APPENDIX 2A

REGION 1 RESULTS: UPPER SACRAMENTO VALLEY

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ABSTRACT

The Upper Sacramento Valley is a major source of water for the state of California. CALVIN, an economic optimization model, re-allocates and re-operates water within the region in the most economically beneficial manner. The Base Case replicates the current water management system and the Unconstrained Case indicates what would happen in an ideal water market or other economically-driven management. The only economically driven demands in this region are in the agricultural areas. Environmental demands and the minor urban demands are modeled as fixed deliveries. Results indicate that the Upper Sacramento Valley would benefit somewhat from an ideal market. Intra-regional transfers as well as changes in conjunctive use operations make this possible. Changes in environmental flow requirements would have the greatest effect on water management. Changes in conveyance and reservoir facilities could have only small economic effects if accompanied by changes in allocations and operations. The Unconstrained alternative tends to use groundwater as an additional source of over-year storage for major droughts.

INTRODUCTION

The CALVIN modeling approach sub-divides the state of California into five regions. Region 1, the northern-most region, represents the Upper Sacramento Valley, above the confluence with the Feather River. This appendix describes the major reservoirs, water supply sources, facilities and demands in Region 1. Additionally, this appendix includes descriptions and preliminary results from the Base Case and Unconstrained Case modeling alternatives. The results are analyzed and some initial conclusions are presented.

REGION 1 MODEL DESCRIPTION

Region 1 covers depletions areas DA58, DA10, DA12 and DA15, that correspond to Central Valley Production Model (CVPM) agricultural demand regions 1 through 4. Model representation of this area is shown in Figure A-1. Four reservoirs are represented in the model. Three reservoirs, Shasta, Clair Engle and Whiskeytown, are operated by USBR. Black Butte Lake, the fourth, is owned and operated by the USACE. Four groundwater basins are also included in the model, one for each CVPM agricultural demand region.

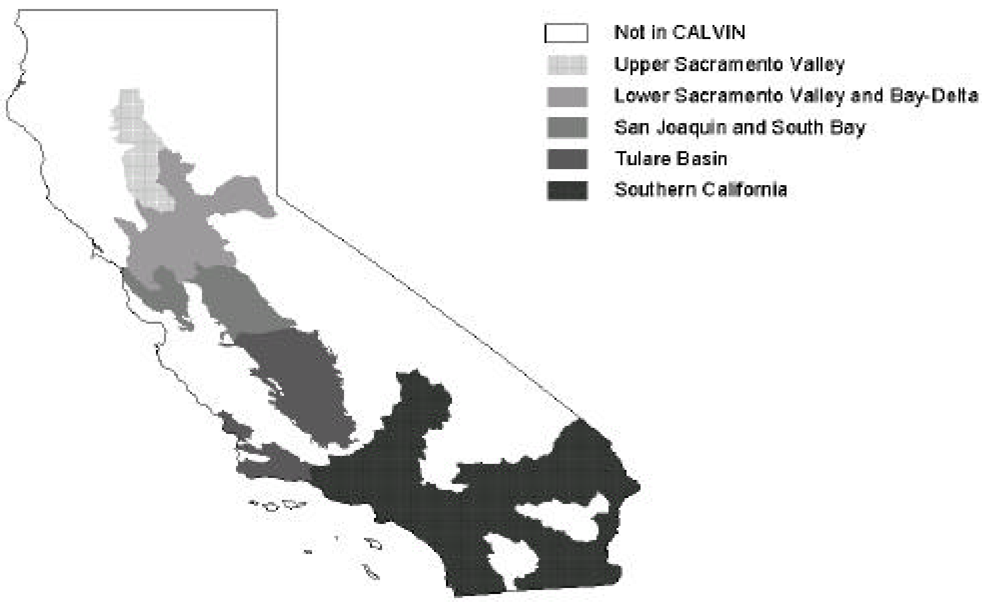

Figure A-1: Region 1: Upper Sacramento Valley

Lake Shasta and Clair Engle Lake form the northern boundary of Region 1. Inflows to these two lakes, along with the inflow to Whiskeytown Lake, comprise the initial boundary flows into the model. There are three outflows from the region. The first is the irrigation diversions and flood flows from the Knight's Landing Ridge Cut (KLRC) to DA65 and the Yolo Bypass. The second are the flows in the Sacramento River near Ord Ferry (downstream of the Colusa Basin Drain). The outflows from the Knight's Landing Ridge Cut and Sacramento River near Ord Ferry form the southern boundary of Region 1. The third are outflows from Region 1 (to Region 2) that consist of left bank diversions from the Sacramento River via RD1500 drain to Sutter Bypass. For additional information regarding boundary flow assumptions and information, refer to Appendix I: Base Case Details.

The Sacramento River is the key river in the region. It is fed by the releases from Shasta and Clair Engle, along with fourteen significant tributaries. These tributaries include Clear Creek, Cottonwood, Cow, Battle, Paynes, Seven Miles, Stony, Antelope, Mill, Dry, Deer, Big Chico, Thomas and Elder Creeks. The Colusa Bain Drain acts as a tributary for runoff from the Vaca Mountains. Additional flows enter the Sacramento River from local runoff and gains and losses to groundwater. With the exception to Stony Creek, all inflows from these tributaries represent unimpaired flow.

Regional water demands are primarily from agriculture, but there are small urban demands. The largest urban water demands occur at Redding. In addition to the urban and agricultural demands areas, Region 1 also includes the Sacramento, Delevan and Colusa National Wildlife Refuges. All agricultural demands are represented using economic penalties. Urban demands in Region 1 are comparatively small and are represented as fixed monthly constraints. The National Wildlife Refuges are aggregated into a single demand, which are similarly represented as a fixed constrained demand.

All demands are met by a mixture of surface water diversions and groundwater pumping. Major diversions from the Sacramento River are made at the Red Bluff Diversion Dam into the Corning and Tehema-Colusa Canals and into the Glenn-Colusa Canal north of Hamilton City. Other diversions from the Sacramento River include deliveries to the City of Redding, to the Cow Creek Unit of the CVP and to riparian land. Irrigation diversions also occur from Clear Creek, Stony Creek and the Colusa Basin Drain.

Management Alternatives

Two management alternatives were analyzed for Region 1. The first is the Base Case, or the constrained run. The Base Case constrains CALVIN to operate the system in accordance to current projected operations from the 2020 level of demand. Reservoir operations are Based on the Department of Water Resources Planning Simulation Model (DWRSIM). Deliveries are Based on Central Valley Groundwater and Surface Water Model (CVGSM) developed from the CVPIA Programmatic EIS. In the Base Case, this means that deliveries to each CVPM agricultural region are fixed, rather than allowing the model to determine flows Based on economic benefits.

The second alternative is the Unconstrained Case, which allows for an almost complete economic optimization. Most of the flow and storage constraints are removed to allow CALVIN to deliver water to places where the greatest economic benefit will be derived. Only a handful of policy constraints remain in the Unconstrained Case. Environmental minimum instream flows remain in place, as well as fixed refuge deliveries. Surface reservoirs are constrained by monthly flood control limits to the conservation pool and by minimum operating levels. Groundwater has a maximum storage constraint. Finally, all physical capacity limitations remain in place.

In both the constrained and the Unconstrained management alternatives the end-of-period surface water reservoir storages are constrained to match the results from the DWRSIM. End-of-period groundwater storage is also constrained. In both the Base and Unconstrained Cases it is constrained to match the results from CVGSM.

Base Case Assumptions and Limitations

The Base Case, or constrained management alternative, represents the current infrastructure, contractual agreements, and legislative requirements. Deliveries to urban and agricultural regions are fixed times series, as are reservoir storages except for Black Butte for which projected storage regulations were not available. Instead releases from Black Butte dam are constrained to match inflows to DWRSIM. Groundwater pumping to the agricultural regions is constrained to match pumping in CVGSM. Groundwater pumping for urban water supply is fixed so that all demands not met from surface water are met. Very little optimization takes place during the Base Case, mostly for parts of the system where information on constraints was insufficient.

Like all models, CALVIN is subject to some limitations. Among those limitations are the ways in which environmental flows are modeled and the way urban and agricultural demands are determined. These limitations are reviewed in Chapter 5.

Recently California has seen an increase in the regulations regarding environmental water demands. Minimum instream flows for native wildlife, as well as supplies for refuges have begun to play major roles in water allocations and availability. As yet, there are few recognized and accepted economic values that can be assigned to environmental water. For that reason, CALVIN models environmental water demands as constraints on the system. The minimum instream flows are modeled as lower bounds on flow through a link.

The refuge demands are modeled as fixed time series of deliveries that must be met each month of each year. However, the full Level 2 (L2) demands occasionally exceed the available water into the region. When that occurs a modified L2 demand is used. The modified L2 demand is either the full Level 2 demand (when there is sufficient supply) or the entire amount of available water into the region (when there is insufficient supply to meet the full L2 demands). See Appendix 1F for details. Delta environmental flow requirements are modeled as a fixed time series of Delta outflows, insuring that the required amount will be delivered in every month.

Another limitation of CALVIN is that it only uses "normal" year urban and agricultural demands, rather than varying the demands by year type. Similarly water use efficiencies are represented as a fixed value and do not vary by month or year. CVGSM NAA deliveries are Based on variable agricultural demands that generally increase in dry years and decrease in wet ones. Generally, crop water requirements are lower and rainfall higher in wet years, thus lowering applied water demand in wet years. The converse is true in dry years. However use efficiencies tend to be lower in wet years given the ready availability of water and rainfall. The use of average year demands in CALVIN can result in over and/or under estimations of the water demands of a given region in a given year.

Region 1 as been calibrated so that in the Base Case, groundwater storages match CVGSM and flows in the Sacramento River near Red Bluff (just upstream of the Red Bluff Diversion Dam) and at Ord Ferry (southern boundary of Region 1) match DWRSIM flows. Calibration requires that water must occasionally be added or removed from the model. Details on the calibration of Region 1 appear in Appendix 2H.

Unconstrained Policy Assumptions and Limitations

The second alternative is the Unconstrained Case, which represents an ideal water market. The only constraints are the physical limitations of the current system, the necessary flood control pools and the environmental water requirements. Most fixed flow constraints are removed for the Unconstrained Case. The model is allowed to deliver water to the agricultural and urban regions Based on economic benefit.

In the Unconstrained Case, end of period surface reservoir storages and groundwater storages are constrained to match the ending storages in the Base Case. A future alternative will have the end-of-period groundwater storage Unconstrained, which should allow for more conjunctive use opportunities.

Finally, the environmental requirements established in the Base Case remain in place, usually acting as lower bounds. The minimum instream flows remain unchanged from the Base Case. The refuge demands remain at the modified L2 demand levels.

The Unconstrained Case has many of the same limitations as the Base Case. In addition, CALVIN employs perfect foresight, which allows it to anticipate droughts and floods. This results in over-confident or optimistic over-year storage operations. Prior to wet years carryover storage is too low and prior to dry years carryover storage is too high. Perfect foresight of future reservoir inflows allows the model to reduce spills. Surface deliveries are therefore slightly higher and storage values under the ideal water market allocations tend to be less than they would actually be under realistic conditions of imperfect foresight. Perfect foresight leads to over-performance of existing facilities and an under-valuation of system expansion in the Unconstrained alternative.

COMPARISON OF MODEL RESULTS

The following section presents results from the two modeling alternatives. For each demand region (agricultural and urban), three results are presented. These are the supply source break down (detailing each demand), the volume of deliveries on an annual average basis, and the cost of scarcity (also on an annual average basis). Next the economic indicators (marginal value of water and shadow prices) are discussed. The opportunity costs of the environmental requirements also are presented. Finally shadow prices on the boundary flow constraints are compared with those of Region 2 to identify the economic incentives for water transfers across regions.

Water Delivery Results

In both the Base and Unconstrained Cases, Region 1 experiences scarcity. The scarcities and annual water budget for the region is presented in Table A-1. *Scarcity*, as used here, is the difference in the amount of water that would be used if water were freely available (at a price of zero and without other limitations) minus modeled water deliveries.

Table A-1: Summary of Water Budget

	Base Case	Unconstrained Case	
	Average	Average	Drought[a]
Water Demands			
Urban	167	167	167
Agricultural	3577	3577	3577
Environmental[b]	120	120	120
Total	**3864**	**3864**	**3864**
Deliveries (less conveyance losses)			
Surface Water	2211	2202	1857
Groundwater	1296	1299	1640
Reuse	200	193	192
Total	**3706**	**3693**	**3688**
Scarcity	**157**	**170**	**176**

[a] Water years of 1929-1934, 1976-1977, and 1987-1992.
[b] The Sacramento West Refuge requires 93 taf per year. However conveyance losses from the point of diversion require an additional 27 taf/year to be diverted.

There is an annual average scarcity of 157 taf/year during average water years in the Base Case. Of the 157 taf/year of scarcity, 14 taf/year of the scarcity is to the environment. The remaining scarcities (144 taf/year) go to the agricultural regions. The Unconstrained Case has a higher annual average scarcity (170 taf/year). Again 14 taf/year of scarcity is to the environment. The remaining scarcity (156 taf/year) is to the agricultural regions. The average drought scarcity is higher than the annual average. Reductions in water deliveries occur in the Unconstrained Case in the process of shifting water to agricultural regions with higher economic value.

It should be noted that the total environmental requirements are consumptive use requirements and do not include the minimum instream flows. The Sacramento West Refuge demands are the only consumptive use environmental demands in Region 1. Both modeling alternatives have the same demands, and are modeled as a fixed times series of flows.

Delivery-reliability curve for agricultural water is presented in Figures A-2. The delivery-reliability curve for urban demand is omitted because there are no urban scarcities. The environmental water delivery-reliability curve is also omitted because there is no variation between the Base and Unconstrained Cases. A total aggregate delivery-reliability curve for all of Region 1 is presented in Figure A-3.

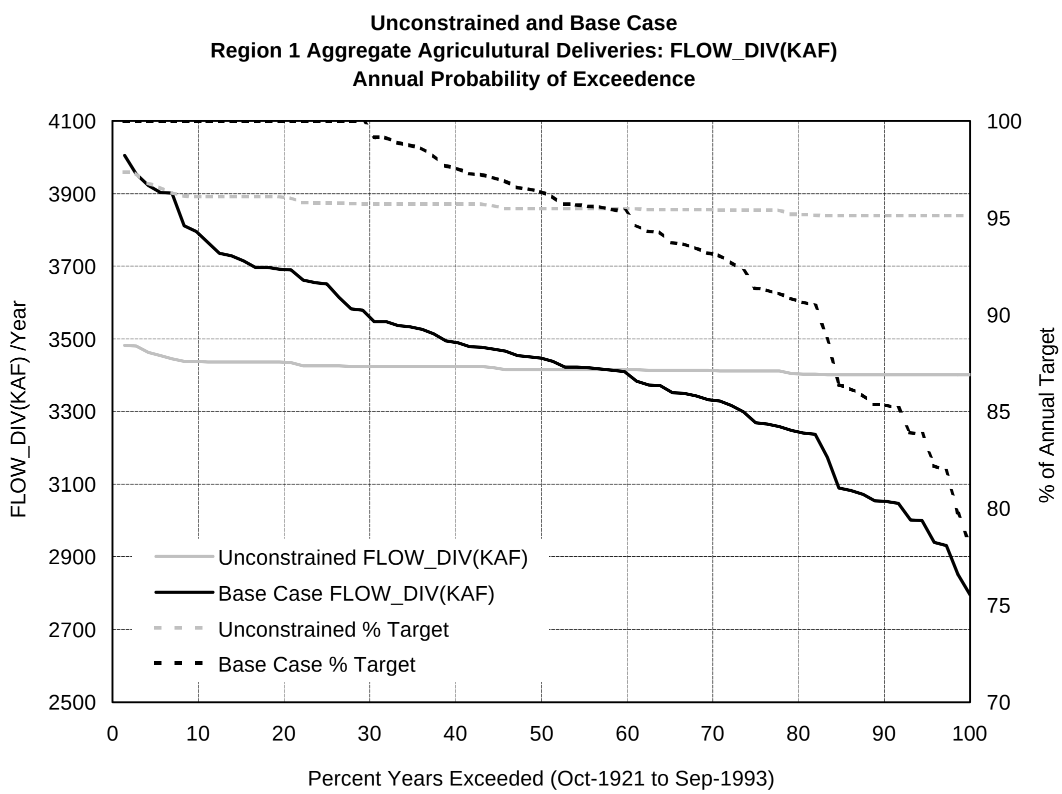

Figure A-2: Total Aggregate Agricultural Deliveries

The Unconstrained Case does not deliver full demands, however the minimum delivery is approximately 95% of the demand. The Base Case deliveries full demand about 29 % of the time and 95% of the demands 60% of the time. In the remaining 40% of the time, the Base Case deliveries less than the Unconstrained alternative. The range of deliveries is much smaller in the Unconstrained Case (the maximum is 97% and the minimum is 95%) than it is in the Base Case (the maximum is 100% and the minimum 78%).

