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CalWater Fix Economic Analysis

DRAFT

PREPARED FOR

California Natural Resources Agency

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Table of Contents

I. Introduction

The existing system of pumps and water transport canals south of the Delta can move 15,000 cubic feet per second through the combined State Water Project and Central Valley Project. These facilities deliver water to farms and cities in the San Joaquin Valley, Southern California, the Bay Area and the Central Coast. On average, roughly 60% of the non-refuge supplies delivered by these facilities go to agriculture and the remaining 40% go to urban users.

While the state and federal projects have performed well since their creation and have generated significant benefits to their customers and other Californians, the system has proven to be vulnerable to several emerging risks. In the short-term, tighter environmental regulations aimed at protecting Delta-dependent species and their habitats have reduced project deliveries, and are expected to continue to do so. Volumes of water exported through the Delta have decreased over time, partly as a result of increased environmental regulation. Going forward, Delta exports may deteriorate further, due to the likelihood of more stringent protections for the Delta smelt and other species.

The Delta's water infrastructure is also vulnerable to seismic risks. These risks may be small in any given year, but cumulate over time. Over the next two decades, it is more likely than not that the state will experience a large earthquake in or near the Delta that would disrupt water deliveries for some period of time. Looking further into the future, climate change impacts will result in sea level rise that would cause water quality in the south Delta to deteriorate, making it impossible to operate the state and federal pumps for large periods of time.

The proposed CalWater Fix addresses these immediate and longer-term risks to the Delta's water infrastructure. The proposed project is to construct three new intakes on the Sacramento River and two tunnels with a combined diversion capacity of 9,000 cfs, which is less than the capacity of the current system. The project is expected to result in combined state and federal deliveries of approximately 4.9 MAF upon completion of the project.

There are two basic questions with respect to the economics of the CalWater Fix. First, is the project affordable? That is, do the water users who would pay for the construction and operation of the tunnels have the ability to repay the associated debt and operating costs? The recent Treasurer's report answered this question in the affirmative, while acknowledging that it is a much closer call for agriculture than for urban users. Second, does investment in the CalWater

Fix generate benefits to the water users that are greater than the costs? This is the classic benefit-cost question, and it is often a more exacting test than ability to pay.

Answering the cost-benefit question requires comparing the costs of the WaterFix to the costs of reducing agricultural and urban water use and the cost of investing in alternative water supplies. Potential urban water supply alternatives include desalination, recycling, stormwater capture, groundwater remediation including brackish water desalination, and others. Feasible agricultural water supply alternatives are much more limited. As a result, fallowing is the primary way that farmers will cope with reduced water deliveries in the future.

The purpose of this report is to examine the relative direct benefits and costs of the WaterFix, and to outline some of the major indirect economic effects of implementing the program. The benefits of the tunnels are analyzed with respect to a no-tunnel baseline with the same operating criteria as the WaterFix. It is apparent that the WaterFix would not be a sensible investment from a water supply perspective if current levels of Delta deliveries were guaranteed into the future. However, it is expected that Delta operations will be subjected to tighter environmental regulations, and it is with respect to this tighter future baseline that I assess the benefits of the WaterFix.

With respect to direct impacts, I conclude that the WaterFix passes a cost-benefit test in aggregate. Urban users clearly have the ability to afford the project and receive most of its benefits (nearly twice the level of their allocated costs). However, under the currently negotiated operating criteria, the WaterFix does not produce benefits in excess of costs for most agricultural water users.

This analysis assumes that the federal government or some other entity makes a roughly $3.9 billion contribution to the capital and operating costs of WaterFix to cover the costs allocated to the exchange contractors and refuges. If these costs must be borne by the other Delta water users, then the net benefits of the project are even more negative for agricultural contractors.

It should be noted that these overarching conclusions regarding the economics of WaterFix can be altered by several factors. In particular, by facilitating cross-Delta conveyance, the WaterFix can facilitate additional water transfers from the Sacramento Valley to urban and agricultural users south of the Delta. Further, the WaterFix increases the benefits of additional storage projects both north and south of the Delta. Neither of these benefits is quantified in this analysis.

