Appendix 22F
Agricultural Supply Economics Modeling

Line items and numbers identified or noted as “No Action Alternative” represent the “Existing Conditions/No Project/No Action Condition” (described in Chapter 2 Alternatives Analysis). Table numbering may not be consecutive for all appendixes.”

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APPENDIX 22F
Agricultural Supply Economics Modeling

22F.1 Introduction

Economic impacts to agricultural production in regions of California, including benefits and costs, occur with changes in agricultural water supply. This study focuses on changes in areas served by the State Water Project (SWP) and Central Valley Project (CVP) in California. Changes in agricultural production, as a result of changes in agricultural water supply, are estimated using an economic optimization modeling framework. The model used in this study is the Statewide Agricultural Production (SWAP) model. The SWAP model is the most current in a series of production models of California agriculture developed by researchers at the University of California at Davis under the direction of Professor Richard Howitt in collaboration with the California Department of Water Resources (DWR) with supplemental funding provided by the United States (U.S.) Department of the Interior (Interior), Bureau of Reclamation (Reclamation). The SWAP model is used to estimate changes in producer and consumer surplus to the agricultural economy in California.

22F.2 Statewide Agricultural Production (SWAP) Model

22F.2.1 Description

The SWAP model is a regional agricultural production and economic optimization model that simulates the decisions of farmers across 93 percent of agricultural land in California. The model assumes that farmers maximize profits (revenue minus cost) by choosing total input use (e.g., total crop acres) and input use intensity (e.g., applied water per acre) subject to market, resource, and technical constraints. Farmers are assumed to face competitive markets, where no one farmer can influence crop prices, but an aggregate change in production can affect crop price. This competitive market is simulated by maximizing the sum of consumer and producer surplus.

The SWAP model was developed by Professor Richard Howitt and collaborators and has been used in a wide range of policy analysis. At the time of preparation of this appendix, a documentation manuscript is under review at the *Journal of Environmental Modeling and Software* (Howitt et al., 2012). The original use for the model was to estimate the economic scarcity costs of water for agriculture in the statewide hydro-economic optimization model for water management in California, CALVIN.[1] The SWAP and CVPM models have been used for numerous policy analyses and impact studies over the past 15 years, including the impacts of the Central Valley Project Improvement Act, Upper San Joaquin Basin Storage Investigation, the SWP drought impact analysis, and the economic implications of Sacramento-San Joaquin (Delta) conveyance options. More recently, the SWAP model has been used to estimate economic losses due to salinity in the Central Valley, economic losses to agriculture in the Delta, economic losses for agriculture and confined animal operations in California's Southern Central Valley, and economic effects of water shortage to Central Valley agriculture. It is also being used in several ongoing studies of water projects and operations.

[1] CALVIN website and additional information: http://cee.engr.ucdavis.edu/CALVIN

The SWAP model estimates the changes in agricultural production using a simulation/optimization framework based on the principle of Positive Mathematical Programming (PMP) (Howitt, 1995). The model takes land allocation, input use, crop prices, yields, and costs as input and estimates how agricultural production will respond to changes in water supply, prices, costs, or other policy shocks. The benefit (or cost) of changes in water supply or other policies can be determined from the change it produces in the net value of agricultural production relative to a base (e.g., no action alternative) condition. Data have been developed, and updated under the Sites Reservoir Project (Project), to use the SWAP model for 27 homogenous agricultural regions in the Central Valley of California. Additional model data are available for agriculture along the Central Coast and Southern California, but these are omitted from this analysis.

The SWAP model was designed to be data-driven in order to easily represent different analytical circumstances without changing the model code. For example, the model can be linked to agronomic crop yield models by incorporating this information into the economic production functions. If unique situations require recoding, the source has been well documented and written with an emphasis on flexibility to facilitate different analytical needs.

22F.2.1.1 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. 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 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 (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 Constant Elasticity of Substitution (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 steps. Calibrating production models using PMP has been reviewed extensively in the peer-reviewed literature. These models are widely accepted and used for policy analysis (Heckelei et al., 2012).

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).

22F.2.1.2 Interactions with 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. CALSIM II operates over the 1922-2003 hydrologic period, and deliveries are driven by specified target delivery quantities that the model tries to meet based on available inflows and storage on the SWP and CVP systems for each year of hydrology used. An existing linkage tool has been developed to translate CALSIM II delivery output to a corresponding SWAP input file.

Changes in depth to groundwater affect pumping costs and agricultural revenues. Changes in groundwater depth and resulting changes in groundwater pumping costs are included from CVHM model output.

The SWAP model includes endogenous sub-routines that the analyst can choose to include. These sub-routines are self-contained modules within the model and may be included/excluded without changes to a single line of code within the model. The sub-routines include crop demand shifts, technological production innovation, changes in power costs, and changes in groundwater levels and pumping costs.

The SWAP model can be linked to agronomic or hydrologic models; however, this is not the case for this analysis. In previous studies, SWAP has been linked to agronomic crop yield models to estimate effects of climate change. Additionally, SWAP has been linked to hydrologic models like CALVIN to evaluate water markets in California. The SWAP model can be used to incorporate a range of exogenous information through linkage to other models.

