State Water Resources Control Board
California Environmental Protection Agency

DRAFT
APPENDIX X*: AGRICULTURAL ECONOMIC EFFECTS OF LOWER SAN JOAQUIN RIVER FLOW ALTERNATIVES

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*Lettering of Appendix to be determined during the preparation of the Draft Substitute Environmental Document

Appendix X

DRAFT Agricultural Economic Effects of Lower San Joaquin River Flow Alternatives

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X.2 Introduction

Agricultural production in the Lower San Joaquin River (LSJR) watershed is dependent on irrigation water supply from various sources, including surface water diversions, groundwater pumping, and deliveries from the state and federal water projects. The LSJR flow objectives have the potential to affect the amount of allowable surface water diversions from within the LSJR watershed, and hence agricultural production dependent on those diversions.

The analysis in this appendix estimates the potential effects to agricultural production and related sectors of the LSJR watershed economy from estimated changes in allowable surface water diversions needed to meet the LSJR flow alternatives. This analysis does not address potential effects to other beneficial uses or environmental resources potentially caused by the LSJR flow alternatives. Those effects are addressed separately in various chapters of the Substitute Environmental Document (SED).

The analysis in this appendix follows three major steps, each described in Sections X.3 through X.5 below. First, the effects on allowable surface water diversions for each of the LSJR alternatives are estimated relative to baseline conditions using the Water Supply Effects (WSE) model. For the purposes of the analysis, baseline flow conditions are those representing what existed in the LSJR watershed in 2009. Second, the Statewide Agricultural Production (SWAP) model, an agricultural production model, is used to estimate the direct effect of these changes on agricultural production and related revenues. Third, Impact Analysis for Planning (IMPLAN), a regional economic model, is used to estimate the total economic and jobs effects, including the indirect and induced effects, of these changes in agricultural production on all connected sectors of the regional economy.

There are three LSJR flow alternatives, each consisting of specified percentage of unimpaired flow requirement for the Stanislaus, Tuolumne, and Merced Rivers. For a particular alternative, each tributary must meet the specified percentage of its own unimpaired flow at its confluence with the LSJR during the months of February through June. The percentage unimpaired flow requirements are 20%, 40% and 60% respectively for each LSJR flow alternative, and apply when flows are otherwise below a specified trigger level. Flows must not drop below specified levels on each tributary, and together must maintain a minimum flow on the SJR at Vernalis. Specific trigger and minimum flow levels and other details of the LSJR flow alternatives are presented in Section 3.2 of the SED, and are the basis for how the alternatives are modeled in this appendix.

The allowable surface water diversions and associated agricultural production generated by SWAP and related economic value estimated by IMPLAN for each of the LSJR flow alternatives are compared against those estimated for baseline flow conditions in the LSJR watershed. The net difference is the agricultural production and related economic effect attributed to implementing that alternative. The analyses incorporates several conservative assumptions as detailed in Sections X.3 through X.5, including: no increased use of groundwater to augment water supply reductions for the SWAP analysis and fixed trading patterns between industries for IMPLAN. In general, as flow requirements on each of the rivers increase, the surface water diversions would need to decrease, and have a corresponding effect on agricultural production and the regional economy.

X.3 Surface Water Diversion Estimates

This section describes inputs to the State Water Board LSJR WSE model and its estimates of allowable agricultural surface water diversions for the three LSJR flow alternatives. It also describes the differences between those estimates and the baseline condition. An overview of the WSE model and its calculations are presented in Appendix X (draft technical report). To improve the resolution of this analysis, in addition to the 20%, 40%, and 60% unimpaired flow LSJR alternatives, model runs were also performed at intermediate levels of 30% and 50% of unimpaired flow. Estimates of the surface water diversions allowable under baseline conditions were obtained directly from the "*Current (2009) Conditions*" CALSIM II model run from the California Department of Water Resources (DWR) *State Water Project Reliability Report 2009.* These estimates are then used as inputs to the agricultural production model described further in Section X.4.

X.3.1 WSE Model Inputs and Approach

The WSE model is a monthly water balance spreadsheet model that estimates allowable surface water diversions and reservoir operations needed to achieve the target flow requirements of the LSJR flow alternatives on the three east-side tributaries to the LSJR. A more detailed description of the calculations in the model is presented in Appendix X (draft technical report). The model allows for user-defined constraints on each tributary, including: 1) minimum and maximum monthly flows, 2) diversion delivery rule curves, 3) monthly diversion distribution patterns, and 4) reservoir flood control storage limitations. Within these constraints the model uses a water balance to calculate the resulting river flows, allowable surface water diversions, and reservoir storage levels. Model calculations are performed on a monthly time step for each tributary using the 82 years of CALSIM II hydrology as input to New Melones, New Don Pedro, and Lake McClure respectively.

Model Inputs

The following sets of inputs were used in the WSE model to estimate the effects of the LSJR Flow Alternatives:

- Table X-1 contains the minimum monthly flow requirements and maximum trigger levels for each tributary. The target percent unimpaired flow requirements for a particular LSJR flow alternative only apply when flows are below the specified trigger level on each tributary. This eliminates the percentage unimpaired flow requirement when flows are above a level that could potential contribute to flooding or other negative downstream effects; although reservoir flood control releases, as required by the U.S. Army Corps of Engineers (USACE), could otherwise cause river flows to exceed these limits. Flows must not drop below specified levels on each tributary, and together must maintain a minimum flow on the SJR at Vernalis for the protection of fisheries in the tributaries and LSJR.
- Tables X-2a through X-2c show the user-defined diversion delivery rule curves used in this analysis for each of the three main reservoirs (New Melones, New Don Pedro, and Lake McClure). These rule curves relate the end of January storage each year to the allowable total surface water diversions (as a percentage of the maximum allowable annual diversion) for the remainder of that year, starting in February and ending the following January. In their respective tables, January storage for each reservoir is divided into four levels with corresponding annual cutback percentages for diversions. The first and fourth levels represent maximum storage and dead-pool (minimum) storage for each reservoir. The curves were

developed iteratively to maximize diversions and minimize the number of years resulting in carryover storage lower than 300 thousand acre feet (TAF), 500 TAF, and 200 TAF for New Melones, New Don Pedro, and Lake McClure reservoirs respectively. Maximum allowable annual surface water diversions were established at 750 TAF, 1,100 TAF, and 625 TAF on the Stanislaus, Tuolumne, and Merced rivers respectively based on the maximum diversion rates allowed in the CALSIM model.

- Table X-3 shows how the annual allowable surface water diversions (as determined by the diversion delivery rule curve describe above) are distributed across each month of the year starting in February and ending the following January. As explained in Appendix X (draft technical report), the monthly diversion distribution patterns used for each tributary are derived from the same pattern exhibited in the CALSIM baseline model run.
- Table X-4 contains the flood control storage limitations used in the WSE model for New Melones, New Don Pedro, and Lake McClure reservoirs. These are based on a monthly interpretation of USACE flood control curves for each reservoir. When storage would otherwise be greater than these limitations, the WSE model releases the additional flow to bring the storage levels down to the limitation.

Table X-1. Minimum Monthly Flow Requirements and Maximum Trigger Levels Input to WSE Model for Each LSJR Flow Objective Alternative

Calendar Month	Minimum Monthly Flow (cfs)			Maximum Trigger Flow (cfs)		
	Stanislaus	Tuolumne	Merced	Stanislaus	Tuolumne	Merced
2	150	200	150	2,500	3,500	2,000
3	150	200	150	2,500	3,500	2,000
4	150	200	150	2,500	3,500	2,000
5	150	200	150	2,500	3,500	2,000
6	150	200	150	2,500	3,500	2,000

Notes: No flows set for July through January as no changes from baseline flow are made in those months.
cfs = cubic feet per second

Table X-2a. Stanislaus River Diversion Delivery (Cutback) Curves at New Melones Reservoir for each LSJR Flow Objective Alternative

New Melones Stanislaus	20% Alternative		30% Alternative		40% Alternative		50% Alternative		60% Alternative	
	Storage (TAF)	Delivery (%)	Storage (TAF)	Delivery (%)	Storage (TAF)	Delivery (%)	Storage (TAF)	Delivery (%)	Storage (TAF)	Delivery (%)
Level 1	1,970	100%	1,970	100%	1,970	100%	1,970	90%	1,970	80%
Level 2	1,500	95%	100	50%	100	40%	100	35%	100	30%
Level 3	100	50%	99	0%	99	0%	99	0%	99	0%
Level 4	99	0%	NA	NA	NA	NA	NA	NA	NA	NA

Table X-2b. Tuolumne River Diversion Delivery (Cutback) Curves at New Don Pedro Reservoir for Each LSJR Flow Objective Alternative

New Don Pedro – Tuolumne	20% Alternative		30% Alternative		40% Alternative		50% Alternative		60% Alternative	
	Storage (TAF)	Delivery (%)	Storage (TAF)	Delivery (%)	Storage (TAF)	Delivery (%)	Storage (TAF)	Delivery (%)	Storage (TAF)	Delivery (%)
Level 1	1,690	95%	1,690	85%	1,690	80%	1,690	70%	1,690	65%
Level 2	1,000	55%	850	45%	1,000	45%	1,000	38%	1,000	30%
Level 3	115	20%	115	15%	115	10%	115	5%	115	0%
Level 4	114	0%	114	0%	114	0%	114	0%	NA	NA

Table X-2c. Merced River Diversion Delivery (Cutback) Curves at Lake McClure for Each LSJR Flow Objective Alternative.

Lake McClure Merced	20% Alternative		30% Alternative		40% Alternative		50% Alternative		60% Alternative	
	Storage (TAF)	Delivery (%)	Storage (TAF)	Delivery (%)	Storage (TAF)	Delivery (%)	Storage (TAF)	Delivery (%)	Storage (TAF)	Delivery (%)
Level 1	675	95%	675	90%	675	85%	675	80%	675	75%
Level 2	100	40%	300	60%	100	30%	100	25%	100	20%
Level 3	99	0%	100	30%	99	0%	99	0%	99	0%
Level 4	NA	NA	99	0%	NA	NA	NA	NA	NA	NA

Table X-3. Monthly Distribution Pattern (Starting in February Through the Following January) for Annual Allowable Diversions on Each Tributary

Calendar Month	Stanislaus (% of annual)	Tuolumne (% of annual)	Merced (% of annual)
2	1.5%	2.1%	0.2%
3	4.7%	5.1%	3.3%
4	10.9%	11.1%	10.3%
5	15.4%	15.0%	16.1%
6	16.1%	15.4%	19.7%
7	17.4%	18.3%	21.3%
8	16.0%	15.7%	17.4%
9	9.3%	8.6%	8.2%
10	4.1%	4.8%	3.0%
11	2.0%	0.7%	0.2%
12	1.3%	1.0%	0.2%
1	1.3%	2.1%	0.1%
Total	100%	100%	100%

Table X-4. Monthly Flood Control Storage Limitations Applied to New Melones, New Don Pedro, and Lake McClure Reservoirs in the WSE Model

Calendar Month	New Melones (TAF)	New Don Pedro (TAF)	Lake McClure (TAF)
1	1,970	1,690	674.6
2	1,970	1,690	674.6
3	2,030	1,690	735
4	2,220	1,718	845
5	2,420	2,002	970
6	2,420	2,030	1,024
7	2,300	2,030	1,024
8	2,130	2,030	1,024
9	2,000	1,773	850
10	1,970	1,690	674.6
11	1,970	1,690	674.6
12	1,970	1,690	674.6

Based on monthly interpretation of USACE defined flood curves.

Maximum storage volume (to spillway) in New Melones = 2,420 TAF; New Don Pedro = 2,030 TAF; and Lake McClure = 1,024 TAF

X.3.2 Summary of Results

The WSE model generates a time series of estimated allowable monthly diversions from 1922 through 2003. For the purposes of this analysis these monthly values are added together for a given year and presented as annual allowable diversions in TAF. The results are also presented for each alternative as an annual difference in TAF and as a percent difference, both relative to baseline conditions. The results of the WSE model needed for subsequent agricultural production and economic effects analysis are presented below. The WSE results are presented both as totals for the entire watershed and for the individual tributaries.

Entire LSJR Project Area

Water supplies and related conditions in the LSJR watershed are highly variable over time, and associated data or modeling results are sometimes better characterized by exceedance plots than by simple average or median statistics. Figure X-1 presents an exceedance plot of WSE estimates for total LSJR watershed annual surface water diversions for each of the LSJR flow objectives and the baseline condition across the 82 years of simulation.

For a particular LSJR alternative, the diversions estimated for a given year, may be above or below that same year's estimate for the baseline condition. This difference in annual diversions above or below the baseline condition is calculated across all 82 years of simulation for each LSJR flow alternative and presented on an exceedance plot in Figure X-2. To put in relative terms, these same annual differences are presented in Figure X-3 as a percent difference above or below the baseline condition.

