

## Appendix Q - Attachment 2

# Appendix Q2 California Water Economics Spreadsheet Tool (CWEST) Model Documentation

This appendix documents the California Water Economics Spreadsheet Tool (CWEST) model used to support the impact analysis in the EIS. The CWEST version used for the EIS is the same version used in *Final Environmental Impact Statement of the Coordinated Long-Term Operation of the Central Valley Project and State Water Project* (Reclamation 2015). The methodology and assumptions are provided.

## Q.2 CWEST Model Methodology

This section summarizes the CWEST development history, methodology, and coverage. It describes the overall analytical framework and the geographical extent of the economic evaluation of the alternatives. The EIS alternatives include several major components that will have significant effects on CVP and SWP operations and the quantity of delivered water to CVP and SWP M&I contractors. CWEST was developed to provide consistent and transparent analysis of economic benefits of CVP and SWP M&I water supplies for CVP contractors and SWP Table Q2.1-1 contract holders under 2030 conditions using publicly available information. Most demand data and data on local supply levels are from 2010 Urban Water Management Plans (UWMPs).

CWEST is an economic simulation and optimization tool that represents each individual CVP and SWP M&I contractor's decision making. It provides estimates of water supply costs for each contractor. The logic and methods are built on those used by other California M&I water economics tools. Similar to the existing California M&I water economics tools, CWEST minimizes the total costs of meeting annual M&I water demand subject to constraints. These costs include: conveyance and operations costs, costs of existing and new permanent supplies, transfer or other options costs, costs of local surface and groundwater operations, lost water sales revenues, and end-user shortage costs. The level of demand, quantity and type of local water supplies, and costs represent a 2030 development condition. The assumptions, sources of information, and description of the tool are discussed below.

### Q.2.1 CWEST Development History

CWEST was developed in response to the requirements of the *Final Environmental Impact Statement of the Coordinated Long-Term Operation of the Central Valley Project and State Water Project* (Reclamation 2015) quantitative analyses. CWEST provides a transparent and flexible tool that is applicable to many studies.

### Q.2.2 Modeling Objectives

The EIS modeling objectives accomplished with CWEST included the evaluation of the following potential impacts:

- Effects on CVP and SWP M&I contractor costs and revenues

- Effects on end users from experiencing shortage costs
- Annual quantities of transferred water to CVP and SWP M&I contractors

### **Q.2.3 CWEST Methodology**

CWEST is representation of how CVP and SWP M&I contractors will meet 2030 water demand levels at the lowest economic cost, subject to constraints. The model assumes that each CVP and SWP M&I contractor uses its contract delivery (modeled in CalSim II), local supplies, and imported water (if applicable) to meet annual demand. CWEST operates on an annual time step for the hydrologic period. The current application uses CVP and SWP delivery results modeled by CalSim II for the period 1922 to 2003, but CWEST can easily be adapted to other input data and period of record. In years where available supplies are lower than demand, the CVP and SWP M&I contractor will use local stored supplies, purchase or transfer water on a market, or short its customers—all of which result in an economic cost. If these shortage costs happen often throughout the modeled hydrologic period the CVP and SWP M&I contractor may choose to invest in additional fixed-yield supply. This tradeoff between incurring shortage costs and investing in additional fixed-yield supply is the central economic optimization in CWEST.

CWEST uses water supply costs that represent the specific situation and supply conditions for each CVP and SWP M&I contractor. Transfer and groundwater pumping costs vary by water year type or by the region. All of these shortage costs are based on linear cost functions except for the end-user shortage costs. This cost function for retail water is non-linear; therefore, CWEST uses Excel Solver® to find the optimal level of additional fixed-yield supply. At least one fixed-yield supply is included for every agency to choose when optimizing. Types of projects include stormwater, conservation, recycling, groundwater capacity, or desalination. The Metropolitan Water District of Southern California (MWDSC) can choose from five different fixed-yield project supply types, each with a unique increasing marginal cost function. The quantity of fixed-yield supply is a choice when optimizing and the cost for the new supply must be paid each year.

When annual supplies are in excess of demand, CWEST allows CVP and SWP M&I contractors to reduce groundwater pumping, put water into local or regional storage (if applicable), or turn back the water. Each CVP and SWP M&I contractor deals with excess water differently. Reduction in groundwater pumping results in a benefit based on the variable costs of groundwater pumping. Turning back water provides a cost savings based on the avoided conveyance charges. Fixed local supplies such as recycled water or desalination are not reduced in response to annual supply in excess of demand.

### **Q.2.4 CWEST Coverage**

Individual CVP and SWP M&I contractors are grouped into areas. Table Q2.1-1 displays the CVP and SWP M&I contractors included in each area.

**Table Q2.1-1. CVP and SWP M&I Contractors included in the EIS**

<b>Central Valley Region— Sacramento Valley</b>	<b>Central Valley Region—San Joaquin Valley</b>	<b>San Francisco Bay Area Region</b>	<b>Central Coast Region</b>	<b>Southern California Region</b>
El Dorado Irrigation District	All other Friant-Kern M&I contractors (Arvin-Edison Water Storage District, Delano-Earlimart Irrigation District, Lindsay-Strathmore Irrigation District)	Alameda County FC&WCD, Zone 7	San Luis Obispo County FC&WCD	Antelope Valley-East Kern Water Agency
Folsom, City of	Avenal, City of	Alameda County Water District	Santa Barbara County FC&WCD	Castaic Lake Water Agency
Napa County Flood Control & Water Conservation District (FC&WCD)	Coalinga, City of	Contra Costa Water District		Coachella Valley Water District
Placer County Water Agency	Fresno, City of	San Benito County Water District, Zone 6		Crestline-Lake Arrowhead Water Agency
Redding, City of	Huron, City of	Santa Clara Valley Water District		Desert Water Agency
Roseville, City of	Kern County Water Agency			MWDSC
Sacramento County Water Agency	Lindsay, City of			Mojave Water Agency
San Juan Water District	Orange Cove, City of			Palmdale Water District & Littlerock Creek Irrigation District
Shasta Lake, City of, Shasta County Water Agency, Centerville CSD (CSD), Mountain Gate CSD, and Shasta CSD	Stockton East Water District			San Bernardino Valley Municipal Water District
Solano County Water Agency	Tracy, City of			San Geronio Pass Water Agency
West Sacramento, City of				
Yuba City, City of				