SWAP output can be used as part of the input to regional economic analysis using the IMPLAN model. SWAP can estimate changes in agricultural revenues, and these changes can be provided to IMPLAN. Agricultural revenue losses (or gains) translate into upstream and downstream changes in the local economy.

22F.2.1.3 Assumptions and Limitations

The SWAP model is an optimization model that makes the best (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. Economic analysis using SWAP must rely on an accompanying groundwater analysis or at least on careful specification of groundwater assumptions.

22F.2.1.4 SWAP Regions and Crop Definitions

The SWAP model has 27 base regions in the Central Valley. The current model covers agriculture in the original 21 CVPM regions, the Central Coast, the Colorado River region that includes Coachella, Palo Verde and the Imperial Valley and San Diego, Santa Ana and Ventura and the South Coast. There are a total of 37 regions in the current model, and only 27 regions in the Central Valley are considered for this analysis. Figure 22F-1 shows California agricultural area covered in SWAP. Table 22F-1 details the major water users in each of the regions.

22F.2.1.5 SWAP Data

SWAP model data include land use, crop prices, yields, input costs, water costs, use, and availability, and relevant elasticity estimates. In order to highlight the important aspects of the SWAP model inputs, data are summarized by three regions: Sacramento, North San Joaquin, and South San Joaquin. All input data were reviewed and, where applicable, updated under this analysis. The current version of the model (6.0) calibrates to land use data for 2005. DWR is in the process of developing more detailed annual time series data on agricultural land use, but the current version of the SWAP model calibrates to 2005 as a relatively normal base year.

Crop yields and production costs are from current University of California Cooperative Extension (UCCE) Crop Budgets, and crop prices are from County Crop Reports prepared by Agricultural Commissioners in each county. The UCCE Crop Budgets are designed based on best, or at least above average, management practices for a representative field. This is reflected in the descriptive text accompanying the published budgets, and was verified by personal communication with UCCE specialists. For example, yields used in the crop budgets’ net return analysis are determined based on the extension specialist’s knowledge and judgment, and represent good growing conditions and best management practices. In contrast, crop prices and yields reported by Agricultural Commissioners represent average conditions and practices; thus, yields are average for the county, and are generally lower than those used in the Crop Budgets.