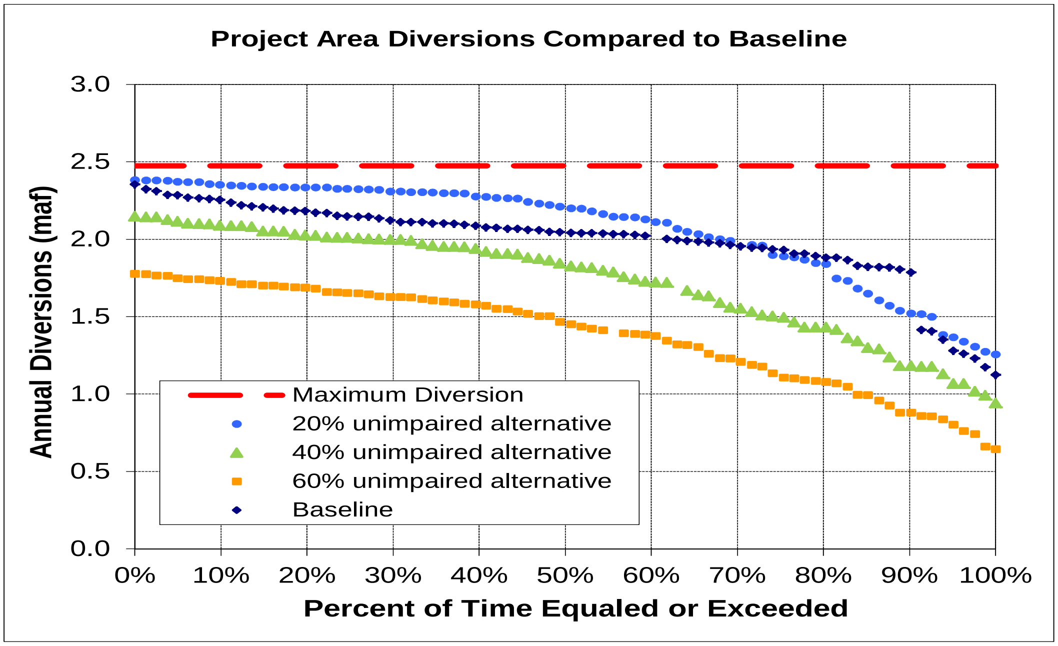

Figure X-1. Exceedance Plot of WSE Estimates for Total LSJR Watershed Annual Surface Water Diversions for Each of the LSJR Flow Objectives and the Baseline Condition Across the 82 Years of Simulation

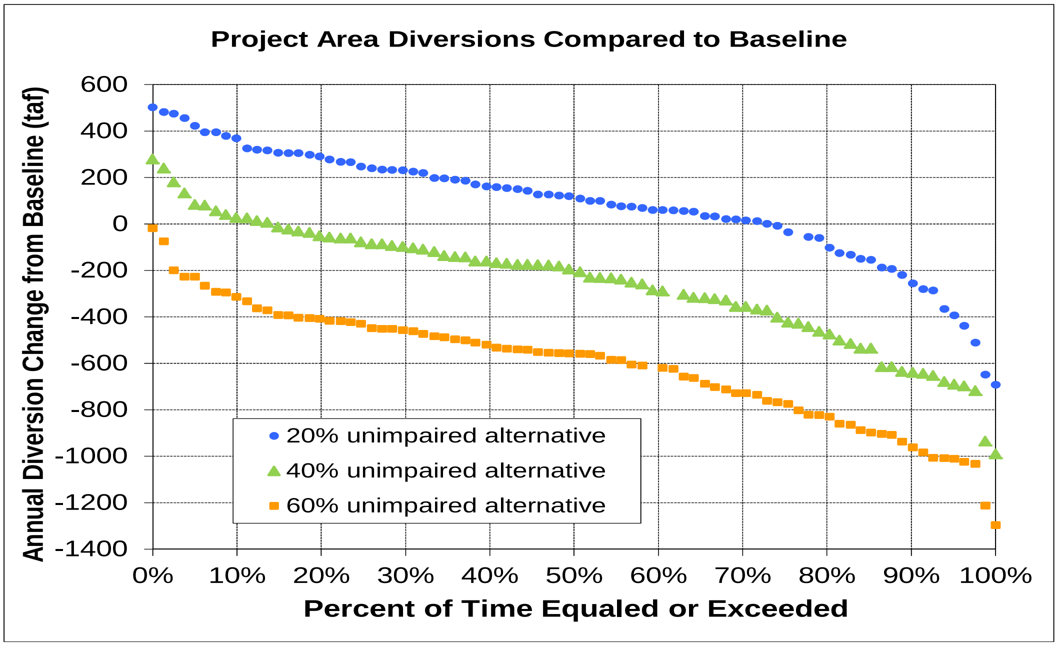

Figure X-2. Exceedance plot of WSE Estimates of the Difference in Total LSJR Watershed Annual Surface Water Diversions for Each of the LSJR Flow Objectives and the Baseline Condition

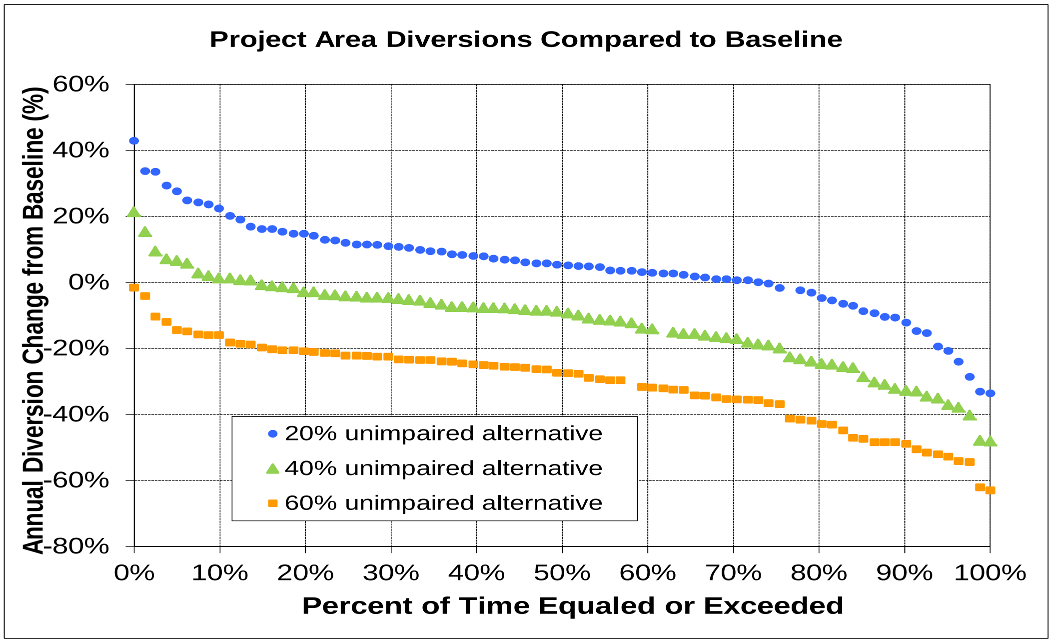

Figure X-3. Exceedance Plot of WSE Estimates for Total LSJR Watershed Annual Surface Water Diversions for Each of the LSJR Flow Objectives, as a Percent Difference Above or Below the Baseline Condition, Across the 82 Years of Simulation

Tributary Breakdown

Table X-5 summarizes the average difference in allowable diversions above or below the baseline condition, and the average percent difference from the baseline, for each of the three tributaries and the entire LSJR watershed across 82 years of simulation. This information provides a general picture of the relative distribution between the tributaries of the diversion reductions that would be needed. In general, as the percent of unimpaired flow increases, the average difference in diversions for a particular alternative relative to baseline conditions increases (i.e., greater diversion reductions would be needed to accommodate the increase in unimpaired flow). Potential diversion reductions on the Stanislaus River are generally less than those potentially needed on the Tuolumne and Merced Rivers. This is due to the generally higher level of existing flows on the Stanislaus River, as described in Chapter 2 of Appendix X (draft technical report).

Table X-5. Average Difference in Diversions Above or Below the Baseline Condition, Along with the Average Percent Difference from the Baseline, for Each of the Three Tributaries and the Entire LSJR Watershed Across 82 Years of Simulation

Percent of Unimpaired Flow Alternative	Stanislaus (TAF)	Tuolumne (TAF)	Merced (TAF)	LSJR Watershed (TAF)
20% Alternative	+96	-5	-10	+83
40% Alternative	+4	-172	-87	-255
60% Alternative	-115	-328	-163	-606
	(%)	(%)	(%)	(%)
20% Alternative	+18%	0%	+1%	+5%
40% Alternative	+1%	-19%	-14%	-13%
60% Alternative	-20%	-37%	-29%	-31%

Figure X-4 through Figure X-6 presents exceedance plots of the difference in annual allowable diversions above or below the baseline condition for each LSJR flow alternative across all 82 years of simulation on the Stanislaus, Tuolumne, and Merced Rivers respectively. This provides the distribution and variability of the differences on each tributary. Positive values indicate diversions for a given year could be greater than baseline conditions, and negative values indicate diversions in a given year would need to be less than baseline conditions. Overall more diversion reductions would be needed to meet higher percent unimpaired flow requirements. Potential diversion reductions on the Stanislaus for the unimpaired flow alternatives are generally less than the other two rivers due to the generally higher level of existing flows on the Stanislaus River.

To further describe the variable nature of revenues over the 82 years of simulation, Figures X-7 through X-9 present the WSE estimates of allowable annual diversions from the Stanislaus, Tuolumne, and Merced Rivers respectively for the baseline and the LSJR flow alternatives as time-series over the 82 year simulation. These figures demonstrate the variability of diversions that would be expected through a series of dry and wet water years for baseline conditions and under the LSJR flow alternatives. They also show the differences that would be expected for the three LSJR tributaries.

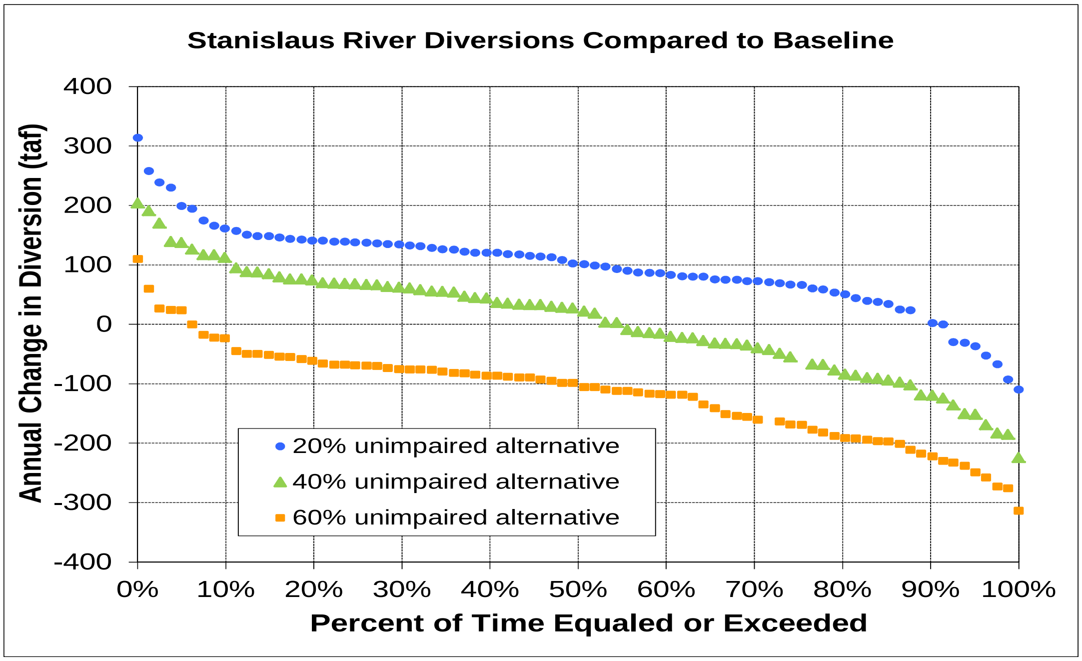

Figure X-4. Exceedance Plot of Difference in Annual Allowable Diversions Above or Below the Baseline Condition for Each LSJR Flow Alternative on the Stanislaus River Across 82 Years of Simulation

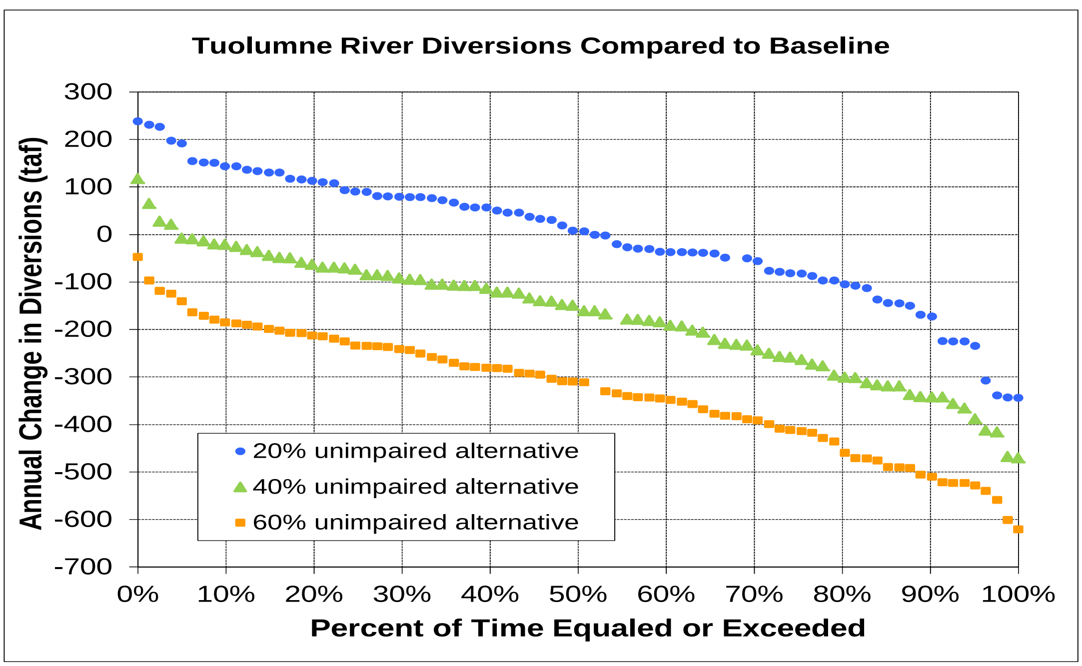

Figure X-5. Exceedance Plot of Difference in Annual Allowable Diversions Above or Below the Baseline Condition for Each LSJR Flow Alternative on the Tuolumne River Across 82 Years of Simulation