CSD = Community Services District

FC = Flood Control

MWDSC = Metropolitan Water District of Southern California

WCD = Water Conservation District

Certain CVP and SWP M&I contractors are not included in the EIS. Table Q2.1-2 displays those CVP and SWP M&I contractors and the reason they are not included. Placeholders for San Gabriel Valley Municipal Water District, East Bay Municipal Utilities District, and Ventura County Watershed Protection District are included in CWEST, but are not modeled for the EIS. If the reason for not including them in the EIS changes, their results can be reported.

**Table Q2.1-2. CVP and SWP M&I Contractors Excluded from EIS Analysis**

<b>CVP and SWP Contractor</b>	<b>Reason</b>
Bella Vista Water District	Contractor not included at time of CWEST development because EIS had no effect from alternatives
Clear Creek CSD	Contractor not included at time of CWEST development because EIS had no effect from alternatives
East Bay Municipal Utilities District	Lack of public information on major water supplies (Mokelumne Aqueduct)
El Dorado County Water Agency	Contractor does not have conveyance at time of CWEST development
Sacramento, City of	Contractor not included at time of CWEST development because EIS had no effect from alternatives
San Gabriel Valley Municipal Water District	Contractor uses project water solely for regional groundwater recharge
Settlement Contractors, Black Butte, Colusa Basin Drain, Corning Canal, and Tehama-Colusa Canal contractors	Contractor not included at time of CWEST development because EIS had no effect from alternatives
Ventura County Watershed Protection District	Contractor not included at time of CWEST development because EIS had no effect from alternatives

CSD = Community Services District

CVP = Central Valley Project

CWEST = California Water Economics Spreadsheet Tool

EIS = Environmental Impact Statement

M&I = municipal and industrial

SWP = State Water Project

### Q.3 CWEST Assumptions

Each of the EIS alternatives were evaluated under the same set of local supply, demand, and cost assumptions for 2030 conditions. The only model input that varied across alternatives is the CalSim II CVP and SWP M&I contractor delivery data.

#### Q.3.1 CVP and SWP M&I Contractor Demand and Supply

CVP and SWP M&I contractor demands developed for CWEST are sourced from publicly available data. The majority of 2030 demands are reported in each CVP and SWP M&I contractor's 2010 UWMP, with exceptions for those that did not create one. The 2030 demand levels for CVP and SWP M&I contractors without published UWMPs are provided by the *Central Valley Project Municipal and Industrial Water Shortage Policy Draft Environmental Impact Statement (CVP M&I WSP)* (Reclamation 2015). The UWMP demands presented for 2030 are assumed to be compliant with the "20% by 2020" legislation. In some cases, additional conservation is presented as part of

2030 supply in the UWMP. If so, this is counted as a demand reduction, not as a new supply in CWEST. Table Q2.2-1 displays the 2030 contract quantities and demand levels included in the model.

**Table Q2.2-1. CWEST Modeled Demands in 2030**

<b>CVP and SWP M&amp;I Contractor</b>	<b>2030 CVP and SWP Contract Quantities (AF)</b>	<b>2030 Demands From UWMP (AF)</b>
Alameda County FC&WCD, Zone 7	80,619	75,500
Alameda County Water District	42,000	71,800
All other Friant-Kern M&I contractors (Arvin-Edison Water Storage District, Delano-Earlimart Irrigation District, Lindsay-Strathmore Irrigation District)	2,926	6,000
Antelope Valley-East Kern Water Agency	141,400	96,558
Avenal, City of	3,500	3,500
Castaic Lake Water Agency	95,200	105,313
Coachella Valley Water District	133,100	212,000
Coalinga, City of	10,000	10,000
Contra Costa Water District	195,000	215,471
Crestline-Lake Arrowhead Water Agency	5,800	2,250
Desert Water Agency	54,000	69,400
El Dorado Irrigation District	7,550	57,039
Folsom, City of	34,000	36,259
Fresno, City of	60,000	201,100
Huron, City of	3,000	3,000
Kern County Water Agency	134,600	51,750
Lindsay, City of	2,500	2,689
MWDSC	2,185,600	4,455,000
Mojave Water Agency	75,800	192,969
Napa County FC&WCD	29,025	21,572
Orange Cove, City of	1,400	2,790
Palmdale Water District & Littlerock Creek Irrigation District	21,300	45,700
Placer County Water Agency	100,000	156,333
Redding, City of	27,140	27,852
Roseville, City of	62,000	49,334
Sacramento County Water Agency	81,438	77,535
San Benito County Water District, Zone 6	8,250	11,583
San Bernardino Valley Municipal Water District	102,600	305,447
San Geronio Pass Water Agency	17,300	66,420
San Juan Water District	82,200	57,265
San Luis Obispo County FC&WCD	8,447	8,150
Santa Barbara County FC&WCD	62,039	75,935
Santa Clara Valley Water District	219,400	409,370

<b>CVP and SWP M&amp;I Contractor</b>	<b>2030 CVP and SWP Contract Quantities (AF)</b>	<b>2030 Demands From UWMP (AF)</b>
Shasta Lake, City of, Shasta County Water Agency, Centerville CSD, Mountain Gate CSD, and Shasta CSD	10,672	10,942
Solano County Water Agency	47,756	82,250
Stockton-East Water District	75,000	64,960
Tracy, City of	20,000	31,000
West Sacramento, City of	23,600	19,273
Yuba City, City of	9,600	29,041