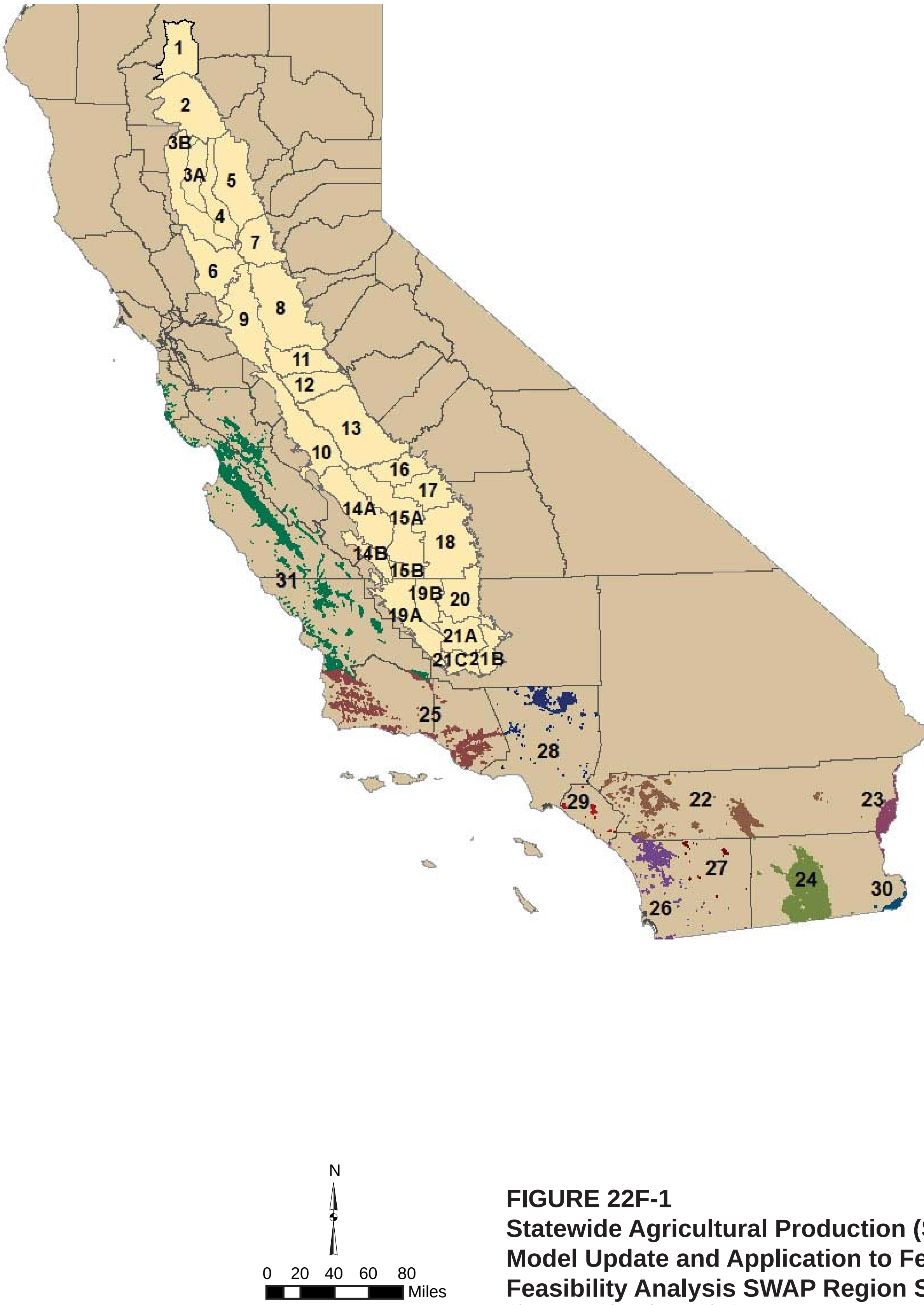

FIGURE 22F-1
Statewide Agricultural Production (SWAP) Model Update and Application to Federal Feasibility Analysis SWAP Region Summary
Sites Reservoir Project EIR/EIS

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Table 22F-1
SWAP Coverage of Agriculture in California
Agricultural Supply Economics Modeling

SWAP Region	Major Surface Water Users
1	CVP Users: Anderson Cottonwood I.D., Clear Creek C.S.D., Bella Vista W.D., and miscellaneous Sacramento River water users.
2	CVP Users: Corning Canal, Kirkwood W.D., Tehama, and miscellaneous Sacramento River water users.
3a	CVP Users: Glenn Colusa I.D., Provident I.D., Princeton-Codora I.D., Maxwell I.D., and Colusa Basin Drain M.W.C.
3b	Tehama Colusa Canal Service Area. CVP Users: Orland-Artois W.D., most of Colusa County, Davis W.D., Dunnigan W.D., Glide W.D., Kanawha W.D., La Grande W.D., and Westside W.D.
4	CVP Users: Princeton-Codora-Glenn I.D., Colusa Irrigation Co., Meridian Farm W.C., Pelger Mutual W.C., Reclamation District 1004, Reclamation District 108, Roberts Ditch I.C., Sartain M.D., Sutter M.W.C., Swinford Tract I.C., Tisdale Irrigation and Drainage Co., 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 M.W.C., miscellaneous Sacramento River water users, Pleasant Grove-Verona W.M.C., and Placer County W.A.
8	Sacramento County south of American River and northern San Joaquin County.
9	Direct diverters within the Delta region. CVP Users: Banta Carbona I.D., West Side W.D., and Plainview.
10	Delta Mendota service area. CVP Users: Panoche W.D., Pacheco W.D., Del Puerto W.D., Hospital W.D., Sunflower W.D., West Stanislaus W.D., Mustang W.D., Orestimba W.D., Patterson W.D., Foothill W.D., San Luis W.D., Broadview, Eagle Field W.D., Mercy Springs W.D., San Joaquin River Exchange Contractors.
11	Stanislaus River water rights: Modesto I.D., Oakdale I.D., and South San Joaquin I.D.
12	Turlock I.D.
13	Merced I.D. CVP Users: Madera I.D., Chowchilla W.D., and Gravely Ford.
14a	CVP Users: Westlands W.D.
14b	Southwest corner of Kings County
15a	Tulare Lake Bed. CVP Users: Fresno Slough W.D., James I.D., Tranquility I.D., Traction Ranch, Laguna W.D., and Reclamation District 1606.
15b	Dudley Ridge W.D. and Devils Den (Castaic Lake)
16	Eastern Fresno County. CVP Users: Friant-Kern Canal, Fresno I.D., Garfield W.D., and International W.D.
17	CVP Users: Friant-Kern Canal, Hills Valley I.D., Tri-Valley W.D., and Orange Cove.
18	CVP Users: Friant-Kern Canal, County of Fresno, Lower Tule River I.D., Pixley I.D., portion of Rag Gulch W.D., Ducor, County of Tulare, most of Delano-Earlimart I.D., Exeter I.D., Ivanhoe I.D., Lewis Creek W.D., Lindmore I.D., Lindsay-Strathmore I.D., Porterville I.D., Sausalito I.D., Stone Corral I.D., Tea Pot Dome W.D., Terra Bella I.D., and Tulare I.D.
19a	SWP Service Area, including Belridge W.S.D., Berrenda Mesa W.D.
19b	SWP Service Area, including Semitropic W.S.D
20	CVP Users: Friant-Kern Canal. Shafter-Wasco, and South San Joaquin I.D.
21a	CVP Users: Cross Valley Canal and Friant-Kern Canal
21b	Arvin Edison W.D.

SWAP Region	Major Surface Water Users
21c	SWP service area: Wheeler Ridge-Maricopa W.S.D.
23-30	Central Coast, Desert, and Southern California

Note:

This list 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.

