Fio1991, where they determined groundwater velocities are low (ten feet per year or less). Hence, we expect present-day TDS concentrations to be similar to those measured by the USGS in 1986, which is corroborated by the general agreement between 1986 sample results and reported 2008 TDS concentrations contours (**SOIL&WATER Figure 10**). In 2002, HydroFocus re-sampled shallow groundwater wells located north of BVWSD and in the area between Firebaugh and Kettleman City. The wells were originally sampled in 1984 (Deverel1984), and comparisons between results confirmed that groundwater quality changes were insignificant even though the two sampling events were separated by more than 20 years (HydroFocus2006).

The TDS concentrations in groundwater beneath the Buttonwillow Service Area vary with depth. For example, URS (2010a and 2010b) analyzed water samples and conducted down-hole specific conductance logging in seven wells. They concluded from the well water sample results that groundwater beneath the proposed well field is relatively higher in TDS concentrations and dominated by sodium and chloride ions, whereas samples from wells located further east are dominated by calcium and sulfate ions. Down-hole specific conductance logging suggested vertical stratification of groundwater salinity at some locations, and high salinity water in discrete zones.

When an aquifer is pumped by partially penetrating wells, upward movement of deeper groundwater to the well screens can occur (herein referred to as “up-coning”). In the San Joaquin Valley, saline (brackish) groundwater of sodium chloride water type reportedly underlies the base of the pumped groundwater zone (Page1973). **SOIL&WATER Figure 14** conceptually illustrates up-coning of brackish groundwater to variable depth pumping wells; the timing and quantity of up-coning groundwater is determined by the spatial distribution of active wells, their depths, the magnitude and timing of pumping, and the actual TDS concentration contrasts in groundwater with depth.

Beneath the Buttonwillow Service Area, Page (1973) mapped the depths to brackish groundwater (defined as groundwater having dissolved solids concentrations greater than about 2,000 mg/L) as generally ranging from less than 500 feet in the north to more than 700 feet in the south (**SOIL&WATER Figure 12**). These depths correspond to the bottom third of model layer 2 and upper 200 feet of model layer 3. Hence, simulated up-coning from model layer 3 can contribute to the volume of extracted groundwater originating as inflow from below the well screens. The applicant and staff-modified models simulated proportional contributions of inflow from beneath the well screens that range from 58- to 63-percent of the extracted volume of groundwater, respectively (the volume of inflow from beneath the well screens divided by the annual pumping rate as reported in **SOIL&WATER Figure 15**). Simulated up-coning in additional model tests completed by staff ranged from 64-percent (**SOIL&WATER Figure 16**) to 15-percent (**SOIL&WATER Figure 17**).

During the 25-year simulation period, not all up-coning is extracted by the partially penetrating wells. Rather, the up-coning groundwater that remains replaces the relatively shallower groundwater that was extracted by the wells. For example, 63-percent of the water extracted from the ZOI is replaced by up-coning from beneath the well screens (simulated up-coning in the staff-modified model as reported in **SOIL&WATER Figure 15**). Assuming a minimum salinity for the up-coning groundwater of 2,000 mg/L, the potential salt load to the zone beneath the well screens is about 13,200 US tons per year – the salt load will be even greater if TDS concentrations in the up-coning groundwater exceed 2,000 mg/L. This loading may contribute to a shift from calcium-sulfate to sodium-chloride dominated water, and an increase in TDS concentrations within the ZOI. This change in water quality could result in significant impacts to other reasonable beneficial uses.

The concentrations of total dissolved solids are reportedly greater west of the well field. The quality of the water extracted by the well field is therefore determined by the spatial distribution of groundwater-flow paths and associated volumetric fluxes into the wells, which delineate the shape and extent of the aquifer zone influenced by the pumping well (the ZOI). Staff utilized the post-processor MODPATH (Pollock1994) to delineate the pumping ZOI for the proposed well field, and the post-processor ZONEBUDGET (Harbaugh1990) to extract the simulated average annual volumetric water fluxes (volumetric water budget). The pumping ZOI and associated volumetric budget simulated by the applicant and staff-modified models are mapped and summarized in **SOIL&WATER Figure 15**.

After 25-years of pumping, the applicant's model results indicate groundwater beneath about 1,400 acres will be extracted by the proposed well field. Most of this water (58-percent) comes from beneath the 300 feet deep well screens, and lesser volumes are contributed by horizontal inflow (34-percent), direct recharge (7-percent) and storage (1-percent). The proposed extraction wells remove substantially more horizontal inflow originating east of the well field (22-percent) relative to the assumed low quality water that originates west of the well field (12-percent).