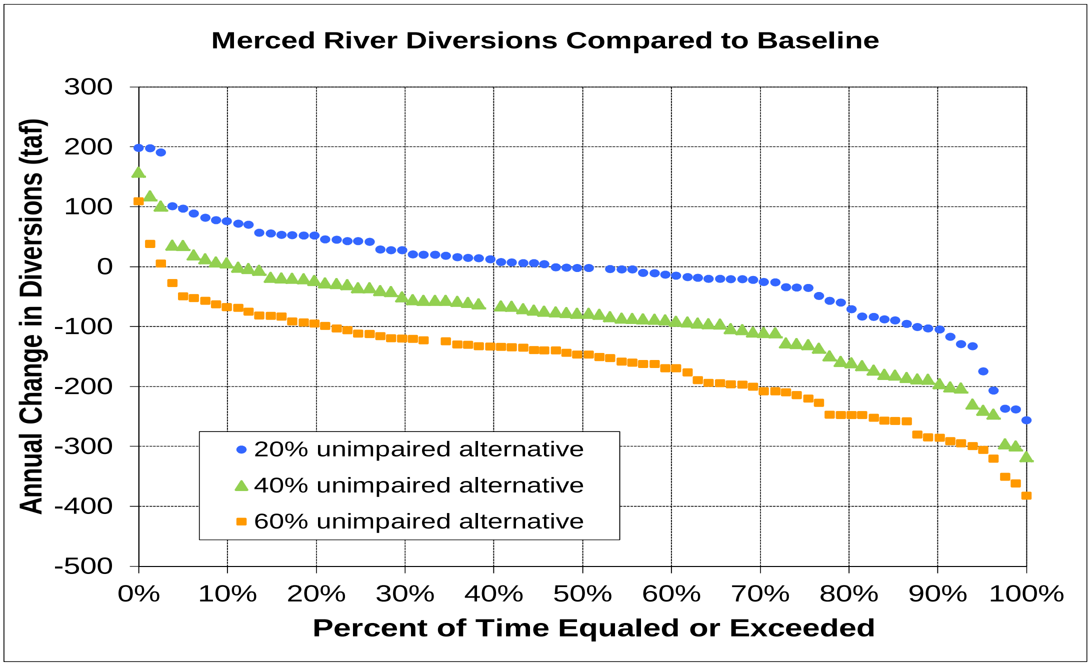

Figure X-6. Exceedance Plot of Difference in Annual Allowable Diversions Above or Below the Baseline Condition for Each LSJR Flow Alternative on the Merced River Across 82 Years of Simulation

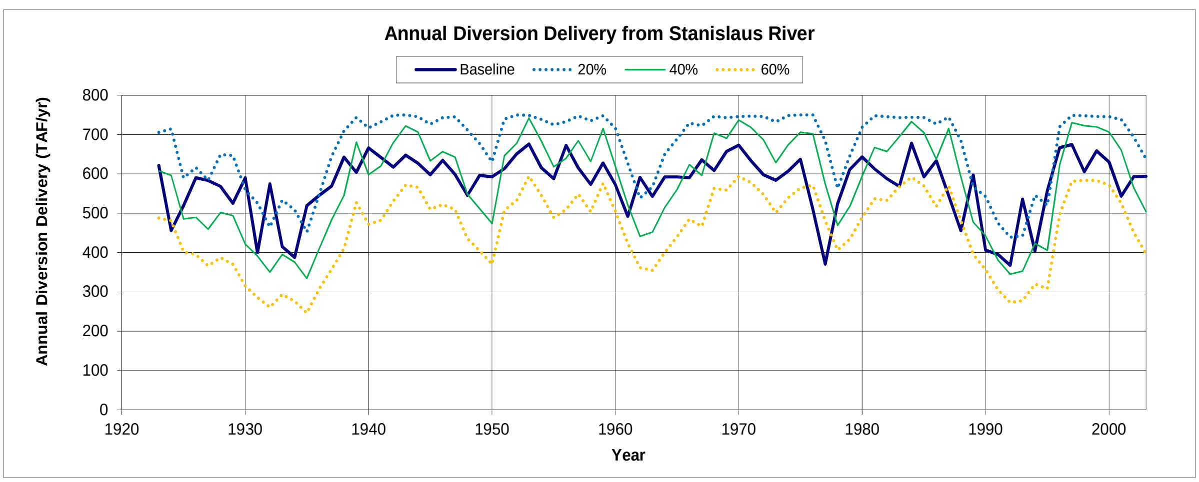

Figure X-7. Estimated Stanislaus River Allowable Annual Diversions from WSE Model for 1922 through 2003

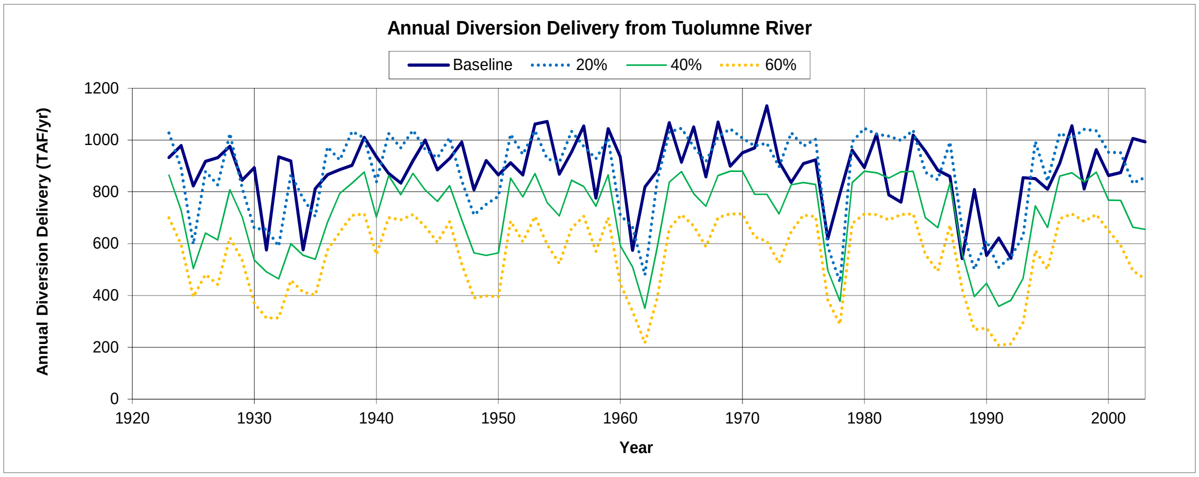

Figure X-8. Estimated Tuolumne River Allowable Annual Diversions from WSE Model for 1922 through 2003

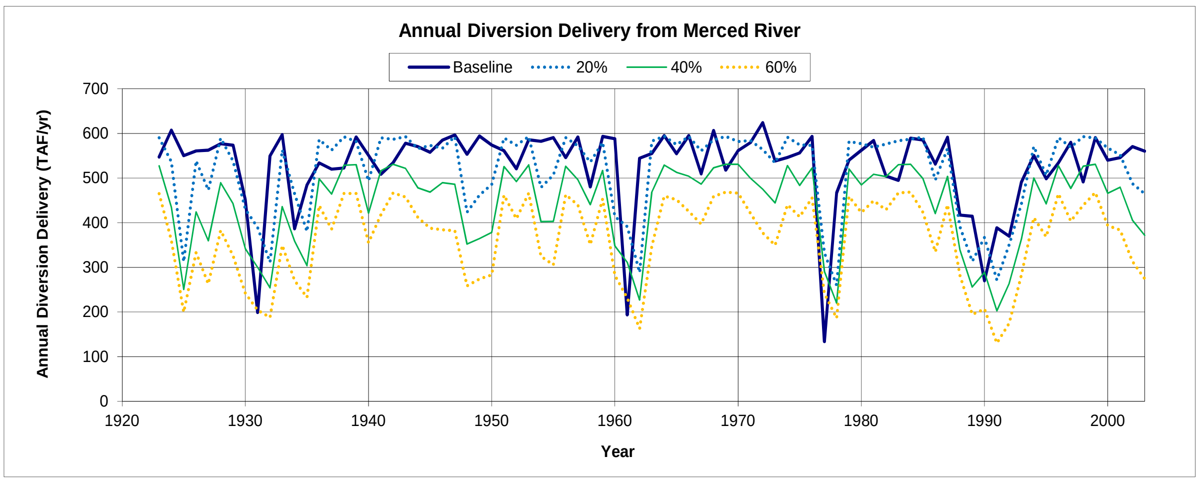

Figure X-9. Estimated Merced River Allowable Annual Diversions from WSE Model for 1922 through 2003

X.4 Effects on Agricultural Production

Changes to the amount of surface water diversions have the potential to effect water available for crop irrigation and thus have the potential to affect agricultural productivity. The estimates of the surface water diversions developed in the previous section are used in the SWAP model to estimate agricultural production and revenues for each of the LSJR flow alternatives. The agricultural production and revenues are then compared to the baseline condition. Because the WSE model simulates changes in surface water diversions over 82 years of hydrology, the results are highly variable across a range of possible annual effects.

X.4.1 SWAP Model Overview

The SWAP model was selected to estimate the agricultural production (crop acreages) and revenues (total production value) associated with the surface water diversions potentially needed under the LSJR flow alternatives and baseline conditions. SWAP is an agricultural production model that simulates the decisions of farmers at a regional level based on principles of economic optimization. The model assumes that farmers maximize profit (revenue minus costs) subject to resource, technical, and market constraints. The model selects those crops, water supplies, and irrigation technology that maximize profit subject to these equations and constraints. The model accounts for land and water availability constraints given a set of factors for production prices, and calibrates exactly to *observed* yearly values of land, labor, water and supplies use for each region.

Justification and Previous Applications

The basis for SWAP is Positive Mathematical Programming (PMP), which is a self-calibrating agricultural production model aimed to maximize farm profits and employing a calibration method that ensures that crop production matches the observed base data in a given year (Howitt 1995). PMP introduces a non-linear cost function derived from the first order conditions of Leontief production constrained model. Additional details on the PMP methodology are presented in several reports and peer reviewed publications including: Howitt et al. (2010), Medellín-Azuara et al. (2010), and Medellín-Azuara et al. (2012).

PMP has become a widely accepted method for analyzing water demand and undertaking policy analysis and are deemed as the dominant method with respect to inductive (statistical) based models to represent agricultural production (Young 2005; Scheierling et al. 2006). This type of model works well with the multitude of resource, policy, and environmental constraints often observed in practice (Griffin 2006). Furthermore, PMP does not require large datasets, is directly based on profit-maximizing behavior of farmers, and is better suited to estimate policy response of farming activities than strictly statistical methods (Howitt et al. 2010). In contrast to statistical methods, SWAP more explicitly accounts for changes in water availability due to reduced diversions as part of the constraint set in the model. By comparing a base case with current diversions and a policy scenario with reduced diversions, the analyst is able to economically quantify changes in revenue, cropping patterns and applied water per unit area.

SWAP also has some comparative advantages over current and previously used agricultural water use models. Two such models are DWR California Agriculture (CALAG) and DWR Net Crop Revenue Models (NCRMs). The following is a brief description of those models and the comparative advantages of SWAP.

- CALAG is an extended and improved version of CVPM. Like SWAP the numerical basis of CALAG is PMP (California Department of Water Resources 2008). CALAG, however, does not explicitly include costs of productions factors in their formulation, and instead use constant variable production costs by crop and region. SWAP in contrast, can capture farmer adjustments in input use such as water per acre changes during drought conditions. Thus CVPM and CALAG are well suited to represent water supply operations but are less useful for modeling detailed changes in production such as water per unit area, labor per unit area or supplies per unit area. SWAP estimates cropping patterns and input use for all policies evaluated, capturing adaptation of crop farming production to changing water availability conditions. When faced with increasing water scarcity, farmers have been shown to adjust in three ways, changes in water per acre, changes in crop mix, and changes in total irrigated acres. CVPM and CALAG are robust models that can account for two of these changes, but SWAP has been extended to incorporate all three adjustments. SWAP incorporates information from both models, in terms of water supply sources and uses regions compatible with both models. SWAP has additional modules to account for technological improvement, climate change, changes in crop prices and water quality.

- The NCRMs are spreadsheet programs that estimate average net crop revenues for 26 crop groups in 27 California counties and regions. These models combine data on acres, and average yields and prices from numerous county and state sources. The spreadsheets price-level adjust cost and gross revenue data to a common year, adjust for changes in various costs, and then calculate weighted-average estimates of a typical grower's annual net crop revenue, whether profit or loss (California Department of Water Resources 2008). However using fixed budgets, it is not possible to model reactions to changes in water availability based on farmers profit-maximizing behavior as can be done in SWAP. Instead, the NCRM spreadsheets provide a snapshot of agriculture but do not capture changes in cropping patterns or production input use as a result of changing water availability.

The SWAP model has been used in a wide range of policy analysis projects. The first formal application of this model was to estimate the economic scarcity costs of water for agriculture in the statewide hydro-economic optimization model for water management in California known as the California Value Integrated Network (CALVIN) model. SWAP provides economic value of water shortage to CALVIN by month and region that is weighted against value of shortage in other uses in deciding water allocation . (Draper et al. 2003). Also, DWR used SWAP subsequent to the CALAG model to aid in development of planning scenarios and studies supporting preparation of the 2009 Water Plan Update (http://www.waterplan.water.ca.gov/cwpu2009/index.cfm#volume4).

SWAP has also been used by the Stockholm Environment Institute as a subsidiary model for a Water Evaluation and Planning (WEAP) model application in the California Central Valley, with other participants such as the U.S. Bureau of Reclamation and consulting firms including CH2M HILL. WEAP is a climate-driven, water resource model that systematically simulates natural water flows and management of infrastructure to balance supply and demand. SWAP takes advantage of the WEAP priority-based allocation and provides cropping patterns for a wide range of water availability conditions. In doing this, SWAP turns a water allocation simulation model into a hydro-economic model that allocates water based on economic value of the final use (Yates et al. 2005).

More recently, SWAP applications have been greatly expanded to include salinity in soil and shallow groundwater in the Sacramento-San Joaquin Delta in California (Lund et al. 2007) and south of the Delta (Howitt et al. 2009a; Tanaka et al. 2008), climate change (Howitt et al. 2009c; Medellin-Azuara, et al. 2007), and drought impact analysis (Howitt et al. 2009b).

X.4.2 Model Inputs and Approach

SWAP was configured to model agricultural production in the main agricultural areas of the LSJR watershed and calibrated to DWR land use and applied water data for 2005. Using output from the WSE model, the SWAP model estimates the agricultural production (crop acreages) and revenues (total production value) resulting from each of the LSJR flow alternatives and the baseline. The annual results for each LSJR flow alternative are then compared to those for the baseline condition to calculate the net effect of the alternatives.

SWAP Regions

SWAP disaggregates the Central Valley using the Central Valley Production Model (CVPM) regions as described in the Central Valley Project Improvement Act Programmatic Environmental Impact Statement (United States Bureau of Reclamation 1997). For analysis of LSJR flow alternatives, CVPM regions 11, 12, and 13 were used in SWAP as shown in Figure X-10. These correspond well to the main agricultural areas of the LSJR watershed.