In addition, allowing for increased water trading among south of Delta water users can greatly increase the benefits of the WaterFix by reallocating supplies to the users with the greatest willingness to pay for them. Allowing willing contractors to sell some of their available supplies also helps address lingering questions about the affordability of the project to certain agricultural users since they would be able to sell their WaterFix benefits for more than the cost share allocated to them. In this sense, additional water trading creates a real "win-win" for the agricultural and urban contractors.

The report also considers the public benefits of WaterFix and demonstrates that the project would provide significant indirect and public benefits to Californians, even those who do not directly consume Delta water supplies. These indirect and public benefits justify a state contribution to the project in addition to the assumed public contribution to cover the costs allocated to the refuges and the exchange contractors. The report also indicates ways in which such a public contribution could be spent. One possibility is to defray construction costs. Another, more attractive possibility is to use any state contribution to acquire more water supplies to increase project yields.

The report also examines different possible configurations of the tunnels. For example, would it be preferable to build a smaller set of tunnels, say 6,000 cfs or even 3,000 cfs as suggested by the NRDC? This scaled-down project would have lower construction costs, but would also result in reduced water supply benefits. The conclusion on this issue is clear: reducing tunnel size is an engineering solution to a governance problem, and makes little economic sense. There are powerful economies of scale in tunnel construction and the incremental cost of building 9,000 cfs tunnels as compared to 6,000 or 3,000 cfs tunnels is far lower than the cost of any available water supply alternative.

Ultimately, different proposals provide different levels of risk reduction at a different cost. The proposed WaterFix investment appears to strike a balance between these risk and cost reduction objectives, as compared to other possible configurations of the project and the available set of water supply alternatives and conservation possibilities.

It is important for the state and its public water agencies relying on Delta water supplies to find the appropriate balance between "small is beautiful" local control, and re-investing in state infrastructure that provides important economies of scale. Delta supplies are delivered through state and federal projects in which large historic, sunk investments have been made, and for which debt is still being repaid. These costs will not be reduced if local utilities shift away from imported water supplies.

It is also important to remember that investing in Water Fix does not eliminate the need to pursue local conservation programs and develop alternative water supplies. WaterFix stabilizes Delta deliveries at roughly the levels of the past two decades, providing insurance against the risk of future declines. Dealing with growth will require that the state's water providers pursue other strategies as well.

II. WaterFix Costs and Cost Allocation Assumptions

The total design and construction enterprise costs for WaterFix are estimated at $14.94 billion in undiscounted terms. Section 7 mitigation requirements during construction will cost between $557 and $817 million. These initial capital costs will not be distributed evenly over the anticipated ten-year construction time frame; rather roughly 40% of costs will be incurred during the first five years and the remaining 60% during the subsequent five years.

The present value of the sum of these initial capital costs, discounted to 2015 using a 3% real rate of interest, is $13.25 billion, incorporating the high-end figure for mitigation. For the first ten years following the end of construction, facility operating and maintenance costs are estimated to be $25 million per year. Thereafter, O&M costs are anticipated to increase to $40 million annually, taking the cost of replacement capital into account. Using a 3% real interest rate and assuming a project life of 50 years, the present value of all future O&M costs is $622 million. The present value of total costs over the entire project lifetime, including construction, mitigation, and operating expenses, is therefore $13.9 billion. This cost measure is the appropriate one to use in a cost-benefit comparison.

For purposes of making cost-benefit comparisons, I assume that project construction and operating costs are apportioned across water users on an equal, proportional basis. That is, I assume that every acre-foot of water exported from the Delta absorbs the same cost. As is typical in cost-benefit analysis, I calculate benefits and costs on an incremental basis, measuring the difference between outcomes with and without the WaterFix investments.

In the analysis that follows, I evaluate benefits and costs under several alternative scenarios. I utilize the EIR No Action Alternative to characterize outcomes under current conditions. Next, I consider benefits and costs under the proposed project of a 9,000-cfs North Delta conveyance facility. Third, I consider the impact of future environmental restrictions by analyzing a scenario with existing conveyance and the same, stricter operating criteria being considered to go with the new conveyance. Last, I consider two scenarios under climate change. These scenarios incorporate a 140-cm rise in sea level, and I evaluate supplies in this case with and without the North Delta conveyance facility.