The staff-modified model (no-flow boundary added and no recharge) simulates a slightly smaller pumping ZOI (1,300 acres). An even greater proportion of extracted groundwater (63-percent) is from beneath the well screens. The proportional contribution of horizontal inflow increases slightly to 36-percent (a net increase of 2-percent), and the remaining water extracted is removed from storage (1-percent); there is no recharge. Although the magnitude of inflow from the east decreases by about 20 AF/yr, its proportional contribution to the water extracted from the aquifer is the same (22-percent). Inflow from the west increases more than 120 AF/yr, and its proportional contribution to the pumpage increases from 12- to 14-percent.

Staff performed additional model testing which showed water quality extracted by the proposed well field is sensitive to assumed aquifer conditions. Utilizing the reported representative storativity (0.007) staff found the simulated pumping ZOI area has limited sensitivity to the change in storage coefficient because most of the groundwater extracted comes from beneath the well screens. The simulated pumping ZOI area mapped in **SOIL&WATER Figure 16** is 1,350 acres and only about 50 acres less than simulated by the applicant's model. The proportional contribution of water extracted from below the well screens increased slightly from 63- to 64-percent, and the relative contributions of horizontal flows originating east and west of the well field remained approximately the same.

Increasing the anisotropy substantially increased the pumping ZOI area from 1,350 acres to almost 3,100 acres (**SOIL&WATER Figure 17**). The proportional contribution of water extracted from below the well screens decreased dramatically from 58- to 15-percent, and the contribution from horizontal inflow increased from 34- to 85-percent; most of the horizontal inflow (53-percent) originates east of the well field and a lesser proportion (31-percent) originates west of the well field.

Estimated TDS Concentrations for Industrial Supply

Staff estimated the range in expected TDS concentrations in water produced by the proposed well field. Staff utilized well water sample results, reported TDS concentrations contours (1970-2007 composite contours and 2001 summer contours), and the 25-year pumping ZOI simulated by the applicant's model (URS2009). Staff utilized the ZOI from the applicant's model because there were negligible differences between the applicant and staff-modified models' ZOIs using a lower value for storativity (0.007). Furthermore, although the ZOI area for the staff-modified model increased following an increase in simulated anisotropy (**SOIL&WATER Figure 17**); it did not encroach into areas with additional sampling locations. The TDS concentration data and

ZOI are mapped in **SOIL&WATER Figure 18**, and the estimated TDS concentrations based on several different approaches, are summarized below in **SOIL&WATER Table 5**.

SOIL&WATER Table 5: Estimated TDS concentrations in water produced by the proposed well field.

ZOI sub-zone	Proportion of ZOI Area (percentage)	Well Field Concentration Estimates			
		1 (mg/L)	2 (mg/L)	3 (mg/L)	4 (mg/L)
A	16.8	1,930	780	2,000	3,000
B	16.5	1,930	399	2,000	3,000
C	18.8	1,930	2,400	2,500	3,000
D	16.2	1,930	2,900	3,000	3,000
E	13.9	1,930	2,030	3,000	3,000
F	17.8	1,930	1,160	2,500	3,000
Mixing Model Results		**1,930**	**1,606**	**2,484**	**3,000**

Approach 1: Representative ZOI quality based on median well water sample concentration.
Approach 2: Representative ZOI quality based on well water sample concentrations in six sub-zones.
Approach 3: Representative ZOI quality based on 1970-2007 composite TDS concentration contours and six sub-zones.
Approach 4. Representative ZOI quality based on summer 2001 TDS concentration contours and six sub-zones.

In the first approach, staff utilized the median observed TDS concentrations from one shallow well sample (1,930 mg/L), three deep well samples (399 to 2,900 mg/L), and one sample from a well of unknown depth (389 mg/L); all the sample locations are located within the simulated ZOI (**SOIL&WATER Figure 18**). The representative TDS concentration of groundwater extracted by the well field using the first approach (median concentration of the five samples) is 1,930 mg/L.

In the second approach, staff considered observed spatial variability in TDS concentrations and assigned a representative concentration to each ZOI sub-zone. The observed concentrations ranged from 389 to 2,900 mg/L (standard deviation of about 70-percent), and the contributing areas represented by the sub-zones range from 13.9- to 17.8-percent of the total ZOI area. The representative groundwater concentrations in sub-zones B, C, D and F were selected based on the water samples from wells located within the respective sub-zones (399, 2,400, 2,900, and 1,160 mg/L, respectively); the representative TDS concentration for groundwater in sub-zone F (1,160 mg/L) was estimated from the average of two samples located in the sub-zone (389 and 1,930 mg/L). No samples are located within sub-zones A and E. For sub-zone A, staff assumed a representative TDS concentration equal to the average of the representative concentrations in adjacent sub-zones B and F (780 mg/L). Similarly, the representative TDS concentration in sub-zone E is assumed equal to the average of the concentrations representing adjacent sub-zones D and F (2,030 mg/L).