For comparison, Figure X-11 shows the boundaries of CVPM regions 11, 12, and 13, along with major irrigation district and LSJR tributary boundaries. While the irrigation district boundaries generally correspond with the CVPM regions, these districts obtain surface water diversions, and provide service to agricultural areas in more than one watershed. Therefore, the surface water diversion reductions for each tributary watershed, as estimated by the WSE model, cannot be used directly as input to the individual CVPM regions of SWAP. The three CVPM regions as a whole, however, adequately encompasses the LSJR watershed, and thus, the surface water diversion reductions for all three tributaries from the WSE model are applied equally across the CVMP regions in SWAP. This effectively provides an average result from SWAP across the entire LSJR watershed, but not for the individual watersheds or CVPM regions.

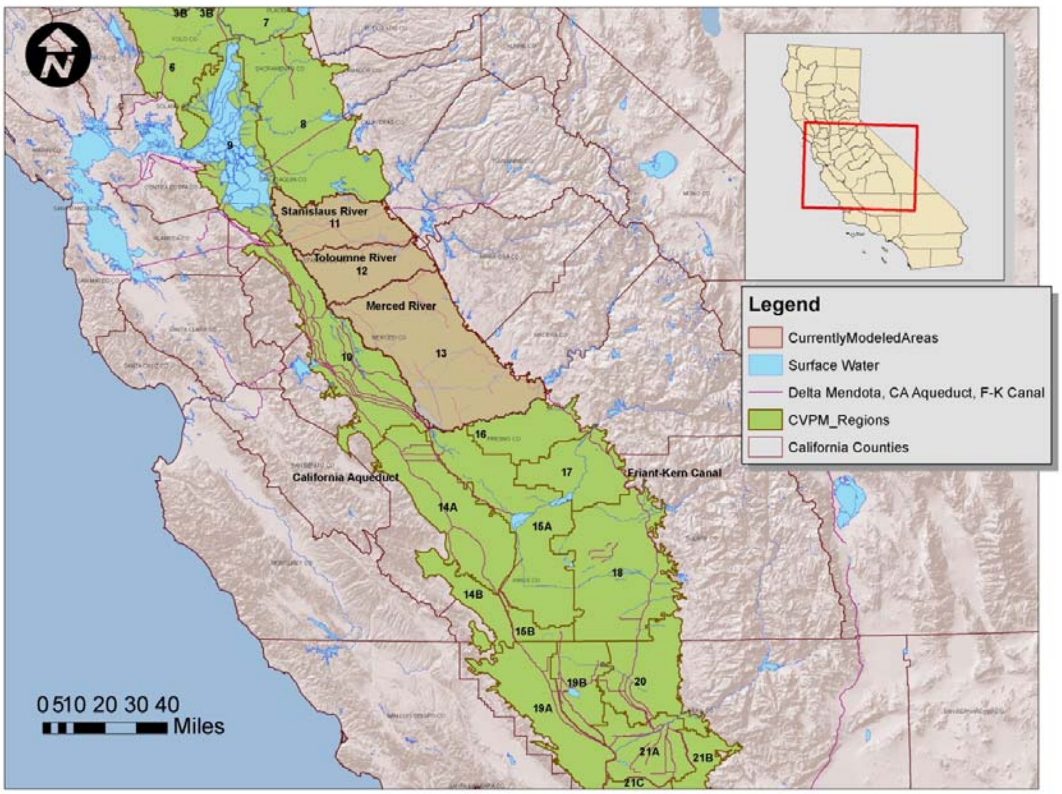

Figure X-10. CVPM Regions Used in SWAP and Those Used in the Project Area (CVPM regions 11, 12, 13)

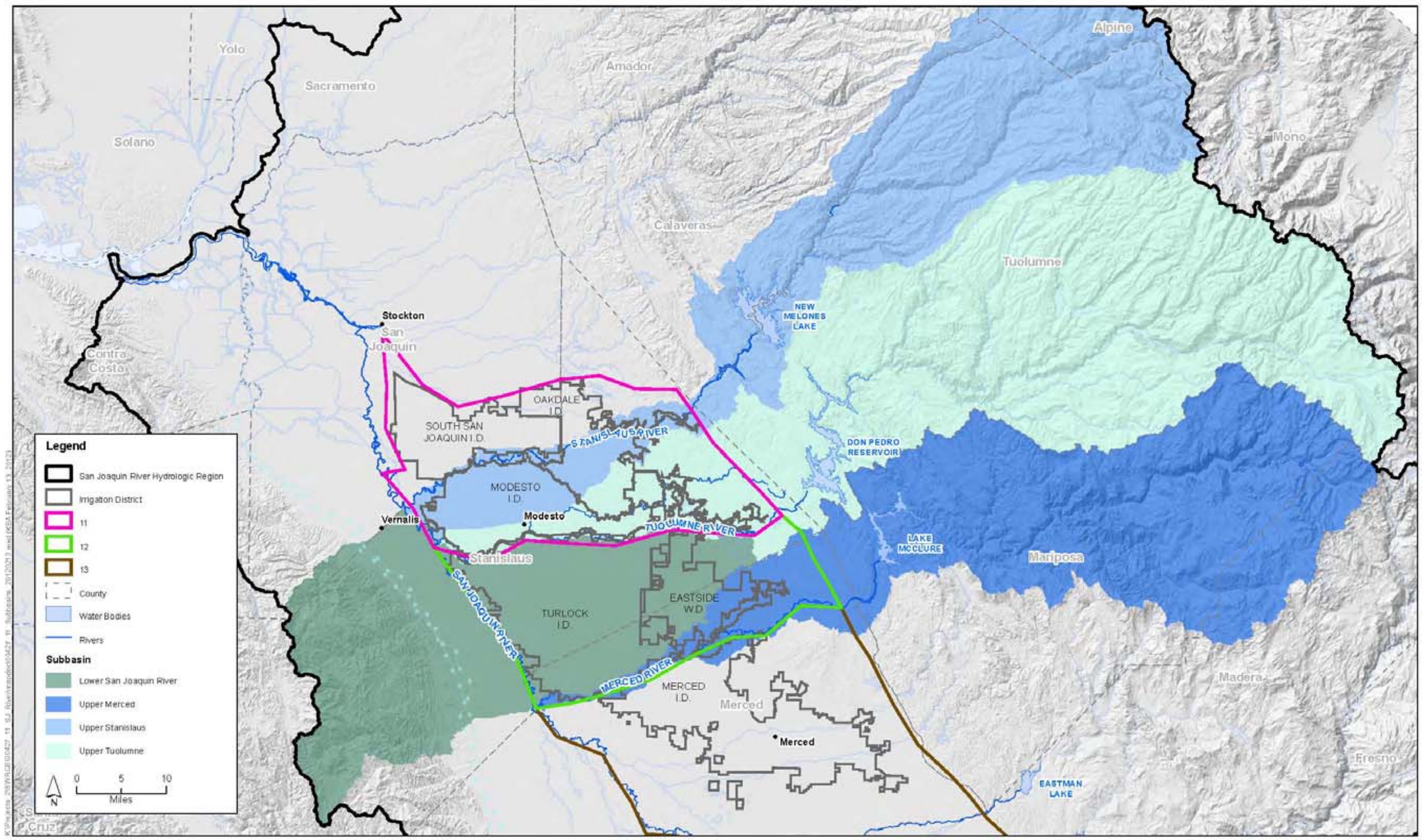

Figure X-11. Major Water District Boundaries Within the Project Area (CVPM regions 11, 12, 13)

SWAP Calibration

SWAP is calibrated to DWR estimates of land use and applied water data for water year 2005. This represents the most recent normal water year in terms of both water availability and crop prices. These estimates were also used for preparation of the 2009 California State Water Plan. To develop these estimates, DWR surveys land and water uses within each county periodically depending on changes that have occurred within that county. Surveys began in 1947 with the first digitized survey completed in 1988, and are available from the DWR website. Table X-6 below lists the counties within the project area and when the latest land use survey was taken. DWR uses the Agriculture Commissioner annual reports to then update crop yields appropriate for water year 2005.

Table X-6. Counties Within Project Area and Date Last Surveyed by DWR

County	Year Last Land Surveyed	Date Last Estimated by DWR from Commissioner Reports
Calaveras	2000	2005
Madera	2001	2005
Mariposa	1998	2005
San Joaquin	1996	2005
Stanislaus	2004	2005
Tuolumne	1997	2005
Merced	2002	2005

The DWR land use surveys contain a breakdown by irrigated and non-irrigated lands and crop groups. The crop groups in SWAP follow the DWR classifications and include: almonds and pistachios, alfalfa, corn, cotton, cucurbits, dry beans, fresh tomato, processing tomato, grains, onion and garlic, pasture, potato, rice, safflower, citrus and subtropical, and vineyards, as well as other orchards, field crops, and truck crops. Table X-7 summarizes across the project area (CVPM regions 11, 12, and 13) the total 2005 acreages for these crop groups, along with the associated water use and production values per acre.

Table X-7. Irrigated Crop Area, Water Use Intensity, and Crop Type by Crop Groups Used in SWAP

Crop Group	2005 DWR Irrigated Crop Area (Acres)	Water Use (Acre-feet/Acre)	Value ($/Acre)	Crop Type
Alfalfa	97,704	4.05	$ 918	Perennial
Almond/Pistachio	296,773	3.32	$ 3,871	Perennial
Corn	148,872	2.48	$ 673	Annual
Cotton	31,577	3.08	$ 906	Annual
Cucurbits	2,709	1.66	$ 3,802	Annual
Dry Bean	1,937	2.15	$ 994	Annual
Field	92,576	2.41	$ 332	Annual
Fresh Tomato	6,778	1.5	$ 5,811	Annual
Grain	21,446	0.74	$ 285	Annual
Onion and Garlic	819	2.01	$ 4,348	Annual
Orchards	66,200	3.39	$ 2,718	Perennial
Pasture	112,218	4.43	$ 631	Annual
Rice	6,370	5.37	$ 754	Annual
Safflower	446	1.58	$ 472	Annual
Subtropical	5,859	2.52	$ 6,639	Perennial
Sugarbeet	2,495	1.25	$ 1,275	Annual
Tomato-Processing	12,428	2.38	$ 2,018	Annual
Truck Crops	30,435	0.96	$ 5,192	Annual
Vine	112,602	2.25	$ 4,066	Perennial

SWAP Simulation of Alternatives and Baseline Condition

These annual surface water diversion changes estimated by the WSE model (described in Section X.3) were input to SWAP to estimate the associated agricultural production (crop acreages) and revenues (total production value). For each water year SWAP uses the PMP methodology to calculate the crop acreage mix that would maximize revenue from the annual available surface water diversions.

For the purpose of this analysis it was assumed that irrigation supplied from groundwater and other sources (e.g., CVP project deliveries, etc.) would not be increased to make up for any decrease in surface water diversions. While some additional alternative supply might actually be available from other sources, for the purpose of economic analysis, this is a conservative assumption.

The SWAP output for a particular LSJR flow alternative or the baseline condition is a time-series of 82 annual estimates of the associated crop acreages, applied water, and revenue across the period of simulation. For the purpose of evaluating each LSJR flow alternative, these estimates for a given year are compared against those for the baseline condition. The result is a time series across all 82 years of simulation of annual differences in crop acreages and revenue associated with LSJR alternative when compared to the baseline condition.

X.4.3 Summary of Results

This section presents SWAP model output characterizing the total agricultural production (crop acreages) and directly-related revenues (total production value) associated with the three LSJR flow alternatives and the baseline condition. Also presented are the differences in these values between the three LSJR alternatives and the baseline condition. As described earlier, SWAP provides an average result across the LSJR watershed.

Effects on Crop Acreage

Table X-8 presents the average over the 82-year study period of the annual irrigated acreage of each crop type for the baseline condition and the average difference, in both acres and percent, between LSJR flow alternatives and the baseline condition. As water becomes less available, the crops most affected are rice, pasture, and field crops, followed by corn. These are affected more because they are relatively high water-use annual crops with lower value crops per acre. The low value crop groups that cover large areas are substantially reduced as the LSJR flow alternative increases from 20% to 60% of unimpaired flow. Figures X-12 through X-15 present the annual crop acreage for each crop group as a time series from 1960 to 2003 for the baseline condition and the 20%, 40% and 60% LSJR flow alternatives respectively., In some years of extreme drought, pasture and field crops are nearly eliminated from production particularly under the 40% and 60% alternatives.

Figure X-16 presents the annual crop acreage for selected crops (cotton, grain, process tomatoes, sub-tropical fruit, rice and dry beans) as a time series from 1960 to 2003 for each of the LSJR flow alternatives. This demonstrates that higher value crops, such as tomatoes are less affected by increased diversion reductions than lower value, high water-use crops, such as rice, and that the effects are generally greater during the higher percentage alternatives. Figure X-17 presents the annual crop acreage for some low-acreage crops (fresh tomatoes, cucurbits, sugar beets, onions/garlic, and safflower) as a time series from 1960 to 2003 for each of the LSJR flow alternatives. Generally, these crops are not as affected by diversion reductions. Perennial crops such as vines, almonds and pistachios, and sub-tropical crop groups experience decreases in production only in prolonged extreme drought such as experienced in the early 1990s. This is shown by a constant acreage from year to year even as the flow objective alternative is increased.