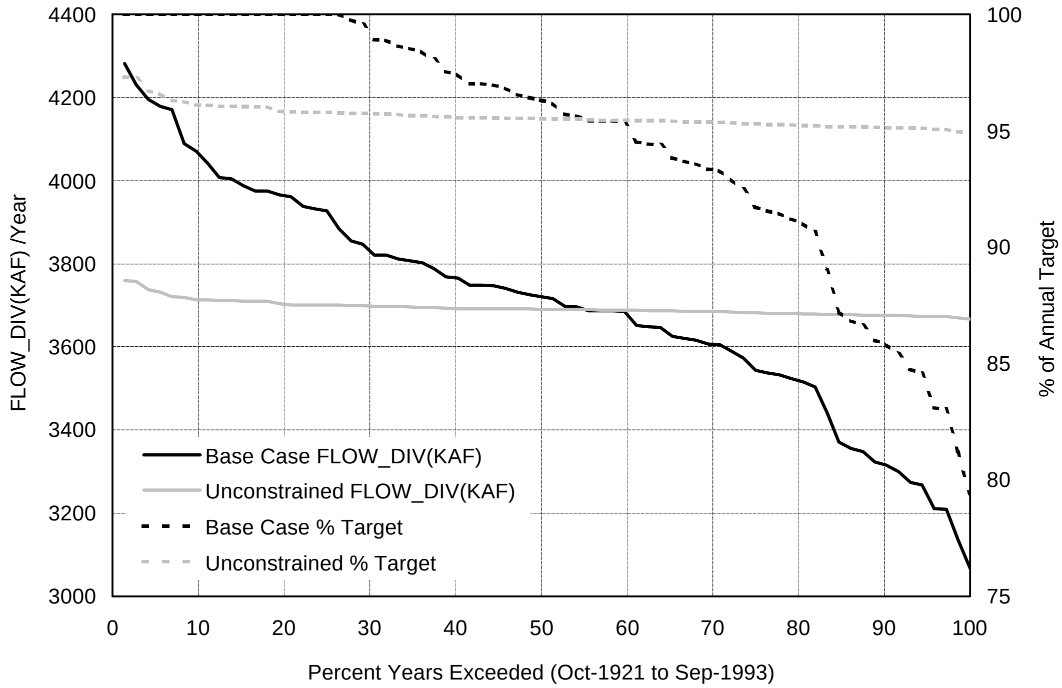

Figure A-3: Total Aggregate Deliveries for Region 1

The Unconstrained Case experiences more overall scarcity than the Base Case, but the spread in deliveries is much less. The minimum reliability in the Unconstrained Case is approximately 95%, while the minimum reliability in the Base Case is approximately 79%. Approximately 55% of the time the Base Case deliveries more water than the Unconstrained. In the remaining 45% of the time, the Unconstrained Case deliveries more water.

Groundwater storage is constrained in the ideal market scenario to match the Base Case ending storage. In general the Unconstrained Case draws the basins down more in the critically dry periods and fills them higher in the wet years, effectively using groundwater for additional over-year storage. The Unconstrained Case experiences similar annual average groundwater pumping for the 72 year run (Figure A-5). Each of the four-groundwater basins has an associated pumping cost (Table A-2). In the Unconstrained Case only GW-2 saw in increase (9 taf/year) in pumping. GW-1 pumping remained the same, and GW-3 and GW-4 saw decreases (3 taf/year each).

Table A-2: Groundwater Storage and Pumping Cost

GW	Pumping	Annual Average Pumping	
Basin	Cost ($/AF)	Base Case	Unconstrained Case

		Average (taf/yr)	Average (taf/yr)	Drought (taf/yr)
GW-1	30	66	66	86
GW-2	28.2	573	582	644
GW-3	23.8	353	350	523
GW-4	16	304	301	387
	TOTAL	**1296**	**1299**	**1640**

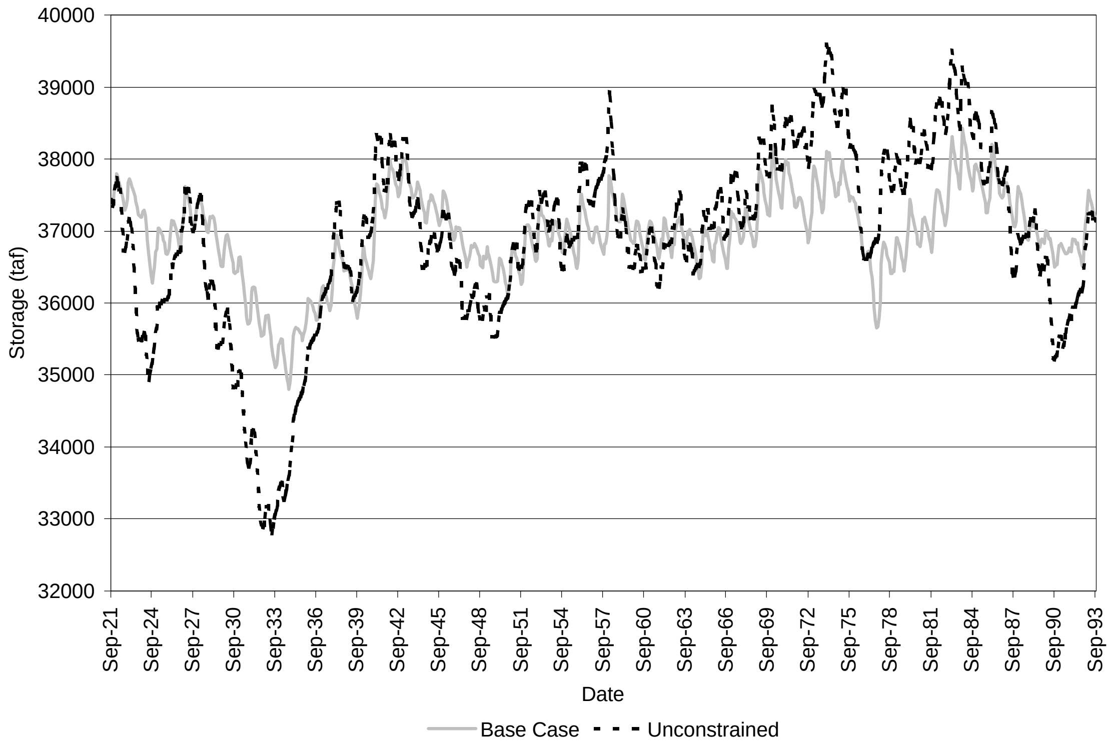

Figure A-4: Aggregate Groundwater Storage Volume

The surface water storage is constrained to match the same ending storage in both model runs. In general, the Unconstrained Case keeps the reservoirs fuller than in the Base Case (Figure A-5). There is a small persuasion on reservoir storage ($0.2/AF), which favors fuller reservoirs. This “persuasion” penalty is not enough to affect the regional economics, but it is enough that HEC-PRM will find a benefit of keeping water in the reservoir as opposed to unvalued releases into the system.

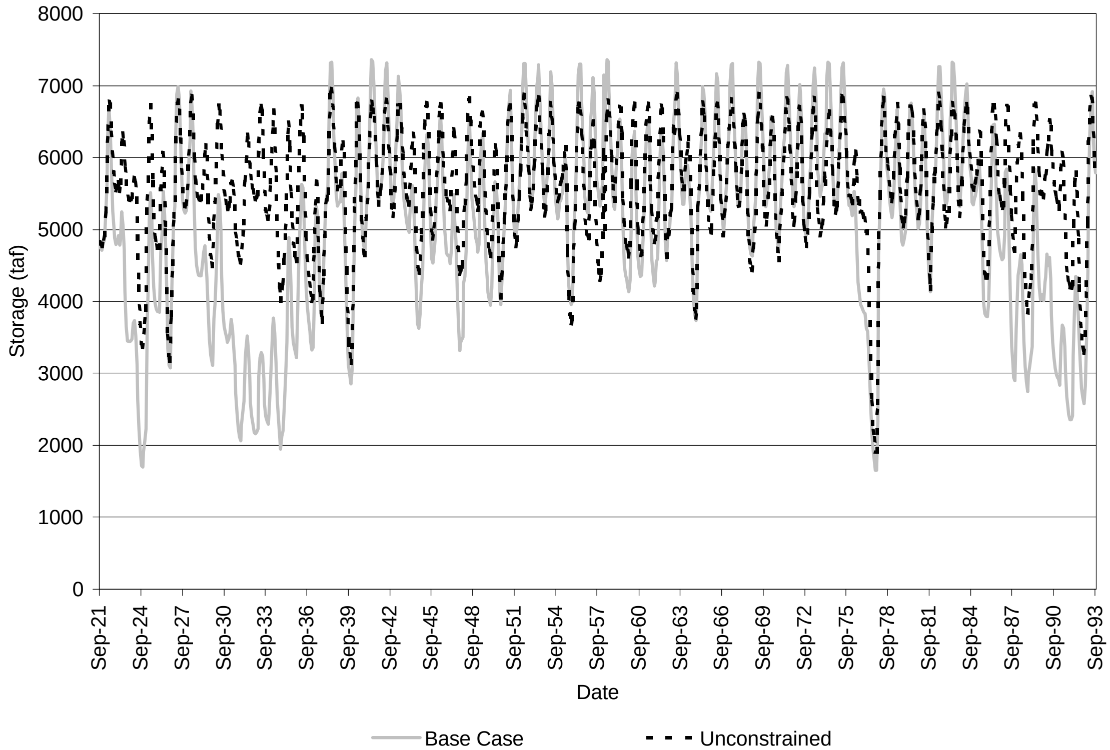

Figure A-5: Aggregate Surface Water Storage Volume

As stated before, CALVIN is an economic optimization model. Its only 'operating rule' is to minimize cost (maximize net benefits). Ideally, the Unconstrained Case models an ideal water market, which reduces the overall net costs (those due to scarcities and operations). Table A-3 presents the costs of agricultural scarcities for an average year for both modeling alternatives and for the drought periods of the Unconstrained Case. Table A-3 presents the operating costs for each of the CVPM regions for an average year and the drought years.

Table A-3: Average Scarcity and Scarcity Cost for Agriculture

	Base Case			Unconstrained Case		
	Annual Average Scarcity (kaf/yr)	% Annual Scarcity	Cost ($1000/yr)	Annual Average Scarcity (kaf/yr)	% Annual Scarcity	Cost ($1000/yr)
Average	144	4.0	6609	157	4.4	5284
Drought	N/A	N/A	N/A	163	4.6	5488

The annual average cost of scarcity decreases in the Unconstrained Case, which indicates that more water is being re-allocated to increase the economic benefits over the entire Upper Sacramento Valley (Region 1). The overall deliveries to the agricultural regions decreased in the Unconstrained Case, from 3433 taf/year to 3420 taf/year. Despite the 13 taf/year decrease in deliveries, there was a decrease of approximately $1.3 million/year in scarcity costs. This would indicate that the while less deliveries were made, the deliveries were made to regions that would yield the most economic benefits.

The annual average operating costs for Region 1 were slightly higher in the Unconstrained Case than in the Base Case due to an increase in groundwater pumping (Table A-4). Note that the operating costs include the cost of groundwater pumping to the urban areas that did not receive any scarcities.

Table A-4: Operating Costs for Region 1

	Base Case	Unconstrained Case
	Operating Cost ($\$10^6$/yr)[a]	Operating Cost ($\$10^6$/yr)[a]
Average	31.4	31.5
Drought	N/A	39.4

[a] Operating costs in Region 1 were solely due to the cost of groundwater pumping.

The increased operating costs were offset by greater decreases in the scarcity costs, leading to a net benefit of $1.2 million/year to the system (Table A-5). This is a very modest 3% reduction in scarcity and operating costs, which would only be a very slight, almost negligible, improvement in the economic welfare of the entire region, probably within the error of the model.

Table A-5: Annual Operating and Scarcity Costs

	Base Case	Unconstrained Case	Net Benefit
	($\$10^6$/yr)[a]	($\$10^6$/yr)[a]	($\$10^6$/yr)[b]
Operating Costs	31.4	31.5	-0.1
Scarcity Costs	6.6	5.3	1.3
Total Cost	**38.0**	**36.8**	**1.2**

[a] Values are for average years only.
[b] A positive value indicates that there was a decrease in the costs from the Base Case to the Unconstrained. A negative indicates that costs increased from the Base Case to the Unconstrained.

<u>Agricultural Supply Sources and Reliability</u>

The ideal water market, as expected, reduces annual average scarcity costs in the agricultural regions and in most Cases reduces operating costs as well. Each agricultural region responds differently to the market. Overall, the system would yield greater economic benefits from an Unconstrained water market, but it does mean that some local areas may suffer more frequent scarcities or increased operating costs (Table A-6).

Table A-6: Total Annual Costs by CVPM Region

		Base Case	Unconstrained Case		
		Average	Average	Drought	ΔAvg
CVPM 1	Total Cost ($\$10^6$)	1.1	1.1	1.7	0.0
CVPM 2	Total Cost ($\$10^6$)	17.8	14.8	16.6	3.0
CVPM 3	Total Cost ($\$10^6$)	11.2	10.9	15.1	0.3
CVPM 4	Total Cost ($\$10^6$)	4.8	6.8	8.3	-2.1[a]
REGION 1	**TOTAL COST ($\$10^6$)**	**34.9**	**33.7**	**41.7**	**1.2**

[a]The operating costs have increased from the Base Case value.

CVPM Region 1

CVPM 1 experiences a slight annual average scarcity in the Base Case (less than 1 taf/year) over the 72-year model period. The volume of scarcity was almost the same in the Unconstrained

Case (less than 1 taf/year, but more than the Base Case). The increased scarcity resulted in an increase in the scarcity cost (by $10K/year). There was also a slight increase in the operating costs ($7K/year). See Table A-7 for details.

Table A-7: CVPM Region 1 Results

	Base Case	Unconstrained Case	
	Average	Average	Drought
Annual Average Scarcity (taf)	1	1	1
Percent Scarcity (%)	1	1	1
Annual Average Scarcity Cost ($1000)	7	17	17
Annual Average Operating Cost ($1000)	1088	1095	1679
Annual Average Total Cost ($$10^6$$)	1.1	1.1	1.7

CVPM 1 relies on the diversions from the Sacramento River and releases from Whiskeytown Lake to meet the region's demands. The majority of the water comes from the Sacramento River below the confluence of Cow and Battle Creek (Table A-8). Due to the high cost of groundwater pumping from GW-1 ($30/AF), the region relies more heavily on surface water.

In the Unconstrained Case the region obtains 75.5% of its demand from surface water supplies. Another 23.8% comes from groundwater pumping. The remaining 0.7% of the demand is not fulfilled. Additional surface water is not available because of requirements further downstream and the cost of groundwater pumping ($30/af) is greater than the benefits derived from the water ($17/af). Therefore, the agricultural user would be, most likely, unwilling to pay the pumping costs for additional water. .

Table A-8: Summary of Agricultural Supplies

Supply Source (or Point of Diversion)	Base Case		Unconstrained Case	
	KAF/year	% Total Supply	KAF/year	% Total Supply
Sacramento River at Keswick	21	14%	29	19%
Whiskeytown Lake	14	9%	11	7%
Sacramento River at DA58	82	53%	76	50%
Groundwater	36	24%	36	24%
Reuse	0	0%	0	0%
CVPM 1 TOTAL	**153**		**152**	
Misc. Left & Right Bank Diversions	5	1%	10	1%
Tehema-Colusa Canal Diversions	2	0%	4	1%
Black Butte Lake	92	14%	84	12%
Corning Canal	32	5%	70	10%
Groundwater	508	80%	518	75%
Reuse	0	0%	0	0%
CVPM 2 TOTAL	**640**		**686**	
Tehema-Colusa and Glenn-Colusa Canal	988		1003	
Refuge Supply	-106		-106	
Tehema-Colusa and Glenn-Colusa Canal (remaining)	882	57%	897	58%
Colusa Basin Drain Diversions	55	4%	90	6%
Sacramento River at DA15	194	13%	153	10%
Groundwater	338	22%	335	22%
Reuse	73	5%	74	5%
CVPM 3 TOTAL	**1543**		**1550**	

Sacramento River at DA15	673	61%	618	60%
Groundwater	299	27%	296	29%
Reuse	126	12%	119	12%
CVPM 4 TOTAL	**1098**		**1032**	
TOTAL DEMAND	3577		3577	
Grand TOTAL (Net Deliveries)	3233		3228	
Grand TOTAL (Reuse)	200		193	
GRAND TOTAL (Applied Water)	**3433**		**3420**	
Scarcity (taf/year)	144		157	
Scarcity Cost (K$/year)	6609		5276	
Percent Scarcity (%)	4%		4%	

In the Unconstrained Case, the region always receives greater than 99% of its demand. In the Base Case the region's reliability is much more varied. It can range from 100% to less than 85%. The deliveries in the Unconstrained Case area consistent at 152 taf/year. See Figure A-6 for details.

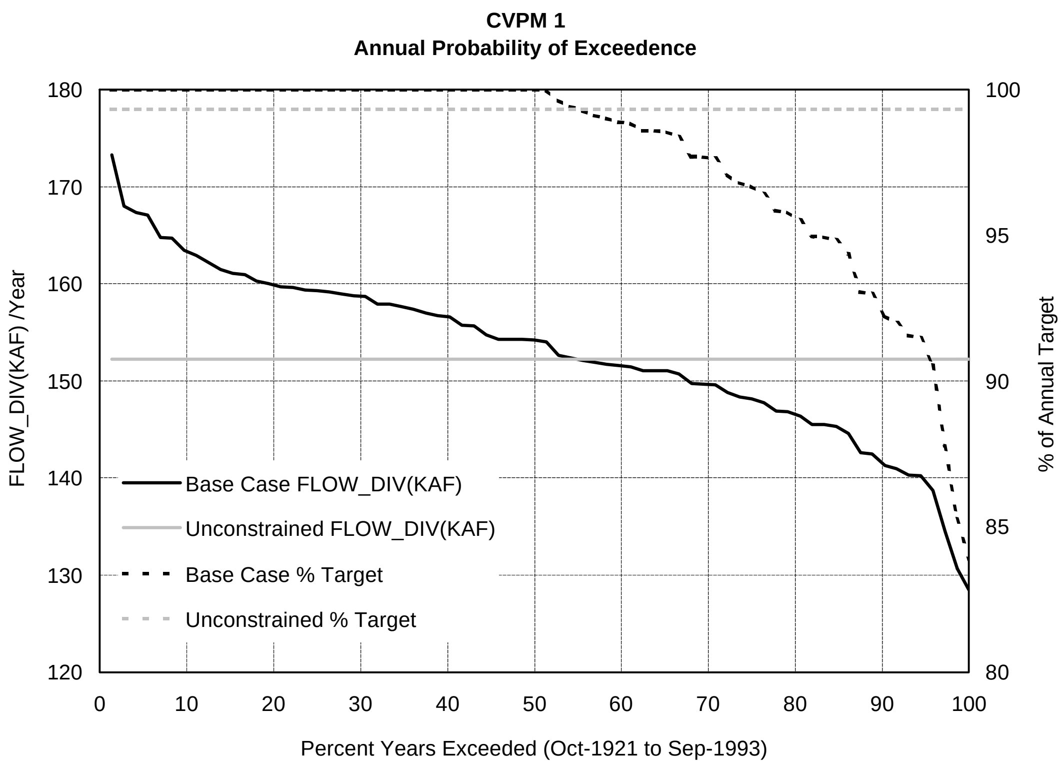

Figure A-6: Exceedence Plot for CVPM 1

In the Unconstrained Case, the region experiences scarcities (consistently less than 1%) in all years. In the Base Case the region received all of its demands about 50% of the time.