Assuming the above TDS concentration estimates are representative for groundwater beneath the ZOI sub-zones, the expected composite TDS concentration in water produced by the well field was equal to the area-weighted average of each sub-zone concentration (almost 1,610 mg/L). Systematically varying observed sample concentrations by 70-percent (the standard deviation of the sample results), the estimated TDS concentration in water produced by the well field ranged from 945 to 2,730 mg/L (calculations not shown in **SOIL&WATER Table 5**).

In the third approach, staff utilized TDS concentrations estimated from the composite 1970-2007 contours. The contours indicate a representative concentration of 2,000 mg/L beneath sub-zones A and B. The TDS concentration contours beneath sub-zones C and F range from 2,000 to 3,000 mg/L; hence, we assigned a representative TDS concentration of 2,500 mg/L to these two sub-zones. Sub-zones D and E are generally both located west of the 3,000 mg/L contour, and we assigned representative TDS concentrations beneath these two sub-zones equal to 3,000 mg/L. Assuming these TDS concentrations are representative for groundwater beneath the ZOI sub-zones extracted by the wells, the expected composite TDS concentration in water produced by the well field was equal to the area-weighted average of each sub-zone concentration (about 2,480 mg/L). After varying the contour concentrations by 50-percent of the contour intervals, the estimated TDS concentration in water produced by the well field ranged from 1,000 to 3,730 mg/L (calculations not shown in **SOIL&WATER Table 5**).

In the fourth approach, staff utilized summer 2001 contours which indicate TDS concentrations in groundwater beneath the well field are equal to 3,000 mg/L (**SOIL&WATER Figure 12**). Although observed TDS concentrations in samples from wells located west of the well field are spatially variable and less than 3,000 mg/L, we conservatively assumed TDS concentrations beneath the entire ZOI everywhere equal to 3,000 mg/L. The expected composite TDS concentration in water produced by the well field calculated by this fourth approach is equal to 3,000 mg/L. If the contour concentrations are varied by 50-percent of the contour interval, the estimated TDS concentration in water produced by the well field ranges from 2,500 to 3,500 mg/L (calculations not shown in **SOIL&WATER Table 5**).

Depending on the approach employed, the expected TDS concentrations in water produced by extraction wells operating in the proposed well field area could range from a minimum of about 945 mg/L to a maximum of 3,730 mg/L. This range in concentrations suggests the proposed groundwater supply is not sufficiently degraded such that it can’t be used for agricultural purposes and possibly as a potential drinking water supply.

Factors Affecting TDS Concentrations in Water from Proposed Well Field

Spatial variability in TDS concentrations in groundwater and the three-dimensional movement of groundwater to extraction wells contribute to uncertainty in the estimated water quality produced by the proposed well field. Observed well water concentrations are limited in number and represent variable sampling dates and well depths. Additionally, extraction wells can intercept groundwater moving both horizontally toward the proposed partially penetrating well screens and upward moving water originating from depths below the well screens.

There are only five samples from wells located within the simulated pumping ZOI, collected over a period of about 50 years (**SOIL&WATER Figure 18**). One of the samples is from a well of unknown depth (389 mg/L). The samples with the lowest TDS concentrations (389 and 399 mg/L) were collected in 1961; whereas the more recent samples collected in 2010 represent different locations and have substantially greater TDS concentrations.

Changes in Water Level and Storage

Many agricultural wells exist within the Buttonwillow Service Area, and a number of wells are monitored for water level and water quality data. Water level data for 64 wells obtained from California Department of Water Resources Water Data Library[3] were assembled and analyzed to identify trends and estimate average annual historical changes in groundwater storage.

In general, water levels were measured semiannually although most records were incomplete. For most years, the water levels were measured during the winter and fall, but in other years the data were collected in the spring and fall. Staff created a subset of 19 wells with at least 35 water level measurements each, spanning the period 1974-2001 (**SOIL&WATER Figure 19**). This subset includes the greatest number of wells with the longest period of over-lapping records and well locations that are spatially distributed across most of the Buttonwillow Service Area.

The Mann-Kendal test and Sen's slope estimator were calculated to determine significant water level trends. The data from most wells (14 of the 19 total wells) show a statistically significant upward trend at the 95% confidence level (**SOIL&WATER Table 6**). The significant upward trends range from 0.28 feet per year (ft/yr) to 1.27 ft/yr (average and median trend of 0.68 and 0.64 ft/yr, respectively).

SOIL&WATER Table 6. Water level trends in Buttonwillow Service Area wells.

Map ID[a]	**Trend** (ft/yr)		
	alpha = 0.05		
	Years	Number of records	Observed
63	1974-2001	45	0.59
64	1974-2001	48	0.34
65	1974-2001	49	0.28
66	1974-2001	45	0.74
67	1974-2001	43	0.65
33	1974-2001	53	0.68
50	1974-2001	50	0.76
68	1974-2001	47	0.90
51	1974-2001	51	(0.44)
69	1974-2001	38	1.01
43	1974-2001	46	0.61
18	1974-2001	42	0.62
70	1974-2001	47	0.62
71	1974-2001	47	1.27
72	1974-2001	50	0.44
73	1974-2001	40	(0.16)
74	1974-2001	46	(0.01)
75	1974-2001	50	(0.01)
76	1974-2001	35	(0.49)
Average (significant trends)	---	---	0.68

[3] www.water.ca.gov/waterdatalibrary

Average (all trends)	---	---	0.56

a) Well locations and map ID numbers are shown in **SOIL&WATER Figure 7**.