Table X-8. Average Annual Acreage of Irrigated Crops for Baseline Condition and Average Difference (in Acres and Percent) Between LSJR Flow Alternatives and Baseline Condition by Crop Group

	Baseline	20% Alternative		40% Alternative		60% Alternative	
Crop Group	(TAF)	+/-TAF	% Change	+/-TAF	% Change	+/-TAF	% Change
Alfalfa	94,180	+569	+1%	-3,439	-4%	-10,283	-11%
Almonds/Pistachios	295,630	+157	<+1%	-670	<-1%	-2,651	-1%
Corn	137,020	+945	+1%	-14,517	-11%	-38,576	-28%
Cotton	30,660	+180	+1%	-468	-2%	-1,213	-4%
Cucurbits	2,700	+2	<+1%	-7	<-1%	-23	-1%
Dry Bean	1,890	+6	<+1%	-42	-2%	-239	-13%
Field	57,510	+5,290	+9%	-23,004	-40%	-42,752	-74%
Fresh Tomato	6,770	+2	<+1%	-4	<-1%	-10	<-1%
Grain	21,220	+75	<+1%	-318	-1%	-1,092	-5%
Onion and Garlic	820	+1	<+1%	-1	<-1%	-4	-1%
Orchards	65,420	+111	<+1%	-542	-1%	-4,422	-7%
Pasture	76,570	+2,603	+3%	-27,400	-36%	-56,386	-74%
Rice	4,520	+54	+1%	-1,595	-35%	-3,442	-76%
Safflower	430	+3	+1%	-14	-3%	-46	-11%
Subtropical	5,850	+2	<+1%	-3	<-1%	-8	<-1%
Sugarbeet	2,480	+3	<+1%	-7	<-1%	-15	-1%
Tomato (Processing)	12,330	+20	<+1%	-57	<-1%	-238	-2%
Truck Crops	30,410	+4	<+1%	-16	<-1%	-55	<-1%
Vine	112,390	+42	<+1%	-107	<-1%	-289	<-1%
TOTAL	958,800	+10,069	+1%	-72,211	-8%	-161,744	-17%

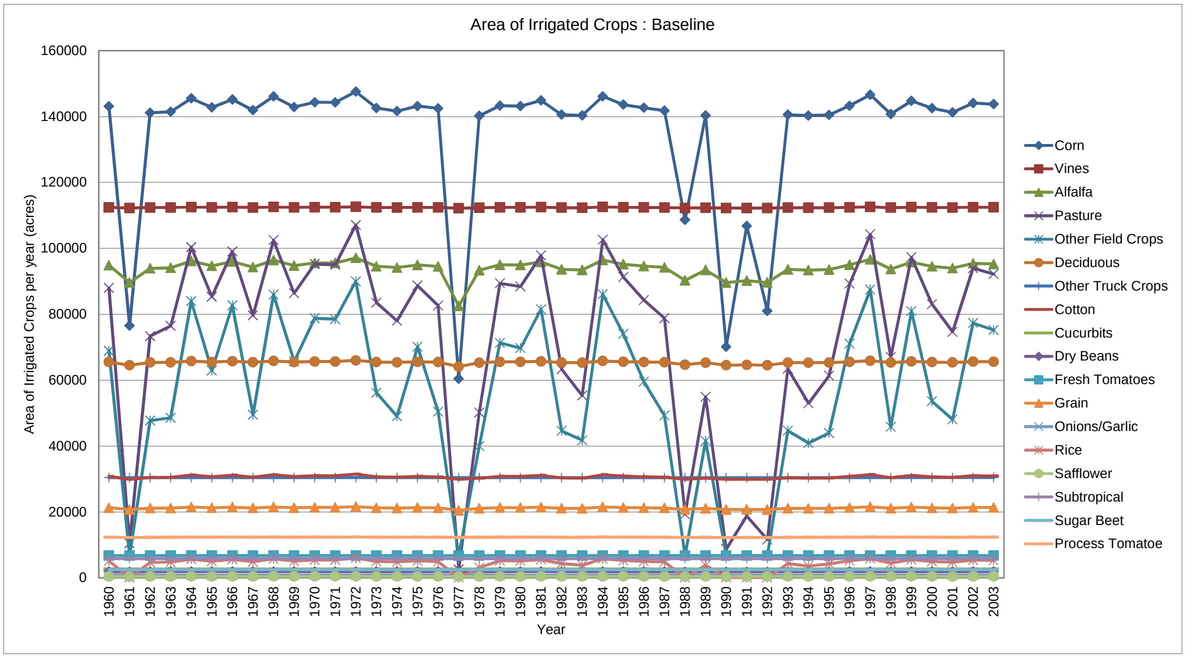

Figure X-12. Annual Crop Acreage by Crop Group Under Baseline Conditions from 1960 to 2003

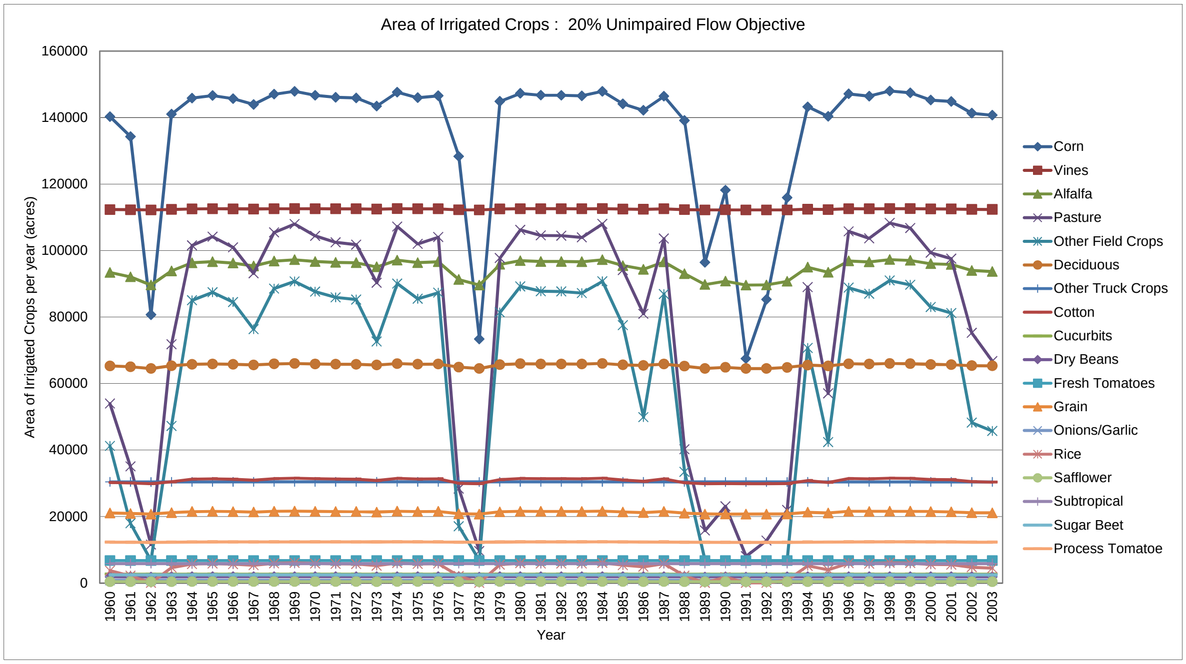

Figure X-13. Annual Crop Acreage by Crop Group Under 20% Unimpaired Flow Alternative from 1960 to 2003

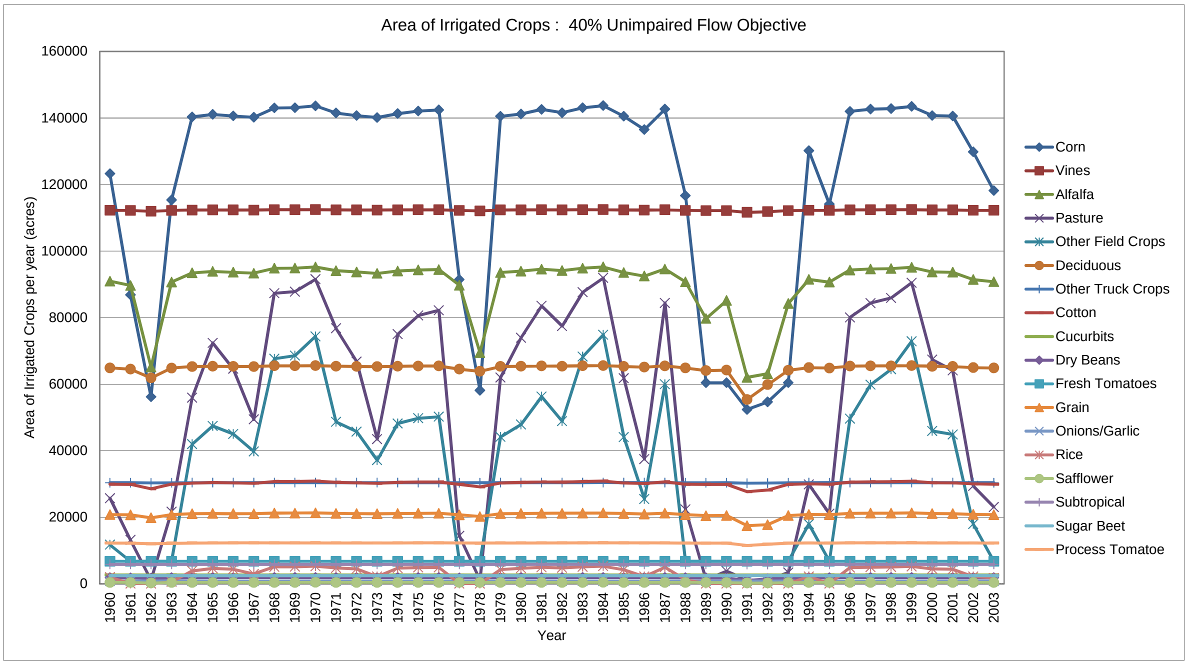

Figure X-14. Annual Crop Acreage by Crop Group Under 40% Unimpaired Flow Alternative from 1960 to 2003

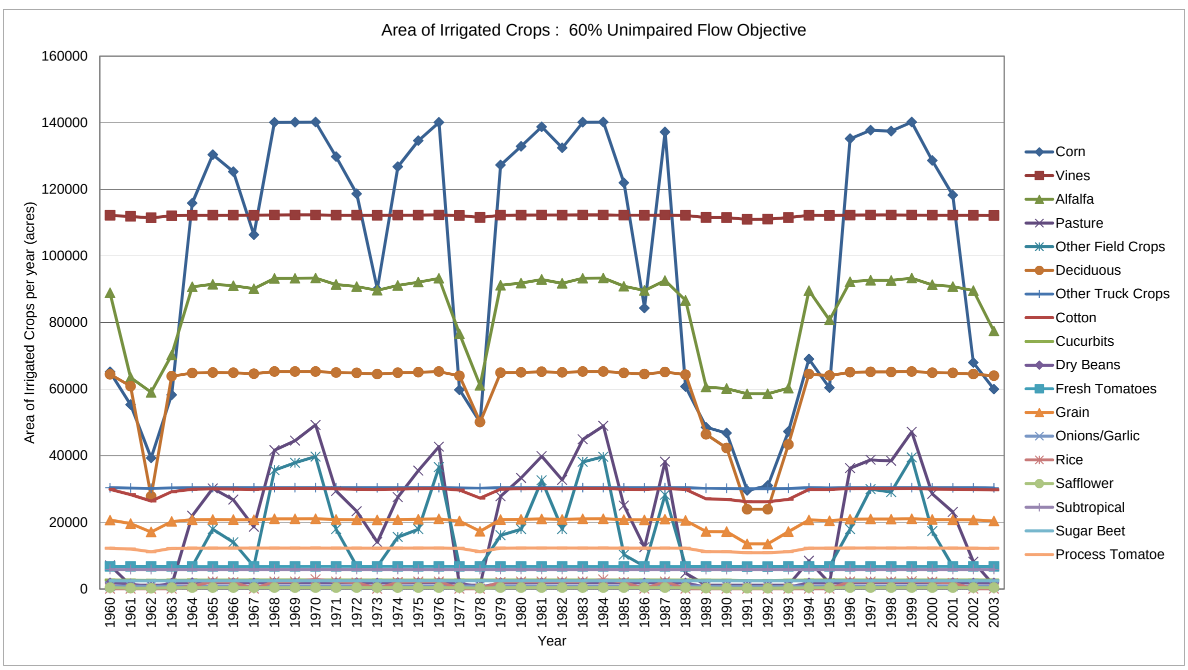

Figure X-15. Annual Crop Acreage by Crop Group Under 60% Unimpaired Flow Alternative from 1960 to 2003

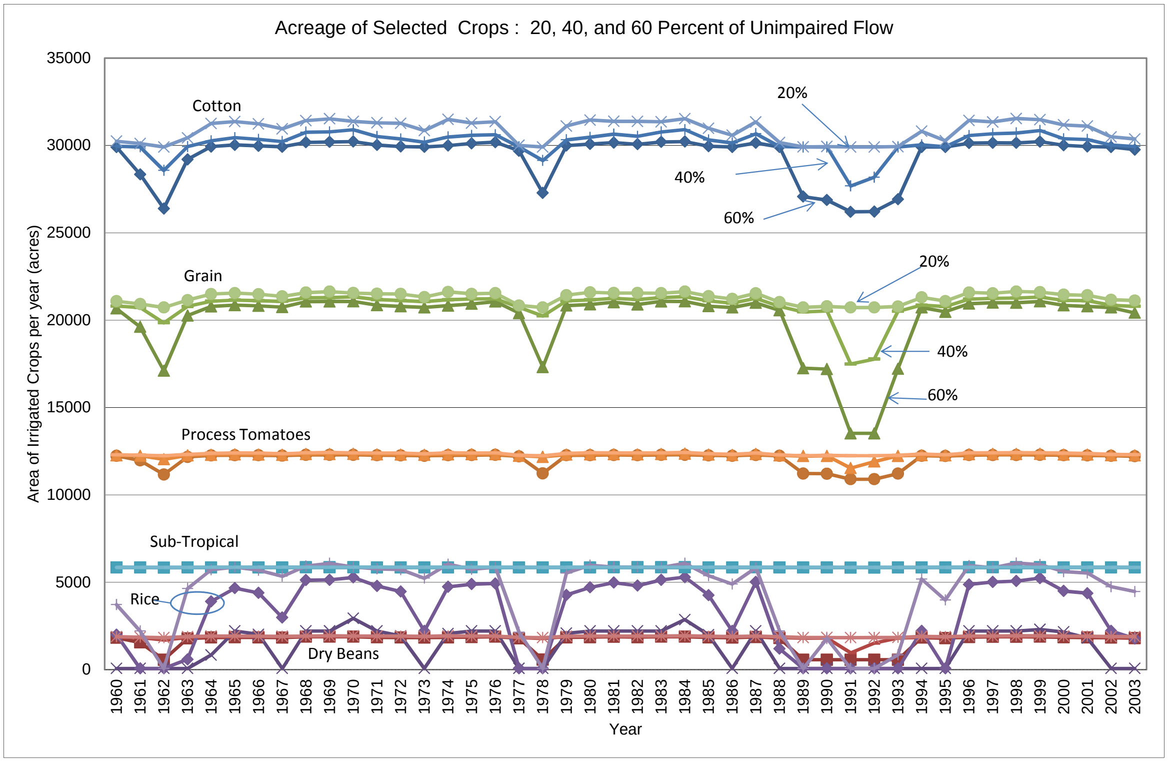

Figure X-16. Annual Crop Acreage by Crop Group Under 20%, 40%, and 60% Unimpaired Flow Alternatives from 1960 to 2003 for Selected Crops

Figure X-17. Annual Crop Acreage by Crop Group Under 20%, 40%, and 60% Unimpaired Flow Alternatives from 1960 to 2003 for Selected Higher-Value Crops with Low Total Acreage

Effects on Agricultural Revenue

SWAP estimates the total direct gross crop revenues generated across CVPM regions 11, 12, and 13 for the three LSJR flow alternatives and the baseline condition. These are the direct revenues generated by farming operations (i.e., gross total production value). It does not include the associated indirect or induced effect on the regional economy, which will be addressed in the next section. SWAP is calibrated and output is reported in 2005 dollars, but is subsequently adjusted using Engineering News Record construction cost indices and reported below in 2008 dollars to correspond with the subsequent regional economic analysis.

