B.F. Sisk Dam Safety of Dam Modification Project

Appendix H: Statewide Agricultural Production Model

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1.0 Introduction

This technical appendix describes the agricultural economic model used in the analysis of B.F. Sisk Dam Corrective Action Study (CAS) and B.F. Sisk Dam Safety of Dams (SOD) Modification Project (Project) Environmental Impact Statement/Environmental Impact Report (EIS/EIR) alternatives. The scenarios evaluated for the CAS include a Future No Action Alternative (NAA), and three policy alternatives: 55-Foot Reservoir Restriction Alternative; 47-Foot Reservoir Restriction Alternative; and Dam Breach Alternative. For the B.F. Sisk Dam SOD Project EIS/EIR, the Reservoir Restriction Alternative analyzes the impacts of the 55-feet Restriction as the worst-case restriction. The CalSim modeling technical appendix (Appendix B) provides additional details regarding the development of the alternatives and the water supply delivered to agricultural users under each alternative.

The Statewide Agricultural Production (SWAP) model is used to evaluate the effects of changes in water supply to agriculture in Central Valley regions. As water supply conditions change within a region as a result of the B.F. Sisk Dam SOD Project, growers may shift the crop mix, fallow land, and adjust input use in the production of crops. The SWAP model evaluates these effects; results for each alternative are compared to the results of the NAA to quantify changes in agricultural production, irrigated acreage, and gross farm revenues.

2.0 SWAP Model Overview

The SWAP model is a regional agricultural production and economic optimization model that simulates the decisions of farmers in the Central Valley. It is the most current in a series of California agricultural production models, originally developed by researchers at the University of California at Davis in collaboration with the California Department of Water Resources (DWR) with additional funding provided by the United States Bureau of Reclamation (Reclamation).

The SWAP model has been peer-reviewed (Howitt et al. 2012). The SWAP model, and its predecessor the Central Valley Production Model (CVPM), have been used for numerous policy analyses and impact studies over the past 20 years, including the impacts of the Central Valley Project Improvement Act (Reclamation and United States Fish and Wildlife Service 1999), Upper San Joaquin Basin Storage Investigation (Reclamation 2008), the State Water Project (SWP) drought impact analysis (Howitt et al. 2009a), and the economic implications of Delta conveyance options (Lund et al. 2007).

2.1 SWAP Model Mechanics

The SWAP model data coverage includes the Central Valley. For this analysis, an agricultural production region representing the San Felipe Unit was added to the SWAP model. The model assumes that farmers maximize profit subject to resource, technical, and market constraints. Farmers sell and buy in competitive markets, and no one farmer can affect or control the price of any commodity. The model selects those crops, water supplies, and other inputs that maximize profit subject to constraints on water and land, and subject to economic conditions regarding prices, yields, and costs. The competitive market is simulated by maximizing the sum of consumer and producer surplus subject to the following characteristics of production, market conditions, and available resources:

- Constant Elasticity of Substitution (CES) production functions for every crop in every region. CES has four inputs: land; labor; water; and other supplies. CES production functions allow for limited substitution between inputs, which allows the model to estimate both total input use and input use intensity. Parameters are calculated using a combination of prior information and the method of Positive Mathematical Programming (PMP) (Howitt 1995).

- Groundwater pumping cost including depth to groundwater.

- California state-wide commodity demand functions.

- Resource constraints on land, labor, water, and other input availability by region.

The SWAP model incorporates project water supplies (SWP and CVP), other local water supplies, and groundwater. As conditions change within a SWAP region (e.g., the quantity of available project water supply increases or the cost of groundwater pumping increases), the model optimizes production by adjusting the crop mix, water sources and quantities used, and other inputs. It also fallows land when that appears to be the most cost-effective response to resource conditions.

The SWAP model is used to compare the long-term response of agriculture to potential changes in SWP and CVP irrigation water delivery, other surface or groundwater conditions, or other economic values or restrictions.

Results from Reclamation’s and DWR’s operations planning model, CalSim II, are used as inputs into SWAP through a standardized data linkage tool. The CalSim II data file for each alternative includes nine water year types. For this analysis, SWAP modeling was completed for “average” and “dry” water years. The average water year is represented as the average water supply across all nine water year types. The dry year is the average of dry and critical water year output from CalSim II. For each scenario and water year type, the CalSim II model provides the SWAP model with CVP and SWP farm-gate irrigation water deliveries for each SWAP model region.

2.2 SWAP Model Theory

The SWAP model self-calibrates using a three-step procedure based on PMP (Howitt 1995) and the assumption that farmers behave as profit-maximizing agents. In a traditional optimization model, profit-maximizing farmers would simply allocate all land, up until resource constraints become binding, to the most valuable crop(s). In other words, a traditional model would have a tendency for overspecialization in production activities relative to what is observed empirically. The method of PMP incorporates information on the marginal production conditions that farmers face, allowing the model to exactly replicate a base year of observed input use and output. Marginal conditions may include inter-temporal effects of crop rotation, proximity to processing facilities, management skills, farm-level effects such as risk and input smoothing, and heterogeneity in soil and other physical capital. In the SWAP model, PMP is used to translate these unobservable marginal conditions, in addition to observed average conditions, into a cost function.

Unobserved marginal production conditions are incorporated into the SWAP model through increasing land costs. Additional land brought into production is of lower quality and, as such, requires higher production costs, captured with an exponential “PMP” cost function. The PMP cost function is both region and crop specific, reflecting differences in production across crops and heterogeneity across regions. Functions are calibrated using information from acreage response elasticities and shadow values of calibration and resource constraints. The information is incorporated in such a way that the average cost data reflected in standard crop budgets (known data) are unaffected.

PMP is fundamentally a three-step procedure for model calibration that assumes farmers optimize input use for maximization of profits. In the first step, a linear profit-maximization program is solved. In addition to basic resource availability and non-negativity constraints, a set of calibration constraints is added to restrict land use to observed values. In the second step, the dual (shadow) values from the calibration and resource constraints are used to derive the parameters for the exponential PMP cost function and CES production function. In the third step, the calibrated CES and PMP cost function are combined into a full profit maximization program. The exponential PMP cost function captures the marginal decisions of farmers through the increasing cost of bringing additional land into production (e.g., through decreasing quality). Other input costs (supplies, land, and labor) enter linearly into the objective function in both the first and third step.

The SWAP model, and calibration by PMP, is a complicated process, thus sequential testing is very useful for model validation, diagnosing problems, and debugging the model. At each stage in the SWAP model there is a corresponding model check. In other words, the calibration procedure has particular emphasis on the sequential calibration process and a parallel set of diagnostic tests to check model performance. Diagnostic tests are discussed in Howitt et al. (2012).

2.3 Constant Elasticity of Substitution Production Function

Crop production in the SWAP model is represented by a CES production function for each region and crop. In general, a production function is a mathematical specification used to capture the relationship between inputs and output. For example, land, labor, water, and other inputs are combined to produce output of any crop. CES production functions in the SWAP model are specific to each region, thus regional input use is combined to determine regional production for each crop. The calibration routine in SWAP guarantees that both input use and output exactly match a base year of observed data.