AF = acre-feet

CSD = Community Service District

CVP = Central Valley Project

FC = Flood Control

MWDC = Metropolitan Water District of Southern California

M&amp;I = municipal and industrial

SWP- State Water Project

UWMP = Urban Water Management Plan

WCD = Water Conservation District

### **Q.3.1.1 Development of 2030 CVP and SWP M&I Contractor Water Supplies**

CWEST uses UWMP reported local supplies expected to be available in 2030. In some cases, UWMP supplies were adjusted for projects that may not be implemented by 2030. CWEST uses the 2030 UWMP “normal” year supplies to represent 2030 supplies in wet, above normal, and below normal years, and “multiple-year drought” supplies are used to represent 2030 supplies in dry and critical years. The Sacramento index is used for CVP and SWP M&I contractors in the Sacramento Valley and the San Francisco Bay Area Region. The San Joaquin index is used for CVP and SWP M&I contractors in the San Joaquin Valley, the Central Coast Region, and the Southern California Region. Local, non-project supply amounts are as summarized in Table Q2.2-2.

**Table Q2.2-2. CWEST Assumed 2030 Non-Project Supplies**

<b>CVP and SWP M&amp;I Contractor</b>	<b>Non-Project Supplies in Below Normal or Better Water Year Type</b>	<b>Non-Project Supplies in Dry or Critical Water Year Type</b>
Alameda County FC&WCD, Zone 7	11,600	2,620
Alameda County Water District	50,800	35,600
All other Friant-Kern M&I contractors (Arvin-Edison Water Storage District, Delano-Earlimart Irrigation District, Lindsay-Strathmore Irrigation District) <sup>1</sup>	3,000	0
Antelope Valley-East Kern Water Agency	40,000	20,000
Avenal, City of <sup>1</sup>	0	0
Castaic Lake Water Agency	77,787	77,787
Coachella Valley Water District	238,840	238,850
Coalinga, City of <sup>1</sup>	0	0
Contra Costa Water District	64,000	51,600
Crestline-Lake Arrowhead Water Agency	481	481

<b>CVP and SWP M&amp;I Contractor</b>	<b>Non-Project Supplies in Below Normal or Better Water Year Type</b>	<b>Non-Project Supplies in Dry or Critical Water Year Type</b>
Desert Water Agency	69,900	89,000
El Dorado Irrigation District	54,789	54,789
Folsom, City of	3,250	11,250
Fresno, City of	228,800	232,400
Huron, City of <sup>1</sup>	0	0
Kern County Water Agency	68,126	40,130
Lindsay, City of <sup>1</sup>	1,210	1,210
MWDSC	3,040,100	3,142,300
Mojave Water Agency	152,921	176,785
Napa County FC&WCD	19,082	21,565
Orange Cove, City of <sup>1</sup>	0	0
Palmdale Water District & Littlerock Creek Irrigation District	39,600	42,059
Placer County Water Agency	68,119	103,119
Redding, City of	13,424	13,424
Roseville, City of	3,397	3,397
Sacramento County Water Agency	74,898	74,898
San Benito County Water District, Zone 6	5,174	5,174
San Bernardino Valley Municipal Water District	314,225	314,225
San Geronio Pass Water Agency	43,952	43,952
San Juan Water District	0	0
San Luis Obispo County FC&WCD	8,288	8,288
Santa Barbara County FC&WCD	79,490	79,490
Santa Clara Valley Water District	246,830	179,980
Shasta Lake, City of, Shasta County Water Agency, Centerville CSD, Mountain Gate CSD, and Shasta CSD <sup>1</sup>	1,064	1,064
Solano County Water Agency	75,276	75,276
Stockton-East Water District	28,000	50,000
Tracy, City of	15,250	16,050
West Sacramento, City of	5,000	5,000
Yuba City, City of	22,748	22,748

<sup>1</sup> CVP and SWP M&I Contractor without 2010 UWMP and supply and 2030 supply conditions are from CVP M&I WSP (Reclamation 2015)

AF = acre-feet

CSD = Community Service District

CVP = Central Valley Project

FC = Flood Control

MWDSC = Metropolitan Water District of Southern California

M&I = municipal and industrial

SWP- State Water Project

WCD = Water Conservation District

**Q.3.1.2 CalSim II Linkage Information**

CalSim II node identification for each CVP and SWP M&I contractor in the EIS analysis is displayed in Table Q2.2-3.

**Table Q2.2-3. CWEST and CalSim II Linkage**

<b>CVP and SWP M&amp;I Contractor</b>	<b>CalSim II Equivalent Nodes</b>
Alameda County FC&WCD, Zone 7	D810_PCO + D810_PMI + D813_PCO + D813_PMI + D810_PIN
Alameda County Water District	D814_PCO + D814_PMI + D814_PIN
All other Friant-Kern M&I contractors (Arvin-Edison Water Storage District, Delano-Earlimart Irrigation District, Lindsay-Strathmore Irrigation District)	2.926*(D910_C1/60)
Antelope Valley-East Kern Water Agency	D877_PMI + D877_PCO + D877_PIN
Avenal, City of	D844_PMI*0.35
Castaic Lake Water Agency	D896_PMI + D896_PCO
Coachella Valley Water District	D883_PMI + D883_PCO + D883_PIN
Coalinga, City of	D844_PMI*0.5
Contra Costa Water District	D420
Crestline-Lake Arrowhead Water Agency	D25_PMI + D25_PCO
Desert Water Agency	D884_PMI + D884_PCO + D884_PIN
El Dorado Irrigation District	D8F_NP + D8F_PMI
Folsom, City of	D8B_NP + D8B_PMI
Fresno, City of	MAX(0.25*60, D910_C1*(60/64.802))
Huron, City of	D844_PMI*0.15
Kern County Water Agency	D851A_PMI
Lindsay, City of	2.5*(D910_C1/60)
MWDSC	D895_PMI + D895_PMI+ D895_PIN+ D899_PCO + D899_PCO + D899_PIN + D27_PMI +D27_PIN + D27_PCO +D885_PMI + D885_PCO + D885_PIN
Mojave Water Agency	D881_PMI + D881_PCO
Napa County FC&WCD	D403B_PMI + D403B_PCO + D403B_PIN
Orange Cove, City of	1.4*(D910_C1/60)
Palmdale Water District & Littlerock Creek Irrigation District	D878_PMI + D878_PCO
Placer County Water Agency	D8H_PMI+D300_NP
Redding, City of	D104_PSC*0.13779 + D104_PMI*0.5
Roseville, City of	D8G_NP + D8G_PMI
Sacramento County Water Agency	D168C+D167B
San Benito County Water District, Zone 6	0.065*D711_PMI+0.518*D710_PAG
San Bernardino Valley Municipal Water District	D886_PMI + D886_PCO
San Geronio Pass Water Agency	D888_PMI + D888_PCO