Annual changes in groundwater storage (ΔS) were estimated using the calculated trends and the following equation:

$$\Delta S = A \cdot Sy \cdot \frac{\Delta H}{t}$$; where,

A is the area of the Buttonwillow Service Area (reported at about 45,000 acres);

Sy is the specific yield (assumed values ranging from 0.15 to 0.20); and,

$\frac{\Delta H}{t}$ is the calculated annual water level trend represented by the Sen's slope estimator (in ft/yr).

The average trend of 0.68 ft/yr indicates the annual increase in groundwater storage ranges from about 4,600 to 6,100 AF/yr (calculated using specific yield values ranging from 0.15 to 0.20, respectively)[4]. The planned well field extraction rate (7,500 AF/yr) exceeds the average annual storage change during 1974 through 2001. Staff also reviewed aquifer testing results reported by URS to evaluate site specific conditions and found the data (2010a) indicate a geometric mean storativity of 0.007. Therefore, if this storativity value were representative for the area it would result in an even lower calculated 1974-2001 storage increase. These estimates suggest project pumping may have a larger impact to groundwater storage beneath the BVWSD than assumed by the applicant, and the proposed project pumping (7,500 AFY) likely exceeds the current annual volume of water contributing to storage beneath the BVWSD. The consumption of stored groundwater will result in long-term water level declines beneath the BVWSD.

Subsidence

Declining groundwater levels can cause dewatering and compaction of fine-grained sediment beds resulting in subsidence of the land surface. Hydrocompaction of moisture deficient deposits above the water table (shallow or near-surface subsidence), fluid withdrawal from oil and gas fields, and tectonic movement also contribute to land subsidence. In the San Joaquin Valley, aquifer-system compaction due to water-level decline and near-surface hydrocompaction are the primary causes of historical subsidence. Aquifer–system compaction could resume if groundwater consumption by the project caused water levels to decline below previous water-level lows.

The Buttonwillow Service Area is located adjacent to two major historic subsiding areas in the southern San Joaquin Valley; the Tulare-Wasco area to the northeast and Arvin-Maricopa area to the southeast. **SOIL&WATER Figure 20** shows lines of equal land subsidence mapped in these areas (Ireland&Others1984). They concluded that during the period 1926 to 1970, land surface declines in the Tulare-Wasco area ranged from a maximum of 12 feet near Pixley to a minimum of 2 feet near Wasco. In the Arvin-

[4] 45,000 acres x 0.68 foot per year x 0.15 = 4,590 acre-feet per year;
45,000 acres x 0.68 foot per year x 0.20 = 6,120 acre-feet per year.

Maricopa area the land surface declines ranged from less than 1 foot to more than 9 feet. The primary cause of subsidence was declining groundwater levels in the confined zone due to the proliferation of wells and groundwater consumption for agricultural operations. In 1998, DWR concluded that about 1-foot of subsidence occurred since 1970 along a 29-mile reach of the California Aqueduct in an area west of Wasco and the Buttonwillow Service Area (Swanson1998).

Since 1994, the Department of Water Resources has operated an extensometer located about 17 miles southeast of the proposed well field. Details of extensometer construction were not available. **SOIL&WATER Figure 21** shows the measured aquifer compaction and expansion from 1994 to 2009. The water levels in the extensometer well and another nearby well (state well identification number of 29S24E11R001M) show declining groundwater levels since 2001. Groundwater levels reported for 2009 appear to be at their lowest since the start of the data record in 1983. We employed the Mann-Kendal test for trend and the Sen's slope estimator to determine the observed subsidence during this period was statistically significant and the downward trend at the 95% confidence level was 0.001 ft per year.

There is no historical evidence for subsidence in the Buttonwillow Service Area or immediate vicinity of the proposed well field. Statistical analyses of groundwater level data from wells located in the Buttonwillow Service Area indicate statistically significant upward water level trends since 1974 that range from 0.28 ft/yr to 1.27 ft/yr. These upward trends indicate groundwater storage increased on average during the 1974 through 2001 period (**SOIL&WATER Figure 19**). If these water level trends reverse, and water levels decline below historical lows, project groundwater use could contribute to an increased risk of land surface subsidence in the Buttonwillow Service Area. As discussed above in 'Changes in Water Level and Storage' the proposed use of 7,500 AF/y may have a larger impact to groundwater storage beneath the BVWSD than assumed by the applicant, and the proposed project pumping likely exceeds the current annual volume of water contributing to storage beneath the BVWSD. The consumption of stored groundwater will result in long-term water level declines beneath the BVWSD that could lead to subsidence. Staff is concerned that given the proximity to the California aqueduct and historic occurrence of subsidence during extensive groundwater use, there may be potential for significant impacts in the region from project pumping.