Because there are scarcities in both the Base and the Unconstrained Case, both alternatives incur a scarcity penalty. On an annual average basis the scarcity is lower in the Base Case than it is in the Unconstrained. Approximately 36 taf/year in a normal year is pumped from the groundwater basin to fulfill the regions demands. However, there is slightly more being with drawn in the Unconstrained than in the Base Case. This is what is the cause of the slightly higher operating costs in the Unconstrained Case.

In general the scarcity costs have increased from \$7K/year to \$17K/year and operating costs have risen from \$1088K/year to \$1095K/year. Overall CVPM 1 is seeing an increase in costs of about \$17K/year. Table A-6 lists that there is no change in the average total costs to the CVPM region because \$17K/year is \$0.017(10^6)/year, which is rounded down to \$0.0(10^6)/year.

CVPM Region 2

CVPM 2 experiences scarcities in both the Base and Unconstrained Cases. However the scarcities in the Unconstrained Case are not as large on an annual average basis. The annual average scarcity for the Base Case and the Unconstrained Case are presented in Table A-9.

Table A-9: CVPM Region 2 Results

	Base Case	Unconstrained Case	
	Average	Average	Drought
Total Annual Average Scarcity (taf)	57	11	11
Percent Scarcity (%)	8.2	1.5	1.5
Annual Average Cost of Scarcity (\$$10^6$)	3.5	0.2	0.2
Annual Average Operating Cost (\$$10^6$)	14.3	14.6	16.3
Annual Average Total Cost (\$$10^6$)	17.8	14.8	16.6

CVPM 2 relies on surface water deliveries via the Corning and the Tehema-Colusa Canals, as well as releases from Black Butte Lake and additional diversions from the Sacramento River. In both the Base and Unconstrained Cases, the region relies heavily on groundwater to meet its demands (Table A-8). 75% of CVPM 2's full demands in the Unconstrained Case and 73% in the Base Case are met by groundwater pumping. As a result, both runs incur large operating costs because they are pumping from the second most expensive groundwater reservoir in the region. There are smaller scarcities, but more groundwater pumping in the Unconstrained Case. The Unconstrained Case yields a net benefit of approximately \$3.0(10^6)/year over the Base Case. The net benefit comes mainly from the \$3.3(10^6)/year decrease in scarcity costs.

As stated above, the cost of groundwater pumping is relatively high (\$28.2/AF), but the value of the crops also is high. The crop value is greater than the cost of groundwater pumping until 98.5% of the demand is fulfilled. At that point groundwater-pumping cost exceeds the benefits derived from additional water use. This corresponds to the region's scarcity (Table A-9), which would indicate that the scarcity is due to groundwater pumping costs exceeding their value for agricultural production.

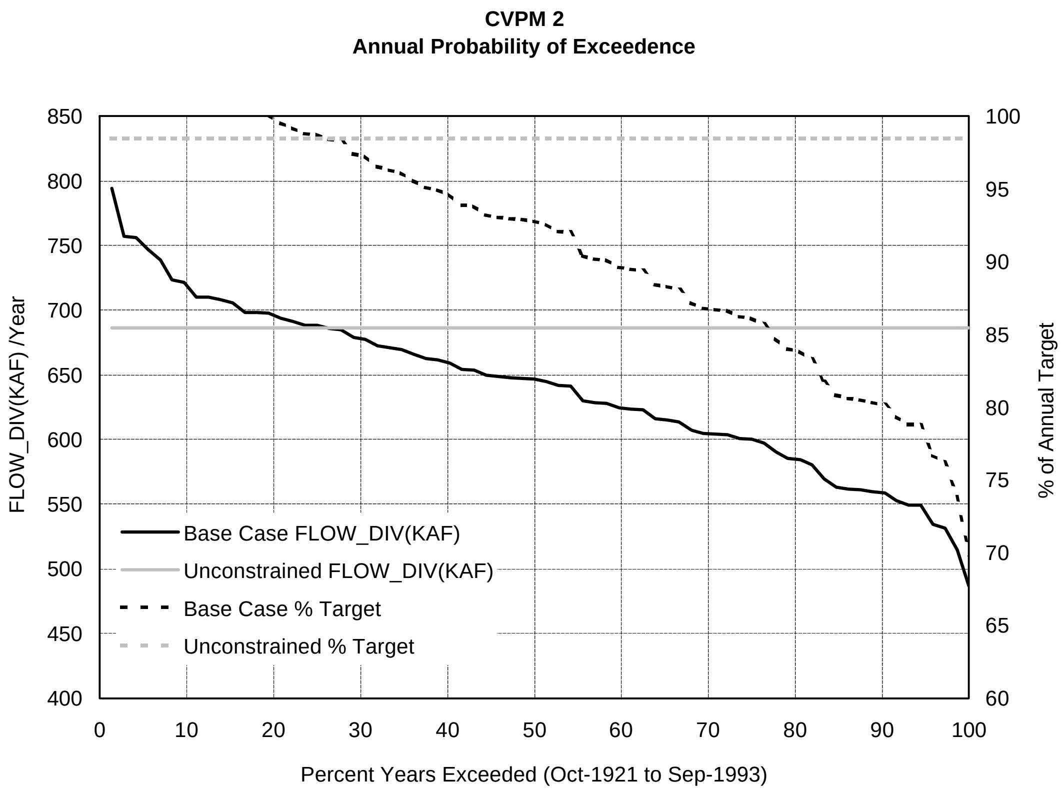

Figure A-7: Exceedence Plot for CVPM 2

In the Unconstrained Case, the region experiences a consistent scarcity of about 0.5% on an annual average basis. The Base Case saw a much wider spread in the deliveries (from 100% to about 70%). See Figure A-7.

CVPM Region 3

CVPM 3 also experiences scarcities in both the Base Case and the Unconstrained Case. As with CVPM 2, the degree of scarcity decreases from the Base Case to the Unconstrained Case (Table A-10). One of the causes of agricultural scarcity to the region is that the supplies must also fill the water requirements of the Sacramento West Refuge.

Table A-10: CVPM Region 3 Results

	Base Case	Unconstrained Case	
	Average	Average	Drought
Total Annual Average Scarcity (taf)	86	79	82
Percent Scarcity (%)	5.3	4.9	5.0
Annual Average Cost of Scarcity ($$10^6$)	3.1	2.9	3.0
Annual Average Operating Cost ($$10^6$)	8.0	8.0	12.1
Annual Average Total Cost ($$10^6$)	11.2	10.9	15.1

CVPM 3 gets surface water from the Sacramento River, the Colusa Basin Drain, and Black Butte Lake, in addition to its groundwater withdrawals. The largest water supply source for CVPM 3 is the Sacramento River (Table A-8). 69.5% and 70.1% of the demands are filled by surface water in the Base Case and Unconstrained Case, respectively. Groundwater withdrawals provide the next largest source, but is considerably less than the surface water supplies. 20.7% and 20.5% of the demands are filled by groundwater withdrawals in the Base and Unconstrained Case, respectively. Finally, re-use water is the smallest source at 4.5% in both alternatives.

There are still significant operating costs associated with the groundwater withdrawals in both cases. The Base Case uses more groundwater than the Unconstrained Case, however it is only by 3 taf/year. The additional 3 taf/year in the Base Case incurs an additional $0.07(10^6)/year operating cost. Since the costs are reported in millions of dollars, the $0.07(10^6)/year is not explicitly seen. The scarcities are less in the Unconstrained Case, resulting in lower scarcity costs. The benefit from the agricultural crops of CVPM 3 always exceeds the cost of groundwater pumping, thus scarcities are not due to the cost of groundwater pumping.

The largest scarcities occur during droughts when significant scarcities occur throughout the system. During these periods, surface water deliveries decrease while groundwater pumping increases. During normal years, CVPM 3 experiences scarcities because of the requirements to Sacramento West Refuge. A significant volume of water is required to flow into the Refuge before any water is diverted to the agricultural regions.

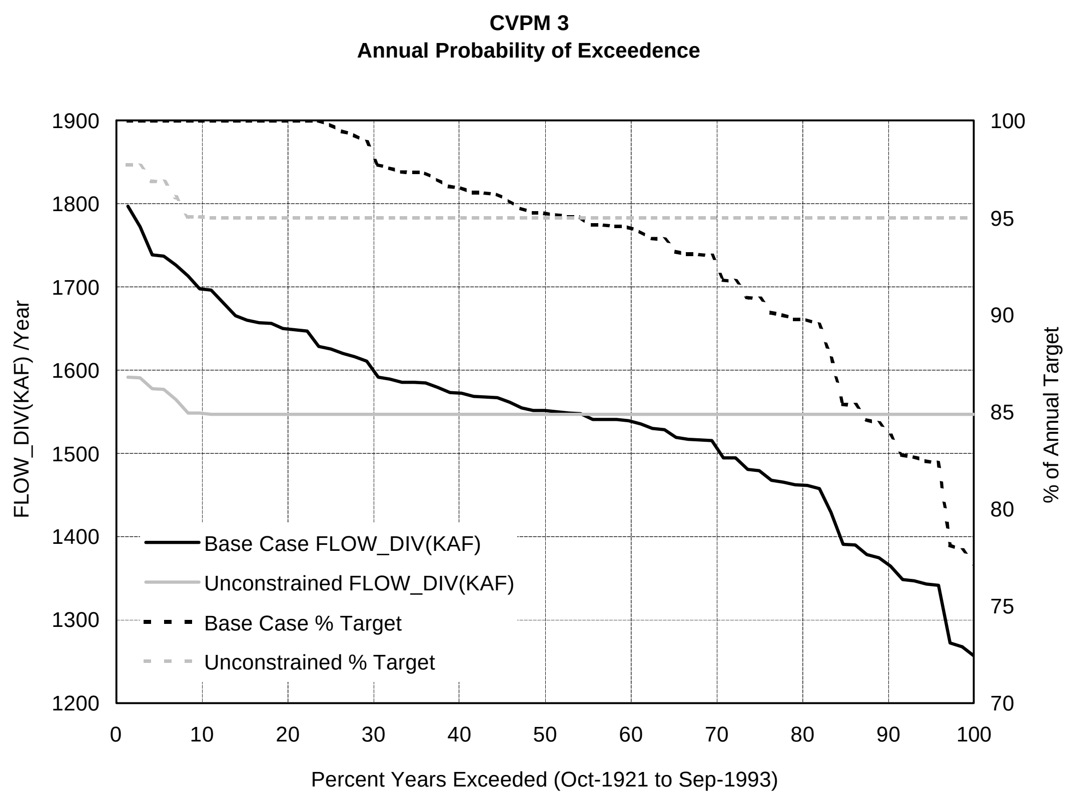

Figure A-8: Exceedence Plot for CVPM 3

The area's water deliveries are fairly consistent in the Unconstrained Case. 89% of the time there is a 5% scarcity. The Base Case is considerably more inconsistent in its reliability (ranging from 100% to less than 80%). The Base Case deliveries 95% of the demand approximately 50% of the time. Figure A-8 for more details.

CVPM Region 4

Finally, CVPM 4 experienced no scarcity in the Base Case. However, in the Unconstrained Case, CVPM 4 experienced an annual average scarcity. Table A-11 presents the annual average scarcities to the region in the Base Case and the Unconstrained Case.

Table A-11: CVPM Region 4 Results

	Base Case	Unconstrained Case	
	Average	Average	Drought
Total Annual Average Scarcity (taf)	0	66	70
Percent Scarcity (%)	0.0	6.0	6.3
Annual Average Cost of Scarcity ($\$10^6$)	0.0	2.1	2.2
Annual Average Operating Cost ($\$10^6$)	4.8	4.7	6.1
Annual Average Total Cost ($\$10^6$)	4.8	6.8	8.3

CVPM 4 has three sources of water, the Sacramento River, groundwater withdrawals and re-use. 61.3% and 56.3% of the demands are met through surface water, 27.2% and 26.9% of the demands are met through groundwater withdrawals and 11.5% and 10.8%. The decreased reliance on groundwater in the region results in lower operating costs. CVPM 4 experiences a net cost of $\$4.0(10^6)$/year in the Unconstrained Case.

Surprisingly CVPM 4's crops are worth $24/AF at the lowest, which is more than the cost of groundwater pumping ($16/AF). However, the region cannot pump an unlimited amount of groundwater, even if it would be economically beneficial. The end of period storage constraint limits the volume of water that can be withdrawn from the groundwater basin.

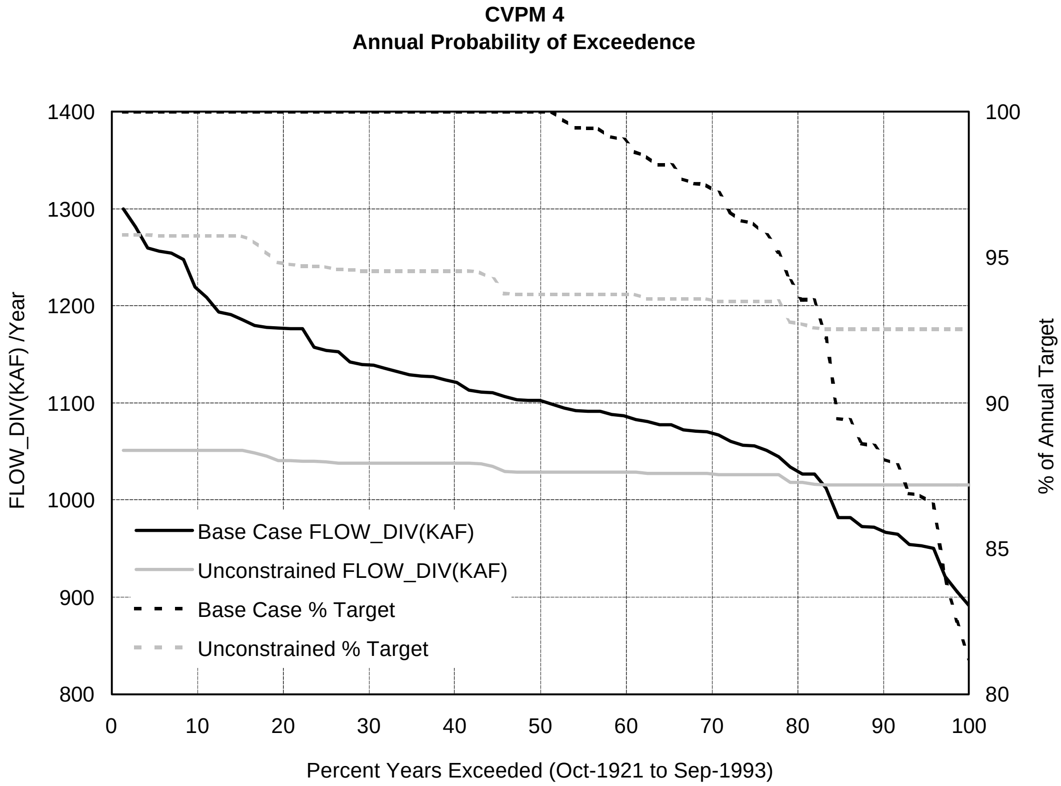

Figure A-9: Exceedence Plot for CVPM 4

In the Unconstrained Case the region experiences scarcities in all years. In the Base Case, there were some years when the region was shorted, but there were also years when full deliveries were made. The Unconstrained Case delivered at least 92.5% of the demand in all years. The Base Case deliveries ranged from 100% to 82% of the demands. The Base Case delivered 92.5% of the demand approximately 83% of the time. See Figure A-9 for details. So while the annual average scarcity increased in the Unconstrained Case, the reliability of the system improved.

Urban Supply Sources and Reliability

Region 1 has no economically driven urban water deliveries. The four urban demands are relatively small and modeled as fixed deliveries from the local groundwater basin. Because the deliveries are fixed without any economic target demands there are no scarcities. However there are operating costs associated with the urban water deliveries due to the groundwater pumping. See Table A-12 for details.

Table A-12: Annual Average Deliveries and Demand of the Urban Regions

	Demand (taf)	Delivery (taf)	Scarcity (taf)	Operating Costs ($$10^6$)
CVPM Urban 1 (Redding)	82	82	0	0.9
CVPM Urban 2	64	64	0	1.8
CVPM Urban 3	16	16	0	0.4
CVPM Urban 4	5	5	0	0.1
Region 1 Urban	167	167	0	3.2

Changes in Deliveries and Scarcity Costs

The Unconstrained Case delivers less water to the agricultural demands on an overall annual average basis. However in individual CVPM regions, the Unconstrained Case may deliver more or less water than the Base Case. CVPM 2 sees the greatest spread in relative water deliveries between the Base Case and the Unconstrained Case. On the other hand, CVPM 1 experiences the least variability, but loses water to other farming areas with Unconstrained allocations. Essentially, CALVIN is recommending an agricultural water market within this region. See Table A-13 and Figure A-11 for details.