<b>CVP and SWP M&amp;I Contractor</b>	<b>CalSim II Equivalent Nodes</b>
San Juan Water Agency	D8D_NP + D8E_NP + D8E_PMI
San Luis Obispo County FC&WCD	[MIN(D869_PMI + D869_PCO,8.447)]
Santa Barbara County FC&WCD	(((D870_PMI + D870_PCO) + ((D870_PMI + D870_PCO) - 8.4)) * (0.852 if WY is W,AN,BN, 0.522 if WY is D,C)]
Santa Clara Valley Water District	D710_PAG * 0.442 + D711_PMI * 0.935 + D815_PCO + D815_PMI + D815_PIN
Shasta Lake, City of, Shasta County Water Agency, Centerville CSD, Mountain Gate CSD, and Shasta CSD	D104_PMI*0.5 + D104_PMI*0.35
Solano County Water Agency	D403C_PMI + D403C_PCO
Stockton-East Water District	D520_SEWD_PMI
Tracy, City of	0.2*[South of Delta % PMI Delivery]
West Sacramento, City of	D165_PSC
Yuba City, City of	D204_PMI

CSD = Community Service District  
 CVP = Central Valley Project  
 FC = Flood Control  
 MWDC = Metropolitan Water District of Southern California  
 M&I = municipal and industrial  
 SWP = State Water Project  
 WCD = Water Conservation District

**Q.3.1.3 Development of Storage Operations**

CWEST includes storage operations for the CVP and SWP M&I contractors with published information on local storage operations, who participate in a regional groundwater bank, or who use significant local groundwater banking to store water. CVP and SWP M&I contractors that participate in Semitropic Water Storage District’s (WSD) groundwater banking program have their capacity share included. Most of MWDC’s portfolio of local storage projects are modeled. See Table Q2.2-4 for the list of storage operations included in CWEST.

**Table Q2.2-4. Storage Operations Assumptions**

<b>Contractor with Storage</b>	<b>Modeled Storage Capacities</b>
Alameda County FC&WCD, Zone 7	78,000 AF Semitropic WSD Share <sup>1</sup> 126,000 AF Local Groundwater <sup>2</sup> 120,000 AF Cawelo Water District <sup>2</sup>
Alameda County Water District	150,000 AF Semitropic WSD Share <sup>1</sup>
MWDC	1,600,000 AF Regional Groundwater Banks <sup>3</sup> 980,000 AF Local Surface Storage <sup>4</sup>
Santa Clara Valley Water District	350,000 AF Semitropic WSD Share <sup>1</sup> 530,000 AF Local Groundwater <sup>5</sup>
Stockton-East Water District	100,000 AF Local Groundwater <sup>6</sup>

<sup>1</sup> (Semitropic 2015)  
<sup>2</sup> (ACWD 2011)  
<sup>3</sup> Includes: Arvin Edison WSD, Semitropic WSD, Kern Delta Water District, Mojave Water Agency Storage Program, Conjunctive Use programs (MWDC 2011)  
<sup>4</sup> Includes: Castaic Lake, Diamond Valley, Lake Mathews, Lake Skinner, and Cyclic Storage (MWDC 2011)

<sup>5</sup> (SCVWD 2011)

<sup>6</sup> Stockton-East UWMP (SEWD 2011)

AF = acre-feet

FC = Flood Control

MWDSC = Metropolitan Water District of Southern California

WCD = Water Conservation District

### **Q.3.2 Water Costs**

Water costs include delivery costs, groundwater pumping costs, additional fixed-yield supply costs, storage operations costs, and shortage costs. Shortage costs include retail revenue losses, transfer and annual option costs, and end-user shortage costs. Increases in M&I deliveries raise total delivery costs, but may decrease shortage costs. Real increases in water and energy costs are used to escalate costs to the 2030 levels needed for the EIS analysis.

#### **Q.3.2.1 Delivery costs and Water Prices**

CVP and SWP M&I deliveries are assigned a delivery cost based on Reclamation CVP M&I (Reclamation 2009) rates and Bulletin 132-10 (DWR 2013), respectively. In years when supply is in excess of demand, even after reductions in groundwater pumping and puts into storage, the quantity of excess water is credited the delivery costs. This represents a CVP and SWP M&I contractor “turning back” water.

The delivery cost for SWP M&I contractors is the variable OMP&R component plus the Off-Aqueduct charge, which is also charged based on amount of deliveries (CCWA 2007). As an example, DWR calculates the Off-Aqueduct charges based on the requested deliveries submitted by the Authority on a calendar year basis. The resulting total is paid by the Authority in twelve equal payments throughout the calendar year. Additionally, in May of each year, DWR provides an amended Off-Aqueduct bill based on the actual water deliveries and power costs for the first six months of the year. The delivery cost of CVP water is the “O&M rate” (Reclamation 2009).

Real energy costs are expected to increase in real terms leading up to 2030. The California Energy Commission mid-demand scenario predicts that real electricity rates will increase 1.7% annually over the 2014 to 2024 period (CEC 2013). This rate of increase is applied to water delivery costs up to 2030. See Table Q2.2-5 for 2030 delivery costs for CVP and SWP M&I contractors.