III. Environmental Compliance Benefits

This section of the report addresses the environmental compliance benefits of the WaterFix. The ESA and other regulations are part of the baseline, and compliance with these laws and associated regulations is not discretionary on the part of the state or the water contractors. The relevant question, then, is whether the WaterFix allows water managers to operate the state and federal projects in a way that increases project yields while still complying with applicable environmental laws and regulations.

A. Water Supply Impacts

Estimates of future SWP deliveries are forecasted using the California Department of Water Resources' CALSIM II model, a generalized water resource simulation that generates hydrologic time series forecasts of large, complex river basins. This model relies on early long-term water demand forecasts for the year 2020 and an extended record of runoff patterns. Data produced using CALSIM II are used to estimate the water to be exported from the Delta and distributed to SWP contractors under the following scenarios:

- EIR No Action Alternative
- Existing Conveyance with Proposed Project Operating Criteria
- Proposed Project
- Extreme Climate Change with Existing Conveyance
- Extreme Climate Change with Proposed Project

Combined state and federal deliveries after implementation of the WaterFix are expected to be 4.9 maf upon completion of the project, including deliveries to refuges and the exchange contractors. This level of deliveries assumes a number of existing and new regulatory constraints that would be included in the proposed action. These include Scenario 6 operations above the OMR criteria and San Joaquin River import-export ratio in the BiOps, Fall X2 and spring outflow requirements for longfin smelt.

If the state does not invest in the WaterFix, an important question is what would be the level of state and federal project deliveries (i.e., what is the appropriate "baseline" to use when evaluating the economic impacts of the WaterFix?). To evaluate this issue, this report considers two no-project cases. The first case is the EIR No Action Alternative that represents current conditions. In this case, total Delta exports are 4.7 maf. The second baseline assumes existing conveyance and the same operating criteria as the proposed action. This scenario is the more likely of the two, and results in an "apples to apples" comparison with the proposed project that isolates the costs and benefits of the tunnels and new intakes. In this version of the baseline, state and federal deliveries decline to 3.9 maf – a reduction of 0.8 maf from current levels, and almost 1 maf below the level of deliveries under the WaterFix. This second scenario is intended to capture the risk of tighter environmental regulations in the Delta that would be imposed to ensure compliance with the Endangered Species Act and other federal laws and regulations.

Tables 1-4 display project deliveries for the subset of agencies that may experience significant yield improvements as a result of implementing the WaterFix. The CALSIM II model projects yield changes for the following groups of water districts:

- Central Valley Project
  - San Felipe
  - SLDMWA Ag Service Contractors
  - Cross Valley Canal
- State Water Project
  - MWD
  - Bay Area Urban
  - Other SWP Urban
  - KCWA
  - Other SWP Ag

Table 1 and Table 3 show yields and changes in yields for each group of CVP contractors. The table shows that the agricultural service contractors in the SLDMWA can expect deliveries averaging 773 thousand acre-feet in the No Action case. With existing conveyance and the same operating criteria as the proposed project, CVP deliveries to these contractors decline to 502 thousand acre-feet annually, a drop of 259 thousand as shown in Table 3. It should be noted that project deliveries to these contractors are actually slightly lower under the proposed action than in the No Action case, an outcome due to the significant constraints the proposed action operating criteria impose on the CVP.

Yields for the SWP contractors are shown in Table 2 and Table 4. Table 2 shows that SWP deliveries to MWD are 1,126 thousand acre-feet in the No Action case and 1,212 thousand acre-feet after implementation of WaterFix, an improvement of only 85 thousand acre-feet as shown in Table 3. Compared to the existing conveyance baseline with tighter operating criteria, however, the WaterFix provides MWD with an additional 291 thousand acre-feet of supply. KCWA benefits by 180 thousand acre-feet when comparing between these same two cases.

Table 3 and Table 4 demonstrate the importance of a north Delta intake as a measure to mitigate the effects of climate change. The extreme climate change scenarios considered here assume 140 centimeters of sea level rise, an effect that results in frequent increase in salinity in the vicinity of the south Delta pumps. For the SLDMWA agricultural service contractors, for example, yields under extreme climate change with the existing conveyance facilities would average only 608 thousand acre-feet per year (assuming the current BiOp operating criteria). After implementation of WaterFix, these yields would be 647 thousand acre-feet, or an increase of 40 thousand acre-feet annually.