Table A-13: Changes in Deliveries

	Base Case	Unconstrained Case	
	Average (taf)	Average (taf)	ΔAvg[a] ($1000)
CVPM 1	153	152	-1
CVPM 2	640	686	47
CVPM 3	1543	1550	7
CVPM 4	1098	1032	-66
TOTAL	3433	3420	-13

[a]A negative value indicates that the annual average deliveries decreased in the Unconstrained Case.

Figure A-10 represent the changes in maximum, minimum and average deliveries in the Unconstrained Case from the average deliveries in the Base Case (ex. Unconstrained Case maximum minus the Base Case annual average). In no case does ideal market water reallocation affect more than ten percent of Base Case deliveries.

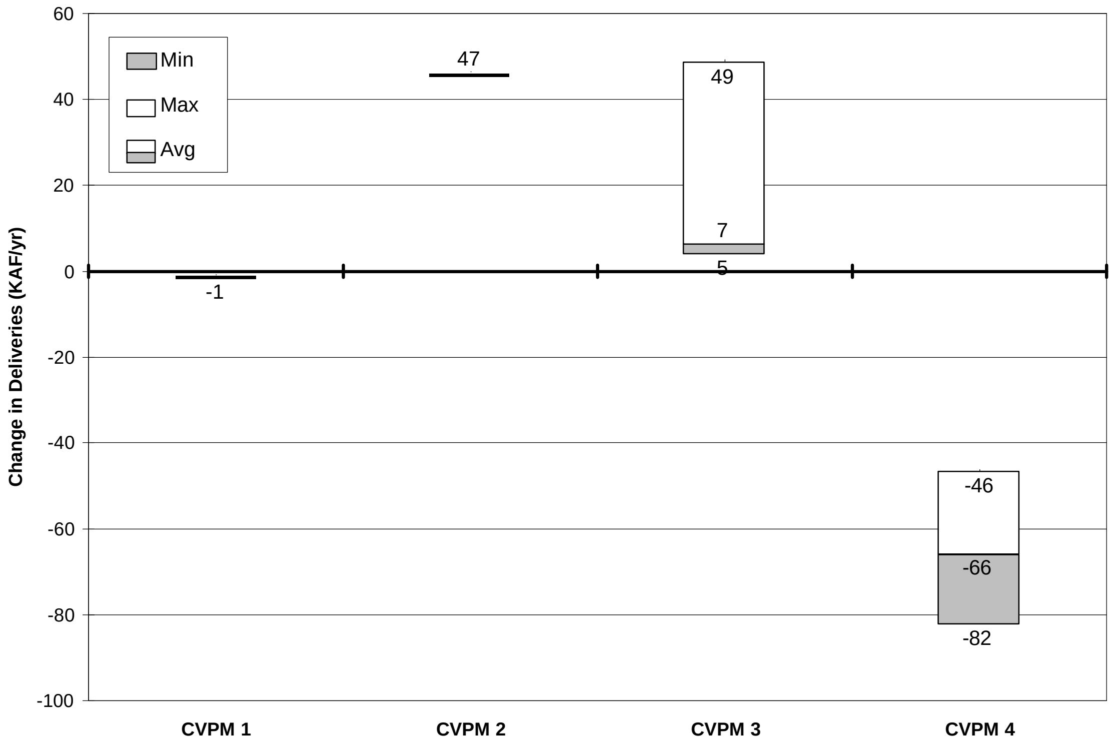

Figure A-10: Change in Annual Deliveries

In two of the demand areas, the annual average cost of scarcity decreases in the Unconstrained Case. The largest decrease is from $3455K to $22K in CVPM 2. The other two demand areas experiences increases in their annual average scarcity cost. The largest is from $0K to $2108 in CVPM 4. The range of scarcity costs (max and min) in the Unconstrained Case shows that there is still the potential for expensive scarcities in the agricultural regions. See Table A-14 for details.

Table A-14: Comparison of Scarcity Costs

	Base Case	Unconstrained Case			
	Avg ($1000)	Min ($1000)	Avg ($1000)	Max ($1000)	Δavg[a] ($1000)
CVPM 1	7	17	17	17	9
CVPM 2	3455	212	212	212	-3243
CVPM 3	3146	1369	2937	3024	-209
CVPM 4	0	1485	2110	2633	2110
TOTAL	6609		5276		-1333

[a]A positive value indicate an increase in scarcity cost in the Unconstrained Case.

Figure A-11 presents the changes in scarcity costs to each of the CVPM regions. It is the difference between the Unconstrained Case value (maximum, minimum and annual average) and the Base Case annual average (ex. Unconstrained Case maximum minus the Base Case annual average).

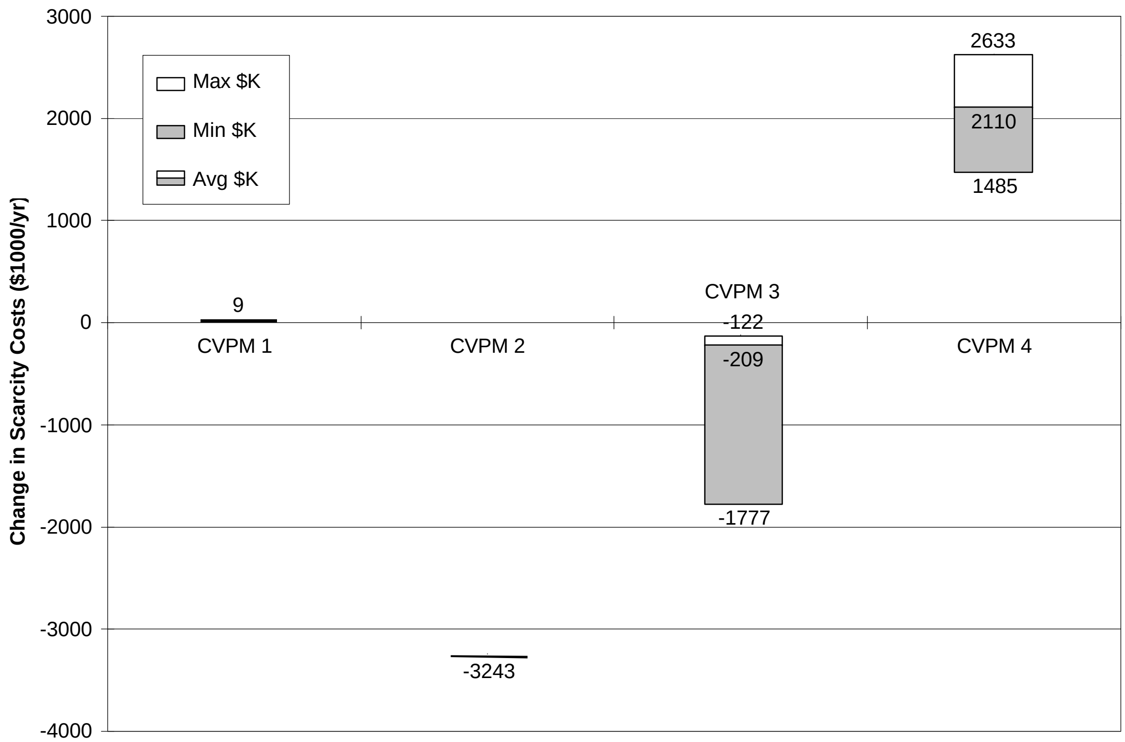

Figure A-11: Changes in Scarcity Costs

The change in scarcity costs for CVPM 1 and 4 are always greater than zero. This indicates that the Unconstrained Case increases the costs for all conditions. The negative change in scarcity costs in CVPM 2 and 3 indicate that the Unconstrained Case decreased the scarcity cost to the region. Therefore the Unconstrained Case indicates that in terms of reduced scarcity costs CVPM 2 and 3 would benefit from the ideal water market, while CVPM 1 and 4 would not. In all Upper Sacramento Valley cases, changes in deliveries and scarcity costs are a very small percentage for each location and region, well within the error inherent in the model and data. Nevertheless, these results illustrate how regional CALVIN results can be used and the relatively effective economic management of water currently within the region; at least for within-region agricultural supply purposes.

The change in water deliveries to the four agricultural areas was re-evaluated using SWAP (see Appendix 1A for details regarding SWAP). A comparison of results for the Base Case and the Unconstrained Case are presented in Table A-15.

Table A-15: SWAP Results

	Base Case	Unconstrained Case	Change (BC–UC)[a]	Percent Change[b]
Crop Acreage (K-acre)	941	944	2	0.2
Gross Revenue ($million)	904	905	1	0.1
Net Revenue ($million)	311	311	0	0.0

[a] Number may not add up do to rounding.
[b] Negative values indicate that there was an increase from the Base Case to the Unconstrained Case

The weighted average efficiency increased by 1.0% from the Base Case to the Unconstrained Case. Region 1 saw an increase in gross revenue and crop acreage, but the net revenue remained the same. The largest change in net revenue was from rice production, which decreased by 3.7%. In general two crops saw decreased net revenues, four saw increases and the other six crops were unchanged.

Environmental Water Requirements

Region 1 has four minimum instream flow locations and one aggregated refuge. Outflows from Lewiston Lake to Trinity River are fixed time series, which guarantee that the required water is released in every time period. The outflows from Whiskeytown Lake to the Sacramento River via Clear Creek are required to meet a minimum instream flow of between 2.8 and 6.1 taf per month. These flows are modeled as lower bounds and as a result are in met each month.

Three separate minimum instream flows requirements exist along the Sacramento River. The first occurs just below Keswick dam and ranges between 181 and 357 taf per month. The second occurs below Red Bluff Diversion Dam and ranges from 108 to 232 taf. The third minimum instream flow occurs at the Navigation Control Point and ranges from 22 to 307 taf per month.

Of the three minimum instream flows along the Sacramento River, the Navigation Control Point minimum is the largest on an annual basis. Therefore it is considered to represent the environmental water demand of the Sacramento River. It is also modeled as a lower bound and is met in every month.

The fourth minimum instream flow requirement is on the diversions from Lewiston Lake to Whiskeytown via Clear Creek Tunnel. Because DWRSIM did not include the minimum in the Run 514, CALVIN also omits the Clear Creek Tunnel minimums.

The annual average minimum instream flows on the four reaches and the annual average scarcity are presented in Table A-16.

Table A-16: Environmental Minimum Instream Flows

	Base Cast	Unconstrained Case	
	Average (taf/year)	Average (taf/year)	Drought (taf/year)
Water Demand			
Trinity River	357	357	341
Clear Creek	42	42	40
Sacramento River	3117	3117	2896
TOTAL	**3516**	**3516**	**3277**
Water Supplies			
Trinity River	357	357	341
Clear Creek	42	42	40
Sacramento River	3117	3117	2896
TOTAL	**3516**	**3516**	**3277**
SCARCITY	**0**	**0**	**0**

In the Base Case, the flows on the three river reaches with requirements always meet or exceed the minimum instream flow. This is also true for the Unconstrained Case. The minimum instream flows were not included in the water balance because they are not consumptive. The water required for the minimum instream flows can be used downstream to meet demands. For this reason, the consumptive environmental water requirements are only those of the refuge.

The other environmental water demand occurs at the Sacramento, Delevan and Colusa Wildlife refuges (Sacramento West Refuge). Historical annual average water deliveries form the basis for the Level 2 demands. However, there are periods when the entire surface water volume available to the refuge in the Base Case was less than the L2 demands. In these periods a modified L2 demand is delivered, which causes the refuge to experience scarcities. These scarcities, as well as the annual average demand are presented in Table A-17.

Table A-17: Sacramento West Refuge Water Budget

	Average	Drought
Refuge Level 2 Demands	120	120
Refuge Deliveries	106	106
SCARCITY	**14**	**14**

The deliveries to the refuge are modeled as fixed time series of deliveries in both the Base Case and the Unconstrained Case. The full L2 demands were not imposed in the Unconstrained Case. For the purpose of comparison, the modified L2 demands were used because of the lack of widely accepted environmental economic data.

It should be noted that the refuge requires approximately 93 taf/year. However, conveyance losses require that more water be diverted. Thus, 120 taf/year should be diverted to guarantee the required 93 taf/year at the refuge. However, due to the modified L2 demands used in CALVIN, only 106 taf/year is actually diverted, providing approximately 83 taf/year after losses.

In total, the environment experiences approximately 14 taf of scarcity on an annual average basis in the Base Case. That is roughly 10% of the total annual average demand. In the Unconstrained Case, the environment experiences the same scarcity (14 taf) per year.

Regional Water Values

Water Users' Willingness to Pay for Additional Water

Additional water is only needed in regions where the demand is not fulfilled. In these cases the water users will have some amount of money that they would theoretically be willing to pay to get an additional unit of water. The economic results from PRM in the Base Case are not applicable due to the highly constrained system. For that reason, the marginal willingness to pay for the agricultural users in the Base Case can only be considered on a regional level. The regional willingness to pay is taken as the highest marginal willingness to pay seen by any CVPM region. Region 1 results are presented in Figure A-12.

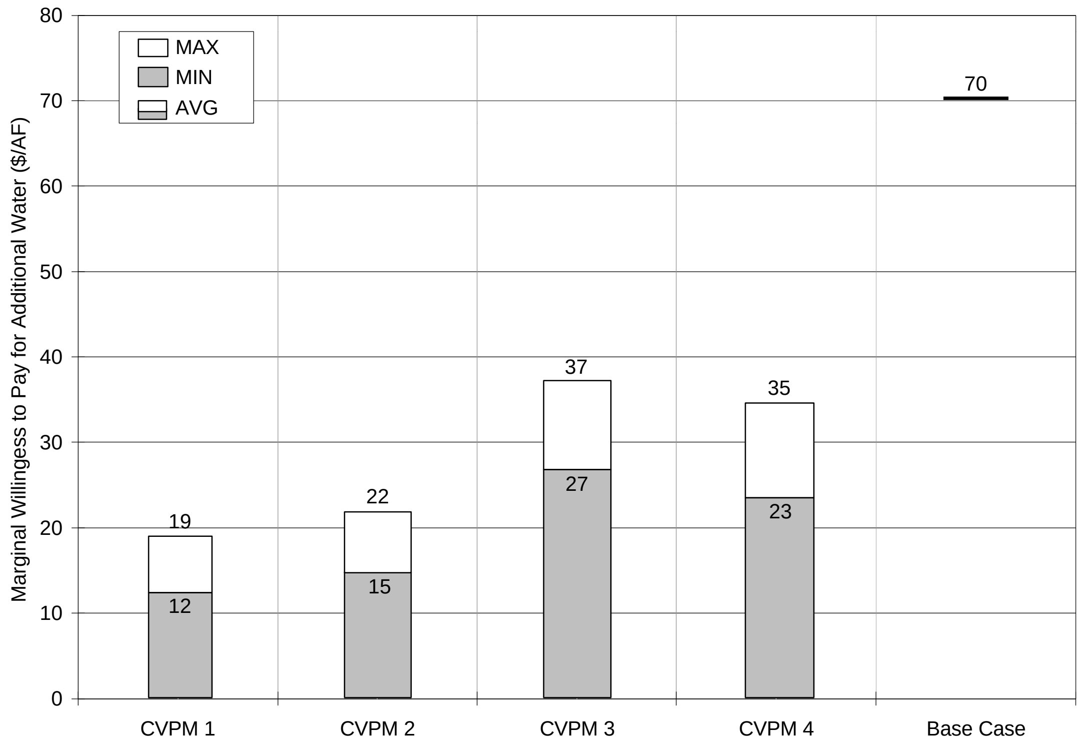

Figure A-12: Agricultural Marginal Willingness to Pay

In the Base Case, the marginal willingness to pay for an additional unit of water was approximately $70/AF. Due to the highly constrained deliveries in the Base Case, the marginal willingness to pay in the Base Case was taken as the highest marginal willingness to pay from any of the users.

In the Unconstrained Case, every region has peak marginal willingness to pay value (the maximum), which corresponds to periods of drought.   CVPM 1 has a small average marginal willingness to pay (approximately $12/AF), which reflects the 0.7% annual average scarcity that the region receives. The highest average willingness to pay occurs in CVPM 3 (which also the highest maximum willingness to pay). Note that at in all CVPM regions (in the Unconstrained Case) the minimum willingness to pay is $0/AF, which reflects periods when full deliveries are made.

The Base Case average marginal willingness to pay is higher than all of the peak marginal willingness to pay in the Unconstrained Case. This indicates that scarcities to the region, while slightly greater in volume, are not as severe economically as in the Base Case. The agricultural regions may still have periods of scarcities, but the costs of those scarcities (as benefits lost) are less. Therefore, the ideal market would better be able to handle the periods of droughts and scarcities than the current system, though in this case only slightly.

Demand for Inter-regional Transfers

There are no inflows into Region 1 from other regions. The entire supply of water to the region comes from inflows from creeks, river and reservoir releases.

On the other hand, Region 1 has three locations where water would flow into an adjacent region. In the Base Case the marginal value to reducing the outflows was approximately $118.9/af. In the Unconstrained Case, there is still significant value to reducing the required boundary flows, however the marginal values reflect the reduced scarcity in the region. Table A-18 presents the annual marginal value of the outflow requirements.

Table A-18: Marginal Value on Boundary Flows

Outflow Requirements	Base Case Average ($/AF)	Unconstrained Average ($/AF)
Sacramento River Diversion via drain RD1500	118.9	45.1
Sacramento River Flow to Region2	118.9	44.4
Knights Landing Diversion to Region 2	118.9	41.7

As expected, the marginal value of water decreases in the Unconstrained Case. The Unconstrained marginal values of water to Region 1 can be compared with the marginal values of water from Region 2 (from another regional model run) to indicate the desirability of inter-regional transfers (for these two regions only). Table A-19 presents a comparison of the marginal value of additional water in the Unconstrained Case to Region 2.