COMPLIANCE WITH LORS

WATER USE LORS AND STATE POLICY AND GUIDANCE

The Energy Commission has at least four sources for statements of policy relating to water use in California applicable to power plants. They are the California Constitution, the Warren-Alquist Act, the Commission's restatement of the State's water policy in the 2003 Integrated Energy Policy Report ("IEPR"), and the State Water Resources Control Board ("SWRCB" or "Board") resolutions (in particular Resolutions 75-58 and 88-63).

California Constitution

Article X, section 2 prohibits the waste or unreasonable use, including unreasonable method of use, of water, and it requires all water users to conserve and reuse available water supplies to the maximum extent possible (Cal. Const., art. X, § 2). Groundwater is subject to reasonable use (*Katz v. Walkinshaw* (1903) 141 Cal. 116).

Warren-Alquist Act

Section 25008 of the Energy Commission’s enabling statutes echoes the Constitutional concern, by promoting “all feasible means” of water conservation and “all feasible uses” of alternative water supply sources (Pub. Resources Code § 25008).

Integrated Energy Policy Report

In the 2003 Integrated Energy Policy Report (IEPR or Report), the Energy Commission reiterated certain principles from SWRCB’s Resolution 75-58, discussed below, and clarified how they would be used to discourage use of fresh water for cooling power plants under the Commission’s jurisdiction. The Report states that the Commission will approve the use of fresh water for cooling purposes only where alternative water supply sources or alternative cooling technologies are shown to be ‘‘environmentally undesirable” or “economically unsound” (IEPR (2003), p. 41). In the Report, the Commission interpreted “environmentally undesirable” as equivalent to a “significant adverse environmental impact” under CEQA, and “economically unsound” as meaning “economically or otherwise infeasible,” also under CEQA (IEPR, p. 41). CEQA and the Commission’s siting regulations define feasible as “capable of being accomplished in a successful manner within a reasonable amount of time,” taking into account economic and other factors (Cal. Code Regs., tit. 14, § 15364; tit. 20, § 1702, subd. (f)). At the time of publication in 2003, dry cooling was already feasible for three projects—two in operation and one just permitted (IEPR, p. 39).

The Report also notes California’s exploding population, estimated to reach more than 47 million by 2020, a population that will continue to use “increasing quantities of fresh water at rates that cannot be sustained” (IEPR, p. 39).

State Water Resources Control Board Resolutions

The SWRCB not only considers quantity of water in its resolutions, but also the quality of water. In 1975, the Board adopted the *Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Power Plant Cooling* (Resolution 75-58). In it, the Board encourages the use of wastewater for power plant cooling. It also determined that water with a TDS concentration of 1,000 mg/L or less should be considered fresh water (Resolution 75-58). One express purpose of that Resolution was to “keep the consumptive use of fresh water for power plant cooling to that *minimally essential*” for the welfare of the state (*Ibid*; emphasis added).

In 1988, the Board determined that water with TDS concentrations of 3,000 mg/L or less should be protected for and considered as potential supplies for municipal or domestic use unless otherwise designated by one of the Regional Water Quality Control Boards (Resolution 88-63).

STAFF ANALYSIS

Staff evaluated the reasonableness of water use using multiple sources of guidance. Ultimately, staff attempts to uphold Article X, Section II of the California Constitution which states that water shall not be wasted. In the context of power plant water use, this equates to the “least of the worst,” which means a project should demonstrate that it uses the least amount of the poorest quality water available.

The project proposes to use up to 7,500 AF/y, which is significantly more water per megawatt than other recently licensed projects. Staff understands that approximately 30% of the proposed water use would go to the gasification process, but even then the projected water use required to produce 300 MW is inordinately high.

Presumably at the time of the original AFC (July, 2008), the applicant also considered the pumping in the context of SWRCB Resolution 75-58 which states that water with TDS above 1,000 mg/L might be a preferential source for power plant cooling. Recent Energy Commission proceedings defined the intent of 75-58 and the SWRCB concluded that 75-58 does not apply to groundwater. Furthermore, staff does not agree that the proposed pumping would constitute reclamation. Water below 2,000 mg/L TDS would certainly not qualify as significantly degraded (**SOIL&WATER Table 4)**, based on data that indicates this water is not only suitable for agriculture, but widely used in the region for this purpose. Water between 2,000 and 3,000 mg/L TDS could generally be considered degraded in terms of agriculture supply, which is the region’s primary use, but would still be a source worthy of protection for potential domestic supply (SWRCB, Resolution 88-63). Recent studies and intervenors that farm in the area point out that the water supply is still beneficial for irrigation of crops grown in the district and should be protected for those purposes. A source worthy of protection, is at the very least, not degraded enough to justify reclamation but still subject to reasonable use. The applicant’s belief that the project could reclaim portions of the BVWSD may be true, but staff would not label pumping as a reclamation activity when there may be other reasonable beneficial uses of a supply with TDS concentration of 2,000 to 3,000 mg/L. Staff must only support the use of groundwater greater than 3,000 mg/L for cooling, given the high volume required for this project and the need to be consistent with using “the least of the worst”. Staff’s estimated range from a minimum of about 945 mg/L to a maximum of 3,730 mg/L in TDS concentrations using the limited groundwater quality data available suggests it is likely the proposed pumping would not produce a sufficiently degraded supply.