Using production costs from UCCE Crop Budgets (which are above average) together with average prices and yields reported in the County Agricultural Commissioner reports will generally lead to lower net returns than would be representative of California growers and, in some cases, results in negative net returns. Hence, policy analysis under this approach would be biased. More importantly, the SWAP model is designed to replicate actual growing conditions. To accurately estimate expected project benefits, UCCE Crop Budgets are used for both costs and yields, with prices still drawn from county averages reported in the Agricultural Commissioner crop reports. Under this approach, policy analysis reflects the net farm income that can be attained if extension specialists' recommendations were followed. This can result in both revenues and costs that are somewhat higher than average for a region, but that is more acceptable than systematically underestimating net revenues (benefits).

22F.2.1.6 SWAP Land Use Data

Crops are aggregated into 20 crop groups that 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, and production costs and returns are represented by a single proxy crop for each group. A proxy crop is used because UCCE budgets are only available for select crops and, as such, production data are not available for every crop group. The current 20 crop groups were defined in collaboration with DWR and updated in March 2011. For each group, the representative (proxy) crop is chosen based on four criteria: (i) a detailed production budget is available from U.C. Cooperative Extension, (ii) it is the largest or one of the largest acreages within a group, (iii) its water use (applied water) is representative of water use of all crops in the group, and (iv) its gross and net returns per acre are representative of the crops in the group. The relative importance of these criteria varies by crop. Crop group definitions and the corresponding proxy crop are shown in Table 22F-2.

Table 22F-2
SWAP Crop Groups
Agricultural Supply Economics Modeling

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

SWAP Definition	Proxy Crop	Other Crops
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, Misc. Citrus, Olives
Vine	Wine Grapes	Table Grapes, Raisins

The SWAP model calibrates to a base year of observed land use, 2005. The SWAP model includes 37 individual SWAP regions. Regions 1-21C represent the Central Valley, and 2005 land use data were prepared by analysts at DWR. DWR develops land use estimates for small regions that it calls Detailed Analysis Units (DAU). These are aggregated within a GIS to create land use for the individual SWAP regions, and further aggregated to the larger hydrologic regions that DWR reports in the California Water Plan Update (2009). Table 22F-3 summarizes land use in 2005 by Central Valley regions.

Table 22F-3
Crop Acreage in 2005
Agricultural Supply Economics Modeling

Crop Group	Sacramento	North SJV	South SJV	Crop Group	Sacramento	North SJV	South SJV
Alfalfa	180,140	167,350	351,900	Other Field	67,030	138,940	228,000
Almonds/Pistachios	150,050	328,340	325,600	Other Truck	32,990	52,950	123,600
Corn	165,800	176,890	326,400	Pasture	162,920	123,860	20,600
Cotton	6,090	115,100	542,800	Potato	1,860	100	23,300
Cucurbits	34,470	23,610	33,500	Processing Tomatoes	130,020	52,890	119,500
Dry Bean	32,730	15,920	13,700	Rice	552,110	12,710	0
Fresh Tomatoes	12,070	16,530	9,900	Safflower	41,740	2,200	5,100
Grain	152,910	30,030	181,700	Sugar Beet	0	7,900	13,100
Onions/Garlic	2,200	4,920	38,100	Sub-tropical	28,350	6,760	212,400
Other Deciduous	305,530	86,340	209,500	Grapes	138,370	114,470	339,400

Source: DWR, 2009.

22F.2.1.7 SWAP Crop Price Data

The SWAP model is designed to represent actual conditions growers faced in 2005. 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 a 3-year simple average of county-level crop prices. Three-year 2005 to 2007 averages of crop prices are calculated using the counties in each of the three Central Valley regions within SWAP: Sacramento, North San Joaquin, and South San Joaquin. Crop prices for each of the SWAP regions within the Central Valley correspond to one of these three areas.

Data for county-level crop prices are obtained from the respective County Agricultural Commissioners' annual crop reports. These are compiled and released by the U.S. Department of Agriculture annually. Data are summarized by crop and Central Valley region in Table 22F-4.

Table 22F-4
Crop Price per Ton (2005 dollars)
Agricultural Supply Economics Modeling

Crop Group	Sacramento	North SJV	South SJV	Crop Group	Sacramento	North SJV	South SJV
Alfalfa	132.19	157.28	152.28	Other Field	141.84	141.84	141.84
Almonds/Pistachios	4234.96	4226.68	4258.90	Other Truck	582.00	582.00	582.00
Corn	121.04	156.06	156.06	Pasture	220.00	220.00	220.00
Cotton	2016.50	2016.50	2016.50	Potato	224.60	224.60	224.60
Cucurbits	464.10	464.10	464.10	Processing Tomatoes	51.10	52.25	53.80
Dry Bean	796.73	778.92	758.19	Rice	245.66	220.87	222.40
Fresh Tomatoes	463.65	463.65	560.60	Safflower	299.41	315.56	315.56
Grain	142.68	162.69	163.00	Sugar Beet	41.50	41.50	41.50
Onions/Garlic	600.90	600.90	600.90	Sub-tropical	452.10	452.10	452.10
Other Deciduous	1502.47	1601.28	1674.88	Grapes	610.00	610.00	610.00

Source: County Agricultural Commissioners, various years.