Table Q2.2-5 also shows representative retail water prices for each CVP and SWP M&I contractor. MWDSC projects their water rates will have a 1.364% real rate of increase annually between 2014 and 2024. Other CVP and SWP M&I contractors have not made long-range projections of real retail prices, so CWEST applies MWDSC’s real rate of increase to all CVP and SWP M&I contractor retail water prices to estimate 2030 levels. Retail water prices are used to estimate revenue losses to CVP and SWP M&I contractors from a shortage.

**Table Q2.2-5. Conveyance and Retail Water Price Assumptions**

<b>CVP and SWP M&amp;I Contractor</b>	<b>CVP and SWP Delivery costs in 2030 (\$/AF)<sup>1</sup></b>	<b>Retail Water Price in 2030 (\$/AF)<sup>2</sup></b>
Alameda County FC&WCD, Zone 7	42	1,162
Alameda County Water District	30	1,528
All other Friant-Kern M&I contractors (Arvin-Edison Water Storage District, Delano-Earlimart Irrigation District, Lindsay-Strathmore Irrigation District)	16	228
Antelope Valley-East Kern Water Agency	145	580
Avenal, City of	16	1,130
Castaic Lake Water Agency	99	1,462
Coachella Valley Water District	\$162	\$472
Coalinga, City of	\$24	\$228
Contra Costa Water District	\$26	\$1,577
Crestline-Lake Arrowhead Water Agency	\$173	\$402
Desert Water Agency	\$139	\$527
El Dorado Irrigation District	\$16	\$475
Folsom, City of	\$16	\$235
Fresno, City of	\$16	\$228
Huron, City of	\$16	\$228
Kern County Water Agency	\$18	\$290
Lindsay, City of	\$16	\$228
MWDSC	\$122	\$1,374
Mojave Water Agency	\$232	\$1,175
Napa County FC&WCD	\$33	\$1,921
Orange Cove, City of	\$16	\$228
Palmdale Water District & Littlerock Creek Irrigation District	\$192	\$580
Placer County Water Agency	\$16	\$594
Redding, City of	\$16	\$514
Roseville, City of	\$16	\$197
Sacramento County Water Agency	\$25	\$454
San Benito County Water District, Zone 6	\$32	\$890
San Bernardino Valley Municipal Water District	\$154	\$402
San Geronio Pass Water Agency	\$323	\$624
San Juan Water Agency	\$16	\$235
San Luis Obispo County FC&WCD	\$156	\$2,429
Santa Barbara County FC&WCD	\$157	\$1,719
Santa Clara Valley Water District	\$27	\$1,204
Shasta Lake, City of, Shasta County Water Agency, Centerville CSD, Mountain Gate CSD, and Shasta CSD	\$16	\$596

<b>CVP and SWP M&amp;I Contractor</b>	<b>CVP and SWP Delivery costs in 2030 (\$/AF)<sup>1</sup></b>	<b>Retail Water Price in 2030 (\$/AF)<sup>2</sup></b>
Solano County Water Agency	\$21	\$1,198
Stockton-East Water District	\$15	\$507
Tracy, City of	\$16	\$582
West Sacramento, City of	\$16	\$454
Yuba City, City of	\$0	\$681

<sup>1</sup> (Reclamation 2009) and (DWR 2013) escalated from 2010 to 2030 in proportion to the change in real energy prices (CEC 2013)

<sup>2</sup> Published retail prices were chosen from representative locations (Black and Veatch 2006) and updated using MWDCS

AF = acre-feet

CSD = Community Service District

CVP = Central Valley Project

FC = Flood Control

MWDCS = Metropolitan Water District of Southern California

M&I = municipal and industrial

SWP- State Water Project

WCD = Water Conservation District

### **Q.3.2.2 Additional Fixed-Yield Supply Costs**

For each CVP and SWP M&I contractor, at least one fixed-yield supply is available to choose in optimization. Examples are reclamation water projects, desalination, new groundwater development, and some types of conservation. Fixed-yield supplies provide the same amount of water every year and the annualized cost for operations and capital is paid every year. The model selects a level of fixed-yield supply that minimizes total cost over the hydrologic period. Table Q2.2-6 shows the fixed-yield supply included for each CVP and SWP M&I contractor and its annualized cost except for those with multiple fixed-yield supplies to choose from.

A variety of data sources were used to obtain capital costs of representative projects including the UWMPs, IRWM grant applications, and other public information.

For some CVP and SWP M&I contractors in the Sacramento Valley, the model chooses an optimal increase in total groundwater pumping capacity when that is the additional fixed-yield supply to choose. The model currently uses information from four representative urban well developments in Sonoma County (SCWA 2010). The annualized cost of well development for four wells was \$358 per AF. When a CVP and SWP M&I contractor chooses to increase their groundwater pumping capacity, the annual pumping cost is added to obtain a total cost per AF per year.

**Table Q2.2-6. Information on Additional Fixed-Yield Supplies**

<b>CVP and SWP M&amp;I Contractor</b>	<b>Additional Fixed-Yield Supply Costs (\$/AF)<sup>1</sup></b>	<b>Type or Name of Additional Fixed-Yield Supply</b>
Alameda County FC&WCD, Zone 7	Variable—See Table Q2.2-8	Variable—See Table Q2.2-8
Alameda County Water District	Variable—See Table Q2.2-8	Variable—See Table Q2.2-8
All other Friant-Kern M&I contractors (Arvin-Edison Water Storage District, Delano-Earlimart Irrigation District, Lindsay-Strathmore Irrigation District)	\$449	Develop Groundwater <sup>1</sup>