The generalized CES production function allows for limited substitution among inputs (Beattie and Taylor 1985). This is consistent with observed farmer production practices (farmers are able to substitute among inputs in order to achieve the same level of production). For example, farmers may substitute labor for chemicals by reducing herbicide application and increasing manual weed control. Or, farmers can substitute labor for water by managing an existing irrigation system more intensively in order to increase efficiency. The CES function used in the SWAP model is non-nested, thus the elasticity of substitution is the same between all inputs.

2.4 Crop Demand Functions

The SWAP model is specified with downward-sloping California state-wide demand functions. The demand curve represents willingness-to-pay for a given level of crop production. All else constant, as production of a crop increases the price of that crop is expected to fall. The extent of the price decrease depends on the elasticity of demand or, equivalently, the price flexibility. The latter refers to the percentage change in crop price due to a percent change in production. The SWAP model is specified with linear demand functions.

2.4.1 Demand Shifts

The nature of the demand function for specific commodities can change over time due to tastes and preferences, population growth, changes in income, and other factors. The SWAP model incorporates linear shifts in the demand functions over time due to growth in population and changes in real income per capita. Changes in consumer tastes and preferences are difficult to predict and will have an indeterminate effect on demand and are consequently not considered in the model.

3.0 SWAP Model Data

The SWAP model requires a wide range of data to simulate the supply and demand for statewide agricultural production. The necessary data are not available from a single source and are instead compiled from various publically available sources, including state and federal agencies, academic publications, and water district reports. A SWAP model data update was completed between 2009 and 2011 under contract with Reclamation. The model data and code is currently being updated under contract with the California Department of Food and Agriculture. The model update completed in 2011 is known as SWAP version 6 and this version was used for analysis of the B.F. Sisk Dam SOD Project alternatives. Importantly, SWAP version 6 is used in the B.F. Sisk Dam SOD Project analysis because it includes a National Economic Development (NED) post-processing routine which ensures benefits are consistent with federal guidelines. The NED post-processor was developed in collaboration with Reclamation concurrent with the SWAP version 6 data update.

3.1 SWAP Regions and Crop Definitions

The SWAP model includes 27 base regions in the Central Valley. For this analysis, a region representing the San Felipe Unit was added to account for changes in CVP water deliveries from San Luis Reservoir. All of the regions are included in the analysis of B.F. Sisk Dam SOD Project alternatives.

All SWAP model regions are included in the economic summaries of the B.F. Sisk Dam SOD Project alternatives. Table 1 summarizes some of the major water users in each of the regions.

Table 1. SWAP Model Region Summary

Region	Major Surface Water Users
1	CVP Users: Anderson Cottonwood Irrigation District (ID), Clear Creek Community Services District, Bella Vista Water District (WD), and miscellaneous Sacramento River water users.
2	CVP Users: Corning Canal, Kirkwood WD, Tehama, and miscellaneous Sacramento River water users.
3a	CVP Users: Glenn Colusa ID, Provident ID, Princeton-Codora ID, Maxwell ID, and Colusa Basin Drain Municipal Water Company (MWC).
3b	Tehama Colusa Canal Service Area. CVP Users: Orland-Artois WD, and Westside WD.
4	CVP Users: Princeton-Codora-Glenn ID, Colusa Irrigation Company, and miscellaneous Sacramento River water users.
5	Most Feather River Region riparian and appropriative users.
6	Yolo and Solano Counties. CVP Users: Conaway Ranch and miscellaneous Sacramento River water users.
7	Sacramento County north of American River. CVP Users: Natomas Central MWC, miscellaneous Sacramento River water users, Pleasant Grove-Verona WMC, and Placer County Water Agency.
8	Sacramento County south of American River and northern San Joaquin County.
9	Direct diverters within the Delta region. CVP Users: Banta Carbona ID, West Side WD, and Plainview.
10	Delta Mendota service area. CVP Users: Panoche WD, Pacheco WD, Del Puerto WD, Hospital WD, Sunflower WD, San Joaquin River Exchange Contractors.
11	Stanislaus River water rights: Modesto ID, Oakdale ID, and South San Joaquin ID.
12	Turlock ID.
13	Merced ID. CVP Users: Madera ID, Chowchilla WD, and Gravely Ford.
14a	CVP Users: Westlands WD.
14b	Southwest corner of Kings County
15a	Tulare Lake Bed. CVP Users: Fresno Slough WD., James ID, Tranquillity ID, Traction Ranch, Laguna WD, and Reclamation District 1606.
15b	Dudley Ridge WD and Devils Den (Castaic Lake)
16	Eastern Fresno County. CVP Users: Friant-Kern Canal, Fresno ID, Garfield WD, and International WD.
17	CVP Users: Friant-Kern Canal, Hills Valley ID, Tri-Valley WD, and Orange Cove.
18	CVP Users: Friant-Kern Canal, County of Fresno, Lower Tule River ID, Pixley ID, and Tulare ID.
19a	SWP Service Area, including Belridge Water Storage District (WSD), Berrenda Mesa WD.
19b	SWP Service Area, including Semitropic WSD.
20	CVP Users: Friant-Kern Canal. Shafter-Wasco, and South San Joaquin ID.
21a	CVP Users: Cross Valley Canal and Friant-Kern Canal
21b	Arvin Edison WD.
21c	SWP service area: Wheeler Ridge-Maricopa WSD.
22	San Felipe Unit

Note: the list above does not include all water users. It is intended only to indicate the major users or categories of users. All regions in the Central Valley also include private groundwater pumpers.

Crops are aggregated into 20 crop groups which are the same across all regions. Each crop group represents a number of individual crops, but many are dominated by a single crop. Irrigated acres represent acreage of all crops within the group, production costs and returns are represented by a single proxy crop for each group. The current 20 crop groups were defined in collaboration with DWR and were last updated in 2011. Crop group definitions and the corresponding proxy crop are shown in Table 2.

Table 2. SWAP Model Crop Groups

SWAP Definition	Proxy Crop	Other Crops
Almonds and Pistachios	Almonds	Pistachios
Alfalfa	Alfalfa Hay	
Corn	Grain Corn	Corn Silage
Cotton	Pima Cotton	Upland Cotton
Cucurbits	Summer Squash	Melons, Cucumbers, Pumpkins
Dry Beans	Dry Beans	Lima Beans
Fresh Tomatoes	Fresh Tomatoes	
Grain	Wheat	Oats, Sorghum, Barley
Onions and Garlic	Dry Onions	Fresh Onions, Garlic
Other Deciduous	Walnuts	Peaches, Plums, Apples
Other Field	Sudan Grass Hay	Other Silage
Other Truck	Broccoli	Carrots, Peppers, Lettuce, Other Vegetables
Pasture	Irrigated Pasture	
Potatoes	White Potatoes	
Processing Tomatoes	Processing Tomatoes	
Rice	Rice	
Safflower	Safflower	
Sugar Beet	Sugar Beets	
Subtropical	Oranges	Lemons, Miscellaneous Citrus, Olives
Vine	Wine Grapes	Table Grapes, Raisins

3.2 Crop Prices and Yields

The SWAP model is designed to calibrate to the actual conditions growers faced in the calibration year. Growers make current planting decisions based on expectations of prices. The SWAP model does not attempt to model how growers form their price expectations; as an approximation, SWAP uses an average of county-level crop prices. Data for county-level crop prices are obtained from the respective County Agricultural Commissioners’ annual crop reports.