The district’s willingness to provide a 7,500 AF/y may be unreasonable considering that the Kern County subbasin is in overdraft and considering that the district average water level increase is not as high as 7,500 AF/y. The KCWA budget for 1970 through 1998 indicates a negative change in storage of 325,000 AF/y. This indicates that the Kern County subbasin was in overdraft during that period and is likely still in overdraft. Over approximately the same time period, the storage change beneath the Buttonwillow Service Area (BSA) estimated from observed water level trends was positive and between 4,600 and 6,100 AF/y. Staff views this increase in storage as definite positive influence on basin storage during a period of significant and widespread storage decline in the Kern County subbasin. However if the proposed project pumping created a negative change in storage within the BSA, this would compound deficits in a basin that appears to be in overdraft. Reasonable groundwater withdrawal from within the BSA should be limited to the verified increase in storage within the BSA, between 4,600 to 6,100 AF/y.

The proposed use would appear more reasonable if it were able to achieve multiple benefits. For instance, if the project was supplied with water from a remediation project the use of water within the Kern County subbasin would be more reasonable. The current location would supply a large volume of groundwater of an unsure quality, TDS concentrations between 1,000 mg/L and 4,000 mg/L. Assuming the worst case scenario, where the supply is closer to 1,000 mg/L, the project may have no quantifiable benefit other than providing an industrial water supply. However if the project were to pump shallow groundwater from the northern Buttonwillow Service Area, which is a known regional issue, it is much more likely that the project could at least lower the shallow groundwater table beneath the root zone and perhaps also remove water with no other beneficial uses. BVWSD's, FEIR states that the district is interested in pumping water from their Target Area A, which has a shallow groundwater problem and is available in sufficient quantity to supply the project.

STAFF'S PROPOSED AREAS OF FURTHER REVIEW

Staff believes that other well configurations or locations could more effectively capture poor quality water or water with no other beneficial uses. If the project's pumping were able to better induce horizontal flow, particularly flow from the east, it is more likely that pumping could remove brackish water from the local aquifer. Staff believes this effect could be accomplished by a couple distinct changes in the pumping strategy.

- As described in this analysis and in the BVWSD FEIR, the northern portion of the district appears to contain low quality water at shallower depths. This water is detrimental to agriculture and should be removed from the crop root zone. In their FEIR, BVWSD identifies the intent to develop brackish groundwater remediation in the northern BSA (Target Area A) and produce up to 4,500 AF/y. This supply could provide a majority of the water supply needed for project operation. Staff believes this opportunity provides a much greater potential for meeting the proposed objectives of remediation and power plant cooling supply. Supply wells located in BVWSD's northern BSA are more likely to remediate agricultural lands and produce a consistent poor quality supply.
- The applicant has not sufficiently evaluated alternative water sources that may better satisfy water policy concerns. The Revised Application for Certification contains a brief description of the alternative water supplies considered for the project. The description of the alternative, agricultural wastewater, is very brief and general. BVWSD's Water Balance (FIER, 2009) indicates that surface outflow from the agriculture-dominated district may be significant. Staff is also aware that BVWSD is exploring methods for treatment and options for reuse of agricultural drainage, see "Low-pressure RO membrane desalination of agricultural drainage water," published in Desalination in 2003. Staff also notes approximately 12,000 to 15,000 acres of the Buttonwillow Service Area located north of the proposed well field is affected by a shallow water table. Use of this alternative water supply by HECA could provide dual benefits of root zone salt balance and improved soil aeration in the affected area.

- Staff is interested in learning more about the proposed well field and potential water quality that may be produced from it. Additional wells may provide useful information about how water quality varies with depth at the proposed well field site and also may help provide clarity in future discussions on water policy and potential impacts.

REFERENCES

AIRe – Association of Irritated Residents to HECA (tn 68076). Status Report and Data Request, dated 10/24/2012. Submitted to CEC Docket Unit on 10/24/2012.

Anderson&Woessner1992- Applied Groundwater Modeling: Simulation of Flow and Advective Transport, Academic Press Inc.