<b>CVP and SWP M&amp;I Contractor</b>	<b>Additional Fixed-Yield Supply Costs (\$/AF)<sup>1</sup></b>	<b>Type or Name of Additional Fixed-Yield Supply</b>
Antelope Valley-East Kern Water Agency	\$568	Regional Aquifer Project <sup>2</sup>
Avenal, City of	\$266	Transfer/exchange <sup>3</sup>
Castaic Lake Water Agency	\$400	None—Assumed \$400
Coachella Valley Water District	\$258	Recycle golf course water <sup>4</sup>
Coalinga, City of	\$274	Transfer/exchange <sup>3</sup>
Contra Costa Water District	\$1,070	Bay Area Regional Desalination <sup>5</sup>
Crestline-Lake Arrowhead Water Agency	\$423	Transfer/exchange <sup>3</sup>
Desert Water Agency	\$416	Additional Colorado River Aqueduct water <sup>3</sup>
El Dorado Irrigation District	\$410	Develop Groundwater <sup>1</sup>
Folsom, City of	\$365	Willow Hill Pipeline Rehabilitation Project <sup>6</sup>
Fresno, City of	\$449	Develop Groundwater <sup>1</sup>
Huron, City of	\$266	Transfer/exchange <sup>3</sup>
Kern County Water Agency	\$314	None—Assumed \$314
Lindsay, City of	\$449	Develop Groundwater <sup>1</sup>
MWDSC	Variable—See Table Q2.2-8	Variable—See Table Q2.2-8
Mojave Water Agency	\$482	Transfer/exchange <sup>3</sup>
Napa County FC&WCD	\$233	Transfer/exchange <sup>3</sup>
Orange Cove, City of	\$449	Develop Groundwater <sup>1</sup>
Palmdale Water District & Littlerock Creek Irrigation District	\$615	Regional Aquifer Project <sup>7</sup>
Placer County Water Agency	\$410	Develop Groundwater <sup>1</sup>
Redding, City of	\$432	Develop Groundwater <sup>1</sup>
Roseville, City of	\$502	Develop Groundwater <sup>1</sup>
Sacramento County Water Agency	\$410	Develop Groundwater <sup>1</sup>
San Benito County Water District, Zone 6	\$384	Transfer/exchange <sup>3</sup>
San Bernardino Valley Municipal Water District	\$366	Beaumont Avenue Recharge Facility <sup>8</sup>
San Geronio Pass Water Agency	\$366	Beaumont Avenue Recharge Facility <sup>8</sup>
San Juan Water Agency	\$138	Regional Indoor & Outdoor Efficiency <sup>6</sup>
San Luis Obispo County FC&WCD	\$475	Raise Lopez Dam 3-5 feet <sup>9</sup>
Santa Barbara County FC&WCD	\$804	Expand Conjunctive Use and Groundwater <sup>1</sup>
Santa Clara Valley Water District	\$1,795	Bay Area Regional Desalination <sup>5</sup>

<b>CVP and SWP M&amp;I Contractor</b>	<b>Additional Fixed-Yield Supply Costs (\$/AF)<sup>1</sup></b>	<b>Type or Name of Additional Fixed-Yield Supply</b>
Shasta Lake, City of, Shasta County Water Agency, Centerville CSD, Mountain Gate CSD, and Shasta CSD	\$216	Transfer/exchange <sup>3</sup>
Solano County Water Agency	\$221	Expand exchange with Mojave Water Agency <sup>3</sup>
Stockton-East Water District	\$338	Delta Water Supply Project <sup>10</sup>
Tracy, City of	\$266	Transfer/exchange <sup>3</sup>
West Sacramento, City of	\$410	Develop Groundwater <sup>1</sup>
Yuba City, City of	\$432	Develop Groundwater <sup>1</sup>

<sup>1</sup> (SCWA 2010) for cost of well development plus pumping cost from Table Q2.2-9

<sup>2</sup> (AVEK 2011)

<sup>3</sup> Transfer cost from Table Q2.2-9 plus delivery cost from Table Q2.2-6

<sup>4</sup> (CVWD 2013)

<sup>5</sup> (BARDP 2011)

<sup>6</sup> (RWA 2011)

<sup>7</sup> (ESA 2014)

<sup>8</sup> (FCS 2013)

<sup>9</sup> (Zone 3 2009)

<sup>10</sup> (ESJGB 2014)

AF = acre-feet

CSD = Community Service District

CVP = Central Valley Project

FC = Flood Control

MWDSC = Metropolitan Water District of Southern California

M&I = municipal and industrial

SWP = State Water Project

WCD = Water Conservation District

Alameda County FC&WCD, Zone 7, Alameda County Water Agency, and MWDSC have multiple additional fixed-yield supplies modeled in CWEST. For MWDSC, five fixed yield options are provided; reclamation, desalination, groundwater recovery, conservation, and stormwater. Cost functions are included that express the average cost of supply as an increasing function of the amount used. Table Q2.2-7 displays the range of average cost for each supply type.

**Table Q2.2-7. CVP and SWP M&I Contractors with Multiple Additional Fixed-Yield Supply Options**

<b>CVP and SWP M&amp;I Contractor</b>	<b>Additional Fixed-Yield Supply Costs (\$/AF)—Type or Name of Additional Fixed-Yield Supply—Maximum Quantity Available (AF)</b>
Alameda County FC&WCD, Zone 7	\$20—Arroyo Valle—Perfection of Existing Permit—3,800 <sup>1</sup> \$30—Reduction of Demineralization Losses—260 <sup>1</sup> \$100—Reduction of Unaccounted-for-Water—1,300 <sup>1</sup> \$110—Enhance Existing In-lieu Recharge—500-830 <sup>1</sup> \$200—Arroyo Las Positas Water Rights—750 <sup>1</sup> \$200—Arroyo Mocho Water Rights—900 <sup>1</sup> \$285—Confirm Byron-Bethany Irrigation District Yield—3,000 <sup>1</sup> \$1,400—Intertie Supply: Long-term Leases—10,900 <sup>1</sup> \$1,500—Recycled Water—Direct—3,700 <sup>1</sup> \$1,600—Groundwater Injection: Recycled Water—2,800 <sup>1</sup> \$2,000—Intertie Supply: Regional Desalination—9,300 <sup>1</sup> \$2,400—Recycled Water—Storage—17,300 <sup>1</sup>
Alameda County Water District	\$410—Conservation—3,600 <sup>2</sup> \$500—Expansion of Newark Facility—5,100 <sup>2</sup>
MWDSC	\$500 to \$1,500 <sup>3</sup> —Groundwater Recovery—92,000 <sup>4</sup> \$600 to \$1,500 <sup>3</sup> —Recycling—360,000 <sup>4</sup> \$192 to \$1,300 <sup>5</sup> —Conservation—346,000 <sup>4</sup> \$300 to \$1,500 <sup>6</sup> —Stormwater Capture—75,000 <sup>4</sup> \$1,300 to \$2,000 <sup>3</sup> —Desalination—84,000 <sup>4</sup>