22F.2.1.8 SWAP Crop Yields

Crop yields for each crop group in the SWAP model correspond to the proxy crops and are based on best management practices. The corresponding costs of production, discussed previously, 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 UCCE production cost budgets prepared by University of California at 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. Crop yield data are summarized by crop and Central Valley region in Table 22F-5.

Table 22F-5
Crop Yield in Tons per acre
Agricultural Supply Economics Modeling

Crop Group	Sacramento	North SJV	South SJV	Crop Group	Sacramento	North SJV	South SJV
Alfalfa	7.00	8.00	8.00	Other Field	6.50	6.50	6.50
Almonds/Pistachios	1.10	1.00	1.40	Other Truck	6.53	6.53	6.53
Corn	6.50	6.57	6.55	Pasture	2.50	2.50	2.50
Cotton	0.63	0.58	0.58	Potato	25.00	25.00	25.00
Cucurbits	16.80	16.80	16.80	Processing Tomatoes	35.00	40.00	40.00
Dry Bean	1.25	1.25	1.25	Rice	5.00	5.00	5.00
Fresh Tomatoes	13.00	13.00	13.00	Safflower	1.30	1.30	1.55
Grain	3.00	3.25	3.28	Sugar Beet	42.00	42.00	42.00
Onions/Garlic	13.00	13.00	13.00	Sub-tropical	12.20	12.20	13.13
Other Deciduous	2.70	2.70	2.70	Grapes	7.00	6.50	6.50

Source: UCCE, various years.

22F.2.1.9 SWAP Interest Rates and Land Costs

Each UCCE budget uses interest rates for capital recovery and interest on operating capital specific to the year of the study. These range from 4 percent to over 8 percent and, as such, require adjustment to a common base year interest rate. Since the SWAP model is designed to replicate base 2005 conditions, interest rates are adjusted to reflect conditions in 2005.

Capital costs are currently included in the SWAP input data as annual capital recovery values in "other supply costs." Capital recovery costs are the annual costs of interest and depreciation on capital investments. For each capital investment, the UCCE budget estimates the purchase price, useful life of the equipment, and salvage value. A scaling of 60 percent is used to reflect a mix of new and used equipment. The sum across all capital investments represents the total capital recovery costs. The interest portion of the capital recovery is adjusted to a rate of 6.25 percent, based on interest rates used in UCCE budgets prepared in 2005. No adjustments are made to the other components of the capital recovery cost calculation.

Interest on operating capital is the interest paid on money used for annual operating costs, such as purchase of seed, fertilizer, and fuel. It is included as part of the other supply costs within SWAP input data. The UCCE crop budgets use a nominal interest rate, which reflects the typical market rate for the year the budget represents. For use in SWAP, the interest on operating capital is adjusted to a rate of 6.25 percent, based on rates used in UCCE budgets prepared in 2005.

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. Table 22F-6 summarizes the land costs in SWAP, in 2005 dollars, by Central Valley region.

Land-related cash overhead includes office expenses, taxes, insurance, management salaries, and other land-specific cash expenses. For some budgets, this includes a portion of the farm that is rented. For these budgets, this expense is included in the cash overhead category; thus, no interest rate adjustment is necessary. As such, it is grouped into the land-related cash overhead component of land costs.

Land capital recovery cost corresponds to the rent value of the land, as calculated by the capital recovery cost of the land. This category is adjusted to reflect a consistent interest rate of 6.25 percent.

The land input costs are based on the UCCE crop budgets, and reflect the assumptions contained in these budgets. For example, grain (wheat as the proxy budget) in the Sacramento Valley is based on a hypothetical 2,900-acre farm that cultivates field and row crops. On the farm, 900 acres are planted to wheat, which are part of a tomato-, alfalfa-, safflower-, corn-based rotation. The assumptions for the hypothetical farm differ by crop and region. Different assumptions may alter the costs of production; however, the UCCE budgets represent the common best management practices in the region.

Table 22F-6
Land Costs per Acre (2005 dollars)
Agricultural Supply Economics Modeling

Crop Group	Sacramento	North SJV	South SJV	Crop Group	Sacramento	North SJV	South SJV
Alfalfa	249	317	317	Other Field	180	180	180
Almonds/Pistachios	453	812	515	Other Truck	220	220	220
Corn	181	168	168	Pasture	92	92	92
Cotton	196	217	217	Potato	680	680	680
Cucurbits	204	204	204	Processing Tomatoes	344	298	298
Dry Bean	154	209	209	Rice	269	269	269
Fresh Tomatoes	308	308	308	Safflower	102	102	102
Grain	95	194	194	Sugar Beet	149	149	149
Onions/Garlic	336	336	336	Sub-tropical	612	612	612
Other Deciduous	526	526	526	Grapes	1,024	1,352	1,352

Source: UCCE, various years.

22F.2.1.10 Other Supply and Labor Costs

Supplies are one of four production inputs into the SWAP model. This category 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.

The supply input costs are based on the UCCE cost of production budgets and, as such, reflect the assumptions contained in these budgets. Different assumptions may alter the costs of production; however, the UCCE budgets represent common best management practices in the region.