3.3 Crop Yields

Crop yields for each crop group in the SWAP model correspond to the proxy crops listed in Table 2 and are based on best management practices. The corresponding costs of production, discussed in Section 3.4, are based on cost studies that also reflect best management practices. Thus, crop yields in SWAP are slightly higher than those estimated by calculating county averages, but are more consistent with the production costs. Crop yield data are compiled from the University of California Cooperative Extension (UCCE) production cost budgets prepared by University of California at Davis (UC Davis) and

Extension Researchers. Yields for each region are based on the most recent proxy crop cost study available in the closest region. For example, if a cost study is not available for a particular crop in the Sacramento Valley, the North San Joaquin Valley study may be used.

3.4 Crop Cost of Production Budgets

Land, labor, and other supply costs of production are obtained from the same UCCE crop budgets used to estimate crop yields. Each UCCE budget uses interest rates for capital recovery and interest on operating capital specific to the year of the study. These range from four percent to over eight percent and, as such, require adjustment to a common base year interest rate. A common rate of six percent is used for all data.

Land costs are derived from the respective UCCE crop budget and include land-related cash overhead plus rent and land capital recovery costs. Where appropriate, interest rates are adjusted as described above.

The labor cost category in the SWAP model includes both machine and non-machine labor. Labor wages per hour differ for machine and non-machine labor and, as such, are reported separately in the UCCE budgets. Both machine and non-machine labor costs include overhead to the farmer of federal and state payroll taxes, workers' compensation, and a small percentage for other benefits which varies by budget. Additionally, a percentage premium (typically around 20 percent) is added to machine labor costs to account for equipment set-up, moving, maintenance, breaks, and field repair. The sum of these components, reported on a per acre basis, is used as input data into the SWAP model.

The supply cost category in the SWAP model includes all inputs not explicitly included in the other three input categories (land, labor, and water), including fertilizers, herbicides, insecticide, fungicide, rodenticide, seed, fuel, and custom costs. Additionally, machinery, establishment costs, buildings, and irrigation system capital recovery costs are included. Each sub-category of supply costs is broken down in detail in the respective crop budget. For example, safflower in the Sacramento Valley requires pre-plant Nitrogen as aqua ammonia at 100 pounds per acre in fertilizer costs. Application of Roundup in February and Treflan in March account for herbicide costs. The sum of these individual components, on a per acre basis, is used as base supply input cost data in the SWAP model.

3.5 Surface and Groundwater

The SWAP model includes five types of surface water: SWP delivery; three categories of CVP delivery; and local surface water delivery or direct diversion. The three categories of CVP deliveries are: water service contract, including Friant Class 1 (CVP1); Friant Class 2 (CL2); and water rights settlement and exchange delivery[1].Water supply data in the 2010 calibration year for SWAP version 6.1 are derived from various sources, described below. CVP and SWP deliveries for the B.F. Sisk Dam SOD Project alternatives are from the CalSim II model, described in Section 2.1.

The volume of deliveries for each water source is estimated using data from DWR, Reclamation, and water district reports. CVP water deliveries were derived from Reclamation operations data. Contract deliveries were obtained from Reclamation; the difference between total and contract deliveries indicates deliveries for water rights settlements. SWP water deliveries are obtained from DWR Bulletin 132 (DWR 2013). Kern County Water Agency provides additional details on SWP deliveries to member agencies by region. Local surface water deliveries were obtained from individual district records and reports, DWR water balance estimates prepared for the California Water Plan Update (DWR 2009), and, where needed, data from the CVPM model. CVPM data were, in turn, provided by the Central Valley Ground-Surface Water Model.

A key source of irrigation water, and often the costliest, is groundwater pumping. The groundwater pumping capacity estimates within SWAP are from a 2014 analysis by DWR in consultation with individual districts. Groundwater pumping capacity is intended to represent the maximum that a region can pump in a year given the aquifer characteristics and existing well capacities. For this analysis, the endogenous groundwater pumping volume for each region from the NAA was applied as the groundwater pumping limits for each of the alternatives. As such, no additional groundwater pumping is allowed to offset reductions in surface water deliveries. This approach was followed to account for the potential future limits on groundwater pumping due to the Sustainable Groundwater Management Act (SGMA). The effects of SGMA on future groundwater availability for agricultural uses are not known at this time so this approach is an approximation.

Groundwater pumping costs are broken out into fixed, energy, and operations and maintenance (O&M) components in the SWAP model. Energy and O&M components are variable. Energy costs depend on the price of electricity. The SWAP model uses the same unit cost of electricity per kilowatt-hour across all

[1] CVP Settlement water is delivered to districts and individuals in the Sacramento Valley based on their pre-CVP water rights on the Sacramento River, and San Joaquin River Exchange water is pumped from the Delta and delivered to four districts in the San Joaquin Valley in exchange for water rights diversion eliminated when Friant Dam was constructed. These two delivery categories are geographically distinct but for convenience are combined into one water supply category in SWAP.

regions. Base electricity costs are derived from Pacific Gas and Electric Company (PG&E) rate books and consultation with power officials at the Fresno, California office. The energy cost is 22 cents per kilowatt-hour, which is an average of PG&E's AG-1B and AG-4B rates (PG&E Various Years). Overall well efficiency is assumed to be 70 percent.

3.6 Crop Water Requirements

Applied water is the amount of water applied by the irrigation system to an acre of a given crop for production in a typical year. Variation in rainfall and other climate effects will alter this requirement. Additionally, farmers may stress irrigate crops or substitute other inputs in order to reduce applied water. The latter effect is handled endogenously by the SWAP model through the respective CES production functions. Applied water per acre (base) requirements for crops in the SWAP model are derived from DWR estimates. DWR estimates are based on Detailed Analysis Units (DAU). An average of DAUs within a SWAP region is used to generate a SWAP region specific estimate of applied water per acre for SWAP crops.

3.7 Elasticities

SWAP uses a number of economic response parameters, called elasticities, to estimate rates of change in variables. An elasticity is the percent change in a variable, per unit of percent change in another variable or parameter. Acreage response elasticity is one component of supply response. It is the percentage change in acreage of a crop from a one percent change in that crop's price. The SWAP model contains both long run and short run estimates, and the analyst decides which of the elasticities to use. Long run acreage response elasticities are used for this analysis.

3.7.1 SWAP Model Data Sources

The SWAP model version 6.1 uses a base year of 2010 for calibration. The calibration year is used to calibrate the underlying economic parameters in the model and does not represent current conditions used in the B.F. Sisk Dam SOD Project alternatives analysis. The calibration year is simply intended to represent "average" production conditions in the Central Valley. The year 2010 was neither abnormally dry nor wet, and crop markets had been relatively stable. Table 3 summarizes input data and sources used in the SWAP model.