<sup>1</sup> (Zone 7 WA 2011)<sup>2</sup> (ACWD 2014)<sup>3</sup> (MWDSC 2010)<sup>4</sup> (LADWP 2011)<sup>5</sup> (Mitchell 2005)<sup>6</sup> (Geosyntec Consultants 2014)

AF = acre-feet

CSD = Community Service District

CVP = Central Valley Project

FC = Flood Control

MWDSC = Metropolitan Water District of Southern California

M&amp;I = municipal and industrial

SWP = State Water Project

WCD = Water Conservation District

### **Q.3.2.3 Transfer Costs and Annual Options**

Annual options are supplies that can be made available to meet demands annually. The model allows for separate costs of these supplies in dry and critical years, and a separate cost in below normal or wetter years. In below normal or wetter years, these supplies are generally transfers or groundwater. In dry or critical years, these supplies are generally transfers; providers are not allowed to pump groundwater in excess of their UWMP levels.

Costs of water transfers are based on publications summarizing observed market prices (Hanak and Stryjewski 2012, Mann and Hatchett 2012, WestWater Research 2013). Transfer prices were created for multiple regions, based on historical transfers in the same area of origin. Colorado River transfer prices are included as a supply option for agencies receiving their SWP Table A water by exchange. Prices are based on planned prices for the water transfer between Imperial Irrigation District and San

Diego County Water Authority. The dry/critical year price is calculated as the weighted average of historical dry and critical year prices, where the weights are the frequency of the two year types in the historic hydrology (18 dry years and 12 critical years). The GNP Implicit Price Deflator was used to bring historical transfer prices to equivalent years.

These prices are intended as representative for purposes of the analysis, and are not predictions. Also, the prices in Table Q2.2-8 are at the source (location of purchase), and do not include delivery costs or losses. A conveyance loss of 18% is assumed for cross-Delta transfers. Water delivery costs from Table Q2.2-5 are included for all transfers.

**Table Q2.2-8. Assumed Water Transfer Prices in CWEST, 2030 Conditions<sup>1</sup>**

	<b>NOD Origin</b>	<b>SOD origin</b>	<b>NOD with Conveyance Loss</b>	<b>Colorado River Transfers</b>
Below Normal or Wetter	\$200	\$250	\$244	\$416
Dry or Critical	\$378	\$480	\$461	\$416

<sup>1</sup> See Section Q2.2.2.3, *Transfer Costs and Annual Options*, for source information.

NOD = North of Delta

SOD = South of Delta

### **Q.3.2.4 Storage Operations and Groundwater Costs**

#### **Q.3.2.4.1 Storage Operations Costs**

Storage operations are included for MWDSC, some CVP and SWP M&I contractors in the San Francisco Bay Area Region, and Stockton-East Water District. The San Francisco Bay Area Region includes some local groundwater storage and Semitropic Water Bank storage for SCVWD, Zone 7 and ACWD. Storage operation costs for MWDSC are based on information provided in its Water Surplus and Demand Management Plan (MWDSC 2011). Semitropic WSD's published put and take costs for banking operations are used in CWEST in addition to the delivery cost (Semitropic 2014). Local groundwater storage operation costs used by San Francisco Bay Area Region CVP and SWP M&I contractors are based on the groundwater costs detailed in Table Q2.2-9. These put and take costs for local groundwater storage operations are also used for Stockton East Water District's modeled operations.

#### **Q.3.2.4.2 Groundwater Costs**

CWEST includes an estimate of cost savings for groundwater not pumped when excess CVP and SWP water is available. Data on groundwater costs are from CVP and SWP M&I contractor UWMPs where possible. When this information is not available in UWMPs, groundwater pumping costs are based on estimates of regional depth to groundwater and electricity price. Depths to groundwater are from DWR's Bulletin 118—Groundwater Basin Maps and Descriptions (DWR 2004). The amount of groundwater available in below normal or wetter, and dry or critical conditions, is based on individual CVP and SWP M&I contractor UWMPs.

Groundwater pumping costs were estimated for each EIS area based on a representative value from published information. CVP and SWP M&I contractors in the Southern California Region have a groundwater pumping cost based on an estimate published in a Groundwater Basin Assessment (MWDSC 2007). Representative groundwater pumping costs in the Central Coast Region are based on recent estimates from the City of Santa Barbara (City of Santa Barbara 2015). Groundwater



pumping costs in the San Francisco Bay Area Region are based published estimates from San Benito County (SBCWD 2014). San Joaquin Valley groundwater pumping costs are based on published estimates from James Irrigation District and Fresno Irrigation District (KBWA 2013). Sacramento Valley had no readily available information on groundwater pumping estimates. Groundwater depth estimates and published estimates of groundwater pumping from the previous sources were used to interpolate groundwater pumping costs in the Sacramento Valley. This method was used to adjust groundwater pumping prices in other regions.