Water supplies and related conditions in the LSJR watershed are highly variable over time, and associated data or modeling results are sometime better characterized by exceedance plots than by simple average or median statistics. To characterize the magnitude and variability of revenues, Figure X-18 presents an exceedance plot of SWAP estimates for total LSJR watershed annual agricultural revenues across the 82 years of simulation for each of the LSJR flow objectives and the baseline condition.

Revenues estimated for a particular year, for a particular LSJR alternative, may be above or below that same year's estimate for the baseline condition. To understand this difference, it's important to *not* compare the exceedance plots in Figure X-18, but rather use a plot of the annual differences. The difference in annual revenue above or below the baseline condition is calculated across all 82 years of simulation for each LSJR flow alternative and presented on an exceedance plot in Figure X-19. Under 60% unimpaired flow requirements the models estimates a decrease in agricultural productivity in all years, while at 20% it estimates many years with an increase. To put in relative terms, these same annual differences are presented in Figure X-20 as a percent difference above or below the baseline condition.

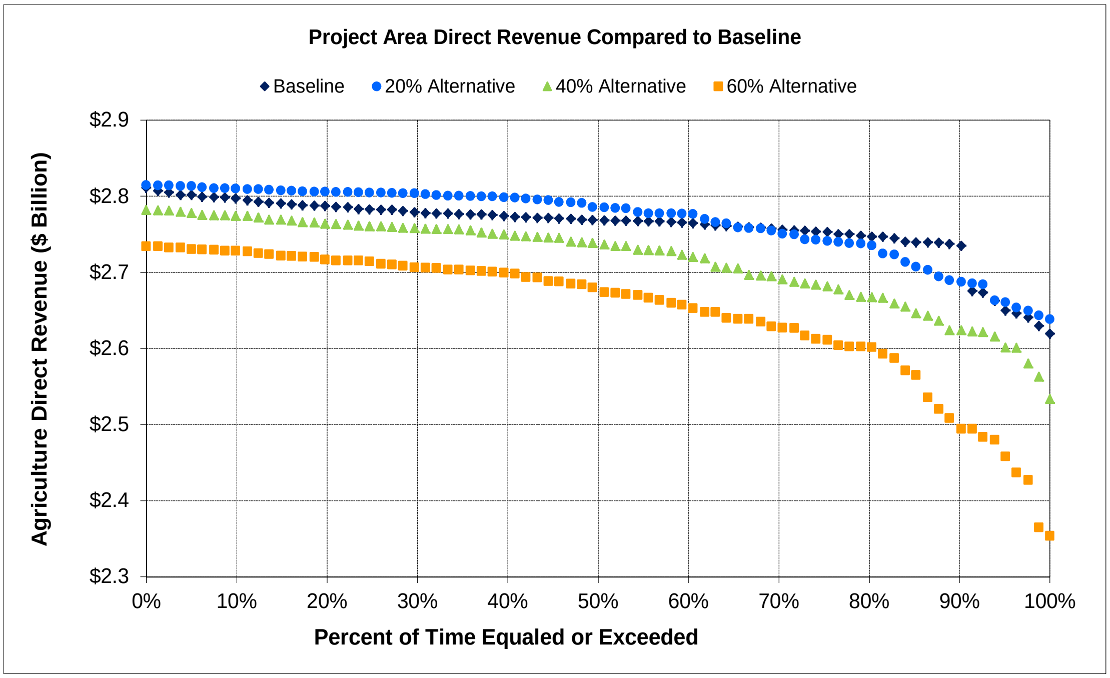

Figure X-18. Exceedance Plot of SWAP Estimates for Total LSJR Watershed Annual Agricultural Revenues for Each of the LSJR Flow Objectives and the Baseline Condition Across the 82 Years of Simulation

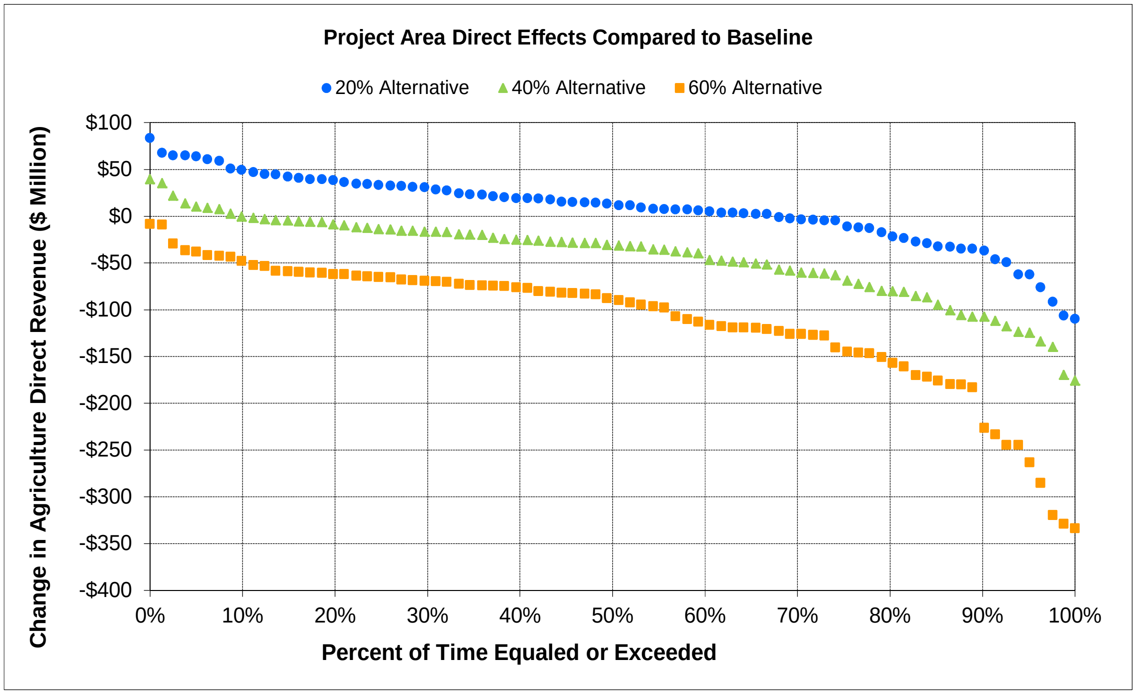

Figure X-19. Exceedance Plot of the Difference in SWAP Estimates of Total LSJR Watershed Annual Agricultural Revenues Between the Three LSJR flow Objectives and the Baseline Condition Across the 82 Years of Simulation

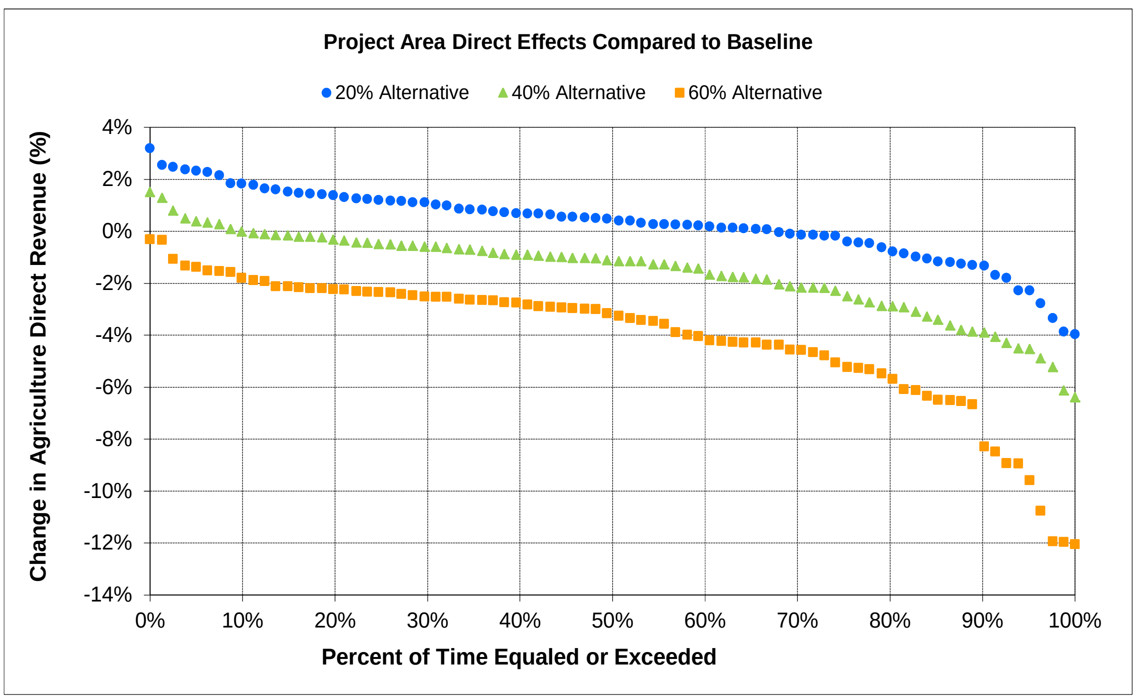

Figure X-20. Exceedance Plot of the Percent Difference in SWAP Estimates of Total LSJR Watershed Annual Agricultural Revenues between the Three LSJR Flow Objectives and the Baseline Condition Across the 82 Years of Simulation

To further describe the variable nature of revenues over the 82 years of simulation, Figure X-21 presents the total annual direct revenue as a time-series for years 1922 through 2003 for the baseline and three LSJR alternatives. To understand the relative magnitude of the effect on revenues associated with the alternatives, Figure X-22 presents the percent difference in total annual direct revenue between the three LSJR alternatives and the baseline condition as a time-series for years 1922 through 2003.

As diversion reductions increase (i.e., as surface water diversions become less available) the effect on agricultural revenues related to an additional increase in diversion reductions begins to climb faster. To demonstrate this, Figure X-23 displays the marginal revenue loss per acre-foot of diversion reduction for LSJR flow alternatives ranging from 25% to 60% of unimpaired flow.

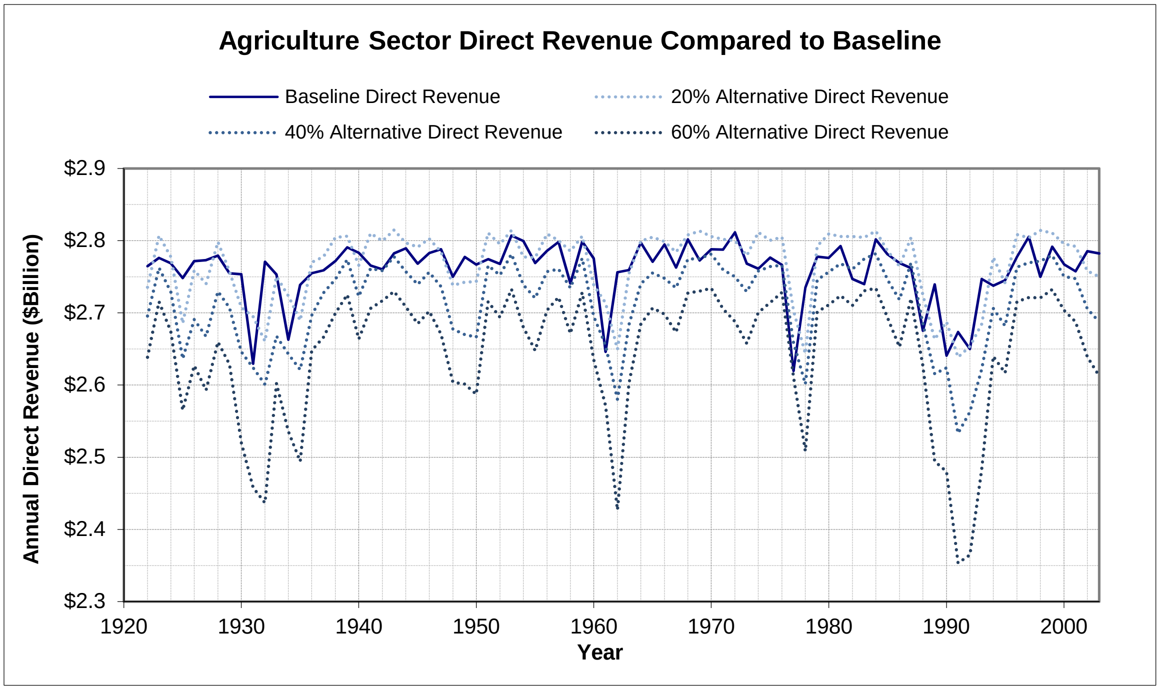

Figure X-21. Total Annual Direct Revenue ($Billion) for Years 1922 through 2003 for the Baseline and Three LSJR Alternatives