Table 3. SWAP Model Input Data Summary

Input	Source	Notes
Land Use	DWR	Base year 2010
Crop Prices	County Agricultural Commissioners	By proxy crop using 2010—2011 average prices
Crop Yields	UCCE Crop Budgets	By proxy crop for various years (most recent available)
Interest Rates	UCCE Crop Budgets	All interest rates normalized to year 2010
Land Costs	UCCE Crop Budgets	By proxy crop for various years (most recent available)
Other Supply Costs	UCCE Crop Budgets	By proxy crop for various years (most recent available)
Labor Costs	UCCE Crop Budgets	By proxy crop for various years (most recent available)
Surface Water Costs	Reclamation, DWR, Individual Districts	By SWAP model region
Groundwater Costs	PG&E, Individual Districts	Total cost per acre-foot includes fixed, O&M, and energy cost
Irrigation Water	DWR	Average crop irrigation water requirements in acre-feet per acre
Available Water	CVPM, DWR, Reclamation, Individual Districts	By SWAP model region and water supply source
Elasticities	Green et al. 2006	California estimates

3.8 Linkage to Other Models

The SWAP model has important interactions with other models. In particular, CalSim II, DWR's project operations model for the SWP and the CVP, is used to estimate SWP and CVP supplies which are inputs into SWAP. An existing linkage tool has been developed to translate CalSim II delivery output to a corresponding SWAP input (on-farm applied water) file. Changes in depth to groundwater affect pumping costs and agricultural revenues. Changes in groundwater depth and resulting changes in groundwater pumping costs can be included from other model, such as CVHM or C2VSim, output, if those models are run concurrently for the project.

4.0 Implementing the SWAP Model for the B.F. Sisk Dam SOD Project Alternatives

Scenario analysis using the SWAP model can focus on a single point in time or on several future points. With reasonable interpolation, this approach will create a true time sequence to calculate net present value of a stream of costs or benefits. The alternatives for the B.F. Sisk Dam SOD Project were evaluated at a single point in time, also called the level of development.

The SWAP model is used to compare responses to changes in irrigation water delivery under the B.F. Sisk Dam SOD Project alternatives. Results from the CalSim II model are used as inputs into SWAP through a standardized data linkage tool. This linkage tool is used for the NAA, 55-Foot Reservoir Restriction Alternative, 47-Foot Reservoir Restriction Alternative, and Dam Breach Alternative.

CalSim II modeling showed that the B.F. Sisk Dam SOD Project alternatives will increase the availability of Article 21 and Section 215 water supplies. These water supplies generally are available outside of high crop water demand periods. As a result, they are often used to recharge groundwater supplies. For this analysis, the available Article 21 and Section 215 supplies were allocated to the SWAP regions according to historic deliveries. It was assumed that the water supply, less a 10 percent loss, was recharged to groundwater. The average annual Article 21 and Section 215 supplies "banked" in groundwater aquifers was then added to the endogenous groundwater pumping limits for the associated SWAP regions. Level of Development and Water Year Type

The B.F. Sisk Dam SOD Project NAA and three alternatives correspond to a 2030 level of development. Each alternative and level of development is evaluated for two water supply conditions - average and dry.

4.1.1 Crop Demand Shifts

Crop demands are expected to shift in the future due to increased population, higher real incomes, changes in tastes and preferences, and related factors. The key changes that are included in the analysis of B.F. Sisk Dam SOD Project alternatives are population and real income. An increase in real income is expected to increase demand for agricultural products. Similarly, population increases are expected to increase crop demand. Changes in consumer tastes and preferences will have an indeterminate effect on demand and are not included in this analysis.

Increases in demand for crops produced in California may be partially offset by other production regions depending on changing export market conditions. For example, today California is the dominant producer of almonds but this may change if other regions increase production. Thus an increase in almond demand could be partially met by other regions. However, additional demand growth from markets like China may offset this effect. The net effect is indeterminate. In the absence of data or studies demonstrating which effect would dominate, California export share is assumed to remain constant for all crops in the future. This assumption is consistent with peer-reviewed publications for the California Energy Commission and the academic journal *Climatic Change,* in addition to the 2009 DWR Water Plan (Howitt et al. 2009a, Howitt et al. 2009b).

Crop demands are linear in the SWAP model and population and real income changes induce a parallel shift in demand. Demand shifts are included for all of the alternative scenarios evaluated for the B.F. Sisk Dam SOD Project, including the NAA. Consequently, comparisons of NAA to each action alternative relates identical future market conditions.

For purposes of the demand shift analysis, a distinction is made between two types of crops grown in California, California specific crops and global commodities. Global commodity crops include grain rice, and corn[2]; all other crop groups are classified as California crops. Global commodity crops are those for which there is no separate demand for California's production. For these crops, California faces a perfectly elastic demand, and is thus a price taker. For California specific crops, California faces a downward sloping demand for a market that is driven by conditions in the United States and international export markets. A routine in the SWAP model calculates the demand shift for the 2030 level of development for the B.F. Sisk Dam SOD Project alternatives.

4.1.2 Electricity Costs

Groundwater is typically the most expensive water supply. Real power costs are expected to increase in the future, and groundwater relies heavily on the cost of electricity for pumping. Energy pumping costs are escalated according to future marginal power cost estimates for the year 2030.

A marginal power cost escalator is determined for the year 2030 and applied to the energy cost component of groundwater costs. The cost escalator is the ratio of the expected future power cost in 2030 to the base power cost in 2010, in 2010 dollars per megawatt hour. Expected future power costs are calculated using the DWR Forward Price Projections analysis using wholesale power costs (DWR 2011). This calculates an average power cost for each month as the average of the peak (upper bound) and off-peak (lower bound) rates. An average of the monthly costs generates an average yearly cost. This cost is used to generate the power cost escalator by taking the ratio of the future year average to the current year average. The power cost escalator for 2030 is 1.51.

4.1.3 Groundwater Depth

The SWAP model can be linked to a groundwater model to estimate change in depth to groundwater, both static and dynamic, to estimate the additional lift, and therefore energy cost, for water year types. Dry years can result in groundwater levels dropping in some regions of the Central Valley, depending on local aquifer conditions. As described above, this analysis limits groundwater pumping to the NAA volume. However, Calim II modeling showed that there will be additional Article 21 and Section 215 water supplies available which will add to groundwater storage and are assumed to be available for agricultural use. Given these conditions, depth to groundwater is not changed from the NAA levels for the alternatives and year types.

[2] Rice demand is very elastic, but not perfectly elastic. For purposes of the demand shifting analysis, it is assumed to be perfectly elastic.

4.1.4 Other Factors

The SWAP model includes a number of sub-routines that are included in studies on a case-by-case basis. All of these other factors are held constant in the B.F. Sisk Dam SOD Project alternatives.

Climate change effects are held constant in the analysis of B.F. Sisk Dam SOD Project alternatives. The SWAP model has been linked to crop models, such as LAWS, to estimate the change in crop yield and crop evapotranspiration and, therefore, applied water requirements. Climate change effects on crop growth remain highly uncertain and are consequently held constant in the analysis.

Crop yields have been increasing for most crops due to technological innovations. Innovations like hybrid seeds, better chemicals and fertilizer, improved pest management, and irrigation and mechanical harvesting advances are some examples. The expected future rate of growth in crop yields remains a contentious topic among researchers. Consequently, yield changes due to technological innovations are held constant in the analysis of B.F. Sisk Dam SOD Project alternatives. It is important to note that the SWAP model does allow for some minor yield response to changing market conditions. This effect is referred to as endogenous yield changes. The SWAP model includes full CES production functions for each crop and region, which allow for some endogenous yield change in response to changing market conditions, but there is no exogenous technological change included in the analysis.