Additional costs associated with groundwater use include lower groundwater tables, subsidence, streamflow depletion, depreciation, and well replacement that should be included. In some locations, groundwater must be treated for water quality, adding additional cost. No consistent source of information is available to assess these other costs, so cost per AF is conservatively increased by 10% to account for some of these costs. Real increases in energy costs were applied to groundwater pumping costs (CEC 2013). Table Q2.2-9 displays groundwater variable costs used in the model.

**Table Q2.2-9. Groundwater Variable Pumping Costs**

<b>CVP and SWP M&amp;I Contractor</b>	<b>Estimated Groundwater Pumping Cost in 2030 (\$/AF)<sup>1</sup></b>
Alameda County FC&WCD, Zone 7	52
Alameda County Water District	52
All other Friant-Kern M&I contractors (Arvin-Edison Water Storage District, Delano-Earlimart Irrigation District, Lindsay-Strathmore Irrigation District)	91
Antelope Valley-East Kern Water Agency	171
Avenal, City of	91
Castaic Lake Water Agency	94
Coachella Valley Water District	171
Coalinga, City of	91
Contra Costa Water District	52
Crestline-Lake Arrowhead Water Agency	171
Desert Water Agency	171
El Dorado Irrigation District	52
Folsom, City of	52
Fresno, City of	91
Huron, City of	91
Kern County Water Agency	168
Lindsay, City of	91
MWDSC	94
Mojave Water Agency	171
Napa County FC&WCD	108
Orange Cove, City of	91
Palmdale Water District & Littlerock Creek Irrigation District	171
Placer County Water Agency	52
Redding, City of	74

<b>CVP and SWP M&amp;I Contractor</b>	<b>Estimated Groundwater Pumping Cost in 2030 (\$/AF)<sup>1</sup></b>
Roseville, City of	52
Sacramento County Water Agency	52
San Benito County Water District, Zone 6	52
San Bernardino Valley Municipal Water District	171
San Geronio Pass Water Agency	171
San Juan Water Agency	52
San Luis Obispo County FC&WCD	298
Santa Barbara County FC&WCD	298
Santa Clara Valley Water District	52
Shasta Lake, City of, Shasta County Water Agency, Centerville CSD, Mountain Gate CSD, and Shasta CSD	74
Solano County Water Agency	108
Stockton-East Water District	91
Tracy, City of	91
West Sacramento, City of	52
Yuba City, City of	74

<sup>1</sup> See Section Q2.2.2.4, *Storage Operations and Groundwater Costs, Groundwater Costs*, for source information.

AF = acre-feet

CSD = Community Service District

CVP = Central Valley Project

FC = Flood Control

MWDSC = Metropolitan Water District of Southern California

M&I = municipal and industrial

SWP- State Water Project

WCD = Water Conservation District

### **Q.3.2.5 Shortage Costs**

Shortages in critical years are handled in an approach that represents common behavior of CVP and SWP M&I contractors. CWEST requires that a 5% end-use drought conservation shortage is implemented before any annual supply is purchased in critical year. Then, a provider can eliminate a shortfall using dry/critical year annual supply. Therefore, end-user shortages only occur during critical years.

Shortage costs are lost retail water revenue plus end-user shortage costs. Revenue losses are based on the water prices displayed in Table Q2.2-5. The model calculates shortage costs based on a constant elasticity of demand (CED) demand function. This form of shortage loss function is standard practice in California water economics studies and has documented descriptions (M.Cubed 2007). The 2030 demand levels in Table Q2.2-6 price defines one point on the demand function, and the slope is defined by the price elasticity.

The short-run demand price elasticity assumed for all providers is -0.1. This elasticity represents a demand elasticity appropriate for drought conditions. A variety of studies have found short-run price elasticities in the range of -0.1 to -0.3 (Thomas and Syme 1988, A&N Technical Services 1996). Urban price elasticity in California is generally believed to be even more inelastic because of demand

hardening, meaning that many actions that people could use to reduce water use in response to shortage will already have been implemented by 2030.

This shortage cost function generates very high costs at high shortage levels, so CWEST can limit the marginal value of water from the CED function. The current cap is set at \$7000 per acre-foot year (AFY) more than the provider's retail water price.

## Q.4 CWEST Results

CWEST generates results for each CVP and SWP M&I contractor, which can be aggregated into regions or a statewide total. Result tables descriptions and interpretations are included below in Table Q2.3-1.

**Table Q2.3-1. Interpretation of Reported Results**

<b>Reported Results</b>	<b>Interpretation</b>
Average Annual CVP and SWP Deliveries (TAF)	Average Annual CVP and SWP delivery quantity for the reported alternative
Delivery Cost (\$1,000)	Delivery cost to deliver SWP/CVP water
New Supply (TAF)	Additional 2030 fixed-yield supply above stated 2030 supplies. This is the cost-minimizing decision variable in the model.
Annualized New Supply Costs (\$1,000)	Cost of optimal quantity of additional 2030 fixed-yield supply. Varies across contractors by type of new supply listed in their UWMPs as likely new supply (e.g., desalination, recycling, conservation)
Surface/GW Storage Costs (\$1,000)	Cost of annual puts/takes into local surface storage, local groundwater storage, or regional groundwater banks (e.g., Semitropic WSD)
Lost Water Sales Revenues (\$1,000)	Loss of retail water sales revenue due to shortage
Transfer Costs (\$1,000)	Cost to purchase and deliver transfer water purchases on annual spot market, or other annual options if applicable
Shortage Costs (\$1,000)	Estimated consumer surplus loss to water shortages
GW pumping savings (\$1,000)	Savings from resulting reduction in groundwater pumping relative to UWMP levels
Excess Water Savings (\$1,000)	Cost savings from contract water not used to meet demand or reduce groundwater pumping
<b>Average Annual Cost (\$1,000)</b>	Lost water sales revenue plus change in delivery, new supply, storage, transfers, options, and groundwater costs

AF = acre-feet

CVP = Central Valley Project

SWP- State Water Project

TAF = thousand acre-feet

UWMP = Urban Water Management Plan

WSD = Water Storage District

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