The benefits of the WaterFix as a climate change adaptation measure are especially dramatic for the SWP. Looking at the summary column of Table 4, the WaterFix preserves 1,159 thousand acre-feet of SWP deliveries that would otherwise be lost. MWD alone enjoys deliveries that are 641 thousand acre-feet higher than without the WaterFix.

Table 1: CVP Yields (AF Thousands)

Scenario	San Felipe	SLDMWA	Cross Valley Canal	Total
NAA	129	773	48	950
PA No Tunnels	106	502	19	627
PA Tunnels	129	760	55	945
140cmSLR No Tunnels	117	608	23	748
140cmSLR Tunnels	114	647	48	809

Table 2: SWP Yields (AF Thousands)

Scenario	South Bay Aqueduct	MWD	Other SWP Urban	Kern CWA	Other SWP Ag	Total
NAA	134	1,126	492	522	97	2,371
PA No Tunnels	115	920	409	417	76	1,937
PA Tunnels	144	1,212	520	596	111	2,582
140cmSLR No Tunnels	97	479	285	369	81	1,311
140cmSLR Tunnels	145	1,120	502	584	119	2,470

Table 3: Change in CVP Yields (AF Thousands)

Scenario	San Felipe	SLDMWA	Cross Valley Canal	Total
PA Tunnels vs. NAA	0	-13	7	-6
PA Tunnels vs. PA No Tunnels	23	259	36	317
140cmSLR Tunnels vs. 140cmSLR No Tunnels	-3	40	25	61

Table 4: Change in SWP Yields (AF Thousands)

Scenario	South Bay Aqueduct	MWD	Other SWP Urban	Kern CWA	Other SWP Ag	Total
PA Tunnels vs. NAA	9	85	28	74	14	211
PA Tunnels vs. PA No Tunnels	29	291	110	180	35	645
140cmSLR Tunnels vs. 140cmSLR No Tunnels	48	641	217	215	38	1,159

B. URBAN WATER SUPPLY BENEFITS

The analysis of urban water supplies and demands is performed at the individual agency level using the Supply-Demand Balance Simulation Model (or SDBSIM), developed by The Brattle Group and detailed in Chapter 9 and Appendix 9A of the Bay Delta Conservation Plan. SDBSIM is a stochastic simulation model that calculates changes in economic welfare of consumers in 36 major water urban agencies receiving Delta water supplies directly or indirectly. These agencies were chosen for analysis because they receive the bulk of the SWP urban deliveries and because they have the largest potential to experience changes in welfare as a result of variations in Delta yields. Some of these agencies are members of the Metropolitan Water District of Southern California, which receives roughly half of all available yields from the SWP. Many of these 36 agencies are wholesalers themselves. For these agencies, it is necessary to model demand and supply conditions in the retail agencies they serve. At the retail level, the analysis covers nearly 120 individual retail agencies throughout California.

The data requirements of such a disaggregated analysis are significant, but this type of approach is necessary to accurately calculate changes in the welfare of urban water customers. Water rates vary widely in California, and knowledge of existing rate structures is essential to calculating changes in consumer welfare following water shortages. Further, accurate estimates of the price elasticity of urban water demand are essential to measuring the costs of mandatory conservation. The SDBSIM incorporates the most comprehensive set of water price and consumption data available in California. This data allows for the use of existing rate structures to calculate impacts and to econometrically estimate the price elasticity of demand at the agency level.

The SWP is the most important source of imported water for the urban agencies included in the SDBSIM. SWP deliveries to these agencies consist of both Table A and Article 21 supplies. Table A supply is a contracted quantity that totals roughly 2.6 MAF per year across all the urban member agencies in the model (California Department of Water Resources 2013). Article 21 deliveries are unscheduled water that is available in wet years, and is essentially the surplus water that remains after all operational, water quality, and Delta requirements are met.