The optimization routine within SWAP selects the crop mix that maximizes the net returns to producer and consumer surplus. When the availability of production inputs such as water are changed, the optimal crop mix may change including the acres planted to permanent crops such as trees and vines. For this analysis, the optimal crop mix for each scenario under average water supply conditions is estimated first followed by the dry year water supply conditions. For the dry years, permanent crop plantings are required to be at least 95% of the permanent crop plantings estimated for the average year. This limits unreasonably large changes in permanent crop acres across water year types while allowing for some replacement of older trees and vines.

The SWAP model allows for deficit irrigation of crops. Agricultural producers may choose to deficit irrigated crops and incur a loss in crop yield if the strategy maximizes net returns. Deficit irrigation typically is the result of water supply shortages and high water costs. The maximum level of deficit in the SWAP model is set at 70 percent of applied water needs for each crop and region. In this analysis, deficit irrigation is allowed in the dry year but not the average water year as there is little empirical evidence suggesting that agricultural producers deficit irrigate during periods of adequate water supplies.

4.2 NED Benefits Calculations

The basic guidelines for evaluating water development projects at the federal level are specified in the “Principles, Requirements, and Guidelines for Federal Investments in Water Resources” (PR&Gs; CEQ 2014). Under the PR&Gs, the federal objective for water contributions is to maximize the contribution to NED consistent with protection of the environment. In order to adhere to the PR&Gs and determine the contribution to NED, a series of adjustments to the SWAP model and data are necessary. Adjustments fall into two categories, pre- and post-processing. Pre-processing adjustments are made prior to optimization with the SWAP model and include adjustments to SWAP input data and exogenous projections of future costs and demands. Post-processing adjustments are applied to SWAP output and include adjustments to prices and costs. They are adjustments needed in order for the results to comply with PR&Gs and Reclamation guidelines for NED analysis. In particular, guidelines require that certain prices be used for valuing changes in physical inputs and outputs. They do not explicitly affect farmers’ decisions, so they are applied after the SWAP optimization. Post-processing adjustments include interest rates, other supply costs, fallow land costs, normalized crop prices, consumer surplus, water costs, and management charges.

All of the NED adjustments follow the SWAP NED adjustments developed in consultation with Reclamation for the North of Delta Offstream Storage (NODOS) feasibility study. The data have been updated to reflect current conditions (e.g., Current Normalized Prices are updated), but the fundamental method is unchanged. This section provides an overview of the approach.

Pre-processing adjustments include changes to the data that occur before SWAP model optimization. This includes demand shifts, energy pumping costs, interest rate adjustment, and other factors as described earlier in this section. These adjustments are made prior to SWAP optimization and are made regardless of whether the project is being evaluated under NED guidelines.

Post-processing adjustments take place after the SWAP model optimization. These include:

1. The PR&Gs require that the federal discount rate be used for all interest and capital recovery calculations. The current (FY18) federal discount rate is 2.75 percent. A post-processing adjustment is applied to cost data components to adjust the interest rate to 2.75 percent.

2. Machinery capital recovery costs are removed from the NED analysis under all scenarios. Additional land coming into irrigated production (with the project versus without the project) would be quite small and is therefore unlikely to require additional machinery investment. By the same logic, buildings capital recovery costs are removed from the NED analysis under all scenarios.

3. Land rent and cash overhead and land capital recovery costs are removed from the NED analysis under all scenarios. The NED analysis is adjusted to remove land costs that are included within the SWAP data file because lands being brought into irrigated production are already considered a sunk investment. Sunk investments are irrelevant to determining the economic feasibility of new project investments.

4. Interest on operating capital and capital recovery charges for permanent crop establishment and for irrigation systems are adjusted using interest factors as noted above.

5. An annual maintenance cost of approximately $40 per acre (in 2017 dollars) is used for the NED analysis to account for fallow land costs, as required by the PR&Gs.

6. Consumer surplus is the benefit (welfare gain) that consumers realize from being able to purchase crops at less than their maximum willingness to pay. As was noted in Chapter 5, and detailed in Appendix B, the severity of changes in water supply deliveries under the reservoir restriction and breach alternatives would be mitigated in part by increases in surplus Section 215 (CVP) and Article 21 and Article 56 (SWP) deliveries. The forecasted changes in water supply deliveries identified were not of a size that would be expected to result in measurable changes to crop prices given the availability of alternative water supply options. Since changes to crop prices would be negligible under the reservoir restriction and breach alternatives, the corresponding changes in consumer surplus would be negligible and is therefore excluded from the B.F. Sisk Dam SOD Project NED benefits calculations.

7. Surface water costs are excluded from the NED benefits calculation. In a NED benefit-cost analysis of a proposed project, the incremental investment and annual costs of the new water supply are accounted for on the cost side of the ledger, so including them as water costs within the benefits analysis would effectively be double-counting.

8. Reclamation guidelines for preparing NED analysis under the PR&Gs recommend including management costs at no less than six percent of variable costs. A six percent management charge is added to the variable production costs in the SWAP model.

9. The PR&Gs state that U.S. Department of Agriculture (USDA) Current Normalized Prices (CNP) must be used for benefits calculations when available. These prices have been adjusted by USDA to remove any federal subsidies because such subsidies represent an NED cost that must be accounted for in comparing project benefits and costs. For crop groups covered by USDA's CNP estimates, SWAP prices were

converted to scaled CNP. For crop groups without available CNP, the SWAP-predicted prices are used. CNP reported in dollars per ton, are as follows: corn $120.36; cotton $1,413.07; dry beans $952.00; grains (wheat) $154.00; rice $312.80; and sugar beets $41.92.

5.0 Description of B.F. Sisk Dam SOD Project Results

This section describes the SWAP model results for NAA and the B.F. Sisk Dam SOD Project action alternatives. Changes in economic conditions are summarized in terms of irrigated acreage, gross farm revenues, groundwater use, and groundwater cost. Water year types summarized in this section include average and dry conditions.

5.1 No Action Alternative

The NAA represents future market and production conditions for Central Valley agriculture if the B.F. Sisk Dam SOD Project is not implemented. The NAA is used to compare the policy alternatives. Table 4 shows the total Central Valley, including CVP and SWP water users, irrigated acreage and gross value of agricultural production under the NAA.

On average, in the Central Valley approximately $30 billion in gross value of production is generated on more than 7 million irrigated acres. Total irrigated acres and value of production is higher in all years than the dry years. The total irrigated area and gross value decreases in dry conditions as growers shift the crop mix to lower water use crops and fallow land in response to constrained surface water supplies. For example, the Central Valley irrigates 7.02 million acres in all years and 6.68 million acres in dry years and the corresponding gross value of production decreases from $29.6 million to $29.1 million. Growers are able to partially offset reduced surface water supplies by deficit irrigating crops in the dry years. Groundwater pumping declines somewhat in dry years as SWAP estimates that agricultural producers will fallow, deficit irrigate, and switch to lower water use crops rather than incur the costs of pumping groundwater up to the allowed limit.