Table 22F-7 summarizes supply costs per acre, in 2005 dollars, by Central Valley region.

Labor is one of four production inputs into the SWAP model. This category 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 setup, 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.

Table 22F-7
Other Supply Costs per Acre (2005 dollars)
Agricultural Supply Economics Modeling

Crop Group	Sacramento	North SJV	South SJV	Crop Group	Sacramento	North SJV	South SJV
Alfalfa	414	544	544	Other Field	465	465	465
Almonds/Pistachios	1,900	1,678	1,607	Other Truck	3,215	3,215	3,215
Corn	329	531	531	Pasture	138	138	138
Cotton	697	538	538	Potato	1,568	1,568	1,568
Cucurbits	2,919	2,919	2,919	Processing Tomatoes	840	1,200	1,200
Dry Bean	397	423	423	Rice	556	556	556
Fresh Tomatoes	4,480	4,480	4,480	Safflower	121	121	121
Grain	227	278	278	Sugar Beet	779	779	779
Onions/Garlic	2,625	2,625	2,625	Sub-tropical	4,333	4,333	4,333
Other Deciduous	1,427	1,427	1,427	Grapes	1,627	1,479	1,479

The labor input costs are based on the UCCE cost of production budgets and, as such, reflect the assumptions contained in these budgets. Different assumptions may alter the costs of production; however, the UCCE budgets represent common best management practices in the region.

Table 22F-8 summarizes labor costs in the SWAP model by Central Valley region.

Table 22F-8
Labor Costs per Acre (2005 dollars)
Agricultural Supply Economics Modeling

Crop Group	Sacramento	North SJV	South SJV	Crop Group	Sacramento	North SJV	South SJV
Alfalfa	18	21	21	Other Field	14	14	14
Almonds/Pistachios	274	318	107	Other Truck	207	207	207
Corn	101	50	50	Pasture	24	24	24
Cotton	130	199	199	Potato	410	410	410
Cucurbits	4,339	4,339	4,339	Processing Tomatoes	373	276	276
Dry Bean	106	55	55	Rice	81	81	81
Fresh Tomatoes	143	143	143	Safflower	35	35	35
Grain	33	14	14	Sugar Beet	65	65	65
Onions/Garlic	682	682	682	Sub-tropical	239	239	239
Other Deciduous	223	223	223	Grapes	828	756	756

Source: UCCE, various years.

22F.2.1.11 Surface and Groundwater Costs

SWAP includes five types of surface water: SWP delivery, three categories of CVP delivery, and local surface water delivery or direct diversion (LOC). 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 (CVPS)[2].

[2] 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

CVP and SWP water costs have two components, a project charge and a district charge. The sum of these components is the region-specific cost of the individual water source.

Over time, the goal is to identify these components of costs for all applicable regions within the SWAP data. The current version of SWAP is capable of handling the water cost components; however, the data, especially district charges, are not available. The surface water cost data gathered for the current version of SWAP represent total costs to growers, but are not broken into the two components.

Table 22F-9 summarizes surface water costs by source, averaged across SWAP regions in the three Central Valley regions.

Table 22F-9
Surface Water Costs in SWAP ($ per acre-foot)
Agricultural Supply Economics Modeling

Source	CVP1	CVPS	CL2	SWP	LOC
Sac	23.53	13.45	14.75	23.25	14.15
NSJV	31.63	15.00	28.00	45.38	16.56
SSJV	60.46	15.00	28.00	67.00	43.92

Source: Reclamation, various years(a); Reclamation, various years(b); DWR, 2008; and various individual district reports. For further information regarding the information cited here, please contact the California Department of Water Resources, Economic Analysis Section, Section Supervisor.

A key source of irrigation water, and often the most costly, is groundwater pumping. 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. This breakdown and cost update was completed in May.

Pumping costs are calculated as two components, the fixed cost per acre-foot based on typical well designs and costs within the region, plus the variable cost per acre-foot. The variable cost per acre-foot is O&M plus energy costs based on average total dynamic lift within the region.

Energy costs depend on the price of electricity. Power costs can be varied by region and according to the time horizon of the relevant analysis depending on the projected cost of power. The current version of SWAP uses the same unit cost of electricity per kilowatt-hour across all regions. Base electricity costs are derived from PG&E rate books and consultation with power officials at the Fresno, California, office. Energy cost is 18.9 cents per kilowatt-hour, which is an average of PG&E’s AG-1B and AG-4B rates. Overall well efficiency is assumed to be 70 percent.

The total dynamic lift (TDL) for each region is in feet, and includes both static lift and additional dynamic drawdown when pumps are operating. Total dynamic lift varies by region and water-year type on SWAP. Thus, in dry years groundwater pumping costs per acre-foot increase due to an increase in depth to groundwater, plus additional drawdown caused by greater regional pumping rates. Base groundwater depth (static pumping lift) estimates are from the CVPM model, which in turn were provided by the Central Valley Groundwater-Surface Water Model (CVGSM). For scenario and projections analysis, changes in groundwater depths must be provided by external analysis, such as a groundwater model. SWAP itself does not project changes in groundwater storage and depth.