Table A-19: Inter-Regional Comparison of Marginal Values

Origin Node	Description	Region1 Annual Average ($/AF)	Region 2 Annual Average ($/AF)
D31	Sacramento River Diversion via drain RD1500	45.1	0.4
C301	Sacramento River Flow to Region2	44.4	0.0
C313	Knights Landing Diversion to Region 2	41.7	0.2

As seen in Table A-19, the value of an additional unit of water into Region 2 from Region 1 is less than the marginal value of the same unit of water in Region 1. This indicates that inter-regional transfers to Region 2 from Region 1 are unlikely on an average basis. However, this is does not mean that transfers from Region 1 to Region 2 are never likely to occur. Figure A-13 presents the difference marginal values of an additional unit of water for Region 1 and Region 2 (Region 1 marginal value minus Region 2 marginal value) at D31. Figure A-14 is the difference in marginal values at C301 and Figure A-15 is at C313.

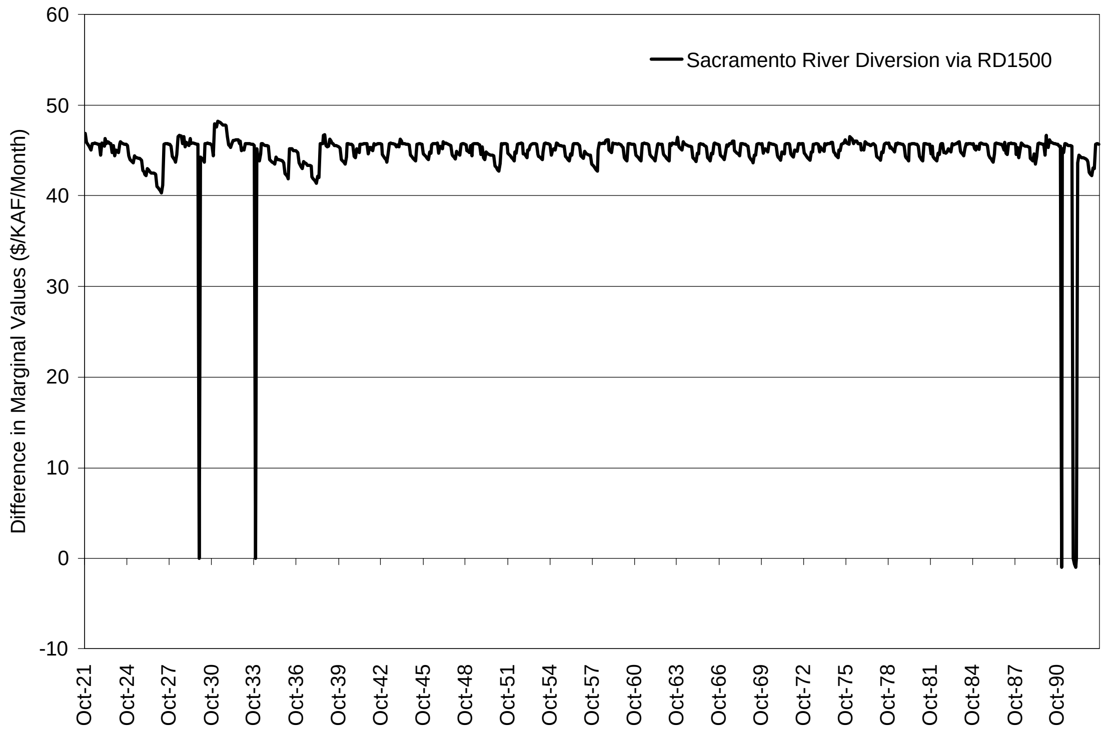

Figure A-13: Difference in Marginal Values at D31

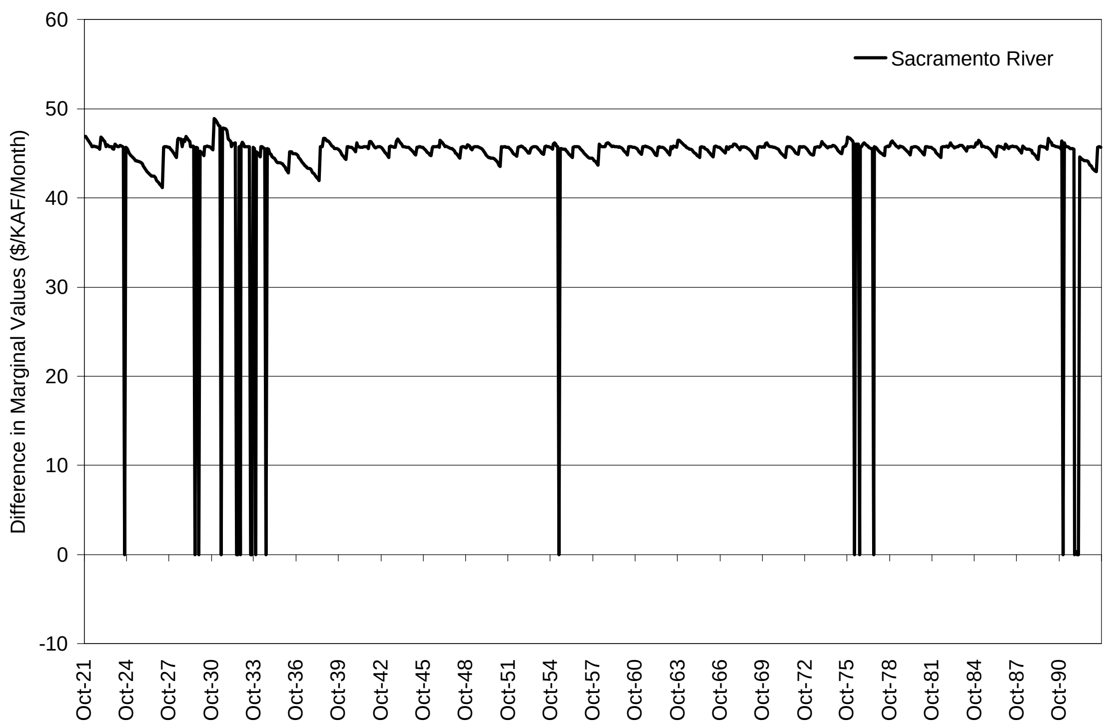

Figure A-14: Difference in Marginal Values at C301

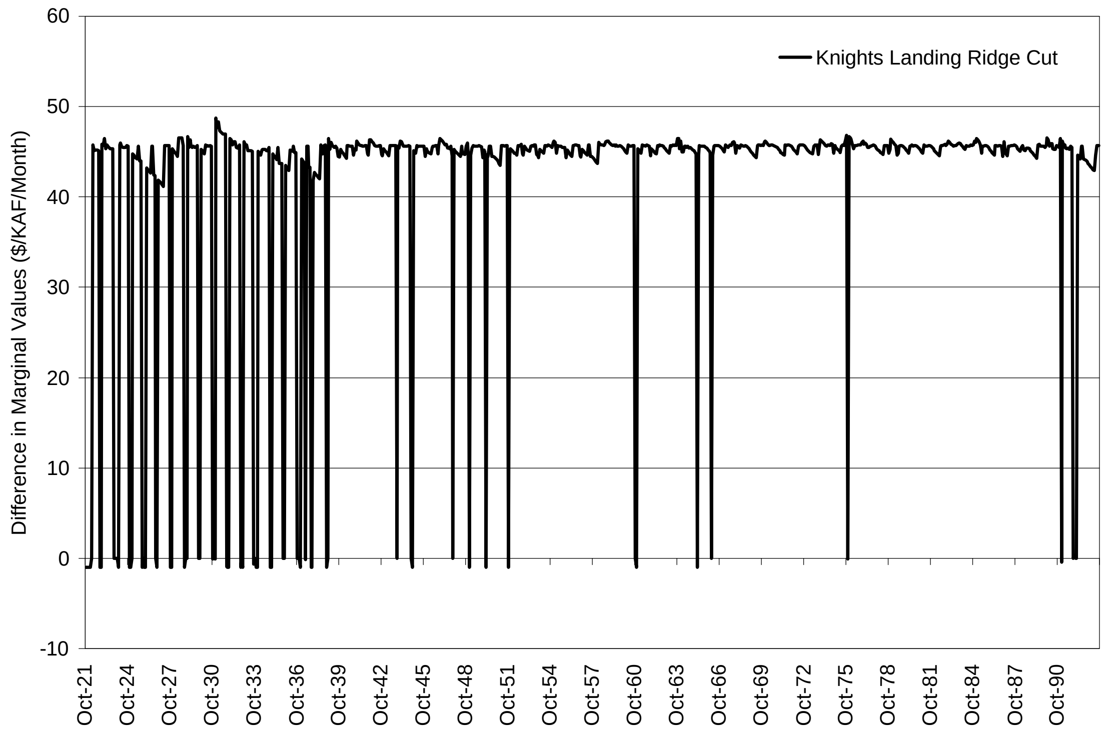

Figure A-15: Difference in Marginal Values at C313

The marginal value of water to Region 2 is never greater than the marginal value of water to Region 1 on the Sacramento River. However, there are 19 periods when the marginal values are approximately equal.

At the Sacramento River Diversion via Drain RD1500 to Region 2 there are three periods when the marginal value of water to Region 2 is greater than the marginal value of the water to Region 1. All three periods occurs during the 1987-1992 drought. For all three periods the difference is approximately less than $1/af/month. Additional, there are 4 periods when the marginal values are approximately equal.

There are 35 periods when the marginal value of water to Region 2 is slightly greater than the marginal value of water to Region 1 at the Knights Landing Ridge Cut. They seem to occur sporadically during the entire 72-year run, and are less than or equal to $1/af/month. There are also 30 periods when the marginal values are approximately equal.

<u>Shadow Values of Environmental Flows</u>

Region 1 has four locations were the minimum instream flow requirements are binding in the Unconstrained Case. In these reaches of the Sacramento and Trinity Rivers, the required minimum flows are causing scarcities to occur to the economically driven agricultural regions. The four reaches are:

- The flows in the Trinity River below Lewiston Lake.

- The flows in the Sacramento River below Keswick.
- The flows in Clear Creek below Whiskeytown Lake.
- The flows at the Sacramento River Navigation Control Point.

In all of these reaches the shadow values from the Unconstrained Case indicate that the agricultural economy of the entire Upper Sacramento Valley would benefit from lower the minimum instream flows, especially during the critically dry periods. Figure A-16 presents the shadow values for three of the environmental instream flow requirements for the entire 72-year run. Figure A-17 presents the shadow values for three of the environmental instream flow requirements during the 1929 to 1934 drought. Figure A-18 presents the shadow values from the 1976 to1977 drought. And finally, Figure A-19 presents the shadow values for the 1987 to 1992 drought. From a water supply perspective, as represented in this model, these instream flow constraints appear to pose modest and infrequent economic costs. The larger and more persistent shadow values for the Trinity River Requirement appear in Figure A-20. It should be noted that that shadow values do not include hydropower values, which can be considerable on the Clear Creek and Trinity River requirements.

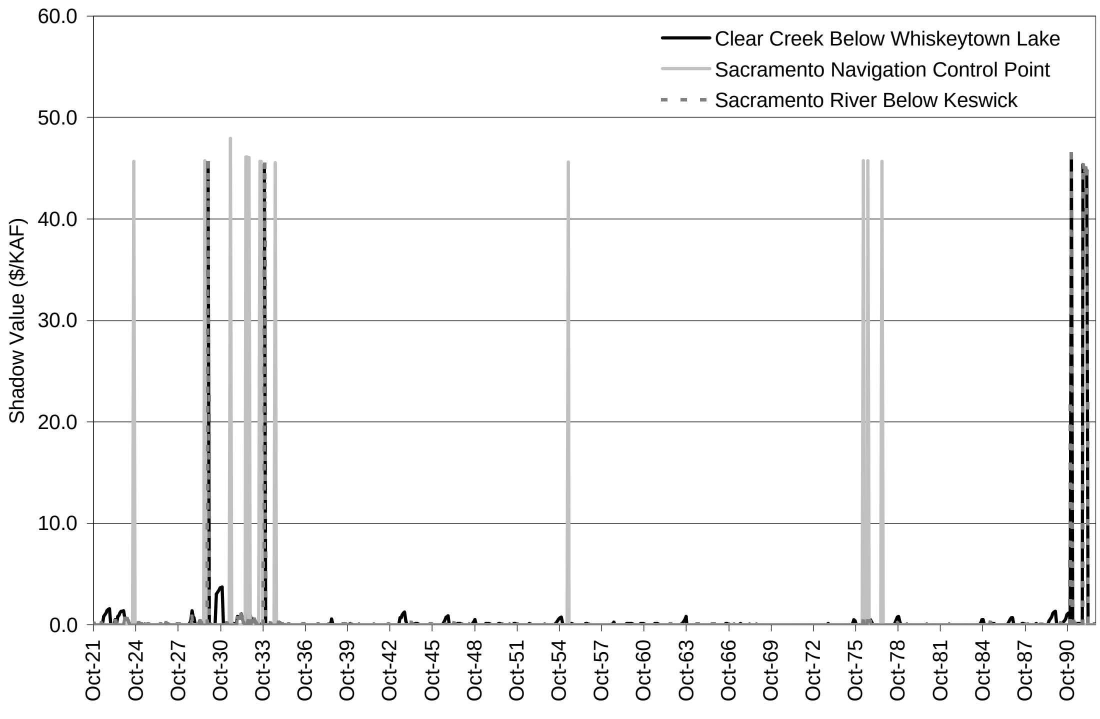

Figure A-16: Environmental Shadow Values

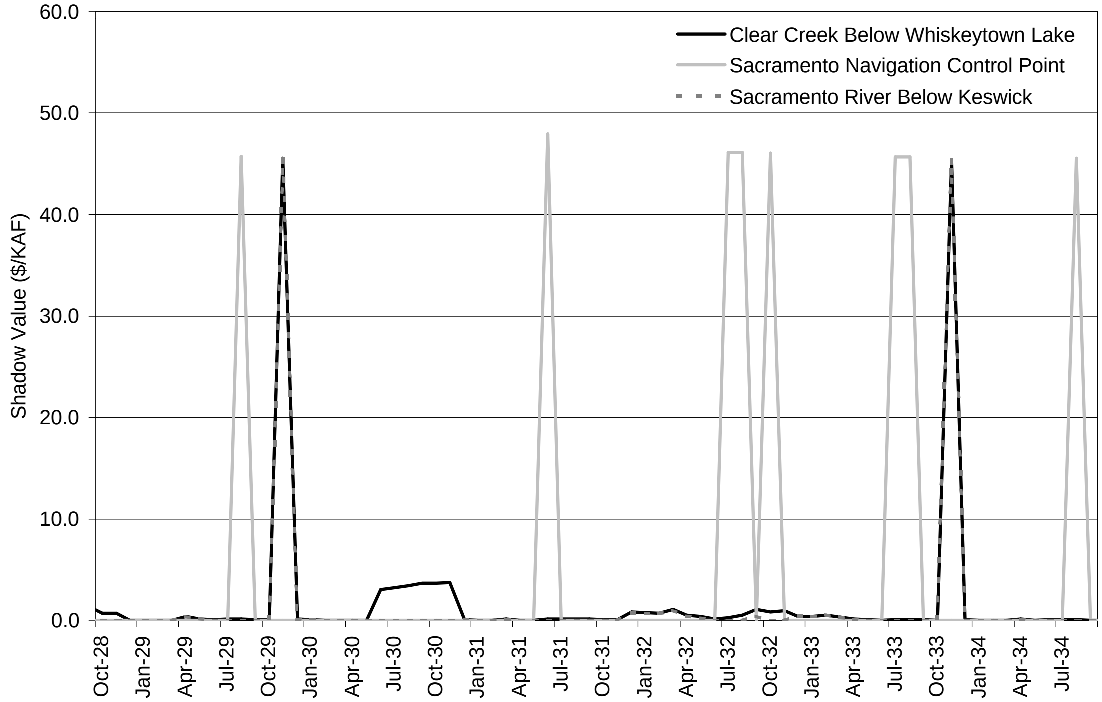

Figure A-17: Environmental Shadow Values for 1929-1934 Drought

Shadow values are consistently high on the minimum instream flows during the 1929-1934 drought. During this drought, the peak shadow values occur during the winter months (October through January) for both Sacramento River below Keswick and Clear Creek below Whiskeytown Lake. During the fall and winter months the shadow values are high because CALVIN would like to be able to retain more water in storage in anticipation of the summer demands. In the summer months, the shadow values on the Navigation Control Point are high because CALVIN would like to have that water available for upstream demands.

The shadow values on Clear Creek below Whiskeytown and on the Sacramento River below Keswick minimums are not high compared to those of the Navigation Control Point minimums during the 1976-1977 drought. During the agricultural months (March through May), there would a net benefit to the system to reduce the minimum instream flows at the Sacramento River Navigation Control Point. This would allow more water to be re-allocated to the CVPM demand regions. There are also a couple of smaller peaks during the during the late summer months to reduce the minimums on the upper Sacramento River minimums. This would also allow more water to be re-allocated to the upstream CVPM regions.