Belitz&Others1993- *Numerical Simulation of Ground-Water Flow in the Central Part of the Western San Joaquin Valley*, USGS Water-Supply Paper 2396.

BVW 2009a - Buena Vista Water Storage District/D. Bartel (tn 53852). Draft Environmental Impact Report (DEIR) for the Buena Vista Water Storage District Buena Vista Water Management Program. Submitted to CEC/Docket Unit on 10/28/09.

BVW 2010a - Buena Vista Water Storage District (tn 55029). Final Environmental Impact Report for the Buena Vista Water Storage District Buena Vista Water Management Program, dated 12/21/09. Submitted to CEC/Docket Unit on 1/26/10.

BVW 2010b – Buena Vista Water Storage District (tn 59009) Statement for HECA Power Plant Projects Proposed Use of Buena Vista Storage District's Brakis Water. Dated on 11/10/10. Submitted to CEC/ R. Jones on 11/15/10.

Craig1961- *Isotopic variations in meteoric waters*, Science, Vol. 133: 1702 – 1703.

Deverel&Others1984- *Areal distribution of selenium and other inorganic constituents in shallow ground water of the San Luis Drain Service Area, San Joaquin Valley, California: A preliminary study*. U.S. Geological Survey Water Resources Investigations Report 84-4319.

Deverel&Fio1991- *Groundwater flow and solute movement to drain laterals, western San Joaquin Valley, California (1) Geochemical assessment*. Water Resource Research 27: 2233-2246.

Deverel&Fujii1988- *Processes Affecting the Distribution of Selenium in Shallow Groundwater of Agricultural Areas, Western San Joaquin Valley, California*, Water Resources Research, Vol. 24(4): 516 – 524.

Deverel&Gallanthine1989- *Relation of Salinity and Selenium in Shallow Groundwater to Hydrologic and Geochemical Processes, Western San Joaquin Valley, California*, Journal of Hydrology, Vol. 109: 125 – 149.

Doneen, L.D., 1954. Salinization of soil by salts in the irrigation water. Trans. Am. Geophysics. Union, 53: 943-950.

Driscoll1995- *Groundwater and Wells*, Second Edition. U.S. Filter. 1995.

DWR 1961 – California Department of Water Resources. "Report on Proposed Belridge Water Storage District." 1961.

DWR 2006 – California Department of Water Resources. California's Groundwater Bulletin 118. Updated 01/20/06.

DWR 2009 - California Department of Water Resources. California Water Plan Update, Bulletin 160-09. 2009.

Ferguson, L. L., Poss, J. A., Grattan, S. R., Grieve, C. M., Wang, D. D., Wilson, C. C., & ... Chao, C. T. (2002). Pistachio rootstocks influence scion growth and ion relations under salinity and boron stress. Journal Of The American Society For Horticultural Science, 127(2), 194-199.

Fio&Deverel1991- *Groundwater flow and solute movement to drain laterals, western San Joaquin Valley, California (2) Quantitative hydrologic assessment*. Water Resource Research 27: 2247-2257.

Fontes&Gonfiantini1967- *Isotopic composition of evaporation waters of two Saharan basins*. Earth Planet. Sci. Lett., Vol. 3: 258 – 266.

Freeze&Cherry1979- *Groundwater*. Prentice Hall, 1979.

Gat&Isaar1974- *Desert isotope hydrology: Water sources of Sinai desert*. Geochim. Cosmochim. Acta, Vol. 38: 1117 – 1131.

Harbaugh2000- *MODFLOW-2000, the U.S. Geological Survey modular ground-water model -- User guide to modularization concepts and the Ground-Water Flow Process*, U.S. Geological Survey Open-File Report 00-92.

HECA 2012b - SCS Energy California/Hydrogen Energy California, LLC /J. L. Croyle (tn 65049). Amended Application for Certification, Vols. I, II, and III, dated 05/02/12. Submitted to CEC Docket Unit on 05/02/2012.

HydroFocus2006- *Results of Groundwater Sampling in Western San Joaquin Valley, August 2002*, San Luis Drainage Feature Re-evaluation Environmental Impact Statement, Appendix E2.

Ireland&Others1984- *Land Subsidence in the San Joaquin Valley, California, as of 1980,* U.S. Geological Survey Professional Paper 437-I.

KCWA 2010 – Kern County Water Agency website. http://www.kcwa.com. Accessed July 2010.

KWB 2010 – Kern Water Bank Authority website. http://www.kwb.org. Accessed July 2010.

McDonald&Harbaugh1988- *A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model,* U.S. Geological Survey Techniques of Water Resources Investigations, book 6, Chap. A1.

Page1973- *Base of Fresh Groundwater (approximately 3,000 micro-mhos) in the San Joaquin Valley, California*: U.S. Geological Survey Hydrologic Investigations Atlas HA-489.

Pollock1994- *User's guide for MODPATH/MODPATH-PLOT, Version 3; a particle tracking post-processing package for MODFLOW, the U.S. Geological Survey finite-difference ground-water flow model*, U.S. Geological Survey Open-File Report 94-464.