Table 4. NAA Central Valley Acres, Value of Production, Groundwater Use and Costs

Analysis Metric	Average	Dry
Total Irrigated Acreage (Acres)		
Sacramento Valley	2,261,552	2,236,690
San Joaquin	1,696,428	1,667,906
Tulare	2,242,573	2,053,771
Kern	818,782	718,407
Total	7,019,335	6,676,773
Surface Water Use (AF)		
Sacramento Valley	6,085,766	5,991,644
San Joaquin	3,027,664	2,936,234
Tulare	3,287,071	2,811,829
Kern	1,378,525	1,100,779
Total	13,779,026	12,840,486
Total Value of Production ($)		
Sacramento Valley	$7,677,826,787	$7,671,414,067
San Joaquin	$6,733,297,278	$6,740,003,045
Tulare	$10,873,569,413	$10,693,786,402
Kern	$4,324,942,071	$4,018,984,953
Total	$29,609,635,549	$29,124,188,467
Annual Groundwater Pumped (AF)		
Sacramento Valley	1,111,522	1,102,084
San Joaquin	1,966,651	1,966,651
Tulare	3,512,522	3,512,522
Kern	1,544,199	1,544,199
Total	8,134,895	8,125,457
Annual Cost of Pumping ($)		
Sacramento Valley	$85,086,967	$84,565,282
San Joaquin	$173,427,467	$173,427,467
Tulare	$457,137,743	$457,137,750
Kern	$320,611,918	$320,611,933
Total	$1,036,264,095	$1,035,742,433

5.2 Results Summary

Table 5 shows the estimated changes in agricultural production, water use, and NED benefits associated with the B.F. Sisk Dam SOD Project alternatives. The values in the table show the change from NAA conditions for total irrigated acres, surface water use, groundwater use, gross crop revenues, and NED benefits for all SWAP regions. SWAP model results disaggregated to smaller geographic regions are provided in subsequent sections of this appendix.

Under each of the alternatives, SWAP estimates that the total irrigated acres will decline from the NAA during all years due to the overall reduction in agricultural water supplies. Irrigated acres decline by approximately 26,000 acres under the 47-Foot Reservoir Restriction Alternative to nearly 141,000 acres under the Dam Breach Alternative. The primary crops fallowed include alfalfa, cotton, and grains. Under the Dam Breach Alternative, a large number of truck crops grown in the San Felipe Unit are fallowed as surface water deliveries are greatly reduced and groundwater pumping is limited.

In the dry years, irrigated acres show a slight increase for the 47 and 55-Foot Reservoir Restriction Alternatives relative to the NAA. This small increase is attributable to a higher total volume (surface and groundwater) of water use under the alternatives relative to the NAA during the dry years. For example, under the 47-Foot Reservoir Restriction Alternative, total water use is approximately 20,982,000 AF in the dry years compared to 20,965,000 AF in the NAA. The increase in water supply availability is due to the increase in Article 21 and Section 215 water supplies that are assumed to be recharged and available for subsequent groundwater pumping. Under the Dam Breach Alternative, the total water supply declines and total irrigated acres decline as a result.

The B.F. Sisk Dam SOD Project alternatives result in reductions in both SWP and CVP agricultural water supplies during both year types. In total, surface water use declines by 139,000 AF under the 47-Foot Reservoir Restriction alternative. The reduction increases to 736,000 AF under the Dam Breach Alternative. In comparison, during the average and dry years, CVP and SWP supplies are approximately 5.2 MAF and 4.1 MAF, respectively.

As described above, groundwater pumping volumes were initially limited to the endogenous levels estimated by SWAP under the NAA for all years. The B.F. Sisk Dam SOD Project alternatives results in a large increase in the volume of Article 21 and Section 215 water supplies. Under the 47-Foot Reservoir Restriction Alternative, the increase in Article 21 and Section 215 supplies results in more than 97,000 AF more groundwater available for agricultural use when compared to the NAA. The annual available groundwater increases by more than 635,000 AF under the Dam Breach Alternative. As a result, groundwater pumping increases under the alternatives as surface water supplies are diminished. Much of the increased pumping occurs in the Kern County region where there is a large capacity to recharge groundwater with available surface water supplies.

During all years, the annual gross revenues from crop production decline by between $13.9 million and $213.9 million. The effects on gross revenues are lower in the dry years and range from an increase of $8.9 million to a reduction of $82.3 million. During dry years, agricultural producers are able to maintain gross revenues by deficit irrigating, switching to less water-intensive crops, and pumping more groundwater. The increased groundwater pumping comes at a cost, however. Groundwater pumping costs increase by more than $15 million under the 47-Foot Reservoir Restriction Alternative and by more than $108 million under the Dam Breach Alternative in dry years. In all years, the estimate

NED benefits decline by $50.3 million to $217.6 million and $9.7 to $110.3 million in the dry years.[3]

Table 5. Summary of SWAP Results by Alternative and Year Type in Comparison to the No Action/No Project Alternative[1]

Analysis Metric	All	Dry[2]
Change in Acres Irrigated		
47' Reservoir Restriction	-26,181	5,141
55' Reservoir Restriction	-33,472	7,181
Dam Breach	-140,595	-27,799
Change in Surface Water Use (AF)		
47' Reservoir Restriction	-139,035	-81,282
55' Reservoir Restriction	-185,826	-119,919
Dam Breach	-735,767	-578,577
Change in Gross Revenues ($)		
47' Reservoir Restriction	-$13,875,959	$8,867,563
55' Reservoir Restriction	-$22,428,137	$10,426,177
Dam Breach	-$213,875,873	-$82,294,860
Change in Groundwater Use (AF)		
47' Reservoir Restriction	66,049	97,174
55' Reservoir Restriction	94,317	137,929
Dam Breach	382,061	501,538
Change in Groundwater Costs ($)		
47' Reservoir Restriction	$15,070,412	$19,906,349
55' Reservoir Restriction	$21,322,836	$28,246,178
Dam Breach	$90,114,494	$108,059,895
Estimated NED Benefits ($)		
47' Reservoir Restriction	-$50,258,364	-$9,671,189
55' Reservoir Restriction	-$57,591,924	-$11,941,708
Dam Breach	-$217,574,682	-$110,333,904

Notes: [1]Positive AF values represent increases in **surface or groundwater use** when compared to the No Action/No Project Alternative and negative values represent decreases. Positive dollar values indicate increases in costs or benefits when compared to the No Action/No Project Alternative, and negative values indicate reductions in costs or benefits.

[2] The dry year is the average of dry and critical water year output from CalSim II.