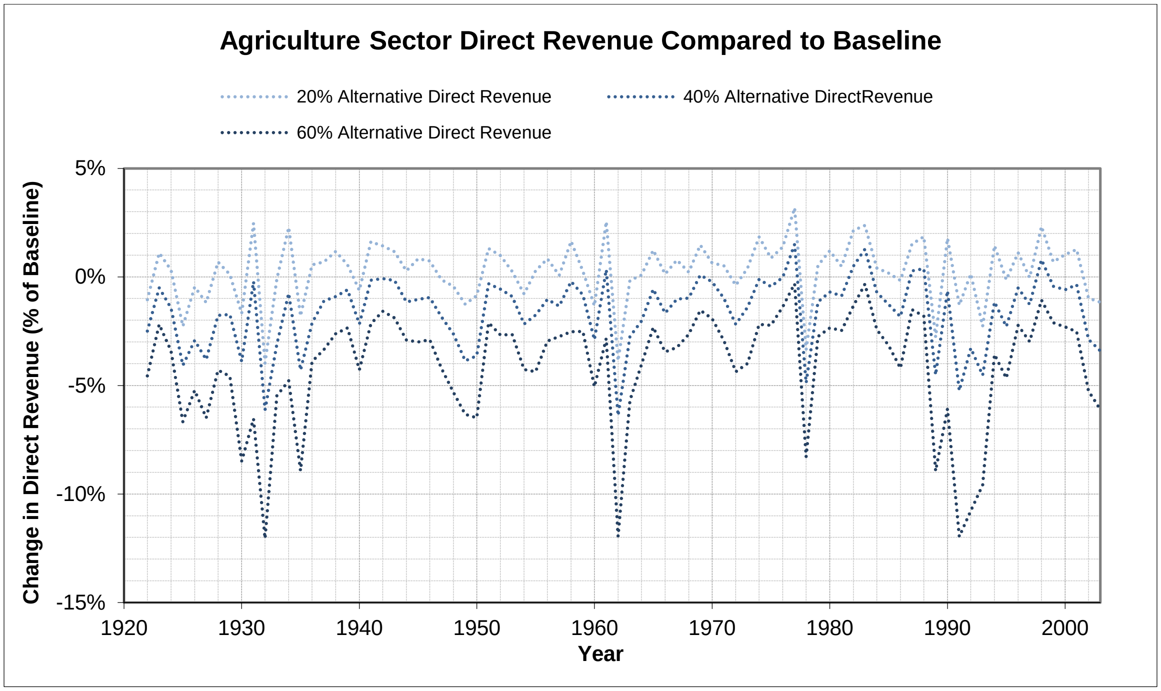

Figure X-22. Percent Difference in Total Annual Direct Revenue Between the Three LSJR Alternatives and the Baseline Condition for Years 1922 through 2003

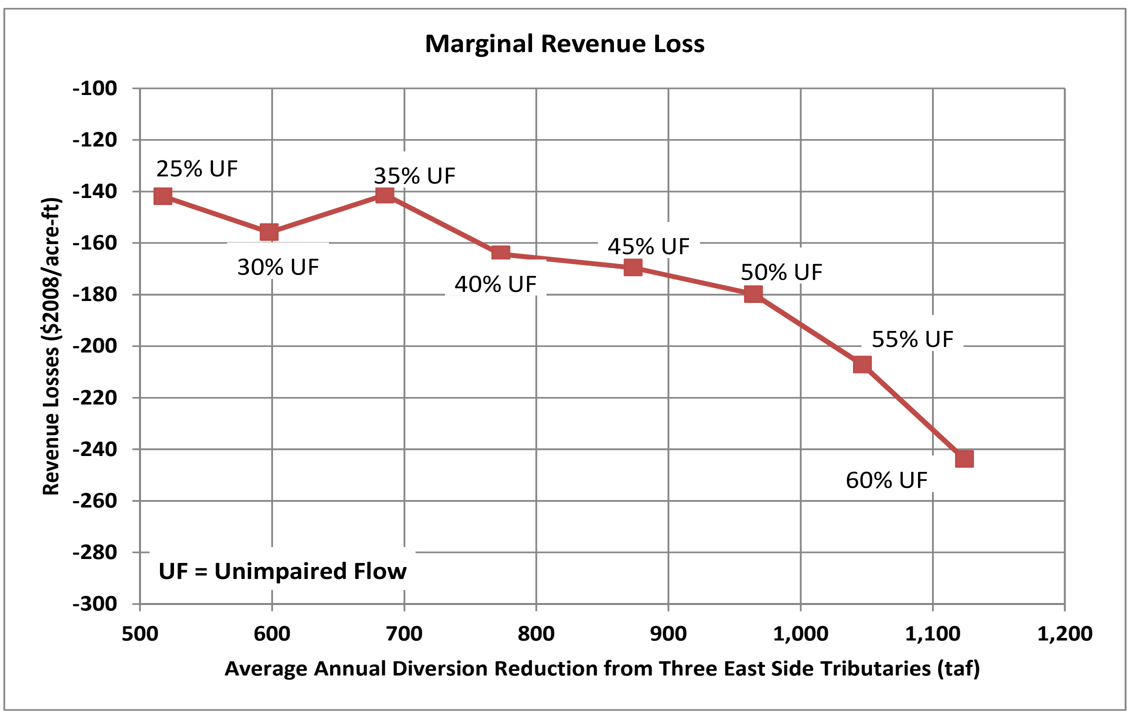

Figure X-23. Marginal Revenue Loss Per Acre-Foot of Additional Diversion Reduction for LSJR flow Alternatives Ranging from 25% to 60% of Unimpaired Flow

X.5 Effects on Regional Economy

The analysis in this section provides estimates of the total regional economic activity associated with agricultural production in the LSJR watershed for each of the LSJR flow alternatives and compares these estimates to baseline conditions. This analysis uses the IMPLAN economic model to estimate the indirect and induced economic activity associated with the direct agricultural-related revenue from the SWAP model (as discussed and presented in the previous section). In general, changes in agricultural production and related jobs would also affect businesses serving farming operations and farm workers. The IMPLAN model applies job and income multipliers to calculate the effects to other connected sectors of the regional economy. The direct agricultural-related revenue effects from the SWAP model and the indirect and induced economic effects from the IMPLAN model together provide an estimate of the total economic sector output and jobs effects for the region.

X.5.1 IMPLAN Model and Approach

Reductions in water deliveries to agricultural users would affect several sectors of the economy, not just agriculture. When farm production falls as a result of reduced water availability, farmers would hire fewer seasonal workers and may lay off some year-round workers. Without jobs, household spending by these workers is likely to fall, affecting retailers and other businesses in the area. In addition, farmers would reduce purchases of equipment, materials, and services from local businesses, reducing jobs and income with these suppliers. The total regional economic effect is the sum of the direct effects to agriculture and these associated indirect and induced effects.

To estimate the regional economic effects the LSJR flow alternatives, the 2009 Impact Analysis for Planning model (IMPLAN) Version 3.0 (2009) was used. IMPLAN has been used for many years by state, federal, and municipal entities throughout the country to calculate economic effects. This includes the California Department of Water Resources, the State Water Board, the U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, the Bureau of Economic Analysis, and the Bureau of Land Management. IMPLAN was used previously by the State Water Board to determine the potential regional effects of reduced farm production in the San Joaquin Valley in the EIR for the Implementation of the 1995 Bay/Delta Water Quality Control Plan (State Water Resources Control Board 1999). This previous use was similar to the current use of IMPLAN to determine the regional economic effects of the LSJR flow objectives alternatives.

IMPLAN is an input-output multiplier model and considers interrelationships among sectors and institutions in the regional economy. Production in the different economic sectors is simulated in IMPLAN by using fixed factors, which account for dynamics such as production per unit of input, value added, and employment. It then applies these factors in a social accounting matrix, which accounts for changes in transactions between producers and intermediate and final consumers in other sectors of the economy. The IMPLAN approach also considers non-market transactions such unemployment insurance payments and associated changes in tax revenues for government.

The IMPLAN model uses region-specific multipliers to estimate the indirect and induced economic effects (positive or negative) of changes in one sector on all other connected sectors in the regional economy. For this analysis, the ten default IMPLAN crop groups were aggregated into sector 111 (crop production) of the North American Industry Classification System (NAICS) Thus direct revenue effect, an output from the SWAP model (described in Section X.4 above), were applied to sector 111 as a whole. The indirect and induced effects are then calculated by applying these multipliers for each sector affected by changes to sector 111. Because multipliers are applied to the direct revenues from the SWAP model, it was possible to limit the modeled area in the regional effects modeling to the area modeled by SWAP and as shown previously in Figure X-10. The majority of the area modeled in IMPLAN is contained within the counties of Madera, Merced, and Stanislaus and is a good representation of the agricultural area in the LSJR watershed.

The IMPLAN model then uses a built-in set of regional multipliers to develop the direct, indirect and induced effects on employment and sector output. As mentioned earlier, changes in agricultural revenues correspond to direct impacts on sector output. The built-in ratios of jobs per unit of sector output are then used to calculate direct impacts of agricultural revenue losses in regional employment. Thus the direct effect to employment is the direct revenue effect multiplied by the agriculture sector employment multiplier. The additional indirect and induced employment effect is the indirect and induced economic effect multiplied by the agriculture sector employment multiplier.

Input-output analysis approach employed by IMPLAN usually overestimates indirect job and income losses. One of the fundamental assumptions in input-output analysis is that trading patterns between industries are fixed. This assumption implies that suppliers always cut production and lay off workers in proportion to the amount of product supplied to farms or other industries reducing production. In reality, businesses are always adapting to changing conditions. When a farm cuts back production, some suppliers would be able to make up part of their losses in business by finding new markets in other areas. Growth in other parts of the local economy is expected to provide opportunities for these firms. For these and other reasons, job and income losses estimated using input-output analysis should often be treated as upper limits on the actual losses expected (SWRCB 1999).

X.5.2 Summary of Results

This section presents estimates of the total economic output from IMPLAN for crop production (Sector 111) and related economic sectors associated with the LSJR flow alternatives. This includes both the direct effects on agricultural-related revenues and jobs as estimated by the SWAP model (which are input to the crop production sector of IMPLAN) and the associated indirect and induced effects on the agriculture-related regional economy and job market as estimated by IMPLAN.

Entire LSJR Project Area

As an overview, Table X-9, presents the baseline average total output from Sector 111 – Crop Production plus all other sectors with associated indirect or induced effects along with the difference from baseline, both in dollars and percent, for each LSJR flow alternative. To better understand the effects as a function of percentage unimpaired flow, output is also presented for 30 and 50% of unimpaired flow. The table further splits the total sector output into average direct effects and average induced and indirect effects. In general, as the percent of unimpaired flow for an alternative increases, the economic and related employment effects also increase.

Table X-9. Average (Over the 82 Years of Simulation) Baseline Economic Output for the Crop Production and Related Sectors and Changes Associated with Various Percentage of Unimpaired Flow Requirements

		Change from Baseline by Percent Unimpaired Flow ($Millions)				
Economic Effects (2008 Dollars)	Baseline ($Millions)	20%	30%	40%	50%	60%
Total Sector Output	$4,701	+$13	-$29	-$75	-$131	-$193
% of Sector	100%	+0.3%	-0.6%	-1.6%	-2.8%	-4.1%
Direct	$2,760	+$7	-$17	-$44	-$77	-$113
Indirect and Induced	$1,941	+$5	-$12	-$31	-$54	-$80

To characterize the magnitude and variability of revenues, Figure X-24 presents an exceedance plot of the total economic output from the IMPLAN crop production and related sectors across the 82 years of simulation for each of the LSJR flow objectives and the baseline condition.

The difference in this total economic output above or below the baseline condition is calculated across all 82 years of simulation for each LSJR flow alternative and presented on an exceedance plot in Figure X-25. To put in relative terms, these same annual differences are presented in Figure X-26 as a percent difference above or below the baseline condition.

The SWAP and IMPLAN modeling output is not disaggregated to the individual tributary watersheds. As demonstrated earlier in Table X-5, the LSJR flow alternatives would be expected to reduce surface water diversions overall on the Tuolumne and Merced Rivers more than those on the Stanislaus River. So likewise, the associated economic effects are not expected to be distributed equally across the three LSJR tributary watersheds.

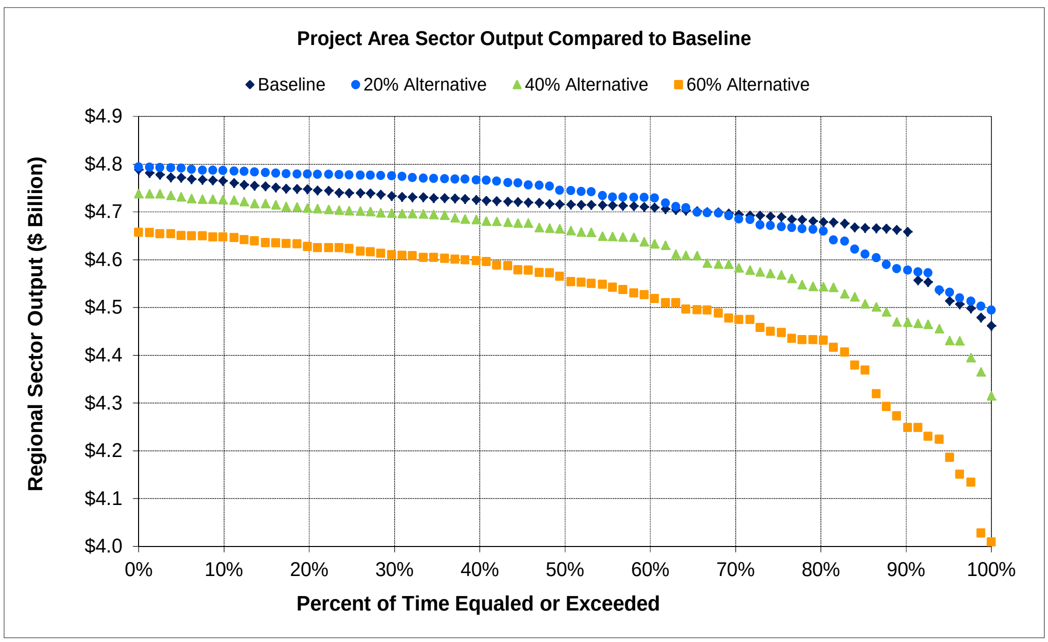

Figure X-24. Exceedance Plot of IMPLAN Estimates for Total Economic Output from the Crop Production and Related Sectors for Each of the LSJR Flow Objectives and the Baseline Condition Across 82 Years of Simulation