Reilly&Others1987- *The principle of superposition and its application in ground-water hydraulics*, U.S. Geological Survey Techniques of Water Resources Investigations 03-B6.

RWQCB 2004 – Water Quality Control Plan for the Tulare Lake Basin, Second Edition, Central Valley Regionally Water Quality Control Board. January 2004.

Swanson1998- *Land Subsidence in the San Joaquin Valley, Updated to 1995,* in Land Subsidence: Case Studies and Current Research. pp 75-79.

URS 2009j - URS/D. Shileikis (tn 54064). Applicant's Responses to CEC Data Requests Set 1, dated 11/11/09. Submitted to CEC/Docket Unit on 11/12/09.

URS 2009i - URS/D. Shileikis (tn 54428). Responses to CEC Data Requests Set One (#1, 2, 6, & 19), dated 12/11/2009. Submitted to CEC/Docket Unit on 12/11/2009.

URS 2010a - URS/D. Shileikis (tn 54762). Applicant's Response to Energy Commission Data Requests Set One (#1, 2, 11, 17, 31b, 32, 33, 36, 64f, 85 and 125 through 132), dated 1/8/10. Submitted to CEC/Docket Unit on 1/8/10.

URS 2010b - URS/D. Shileikis (tn 55121). Applicant's Response to Energy Commission Data Requests Set Two, dated 2/1/10. Submitted to CEC/Docket Unit on 2/2/10.

URS 2010c - URS/D. Shileikis (tn 55122). Applicant's Response to Energy Commission Data Requests Set One, dated 2/1/10. Submitted to CEC/Docket Unit on 2/2/10.

URS 2010j – URS/ (tn:56563) Draft Hydrogeology Data Acquisition Report & Addendum. Submitted to CEC/Docket Unit on 04/30/10.

URS 2010k – URS/ D. Shileikis (tn:57101) Applicant's Responses to the April 2010 CEC Data Response & Issues Resolution Workshop.Dated on 06/10/10. Submitted to CEC/Docket Unit on 06/14/10.

URS 2010L – URS/D.Shileikis (tn:57260) Applicatants Response to April 2010 CEC &

Request for Conditions for HECA. Dated on 06/21/10. Submitted to CEC/Docket Unit on 06/22/10.

URS 2010m - URS/D. Shileikis (tn: 57536) Applicant's Responses to April 12 CEC Data Response & Issues Resolution Workshop, Figures 7-1 & 7-2. Dated on 07/08/10. Submitted to CEC/Docket Unit 07/08/10.

URS 2010w – URS/D. Shileikis (tn 59011) Applicant's Responses to Data Requests Set 3 (153-218). Dated on 11/12/10. Submitted to CEC/Docket Unit on 11/12/10.

USBR 2009 – Delano-Earlimart Irrigation District and Rosedale-Rio Bravo Water Storage District Banking Program 2010-2026. Date December 2009. http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=5611

USDANRCS2008- *Soil Survey Geographic (SSURGO) database for Kern County, California, Northwestern Part*. Fort Worth: http://SoilDataMart.nrcs.usda.gov/.

SOIL AND WATER RESOURCES - Appendix A

Acronyms Used in the Soil and Water Resources Section

amsl	above mean sea level	IEPR	Integrated Energy Policy Report
AF	acre-feet	lbs	pounds
AFY	acre-feet per year	LID	Low Impact Development
BLM	Bureau of Land Management	LORS	laws, ordinances, regulations, and standards
bgs	below ground surface	MCL	maximum contaminant level
BMP	Best Management Practices	mg/l	milligrams per liter
CDPH	California Department of Public Health	mph	miles per hour
CEQA	California Environmental Quality Act	MOU	Memorandum of Understanding
cfs	cubic feet per second	MW	megawatt
CPM	Compliance Project Manager	NEPA	National Environmental Policy Act
DESCP	Drainage, Erosion, and Sediment Control Plan	NPDES	National Pollutant Discharge Elimination System
DTSC	Department of Toxic Substances Control	RCRA	Resource Conservation and Recovery Act
DWR	Department of Water Resources	REC	Recognized Environmental Condition
ESA	Environmental Site Assessment	ROC	Record of Conversation
FEMA	Federal Emergency Management Agency	RWQCB	Regional Water Quality Control Board
ft/day	feet per day	SWPPP	Storm Water Pollution Prevention Plan
fps	feet per second	SWRCB	State Water Resources Control Board
FSA	Final Staff Assessment	TDS	total dissolved solids
ft/ft	feet per foot	μS/cm	microsiemens per centimeter
ft/yr	feet per year	USCS	Unified Soil Classification System
gpd	gallons per day	WWTP	wastewater treatment plant
gpd/ft	gallons per day per foot		
gpm	gallons per minute		