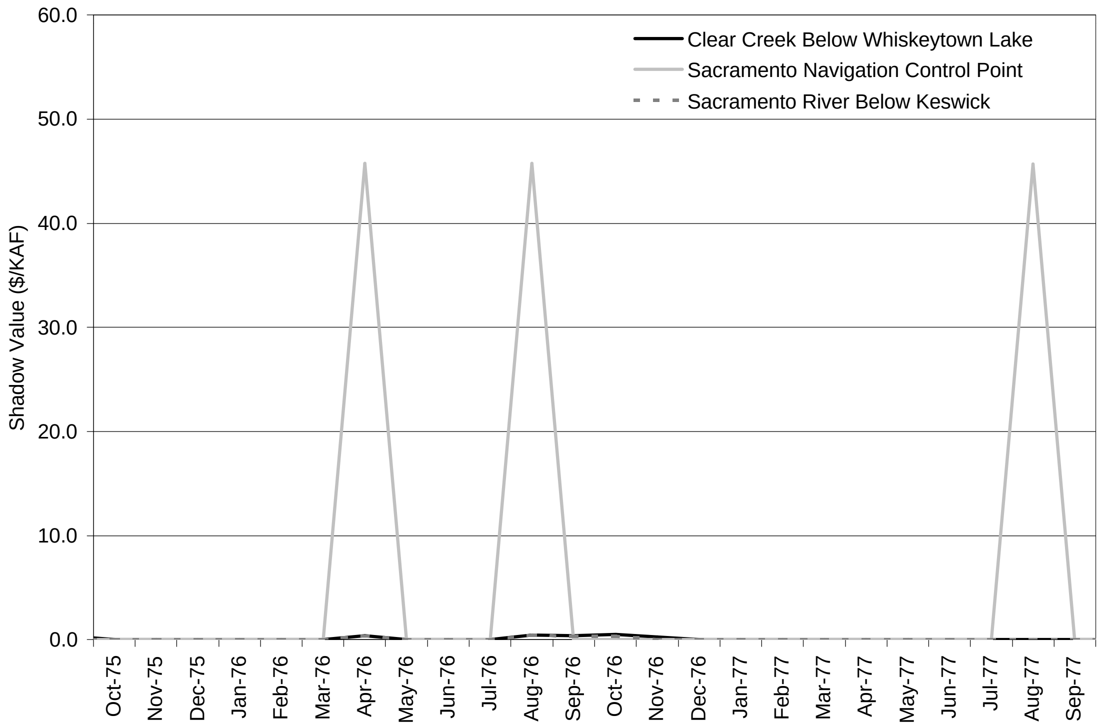

Figure A-18: Environmental Shadow Values for 1976-1977 Drought

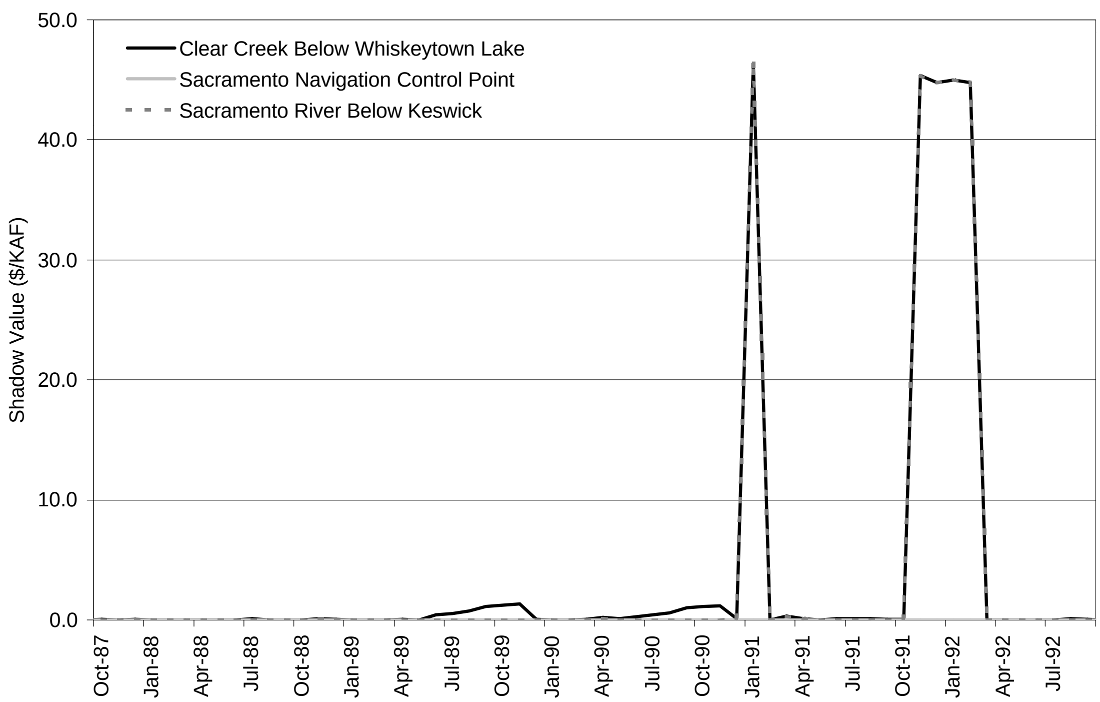

Figure A-19: Environmental Shadow Values for 1987-1992 Drought

The shadow values on the minimum instream flows for the1987-1992 drought occur primarily in the late fall and winter months (November through February). The two upper Sacramento River minimums have almost the same shadow value during the peak periods. There would over $45/AF/month of value to reduce the minimums on Clear Creek and in the Sacramento River during the winter of 1991. There would also be over $44/AF/month of value to reducing the minimums at the end of 1991 and through the beginning of 1992. Again CALVIN would like to retain more water in storage in anticipation of the upcoming dry summer months. The downstream minimum (the navigation control point) is not binding during the 1987-1992 drought and as a result does not have a significant marginal value.

The required Trinity River flows have a consistently high shadow value, indicating that by reducing them there would be economic benefit to the entire system in every month (Figure A-20). Note that the shadow values would be even higher if hydropower had been included. The shadow value peaks during the 1929 drought and show increases during the 1976 drought and the 1987 drought as well.

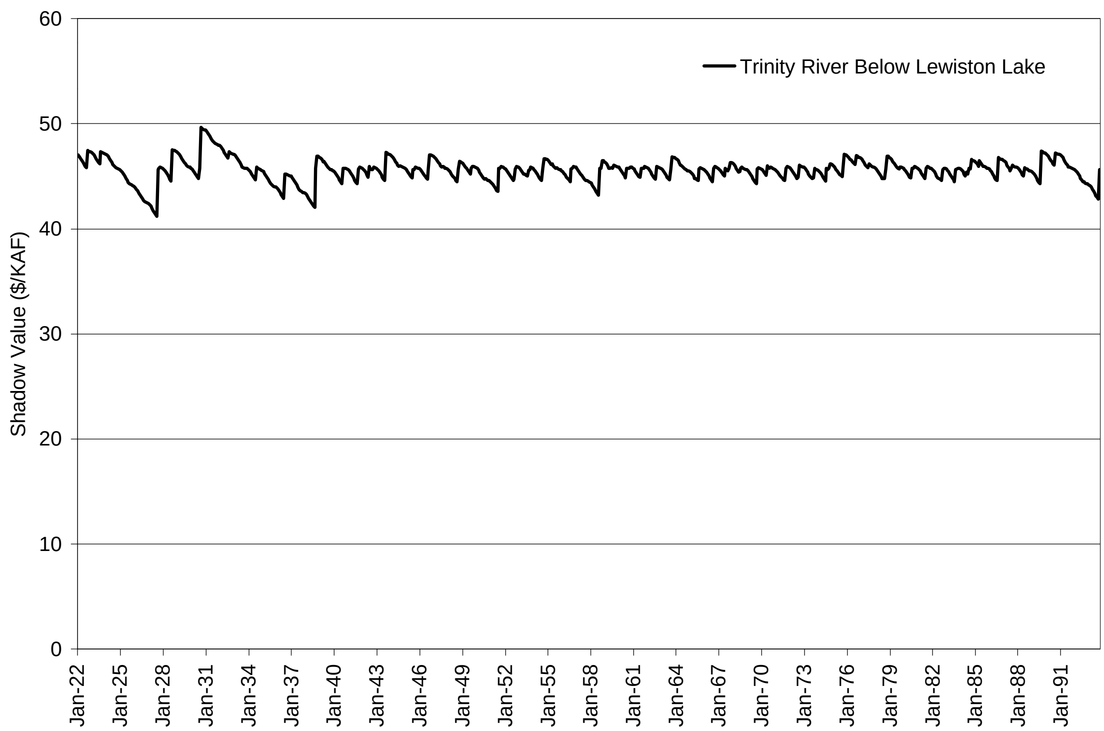

Figure A-20: Environmental Shadows for Trinity River Requirements

The Trinity River requirement has the greatest effect on the system because it limits the volume of water that can be diverted from Clair Engle to Whiskeytown Lake. Also, unlike the other environmental requirements, the Trinity requirement can only be satisfied by releases from Clair Engle and Lewiston Lake. If the requirements were lowered, the additional water could be used to fulfill scarcities in deliveries to the CVPM demands and reduce groundwater-pumping costs.

The maximum shadow values on the environmental minimums occur during the drought years. The maximum, minimum and average shadow values are presented in Table A-20.

Table A-20: Environmental Shadow Values

	Maximum ($/AF)	Minimum ($/AF)	Average ($/AF)
Clear Creek to Sacramento River	46.4	0	0.5
Sacramento Navigation Control Point	48.0	0	0.7
Sacramento River below Keswick	46.4	0	0.4
Trinity River below Lewiston Lake	49.6	41.2	45.6

On a monthly basis, a reduction of the minimums on Clear Creek, Sacramento River and Navigation Control Point would only yield minimal benefits to the system. On the other hand, reduction of the Trinity River minimums would yield significant benefits, since this environmental constraint inflexibly reduces water availability. The maximum benefits to reducing the minimums (approximately $45/af) are consistent with the agricultural users' willingness to pay for an additional unit of water and with the marginal value of reducing the required outflow from the system.

The other source of environmental water demand is the Sacramento West Refuge. Despite delivering less than the actual L2 requirements in almost every month there is some value to lowering the refuge demands even more. The average value is $41.8/AF, with a peak value of $45.4AF. The shadow values on the refuge indicate that reductions in the requirements, as with the Trinity River, would produce substantial benefits to Region 1. There are only six periods when the shadow value is zero (Figure A-21).

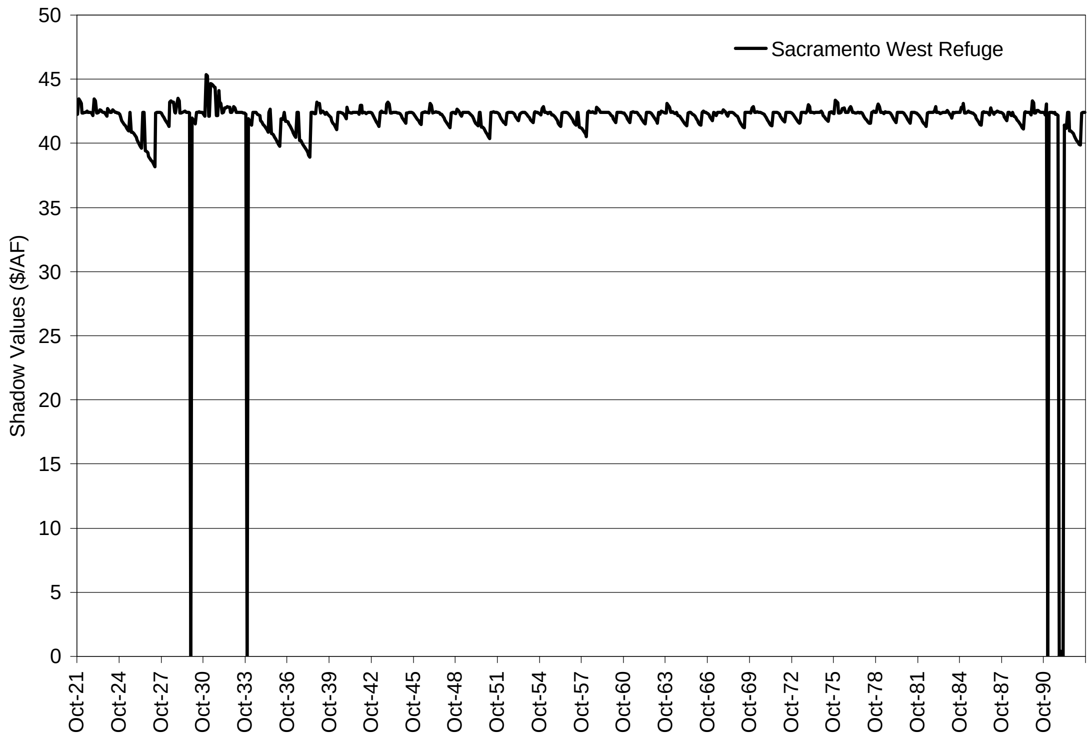

Figure A-21: Sacramento West Refuge Shadow Values

As expected the six zero values occur during the non-agricultural months (thrice in November, twice in January and once in February). In the remaining periods there is some value to reducing the Refuge flows. Figure A-20 indicates that Region 1 would benefit the most from reducing the flows during the droughts (especially the 1929-1934 drought).

POTENTIAL FOR CHANGES

The results for the Upper Sacramento Valley regional CALVIN model can be used to identify locations for facility expansion (with their potential economic values), identify opportunities for improved surface and groundwater operations, examine the economic impacts of environmental water requirements, and identify promising water transfers.

Promising Areas for Facility Expansion

"Hot spots" of potentially valuable increases in storage and conveyance capacity can be identified from the marginal and dual values included in the model results. The shadow values presented in the following section represent the economic value of facility expansion to water supply only and only in the Upper Sacramento Valley. These values do not include value of hydropower for increasing storage capacities, increasing head and operational flexibility to release at peak times. Also the perfect foresight operations of CALVIN can depress the economic values of facilities overall.

Storage Hot Spots

There are four surface water storage facilities in Region 1 (Table A-21). They are Lake Shasta, Clair Engle Lake, Whiskeytown Lake and Black Butte Lake. The largest is Lake Shasta and the smallest is Black Butte. In the Unconstrained Case, all four reservoirs experience periods when expanded storage would be beneficial to the system.

Table A-21: Region 1 Reservoirs

	Capacity (taf)	Max Flood Pool (taf)	Dead Pool (taf)
Shasta	4552	1300	116
Clair Engle	2447	597	400
Whiskeytown	240	34	10
Black Butte	150	93	10

Lake Shasta (SR-4) is largest surface water reservoir in the system. It has a storage capacity of 4.5 MAF, but up to 1.3 MAF can be required for flood protection during the wet months. The dead pool storage volume is 116 taf. In general there would be small water supply benefits to raising Shasta and allowing additional storage. The annual average expected benefit of increasing the storage capacity of Shasta by one acre-foot would be $1.4. In general peak shadow values occur during the winter months just before droughts, when increased storage capacity might be filled for later use (Figure A-22). There is no annual expected benefit of decreasing the dead pool storage volume by one unit. Shasta is the largest reservoir in the state and as a result withdrawals that empty it are unlikely for these two regional model runs.

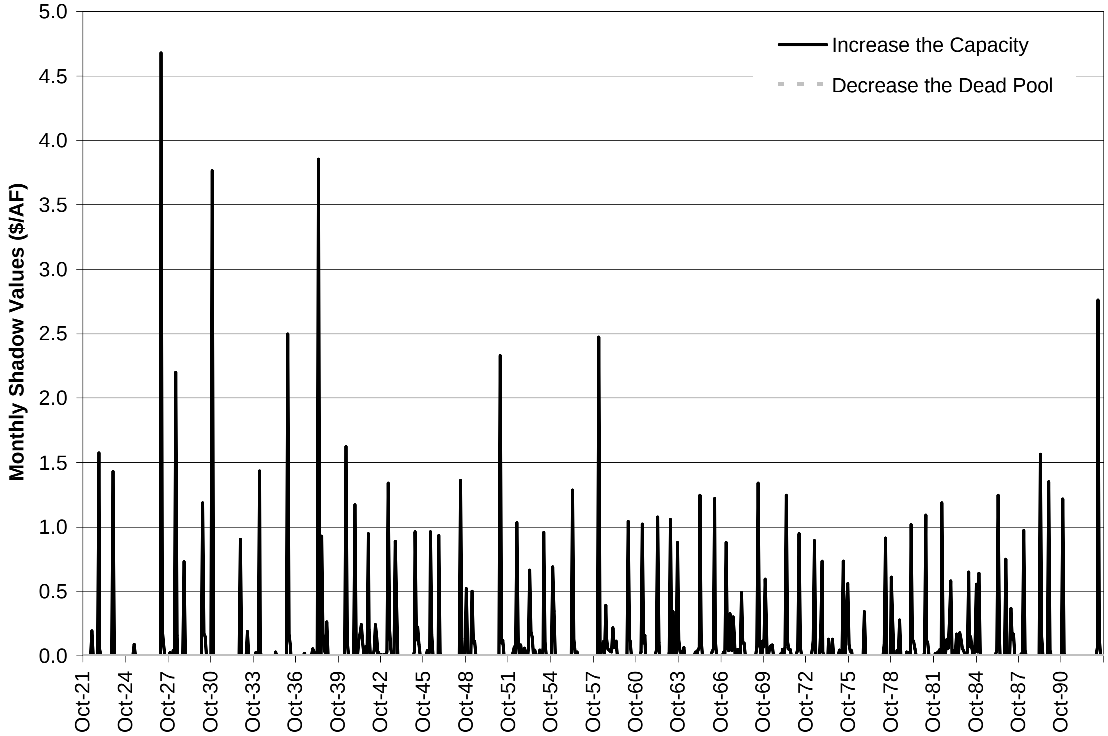

Figure A-22: Monthly Shadow Values for Lake Shasta

Clair Engle is the next largest surface water reservoir. It has a maximum storage capacity of 2.5 MAF, but up to 0.6 MAF can be required for flood protection. The dead pool storage volume is the highest of all the surface water reservoirs in Region 1 at 400 taf. However, even with the large dead pool storage volumes, withdrawals that lower the lake to the minimum volume are unlikely to occur. In the Unconstrained alternative, there is no value to decreasing the dead pool storage volume. On the other hand, increased capacity provides small benefits to the region. The annual average expected benefit of increasing the storage capacity of Clair Engle by one acre-foot would be $1.6. Similar to Lake Shasta, Clair Engle has high peak shadow values during the drought years (Figure A-23).