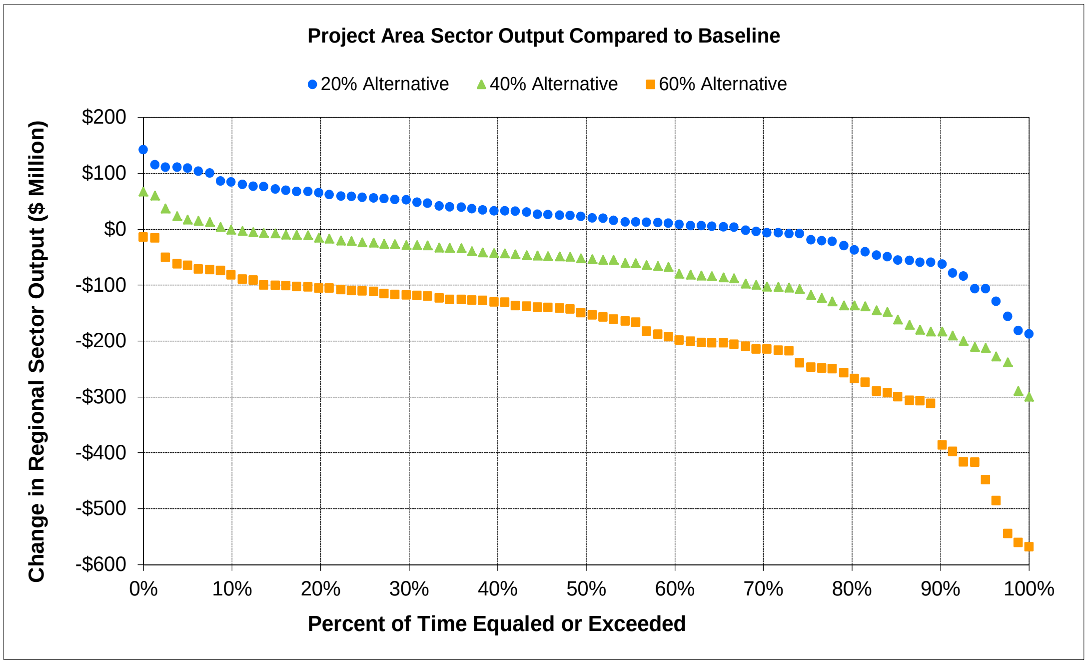

Figure X-25. Exceedance Plot of the Difference in IMPLAN Estimates for Total Economic Output from the Crop Production and Related Sectors between the Three LSJR Flow Objectives and the Baseline Condition across 82 Years of Simulation

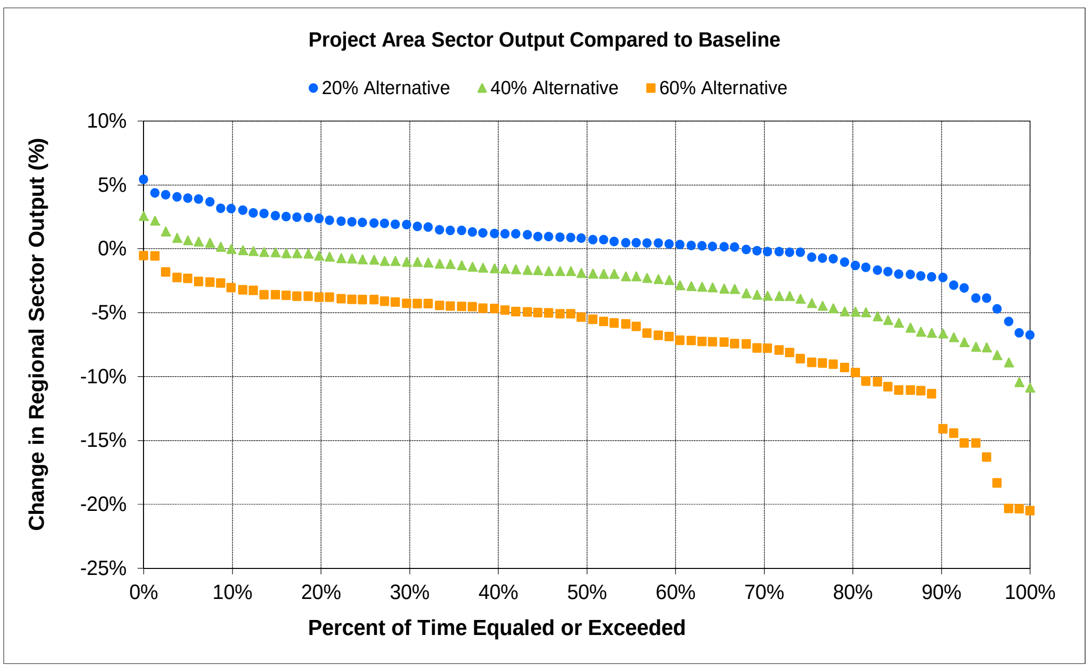

Figure X-26. Exceedance Plot of the Percent Difference in IMPLAN Estimates for Total Economic Output from the Crop Production and Related Sectors Between the Three LSJR Flow Objectives and the Baseline Condition Across the 82 Years of Simulation

In addition to revenue, the IMPLAN model also estimates the number of jobs associated with the crop production and related (indirect and induced) sectors of the economy. The total effects on jobs associated with the LSJR flow objectives are similar, in relative terms, to the effect on economic output. Table X-10 presents a summary of the total number of jobs associated with the IMPLAN crop production and related sectors and how they are affected on average by various percentage of unimpaired flow requirements. It also presents the breakdown of jobs within the crop production sector (direct effects) and those within the related sectors (indirect and induced).

Table X-10. Average (over the 82 Years of Simulation) Number of Crop Production and Related Sector Jobs for Baseline Condition and Changes Associated with Various Percentage of Unimpaired Flow Alternatives.

		Change from Baseline by Percent Unimpaired Flow				
Economic Effects	Baseline	20%	30%	40%	50%	60%
Total Regional Effect to Employment (# jobs)	31,787	+86	-196	-504	-889	-1,302
% of Sector	100%	+0.3%	-0.6%	-1.6%	-2.8%	-4.1%
Direct	13,080	+35	-81	-207	-366	-536
Indirect and Induced	18,707	+50	-115	-297	-523	-766

Figure X-27 presents an exceedance plot of IMPLAN estimates of the total number of crop production and related (indirect and induced) sector jobs each year in the LSJR watershed for each of the LSJR flow objectives and the baseline condition across the 82 years of simulation. The difference in the number of jobs each year above or below the baseline condition is calculated across all 82 years of simulation for each LSJR flow alternative and presented on an exceedance plot in Figure X-28. Figure X-29 presents an exceedance plot of the percent difference in the total number of jobs each year in the LSJR watershed between the three LSJR flow objectives and the baseline condition across the 82 years of simulation. The effect of the LSJR flow alternatives on jobs is similar in relative magnitude to their economic effect.

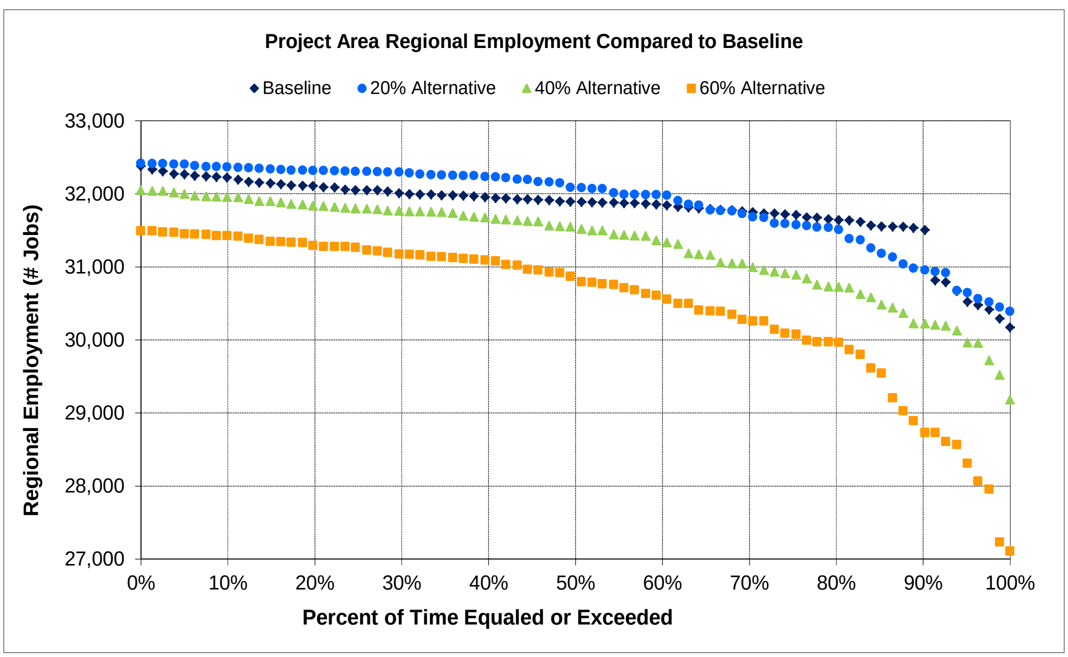

Figure X-27. Exceedance Plot of IMPLAN Estimates for Total Jobs for the Crop Production and Related Sectors in the LSJR Watershed for Each of the LSJR Flow Objectives and the Baseline Condition Across 82 Years of Simulation

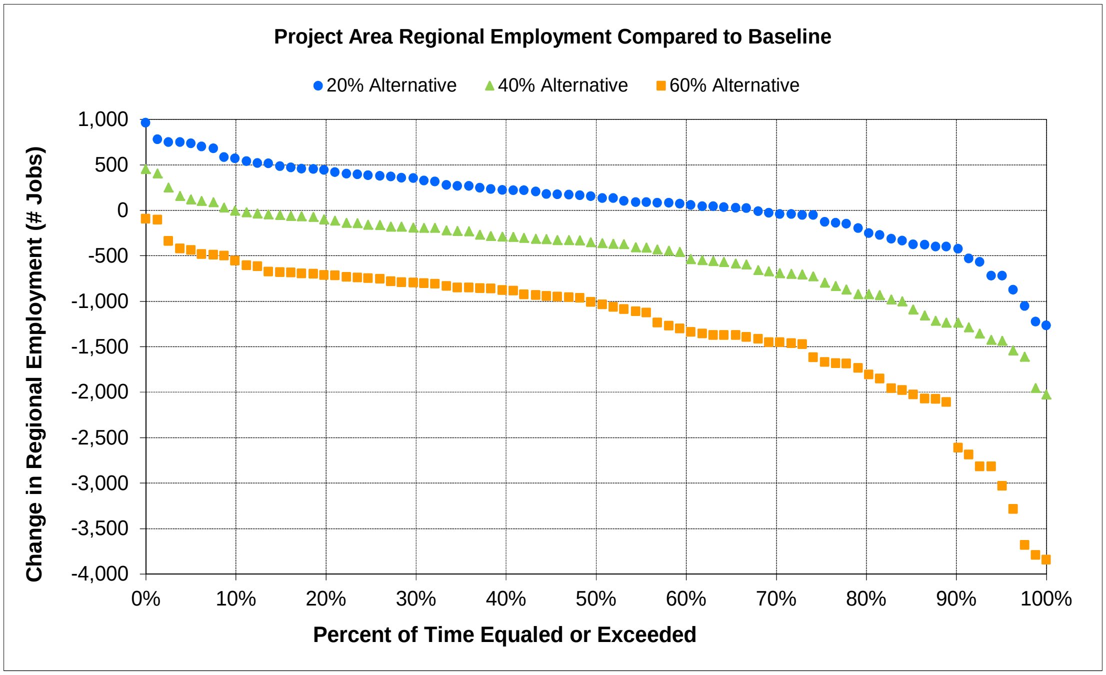

Figure X-28. Exceedance Plot of the Difference in IMPLAN Estimates for Total Jobs for the Crop Production and Related Sectors Each Year Above or Below the Baseline Condition in the LSJR Watershed for the Three LSJR Flow Objectives Across 82 Years of Simulation

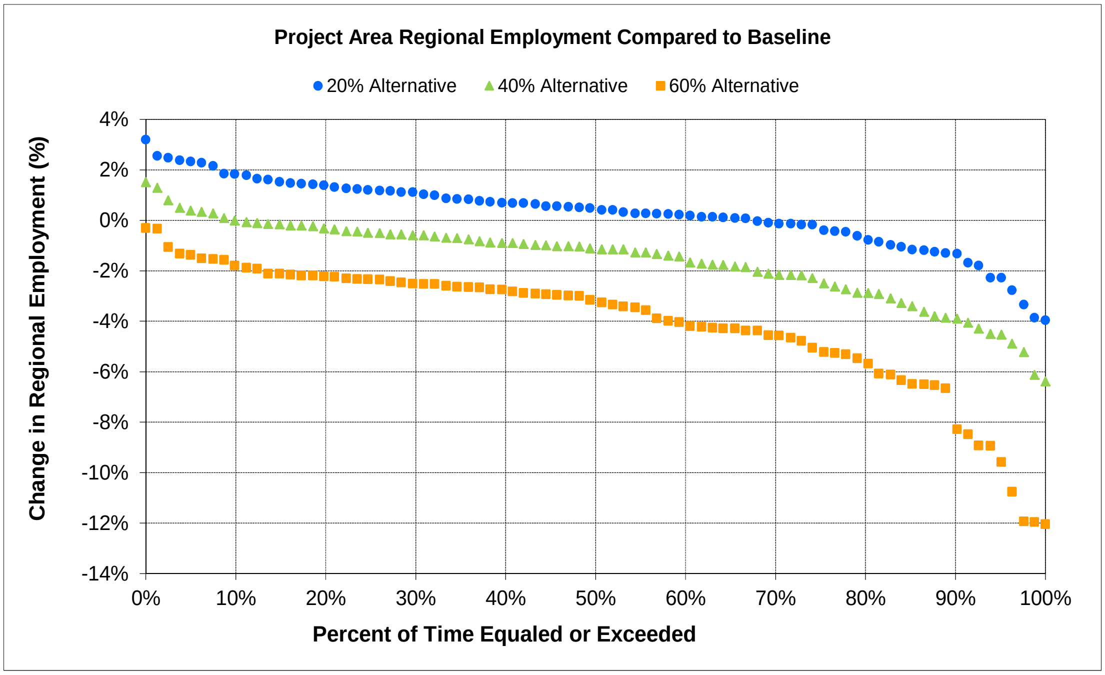

Figure X-29. Exceedance Plot of the Percent Difference in IMPLAN Estimates for Total Jobs for the Crop Production and Related Sectors Each Year Above or Below the Baseline Condition in the LSJR Watershed Between the Three LSJR Flow Objectives and the Baseline Condition Across 82 Years of Simulation

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