5.2.1 47 Foot Reservoir Restriction Alternative

Tables 6 and 7 show the estimated changes in agricultural production and water use associated with the 47 Foot Reservoir Restriction Alternative by production region during all and dry years, respectively. The aggregated results presented above are allocated to four different regions: Sacramento Valley[4]; San Joaquin[5]; Tulare[6]; and Kern[7]. The values in the table show the estimated totals for each analysis metric and the change from NAA conditions. Within the Sacramento Valley, there is no change in irrigated acres during all years and only a small change during the dry years. Much of the reduction in irrigated acres occurs

[3] The NED benefits estimates include the estimated change in consumer surplus which is not reported in the table.
[4] Sacramento Valley includes SWAP Regions 1 through 9.
[5] San Joaquin includes SWAP Regions 10, 11, 12, 13, and 22.
[6] Tulare includes SWAP Regions 14A through 18.
[7] Kern includes SWAP Regions 19A through 21C.

within the Tulare region which experiences a loss of more than 100,000 AF in surface water deliveries during all years. The reduction in surface water supplies is partially offset by an increase of more than 40,000 AF due to additional groundwater recharge. The Kern region also experiences a decline in irrigated acres due to reduced surface water deliveries under the 47 Foot Reservoir Restriction Alternative. However, the decline in irrigated acres and value of production is attenuated by an increase in groundwater pumping. SWAP estimates that agricultural producers will incur $10.1 million in additional annual groundwater pumping costs in the Tulare region and $4.9 million in the Kern region.

Table 6. 47 Foot Reservoir Restriction Alternative Alternatives Results Summary (All Years)

Analysis Metric	47' Reservoir Restriction Alternative	Change from NAA[1]
Total Irrigated Acreage (Acres)		
Sacramento Valley	2,261,552	0
San Joaquin	1,694,086	-2,342
Tulare	2,220,100	-22,473
Kern	817,417	-1,365
Total	6,993,155	-26,181
Surface Water Use (AF)		
Sacramento Valley	6,083,769	-1,996
San Joaquin	3,021,759	-5,905
Tulare	3,185,414	-101,657
Kern	1,349,048	-29,477
Total	13,639,991	-139,035
Total Value of Production ($)		
Sacramento Valley	$7,679,795,095	$1,968,309
San Joaquin	$6,728,830,363	-$4,466,915
Tulare	$10,862,415,617	-$11,153,796
Kern	$4,324,718,514	-$223,557
Total	$29,595,759,589	-$13,875,959
Annual Groundwater Pumped (AF)		
Sacramento Valley	1,111,297	-225
San Joaquin	1,968,526	1,875
Tulare	3,552,936	40,414
Kern	1,568,184	23,985
Total	8,200,943	66,049
Annual Cost of Pumping ($)		
Sacramento Valley	$85,059,439	-$27,528
San Joaquin	$173,554,609	$127,142
Tulare	$467,243,633	$10,105,890
Kern	$325,476,826	$4,864,908
Total	$1,051,334,507	$15,070,412

Notes: [1]Positive AF values represent increases in surface or groundwater use when compared to the No Action/No Project Alternative and negative values represent decreases. Positive dollar values indicate increases in costs or benefits when compared to the No Action/No Project Alternative, and negative values indicate reductions in costs or benefits.

Table 7. 47 Foot Reservoir Restriction Alternative Alternatives Results Summary (Dry Year[1])

Analysis Metric	47' Reservoir Restriction Alternative	Change from NAA[2]
Total Irrigated Acreage (Acres)		
Sacramento Valley	2,236,616	-74
San Joaquin	1,667,369	-537
Tulare	2,052,260	-1,510
Kern	725,669	7,263
Total	6,681,915	5,141
Surface Water Use (AF)		
Sacramento Valley	5,990,888	-756
San Joaquin	2,923,278	-12,956
Tulare	2,765,360	-46,469
Kern	1,079,678	-21,101
Total	12,759,204	-81,282
Total Value of Production ($)		
Sacramento Valley	$7,671,358,201	-$55,866
San Joaquin	$6,736,355,162	-$3,647,883
Tulare	$10,686,560,126	-$7,226,276
Kern	$4,038,782,542	$19,797,589
Total	$29,133,056,031	$8,867,563
Annual Groundwater Pumped (AF)		
Sacramento Valley	1,102,272	188
San Joaquin	1,978,579	11,927
Tulare	3,558,300	45,778
Kern	1,583,481	39,281
Total	8,222,630	97,174
Annual Cost of Pumping ($)		
Sacramento Valley	$84,573,324	$8,042
San Joaquin	$174,460,469	$1,033,002
Tulare	$467,833,011	$10,695,261
Kern	$328,781,977	$8,170,044
Total	$1,055,648,782	$19,906,349

Notes: [1]The dry year is the average of dry and critical water year output from CalSim II.

[2]Positive AF values represent increases in surface or groundwater use when compared to the No Action/No Project Alternative and negative values represent decreases. Positive dollar values indicate increases in costs or benefits when compared to the No Action/No Project Alternative, and negative values indicate reductions in costs or benefits.

5.2.2 55 Foot Reservoir Restriction Alternative

Tables 8 and 9 show the estimated changes in agricultural production and water use associated with the 55 Foot Reservoir Restriction Alternative by production region during all and dry years, respectively. The values in the table show the estimated totals for each analysis metric and the change from NAA conditions.

As shown, the largest reduction in irrigated acres occurs within the Tulare region which experiences the largest decline in surface water deliveries. The San Joaquin and Kern regions also experience a reduction in surface water deliveries. However, the increased groundwater available due to the recharge of Article 21 and Section 215 supplies largely offsets the surface water reduction. While the total irrigated acres in the Sacramento Valley is unaffected by the alternative, the total value of production increases by $2.9 million. This increase is largely attributable to increases in the prices for crops that experience an overall decline in production.

Table 8. 55 Foot Reservoir Restriction Alternative Alternatives Results Summary (All Years)

Analysis Metric	55' Reservoir Restriction Alternative	Change from NAA[1]
Total Irrigated Acreage (Acres)		
Sacramento Valley	2,261,552	0
San Joaquin	1,693,452	-2,976
Tulare	2,213,693	-28,880
Kern	817,167	-1,615
Total	6,985,864	-33,472
Surface Water Use (AF)		
Sacramento Valley	6,083,027	-2,738
San Joaquin	3,019,837	-7,827
Tulare	3,151,484	-135,587
Kern	1,338,851	-39,674
Total	13,593,200	-185,826
Total Value of Production ($)		
Sacramento Valley	$7,680,706,264	$2,879,477
San Joaquin	$6,728,673,930	-$4,623,349
Tulare	$10,852,917,274	-$20,652,139
Kern	$4,324,909,945	-$32,126
Total	$29,587,207,412	-$22,428,137
Annual Groundwater Pumped (AF)		
Sacramento Valley	1,111,364	-158
San Joaquin	1,969,356	2,705
Tulare	3,571,082	58,560
Kern	1,577,410	33,210
Total	8,229,212	94,317
Annual Cost of Pumping ($)		
Sacramento Valley	$85,061,166	-$25,801
San Joaquin	$173,609,816	$182,349
Tulare	$471,570,435	$14,432,692
Kern	$327,345,513	$6,733,595
Total	$1,057,586,931	$21,322,836

Notes: [1]Positive AF values represent increases in surface or groundwater use when compared to the No Action/No Project Alternative and negative values represent decreases. Positive dollar values indicate increases in costs or benefits when compared to the No Action/No Project Alternative, and negative values indicate reductions in costs or benefits.