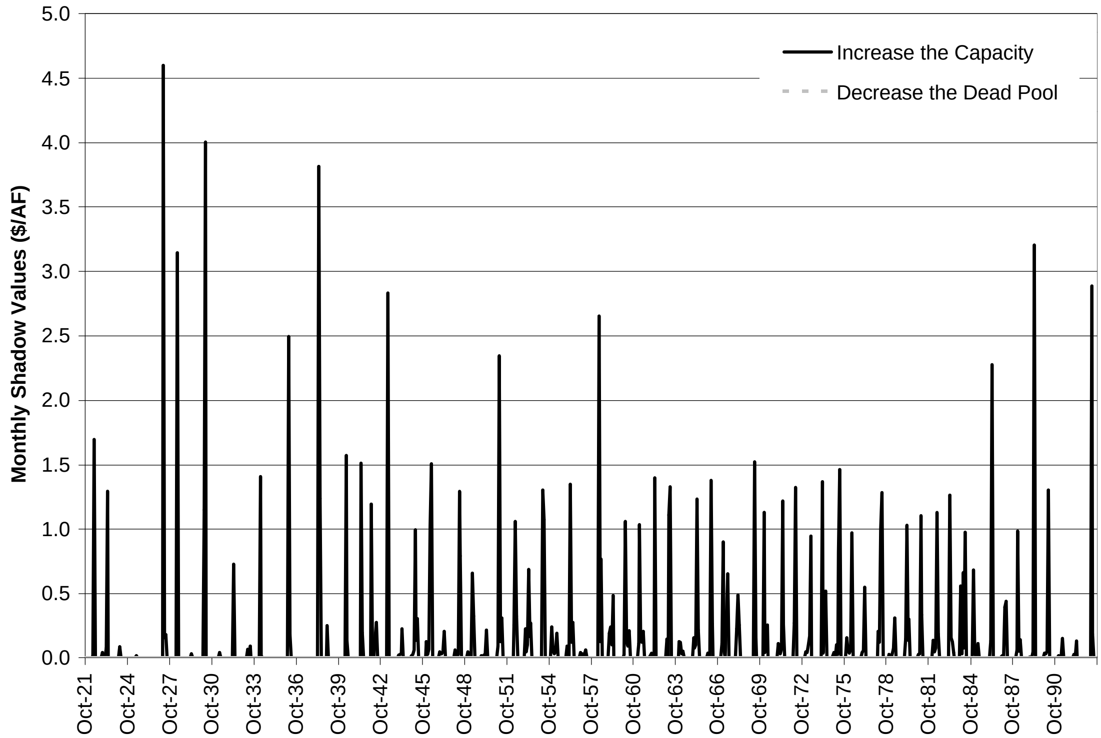

Figure A-23: Monthly Shadow Values for Clair Engle

Whiskeytown Lake has a maximum capacity that ranges from 240 taf during the summer to 206 taf in the winter. The dead pool storage volume is 10 taf. The annual expected benefit from increasing the capacity Whiskeytown by one acre-foot is $0.9. In general, the greatest benefits are derived during the spring months (Figure A-24). CALVIN, with perfect foresight, wants to fill the reservoirs up as much as possible to have water available during the upcoming dry summer months. Whiskeytown, unlike Shasta and Clair Engle, experiences periods when the withdrawals reach the bottom of the usable water supply. There would be a small annual expected benefit of $0.6 derived from lower the dead pool capacity by one acre-foot.

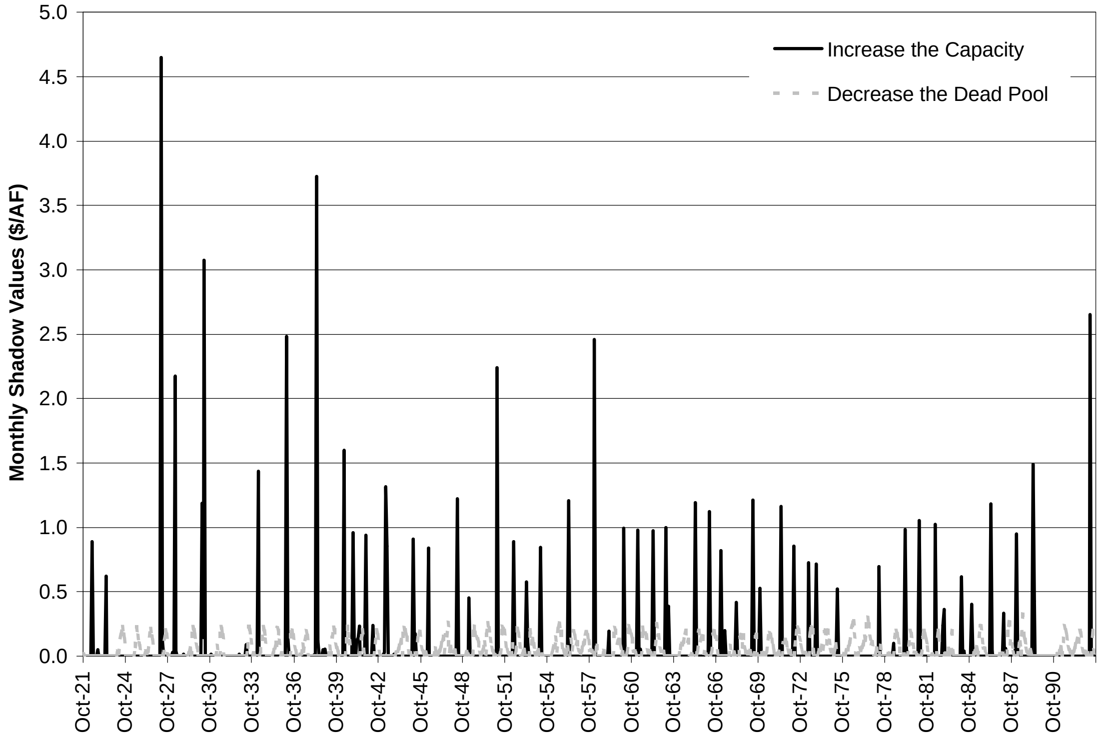

Figure A-24: Monthly Shadow Values for Whiskeytown Lake

The last reservoir is Black Butte Lake, which provides water to CVPM 2, 3 and indirectly 4. It is the smallest of the reservoirs with a maximum capacity of 150.5 taf and dead pool storage of 10 taf. Because it is a major supplier, it is frequently drained to the dead pool. The annual expected benefit of increasing Black Butte Lake's capacity by one acre-foot is $1.4. The expected annual benefit of decreasing the dead pool storage by one acre-foot is $1.4. Releases draw the storage down to the dead pool during the summer months and fill it to capacity during the winter months (Figure A-25).

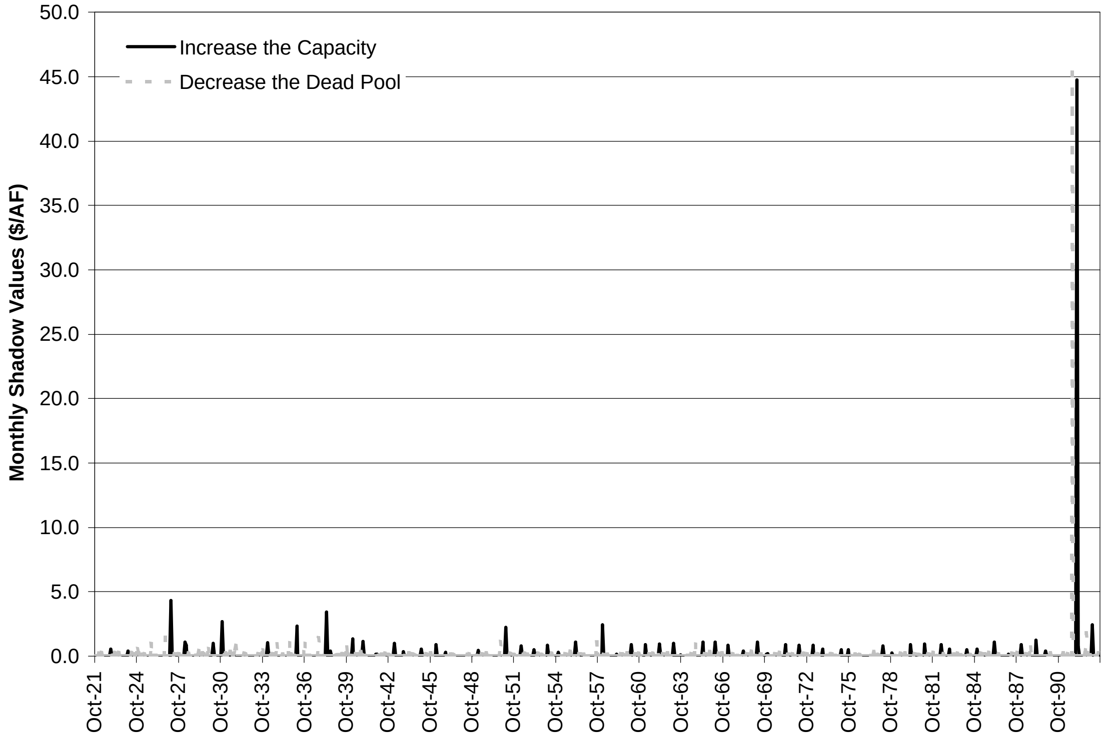

Figure A-25: Monthly Shadow Values for Black Butte Lake

Table A-22 summarizes the above results. If reservoir expansion were to be considered, then the most beneficial location is Black Butte. There is a benefit to both increasing the capacity and decreasing the dead pool. Increasing the capacity of Clair Engle would yield the greatest benefit to the system ($1.6/AF annually), while Whiskeytown has the least ($0.9/AF annually). Overall, the system would benefit more from increased capacity of surface water reservoirs rather than decreasing the dead pool storage. However, the benefits are relatively minimal (as compared to reductions in minimum in stream flows or refuge demands).

Table A-22: Annual Shadow Values for Region 1 Reservoirs

	Increase the Capacity ($/AF)	Decrease the Dead Pool ($/AF)
Shasta	1.4	0.0
Clair Engle	1.6	0.0
Whiskeytown	0.9	0.6
Black Butte	1.4	1.4

The surface water reservoirs storages are constrained in the Unconstrained Case to match the ending storages in the Base Case. For all four reservoirs there is about $45/af value to reducing the end of period storage constraint by one unit.

Table A-23: End of Period Shadow Values for Region 1 Surface Water Basins

	Reduce End of Period Storage ($/AF)
SR-1	45.5

SR-3	45.9
SR-4	45.5
SR-BBL	45.5

The other storage locations in Region1 are the groundwater basins. As stated earlier, the end-of-period groundwater storages in the Base and Unconstrained Cases are constrained to be the same for all four basins. During the 72-year run, the capacities of the groundwater basins are not binding constraints. However, there are economic benefits to reducing the ending storage constraints by one acre-foot (Table A-24) in all four basins.

Table A-24: End of Period Shadow Values for Region 1 Groundwater Basins

	Reduce End of Period Storage ($/AF)
GW-1	17.2
GW-2	21.0
GW-3	24.3
GW-4	31.2

The shadow values on the end-of-period storages indicate that CALVIN would like to be able to pump more water from the groundwater basin making additional surface water available. As stated earlier all CVPM regions experiences scarcities that can be, in part, attributed to the groundwater end-of-period constraint. The largest benefit would come from reducing the end-of-period constraint in GW-4. The cost of groundwater pumping in CVPM 4 is less than the scarcity penalty, but the end-of-period storage constraint prevents additional pumping to fulfill demand.

Conveyance Hot Spots

Region 1 has six major conveyance facilities, but only four have maximum upper bound capacities. The Clear Creek Tunnel, Spring Creek Power Conduit, and Tehema-Colusa Canal have no lower bound and monthly varying upper bounds. The Corning Canal has a constant upper bound. The Glenn-Colusa Canal and Colusa Basin Drain has neither upper nor lower bounds. Only two of the major artificial conveyance systems have binding upper constraints.

The greatest benefits from expanding the conveyance capacity come from expansion of the Corning Canal and Clear Creek Tunnel. The Corning Canal supplies water to CVPM 2. The maximum benefit that could be derived is $55.1/year by expanding the capacity by 1 acre-foot/month. On average, the upper bound capacities for the Corning Canal are binding, especially during the summer growing months. The monthly average benefit from expansion of the Corning Canal is $2.1/year to expand the capacity by 1 acre-foot/month. In general this means there would be benefits to the system of expansion of the Corning Canal in both normal and dry years.

Clear Creek Tunnel has both periods when the Tunnel is filled to capacity and periods when the tunnel is dry. There is a maximum benefit of $31.4/year to the system if the tunnel capacity were expanded by 1 acre-foot/month. The maximum benefits of increased capacity occur in the non-drought years. On an annual average basis, there is a $2.1/year benefit of increasing the capacity of the tunnel by 1 acre-foot/month. Therefore increased capacity of Clear Creek Tunnel would only yield minimal benefits to the system. Details are presented in Table A-25.

Table A-25: Annual Conveyance Shadow Values (Increasing Capacity by 1 acre-foot per month)

	Maximum ($/AF/year)	Annual Avg. ($/AF/year)
Clear Creek Tunnel	31.4	0.6
Spring Creek Power Conduit	0.1	0.0
Tehema-Colusa Canal	0.0	0.0
Corning Canal	55.1	2.1

There are also some values to decreasing the lower bound by one unit on all of the conveyance facilities. Decreasing the lower bound indicates that CALVIN would like to be able to put reverse flow through the conveyance facility. See Table A-26 for the annual benefits of reducing the constraints by one acre-foot per month.

Table A-26: Annual Conveyance Shadow Values (Decreasing Lower Bound by 1 acre-foot per month)

	Maximum ($/AF/year)	Annual Avg. ($/AF/year)
Clear Creek Tunnel	46.5	1.0
Spring Creek Power Conduit	45.0	1.2
Tehema-Colusa Canal	24.0	0.2
Corning Canal	38.2	0.2

The Clear Creek Tunnel and Spring Creek Power Conduit have almost the same maximum (and annual average) benefit of decreasing the lower bound by one unit. This indicates that the model would like to be able to put reverse flow through the tunnel. The Spring Creek Power Conduit goes from Whiskeytown Lake to the Sacramento River below Keswick and the Clear Creek Tunnel goes from the Trinity River at Lewiston to Whiskeytown Lake. A reverse flow would bring Sacramento River water through the tunnel to Whiskeytown and from there it could be used to fulfill CVPM 1 demands, which were not met in full in the Unconstrained Case or continue to the Trinity River. On average there is $1.2/AF/year and $1.0/AF/year to allowing reverse flow through the conduit and tunnel, respectively.

An interesting note on the conveyance facilities is that while there are not large economic benefits from increasing the capacity, there are a significant number of times that the flows within the artificial channels are at the upper bounds. The Tehema-Colusa and Corning Canals are at their maximums during the summer months, while the Spring Creek Power Conduit and Clear Creek Tunnel reach the maximum during the winter months. Table A-27 presents the number of times that each of the facilities are at their maximums for a given month.

Table A-27: Periods of Maximum Capacity Flows in a Conveyance Facility

	Clear Creek Tunnel	Spring Creek Power Conduit	Corning Canal	Tehema-Colusa Canal to CVPM 3	Tehema-Colusa Canal to CVPM 2

January	35	27	0	0	0
February	22	21	0	0	0
March	19	15	0	0	38
April	13	11	63	33	64
May	3	2	60	47	61
June	1	8	48	31	49
July	1	0	58	46	58
August	1	0	61	39	61
September	8	0	62	1	63
October	15	0	52	0	52
November	26	3	0	0	0
December	30	11	0	0	0
Total	174	98	404	197	446

The distribution reflects the location and purpose of each facility. The Corning and Tehema-Colusa are agricultural delivery facilities. The maximum capacity flows during the summer agricultural months would indicate that the model is attempting to deliver as much surface water from the Sacramento River to the agricultural region as possible.

On the other hand the Clear Creek Tunnel and Spring Power Conduit are not primary delivery facilities to the agricultural regions. The maximum capacity flows during the winter months indicate that the model is trying to deliver water from Clair Engle and to a lesser extent, Whiskeytown, to the Sacramento River. The most likely cause is that the model is trying to meet the Sacramento River minimum instream flows without releasing water from Shasta.

Operations and Conjunctive Use Opportunities

Re-operation of the surface water reservoirs and increased conjunctive use opportunities alter the way water is distributed and stored given the existing infrastructure. It should be noted that the CALVIN model results are idealized in the sense of perfect foresight, and do not reflect hydropower, water temperature, and real time flood control operations. The results are interesting and useful, but are not conclusive from the broader operational context.

Surface Water Operations

Between the Base Case and the Unconstrained Case, the volume of surface water used by the Region 1 did not change significantly (from 2221 taf/year to 2202 taf/year). However, the distribution of surface water and operations of the reservoir differed between the two model alternatives.

The surface water reservoirs maintained a higher overall storage volume in the Unconstrained Case, which allowed for more water to be available during the critically dry periods. The average surface water reservoir storage volume was 5.1 MAF in the Base Case and 5.6 MAF in the Unconstrained Case.

The major surface water reservoirs, Shasta and Clair Engle, were kept fuller even during the drought periods. The two smaller lakes, Whiskeytown and Black Butte were filled and drained more often.

Whiskeytown experiences the greatest change in operations. In the Base Case the storages had a repeating annual pattern. It was filled to capacity (240 taf) during the summer months and then released water in the winter months. In the Base Case it appears that Whiskeytown was operated primarily for flood control. In the Unconstrained Case, Whiskeytown has much more erratic storage levels. There are periods when the storage reaches the minimum and periods when the storage is nearly full. In general the greatest storage volumes occur during the winter and spring months. Releases occur primarily in the summer and fall, though it is not always the case. In the Unconstrained Case it is operated to meet the agricultural demands in the region as well as provide flood control.