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.

Table 22F-10 summarizes components of groundwater pumping costs by Central Valley region.

Table 22F-10
Groundwater Cost Components in SWAP
Agricultural Supply Economics Modeling

Source	Fixed Cost ($/acre-foot)	TDL (feet)	Efficiency (%)	$/Kwh
Sac	19.80	80.87	0.7	0.189
NSJV	27.00	88.92	0.7	0.189
SSJV	34.85	222.72	0.7	0.189

Source: PG&E, various years; and various individual district reports. For further information regarding the information cited here, please contact the California Department of Water Resources, Economic Analysis Section, Section Supervisor.

22F.2.1.12 Crop Water Requirements (Applied Water per Acre)

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.

Table 22F-11 summarizes applied water per acre by crop and Central Valley region.

Table 22F-11
Applied Water (acre-feet per Acre)
Agricultural Supply Economics Modeling

Crop Group	Sacramento	North SJV	South SJV	Crop Group	Sacramento	North SJV	South SJV
Alfalfa	4.11	4.84	3.56	Other Field	2.23	2.86	2.27
Almonds/Pistachios	3.12	4.07	3.22	Other Truck	2.11	0.93	0.81
Corn	2.48	2.74	2.30	Pasture	4.27	4.84	3.88
Cotton	2.98	3.43	2.52	Potato	0.00	1.41	n/a
Cucurbits	1.27	2.01	1.36	Processing Tomatoes	2.49	2.60	1.84
Dry Bean	2.03	2.60	1.83	Rice	4.84	8.00	n/a
Fresh Tomatoes	2.75	2.03	1.23	Safflower	0.77	1.89	1.65
Grain	0.75	0.79	1.01	Sugar Beet	n/a	3.5	4.09
Onions/Garlic	3.14	3.58	2.19	Sub-tropical	2.29	2.98	2.84
Other Deciduous	3.01	3.47	3.60	Grapes	1.53	2.89	2.12

Source: DWR, 2009

22F.2.1.13 Regional Water Constraints

Regional water constraints vary under each alternative. Base water availability, by region, is discussed here.

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, 2008). 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 CVGSM.

Groundwater pumping capacity estimates are from a 2009 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 long run analysis, additional pumping capacity could be installed, but careful groundwater analysis should be made to determine hydraulic feasibility. If groundwater analysis is not available, existing capacity constraints are assumed to hold.

Table 22F-12 summarizes available regional water supply, in TAF, by water supply classification.

Table 22F-12
Available Water by Source (thousand acre-feet)
Agricultural Supply Economics Modeling

Source	CVP1	CVPS	CL2	SWP	LOC	GW
Sac	409.47	1323.23	0.00	0.00	3320.30	2537.90
NSJV	370.09	768.20	78.61	3.90	2312.70	1245.00
SSJV	1959.81	0.00	197.85	1372.90	2844.20	3116.30

Source: Reclamation, various years(a), and DWR, 2008. Local supplies (LOC) are from various individual district reports and Groundwater (GW) is from a 2009 internal unpublished study by DWR analysts. For further information regarding the information cited here, please contact the California Department of Water Resources, Economic Analysis Section, Section Supervisor.

22F.2.1.14 SWAP Model 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 1 percent change in that crop's price. The SWAP model contains both long- and short-run estimates, and the analyst decides which of the elasticities to use. Long-run acreage response elasticities are used for this analysis.

Income, own price, and population elasticities govern the shape of the crop-specific demand functions and the nature of demand shifts over time. Own price elasticities of demand were updated in 2009 based on a survey of recent literature (Green et al., 2006). Population elasticities are assumed at unity. Income elasticity estimates are from Green et al. (2006).

Under specific conditions, not satisfied here, the price flexibility is the reciprocal of the absolute lower-bound own-price elasticity (Houck, 1965). The price flexibility is used to calibrate the individual crop demand functions.

Table 22F-13 summarizes the elasticities used in the SWAP model.

Table 22F-13
Various Elasticities by Crop Group
Agricultural Supply Economics Modeling

Crop Group	Flexibility	Income	Population	Own Price	Acreage Response LR	Acreage Response SR
ALFAL	-0.50	0.20	1.00	-0.86	0.51	0.24
ALPIS	-0.70	0.51	1.00	-1.20	0.11	0.03
CORN	0.00	0.00	1.00	0.00	0.45	0.21
COTTN	-0.05	0.05	1.00	-0.95	0.64	0.36
CUCUR	-0.20	0.99	1.00	-0.16	0.05	0.05
DRYBN	-0.20	0.20	1.00	-0.86	0.17	0.13
FRTOM	-0.62	0.89	1.00	-0.25	0.31	0.16
GRAIN	0.00	0.00	1.00	0.00	0.38	0.36
ONGAR	-0.21	0.99	1.00	-0.16	0.19	0.11
OTHDEC	-0.25	0.50	1.00	-1.25	0.11	0.03
OTHFLD	-0.20	0.20	1.00	-0.86	1.89	0.63
OTHTRK	-0.20	0.99	1.00	-0.16	0.19	0.11
PASTR	-0.50	0.00	1.00	0.00	0.51	0.24
POTATO	-0.10	0.20	1.00	-0.16	0.19	0.11
PRTOM	-0.17	0.89	1.00	-0.25	0.28	0.15
RICE	-0.05	0.00	1.00	0.00	0.96	0.96
SAFLR	-0.20	0.20	1.00	-0.86	0.34	0.34
SBEET	-0.10	0.00	1.00	0.00	0.19	0.11
SUBTRP	-0.80	0.50	1.00	-1.25	0.50	0.30
VINE	-0.80	0.51	1.00	-0.28	0.11	0.03