Table 9. 55 Foot Reservoir Restriction Alternative Alternatives Results Summary (Dry Year[1])

Analysis Metric	55' Reservoir Restriction Alternative	Change from NAA[2]
Total Irrigated Acreage (Acres)		
Sacramento Valley	2,236,535	-156
San Joaquin	1,667,081	-825
Tulare	2,050,345	-3,425
Kern	729,994	11,588
Total	6,683,955	7,181
Surface Water Use (AF)		
Sacramento Valley	5,990,489	-1,155
San Joaquin	2,918,398	-17,836
Tulare	2,740,062	-71,767
Kern	1,071,618	-29,161
Total	12,720,567	-119,919
Total Value of Production ($)		
Sacramento Valley	$7,671,382,568	-$31,498
San Joaquin	$6,734,383,840	-$5,619,205
Tulare	$10,683,794,715	-$9,991,687
Kern	$4,045,053,521	$26,068,568
Total	$29,134,614,644	$10,426,177
Annual Groundwater Pumped (AF)		
Sacramento Valley	1,102,417	333
San Joaquin	1,983,069	16,418
Tulare	3,577,720	65,198
Kern	1,600,181	55,981
Total	8,263,386	137,929
Annual Cost of Pumping ($)		
Sacramento Valley	$84,581,315	$16,033
San Joaquin	$174,845,524	$1,418,057
Tulare	$472,299,789	$15,162,039
Kern	$332,261,982	$11,650,049
Total	$1,063,988,611	$28,246,178

Notes: [1]The dry year is the average of dry and critical water year output from CalSim II.
[2]Positive AF values represent increases in surface or groundwater use when compared to the No Action/No Project Alternative and negative values represent decreases. Positive dollar values indicate increases in costs or benefits when compared to the No Action/No Project Alternative, and negative values indicate reductions in costs or benefits.

5.2.3 Dam Breach Alternative

Tables 10 and 11 show the estimated changes in agricultural production and water use associated with the Dam Breach Alternative by production region during all and dry years, respectively. The values in the table show the estimated totals for each analysis metric and the change from NAA conditions. As shown, the economic effects are the highest in the San Joaquin and Tulare regions. These regions experience reductions in surface water deliveries. While there is an increase in the volume of groundwater pumped relative to the NAA, the increase in the available groundwater volume is not sufficient to fully offset the decline in surface water deliveries. The primary crops fallowed include other field, corn silage, other deciduous, other truck, pasture, and processing tomatoes. Within the Kern region, the increase in available groundwater nearly fully offsets the decline in surface water deliveries during all years which results in a relatively small change in irrigated acres and value of production.

Table 10. Dam Breach Alternative Alternatives Results Summary (All Years)

Analysis Metric	Dam Breach Alternative	Change from NAA[1]
Total Irrigated Acreage (Acres)		
Sacramento Valley	2,261,552	0
San Joaquin	1,665,207	-31,221
Tulare	2,140,373	-102,200
Kern	811,609	-7,174
Total	6,878,740	-140,595
Surface Water Use (AF)		
Sacramento Valley	6,079,241	-6,525
San Joaquin	2,993,976	-33,688
Tulare	2,800,469	-486,602
Kern	1,169,572	-208,953
Total	13,043,259	-735,767
Total Value of Production ($)		
Sacramento Valley	$7,698,528,988	$20,702,201
San Joaquin	$6,615,474,956	-$117,822,322
Tulare	$10,753,807,228	-$119,762,185
Kern	$4,327,948,503	$3,006,433
Total	$29,395,759,676	-$213,875,873
Annual Groundwater Pumped (AF)		
Sacramento Valley	1,111,783	261
San Joaquin	1,945,734	-20,918
Tulare	3,735,992	223,470
Kern	1,723,447	179,248
Total	8,516,956	382,061
Annual Cost of Pumping ($)		
Sacramento Valley	$85,058,959	-$28,008
San Joaquin	$171,538,420	-$1,889,047
Tulare	$512,981,746	$55,844,003
Kern	$356,799,463	$36,187,545
Total	$1,126,378,589	$90,114,494

Notes:
[1]Positive AF values represent increases in surface or groundwater use when compared to the No Action/No Project Alternative and negative values represent decreases. Positive dollar values indicate increases in costs or benefits when compared to the No Action/No Project Alternative, and negative values indicate reductions in costs or benefits.

Table 11. Dam Breach Alternative Alternatives Results Summary (Dry Year[1])

Analysis Metric	Dam Breach Alternative	Change from NAA[2]
Total Irrigated Acreage (Acres)		
Sacramento Valley	2,236,345	-346
San Joaquin	1,645,946	-21,960
Tulare	2,021,967	-31,803
Kern	744,716	26,310
Total	6,648,975	-27,799
Surface Water Use (AF)		
Sacramento Valley	5,989,621	-2,023
San Joaquin	2,871,120	-65,114
Tulare	2,488,527	-323,301
Kern	912,640	-188,139
Total	12,261,909	-578,577
Total Value of Production ($)		
Sacramento Valley	$7,679,688,205	$8,274,138
San Joaquin	$6,635,187,533	-$104,815,512
Tulare	$10,653,615,649	-$40,170,753
Kern	$4,073,402,221	$54,417,268
Total	$29,041,893,607	-$82,294,860
Annual Groundwater Pumped (AF)		
Sacramento Valley	1,102,115	31
San Joaquin	1,993,890	27,238
Tulare	3,748,692	236,170
Kern	1,782,298	238,098
Total	8,626,995	501,538
Annual Cost of Pumping ($)		
Sacramento Valley	$84,516,021	-$49,261
San Joaquin	$175,877,951	$2,450,484
Tulare	$514,377,284	$57,239,534
Kern	$369,031,071	$48,419,138
Total	$1,143,802,328	$108,059,895

Notes: [1]The dry year is the average of dry and critical water year output from CalSim II.

[2]Positive AF values represent increases in surface or groundwater use when compared to the No Action/No Project Alternative and negative values represent decreases. Positive dollar values indicate increases in costs or benefits when compared to the No Action/No Project Alternative, and negative values indicate reductions in costs or benefits.

6.0 SWAP Model Limitations

The SWAP model is an optimization model that makes the best (i.e., most profitable) adjustments to water supply and other changes. Constraints can be imposed to simulate restrictions on how much adjustment is possible or how fast the adjustment can realistically occur. Nevertheless, an optimization model can tend to over-adjust and minimize costs associated with detrimental changes or, similarly, maximize benefits associated with positive changes.

SWAP does not explicitly account for the dynamic nature of agricultural production; it provides a point-in-time comparison between two conditions. This is consistent with the way most economic and environmental impact analysis is conducted, but it can obscure sometimes important adjustment costs.

SWAP also does not explicitly incorporate risk or risk preferences (e.g., risk aversion) into its objective function. Risk and variability are handled in two ways. First, the calibration procedure for SWAP is designed to reproduce observed crop mix, so to the extent that crop mix incorporates risk spreading and risk aversion, the starting, calibrated SWAP base condition will also. Second, variability in water delivery, prices, yields, or other parameters can be evaluated by running the model over a sequence of conditions or over a set of conditions that characterize a distribution, such as a set of water year types.

Groundwater is an alternative source to augment SWP and CVP delivery in many subregions. The cost and availability of groundwater therefore has an important effect on how SWAP responds to changes in delivery. However, SWAP is not a groundwater model and does not include any direct way to adjust pumping lifts and unit pumping cost in response to long-run changes in pumping quantities.

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