Individually the CVPM regions reacted differently in the Unconstrained Case compared to the Base Case. CVPM 1 and 3 increased the amount of surface water they used to fulfill demands, while CVPM 2 and 4 used less.

Conjunctive Use Operations

Conjunctive use refers to the use of a combination of groundwater and surface water to meet a regions demand. In both the Base and Unconstrained Cases, all of the CVPM regions used both surface water and groundwater. In both cases the largest user of groundwater (by percent of demand) was CVPM 2 and the smallest was CVPM 3. All of the urban demands are met by groundwater.

In the Unconstrained Case, CVPM 1 withdrew the same amount of groundwater as in the Base Case. CVPM 2 increased the volume of groundwater it pumped, but decreased the percent of the demand that the groundwater fulfilled. Only CVPM 3 and 4 decreased the volume of water withdrawn from the groundwater basin. A comparison of surface water and groundwater consumption for the Base and Unconstrained Cases is presented in Table A-28.

Table A-28: Conjunctive Use in Region 1

	Base Case			Unconstrained Case		
	Surface Water (taf/yr)	Groundwater (taf/yr)	SW/GW[a] (%)	Surface Water (taf/yr)	Groundwater (taf/yr)	SW/GW[a] (%)
CVPM 1	117	36	76/24	116	36	76/24
CVPM 2	131	508	20/80	168	518	25/75
CVPM 3	1131	338	77/23	1141	335	77/23
CVPM 4	673	299	69/31	618	296	56/27
REGION 1	**2052**	**1181**	**63/37**	**2043**	**1185**	**63/37**

[a] SW/GW (%) refers to the percentage of delivery from a surface source (SW) and the percentage of delivery from groundwater (GW). ex. CVPM 1 Base Case: 117/(117+36)=76% and 36/(117+36)=24%.

Groundwater re-charge is of major importance to the lasting sustainability of an aquifer. Areas that withdraw, but do not re-charge the aquifer at an equal rate, suffer from declining groundwater tables and decreasing yield. However, the end-of-period groundwater storage was constrained to be the same in both modeling alternatives.

Due to the cost of groundwater pumping it is only efficient to pump when the cost of the pumping is less than the value of the crops. Because the Base Case replicates the current infrastructure, contractual agreements, and legislative requirements, this would indicate that certain CVPM regions are being subsidized. CVPM 1 experiences minimal scarcities in the Base Case. The amount of scarcity corresponds to the point where the cost of groundwater pumping exceeds the value of the. In a market, farmers would not be willing to purchase additional units of water at a cost benefit.

Groundwater pumping costs are fixed values and do not vary with depth of pumping as they would in practice. As a result, regions such as CVPM 4 can empty the aquifer, which would not happen in the field. Also the groundwater basins are modeled as isolated storage units with no dynamic interaction between them.

Another issue with groundwater use in Region 1 is that in practice not all water users have access to surface water. In cases where a user does not have access to surface water, groundwater must be used. The result is that every region would have some amount of groundwater pumping. Table A-29 presents the minimum groundwater withdrawals that a region would need to make.

Table A-29: Minimum Groundwater Pumping

	Minimum Annual Average Withdrawals (taf/year)[a]	Unconstrained Annual Average Withdrawals (taf/year)[a]
CVPM 1	28.2	36.5
CVPM 2	508.5	517.8
CVPM 3	225.2	334.7
CVPM 4	163.0	295.7

[a] Note that the minimum withdrawals are reported in taf per calendar year (January to December).

In the Unconstrained Case, all four CVPM regions withdraw more groundwater than the minimum from the Base Case. Further details regarding groundwater pumping minimums are presented in Chapter 5: Limitations.

Cooperative Operations

The Unconstrained Case indicates that Upper Sacramento Valley farmers could benefit from an ideal regional water market. Regional scarcities could be significantly reduced and system reliability could be improved. However for this to occur, the CVPM regions within Region 1 must work together. Certain CVPM areas must be willing to incur increased operating costs and/or scarcity costs.

CVPM 1, 2 and 3 would see a net benefit of having an ideal water market established. The greatest benefit would come to CVPM 2. Both the scarcity costs and operating costs would decrease. CVPM 1 and 3 would see an increase in one or the other of the costs. CVPM 1 has a higher scarcity cost, but a lower operating cost. CVPM 3 has a higher operating cost, but a lower scarcity cost. CVPM 4, on the other hand, sees an increase in both their operating costs and their scarcity costs. Table A-30 presents the scarcity costs and operating costs for each of the CVPM regions in an average year.

Table A-30: Costs by CVPM Region

	Base Case			Unconstrained Case			
	Operating	Scarcity	**Total**	Operating	Scarcity	**Total**	**DTotal**

	Costs ($10^6)	Costs ($10^6)	**Costs ($10^6)**	Costs ($10^6)	Costs ($10^6)	**Costs ($10^6)**	**Costs ($10^6)[b]**
CVPM 1	1.1	0.0	**1.1**	1.1	0.0	**1.1**	**0.0**
CVPM 2	14.3	3.5	**17.8**	14.6	0.2	**14.8**	**3.0**
CVPM 3	8.0	3.1	**11.2[a]**	8.0	2.9	**10.9**	**0.3**
CVPM 4	4.8	0.0	**4.8**	4.7	2.1	**6.8**	**-1.1**
Region 1			**34.9**			**33.7**	**1.2**

[a] Values may not add up do to rounding.
[b] A positive value indicates that there was a decrease in the costs from the Base Case to the Unconstrained. A negative indicates that costs increased from the Base Case to the Unconstrained.

CVPM 4 would incur an increased cost of $1.1 million per year under the ideal market. CVPM 1 sees almost no change in the costs from Base Case to the Unconstrained Case. The other two CVPM regions would see an increase in their net benefits if the market were imposed. The overall region would see a $1.2 million per year benefit.

For the Upper Sacramento Valley Region to benefit, CVPM 2 would have to increase their surface water consumption and increase their reliance on groundwater. CVPM 1 would have to decrease their surface water consumption, and keep their groundwater pumping at the same level. CVPM 3 would increase surface water consumption and decrease groundwater pumping. Finally CVPM 4 would decrease both their surface water and groundwater consumption. This would mean that CVPM 2 would have to be willing to shoulder increased operating costs with the expectation that scarcity costs would decrease. And CVPM 4 would have to be willing to incur increased scarcity, so that the rest of the Upper Sacramento Valley would see a net improvement in total costs.

Environmental Requirements

Environmental minimum instream flows and refuge demands have a significant impact on water distribution and allocation within the Upper Sacramento Valley. Increases in environmental water can create additional scarcities in the agricultural regions.

Increasing Environmental Flows

The biggest impact would come from changing minimum flows in the Trinity River. Clair Engle is among the five largest reservoirs in the state, but its ability to deliver water to the agricultural areas within Region 1 is limited by the capacity of the Clear Creek Tunnel and even more by Trinity River minimum flows. Already, the existing minimum flows limit the amount of water available to the region from Clair Engle and Lewiston Lakes. As stated earlier, the Trinity River minimums have the highest average shadow value of all environmental flows.

The Trinity minimums are highest during April, May, and June. The highest agricultural demands occur from April to August. If the Trinity River minimums were increased from their current level, the biggest impact would occur during those three months, as can be seen in Figure A-19, although there is a high Base level of impact in all months, owing to the availability of ground and surface water storage downstream.

Least impact on agricultural demands would occur if the minimums were raised in the winter months (November through February). However increased minimums would result in higher withdrawals from Clair Engle and Lewiston during the winter storage accumulation months that may mean less water will be available water later in the year.

The Sacramento Navigation Control Point minimum also causes impacts on the available water in the region. The Navigation Control Point is downstream of all the demands, so there are opportunities for return water to be used toward meeting the requirement. However, return flows do not fulfill the requirement so some of the water that could otherwise be used by the demand regions must remain in the Sacramento River.

Like the Trinity River minimums, the Sacramento River minimum instream flows peak during the spring. Again, the time when the impacts would be the least to the agricultural regions is the winter. However, just as with Clair Engle and Lewiston, an increase in the winter releases will mean that less water is in storage for use during the dry summer months.

Finally the Sacramento West Refuge withdraws water that would otherwise be available for CVPM 3. The refuge's full level two demands are lowest in the spring, highest in the fall and repeat on an annual basis (Figure A-26). The highest demand occurs in October, coincides with a low agricultural demand. However, as stated earlier, there is almost always some value to the agricultural regions to reducing the refuge deliveries by one unit. Any increase in the demands, even during the non-agricultural months, will increase the costs to the region. The majority of the cost will probably borne by CVPM 3, from which the refuge deliveries are taken. However, that is not to say that the increased demands may not affect other regions due to changes in the stored water volumes in the reservoirs.

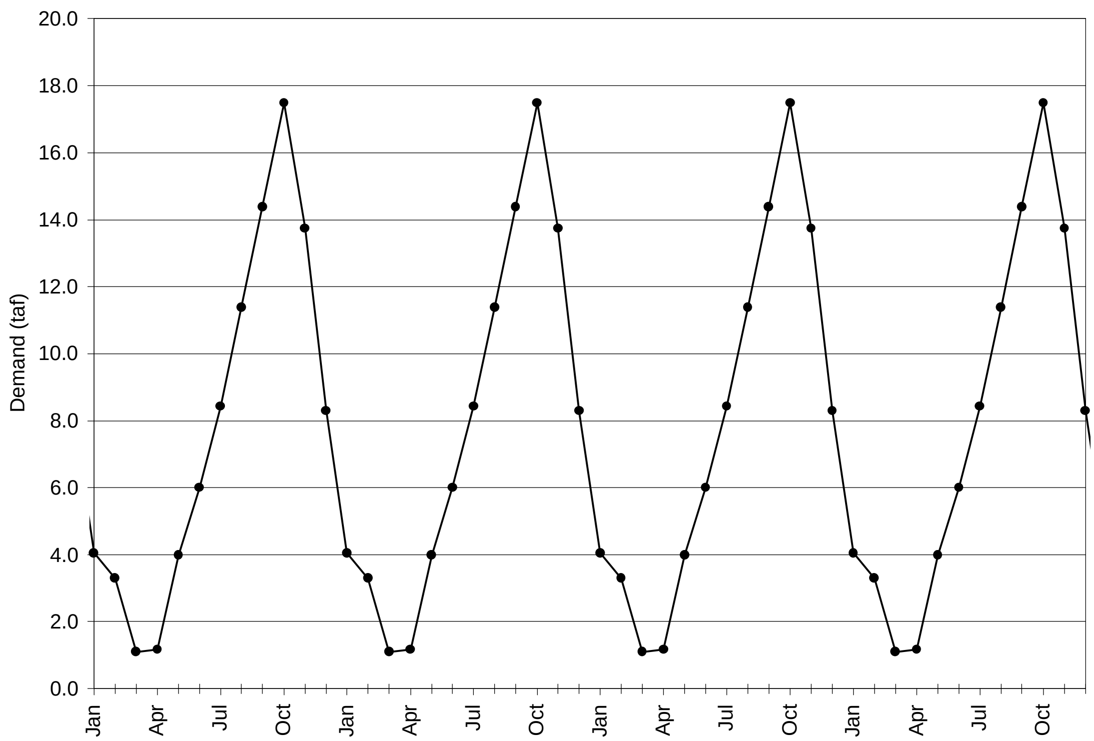

Figure A-26: Sacramento West Refuge Level 2 Demands

It should be noted that the environmental water demands are Based on water needs of the environment, whether for fish, habitat, restoration, etc. in a given month. These demands do not have economic values placed on them in CALVIN, and are not modeled as economically driven demands. Changes to the requirements to maximize the agricultural demands may increase environmental degradation. Increases in the annual environmental water deliveries may not be beneficial if the water is not available when it is needed.

Water Transfers

Users can transfer water between one another depending on the economic benefits of such transfers. The transfers can be between urban and agricultural users as well as between individual agriculture and individual urban users. The results from the Unconstrained Case of CALVIN reflect those transfers made that would improve the overall net benefits to the region.

<u>Costs and Benefits of Intra-regional Transfers</u>

It is unlikely that water transfers between the urban and agricultural sectors of Region 1 would occur because the urban demands are small compared to the agricultural demands. However transfers between the agricultural regions are possible. Changes and exchanges in surface water and groundwater use also can occur.

Currently the CVPM regions all use a mixture of groundwater and surface water to supply their demands. The current split favors surface water (65% to 35% regionally). Some areas could decrease their surface water demands and increase groundwater pumping and visa-versa. The ideal water market would see a slight change in the surface water to groundwater split (63% to 37%).

On a regional basis an ideal water market would improve the economic benefits of the system. Three of the four CVPM regions would decrease their overall costs. Of those, one would see an increase in the operating costs and one would see an increase in the scarcity costs.

CVPM 2 and 3 would benefit in the ideal water market from both operating cost and scarcity cost reductions. Both get more surface water and in turn are able to reduce their groundwater pumping. Because they see neither increases in scarcity costs nor groundwater pumping costs, they should be the most willing to participate in an ideal water market.

CVPM 1 would see a minute increase in both their operating and scarcity costs. It may prove difficult to convince agricultural users to face scarcities, even relatively small ones.

The area least likely to favor an ideal water market is CVPM 4. They experience no scarcities on an annual average basis in the Base Case. However, in the ideal market CVPM 4 decreased their surface water deliveries (by 55 taf/yr) and increased their groundwater pumping to compensate. The increased pumping lead to much higher operating costs in the ideal market. Additionally, CVPM 4 experiences an annual average scarcity of 66 taf/year in the ideal market. Overall CVPM 4 saw a net increase in their costs. In essence, CVPM 4 would not benefit from an ideal market.

Overall the Upper Sacramento Valley would benefit somewhat from the ideal market. Implementation would depend upon cooperation between the agricultural demands. Users that see a decrease in both operating costs and scarcities costs would be more favorable toward the market. Users that see an increase in either (or both) of the costs would be less favorable. Because three of the four users see some type of increase, implementation may prove difficult.

Regional Economic Impacts of Transfers

As presented earlier, the re-allocation of water yielded fairly small changes in the agricultural production of Region 1. The regional irrigation efficiencies increased, as did the gross revenue. On the other hand the net revenues remained unchanged. There are no economic urban demand areas to compete for water, so the increased gross revenues to agricultural are not at the expense of the urban areas. Therefore the transfers of water that resulted in the increased revenues are between agricultural users, rather than between the urban and agricultural users.

Water Transfers and Environmental Water

Environmental water use is modeled as constraints in CALVIN. Water transfers between the environmental demands (consumptive use) and the agricultural demands cannot be determined Based on an economic optimization approach alone.

The three refuges that comprise the Sacramento West Refuge (Sacramento, Delevan and Colusa) are migratory waterfowl habitats. The Bureau of Reclamation (1997) has defined seven primary goals designed to improve, protect and expand the current refuges. Three of the seven goals would make decreases in the refuge flows especially difficult:

1. "Maintenance of additional acres of both summer water and permanent pond habitat types for both

2. "Maintenance of water depths, using year-round water delivery, that provide optimum foraging conditions for the majority of avian species."

3. "Control of undesirable vegetation species, such as cocklebur, using deep irrigation and maintenance

All three of the above goals are designed to insure water deliveries to the refuge during the summer months, when agricultural demands are highest. There was also value to reducing the winter flows through the refuge. However again, reduction in flows would affect the successful implementation of the stated goals.

At this point, while reductions in the refuge demands would provide some benefit to the agricultural areas of the Upper Sacramento Valley, it would be difficult to find a time when the reductions would not have a negative impact on the refuge. One of the few ways in which diversions could be reduced would be to find a way to reduce the consumptive losses on the way to the refuge.

REGIONAL WATER MANAGEMENT IMPLICATIONS

In the current water management system, water is not delivered in the most economically efficient manner. Scarcities are not distributed throughout the region in a way designed to minimize costs or improve reliability. In an ideal market water delivery reliability would theoretically improve. Agricultural scarcities would decrease, which in turn would lower the associated scarcity costs. It is unclear how the environment would do in an ideal market because of the lack of environmental economic data available.

The results from CALVIN can indicate potential areas where modest improvements could be achieved through changes in operations and allocations. However it is important to keep in mind that the results presented in the previous sections indicate that the benefits derived from an ideal market in the Upper Sacramento Valley would be very small relative to the economic value of the region.

Reservoirs would see an increase in their annual average storage volumes in an ideal market. This increased storage means that additional water will be available during the critically dry periods as well as during the high demand months. An ideal market would also be able to improve the system without major changes in the current reservoir capacities. There were only minimal economic benefits associated with changes in any of the reservoir capacities or emergency pools.

Groundwater basins, because of the constrained end-of-period storage volume, see almost no change in the annual average aggregate storage volumes. There are economic benefits to allowing increased withdrawals to occur in certain basins.

There is only a small economic benefit of increasing the capacities of the current conveyance facilities. The greatest benefits would come from an enlargement of the Corning Canal and the Clear Creek Tunnel. The greatest benefits would come from reductions in environmental flows. The Sacramento West Refuge and the Trinity River minimum instream flows would provide the largest economic benefits to the region if reduced.

Inter-regional transfers between Region 1 and Region 2 are unlikely to occur in an ideal market. The value of the water to Region 1 is significantly higher than the value it would have in Region 2. Intra-regional transfers between the CVPM areas of Region 1 are likely to occur in the ideal market.

CALVIN is, in essence, indicating that Region 1 would benefit overall from an ideal market. There would be an increase in the regional operating costs that were offset by reductions in scarcity costs. Overall, the ideal water market would reduce the total costs of Region 1 by almost $1.2 million per year, which is not a large percentage improvement for the region. This indicates that despite some inefficient allocations, on a whole the Upper Sacramento Valley is currently being operated fairly efficiently.

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