22F.2.2 Modules for Policy Analysis (Levels of Development)

The SWAP model includes a number of endogenous routines to project future economic conditions. Future economic conditions such as changing crop prices, technological innovation, and increased urban development are expected to affect the future of agricultural production in California.

22F.2.2.1 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 this analysis are population and real income. An increase in real income is expected to increase demand for agricultural products. Similarly, population increase is 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.

The analysis is concerned with California agriculture and, as such, it is necessary to consider the entire market for California crops, which includes international exports. 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 in the U.S. or the world 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 is a key assumption that is consistent with peer-reviewed publications for the California Energy Commission and the academic journal *Climatic Change* in addition to the 2009 California Department of Water Resources 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 this Project, including the No Action Alternative. Consequently, benefits estimates that compare No Action to one of the Action Alternatives compare identical future market conditions. We perform sensitivity analysis to estimate benefits with and without demand shifts.

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[3]; 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. This analysis does not consider the international trade market for these crops; it is assumed that California's export share will continue to remain small in the future. 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. Since we hold California's export share and international market conditions constant, we are able to estimate shifts based solely on United States conditions. This analysis does not model changes in tastes and preferences, only the shift in demand for these crops that will result from increasing population and real income. A routine in the SWAP model calculates the demand shift depending on the year of the analysis (2025 or 2060).

Since California is a small proportion of global production for commodity crops, the only necessary information to estimate the shift in future demand is the long run trend in real prices. Formally, this analysis assumes that California will retain its small share of the global market for these crops. The derivation of the demand shift equations can be found in Howitt et al. (2012).

We are aware that the assumption of constant export share and international market conditions is strong. As such, we perform sensitivity analysis and run the model with and without demand shifts. In an internal report, we find that total National Economic Development benefits decrease by less than 1.5 percent when demand shifts are not included in the analysis.

22F.2.2.2 Technological Change

Since WWII, 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 is a contentious topic among researchers. One argument is that yield increases have already started to level off and, at the same time, spending on agricultural research and development (R&D) has started to decrease. Thus yield increases are expected to level off in the future as R&D spending continues to decline. Alternatively, some researchers argue that yields are continuing to trend upward and there are

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

many opportunities for further increases, even with limited spending on R&D. There is no general consensus on the expected rate of yield growth in the future, both within California and globally.

For this analysis, the Principles and Guidelines allows for yield increases with several caveats. The most important requirement is that if yields increase, the cost of R&D needs to be incorporated. Furthermore, higher production costs need to be incorporated. No reliable and consistent data are available on the costs of R&D or expected production costs with higher yields; thus, this is omitted from the analysis.

It is important to note that the SWAP model does allow for some 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. As such, there is some endogenous yield change in response to changing market conditions. For example, the SWAP model allows for more inputs (e.g., labor, supplies, and water) to be applied to existing land in order to increase yields. The relationship between inputs and yield varies by crop and region. Each relationship is determined in the PMP routine and based on empirical data. The ability to adjust input use and generate marginally higher yields is consistent with observed practices. In general, this is plus/minus a few percentage points from the mean yield. Note that this is separate from technological (exogenous) yield change. There is no exogenous technological change included in this analysis.

Technological change is omitted from this analysis while demand shifts are incorporated. This means all of the increase in demand will be met with some combination of additional inputs applied to existing land (endogenous yield increases), additional land into production, and shifting crop mix. Supply response to higher prices is typically composed of several components, the largest of which include acreage and yield response. Exogenous technological change is not incorporated in the analysis, so endogenous yield effects and acreage responses may be overstated.

22F.2.2.3 Groundwater Pumping Power Costs

Groundwater pumping is typically the most expensive water supply. Real power costs are expected to increase in the future, and groundwater pumping relies heavily on the cost of electricity. SWAP model input data were updated under this analysis in order to break down groundwater pumping costs into fixed capital, energy, and O&M components. Energy pumping costs are escalated according to future marginal power cost estimates.

For this analysis, there are two future scenarios considered for each of the alternatives: 2025 and 2060. As such, a marginal power cost escalator is determined for each year and applied to the energy cost component of groundwater costs. The cost escalator is the ratio of the expected future power cost in 2025 or 2060 to the base power cost in 2005, in 2005 $/megawatt hour.

The power cost escalator for 2025 is 1.45. Power costs are expected to increase by 45 percent in real terms by 2025. The power cost escalator for 2060 is 2.24. Power costs are expected to more than double in real terms by 2060.

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