The first step toward valuing the urban water supply benefits of the WaterFix is to identify the associated patterns of urban water shortages relative to those occurring under the existing conveyance scenario with the same operating criteria as the WaterFix. These calculations are performed using the SDBSIM, which is a probabilistic water portfolio simulation model that apportions and values shortages on an agency level (as developed by The Brattle Group). The SDBSIM evaluates water shortages in each sector[1] given demand levels over time and water supply forecasts for each of the SWP agencies. The model runs 83 different trials for each agency by rotating through a historical hydrologic sequence. The shortage and demand outputs are then used to calculate the value of losses to consumers associated with a shortage given a constant elasticity of demand and avoided marginal cost of service. The water supplies considered in the SDBSIM consist of the local and imported supplies discussed in the preceding section. The water demands considered in the SDBSIM

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[1] All sectors are composed of single-family residential, multifamily residential, commercial/industrial/institutional, and agriculture.

are based on an econometric forecast model, discussed in detail in the subsequent section. For the purposes of this report, the SDBSIM incorporates the 26 MWD water agencies along with Alameda County, Antelope Valley-East Kern, Castaic Lake, Santa Maria, Mojave, Palmdale, San Bernardino Valley, San Gorgonio, Santa Clara Valley and Zone 7.

The SDBSIM uses an indexed sequential Monte Carlo simulation method to measure the supply-demand balance outcomes for forecasted years given the pattern of historical hydrologic conditions between years 1922 and 2004. It adjusts the demand and supplies of a forecasted year given a past year of hydrologic conditions, then takes the next sequential forecasted year and adjusts the demand and supplies for that year given the next sequential historical hydrologic year conditions, and so on. For example, the SDBSIM would adjust the forecasted demand and supplies for the year 2012 given the hydrologic conditions of the year 1922, and adjust the forecasted demand and supplies of year 2013 given the hydrologic conditions of year 1923, and so on. By preserving the series of climate patterns, or *hydrologic trace*, the model is able to capture the operation of storage resources that are drawn upon and refilled over the forecast horizon given a probabilistic sequence of hydrologic conditions. The model then starts over and shifts the hydrologic year by one for each forecasted year. That is, it will adjust the 2012 forecast given the 1923 historical hydrologic conditions, and accordingly will adjust 2013 given 1924 conditions, and so forth. This shifting process is done 83 times such that each forecasted year is evaluated under each hydrologic condition, while still preserving the order of the hydrologic conditions, resulting in 83 different reliability outcomes for each forecast year. The model considers the hydrologic conditions of 2004 to be followed by those of year 1922. Thus, when forecasting using a trace that starts with a late hydrologic year, it simply loops back around to the beginning of the climate cycle.

For each year, the SDBSIM compares the forecasted demand to the sum of available projected local supplies and imported supplies less conservation savings in order to assess the disparity between the amount of water desired and the amount that can be provided. If a shortage exists, the SDBSIM may release additional supplies from storage or transfer programs until supply and demand are balanced or until these supplies are exhausted. A net shortage for the year results if the gap between supplies and demands is too large to be balanced by storage and transfer programs. If a surplus exists, the SDBSIM may allocate surplus water to various storage accounts until all storage capacity is used; any remaining surplus supplies are considered unused or "wasted" and are not available for use in subsequent years of the forecast. The remainder of this subsection details the supply and demand forecasts used in the SDBSIM.

The value of water supplies to consumers can be accurately measured by combining economic theory and econometric estimation of urban water demand relationships. The economic costs of water supply alternatives are not easily measured at a planning level, however, because they depend heavily on site-specific factors, pertinent regulations, and demands for water of varying quality. However, by examining the actual cost of past alternative water supply projects, it is possible to portray a range of potential costs that can be compared to the costs of conservation.

Table XX shows the cost per acre-foot for recycling projects in Southern California. Recycling project costs per acre-foot are calculated using data on total costs and acre-feet yearly. Because there is a lack of information about length of operations, what total costs include, and other project parameters that are needed for an exact calculation, this analysis assumes the cost per acre-foot is equal to the total present value cost per acre-foot yearly at an interest rate of 4.5%, a representative interest rate available to urban water supply agencies.

There is no single estimate of the cost of recycled water because its cost is closely tied with the details of the project The cost of recycled projects depends on the location at which the water will be used, or, more precisely, on the distance between the recycling plant and end users. Recycled water generally cannot be transported through existing infrastructure, requiring the installation of “purple pipe” to move the water from the recycling plant to end users. These barriers to implementing recycled water projects are the primary reason that goals for recycled water in the California 2005 water Plan update and the California Water Boards Strategic Plan Update: 2008–2012 were not met.

Table XX. Cost of Recycling Projects ($/acre-foot)

Project Title	Project Location	Estimated Cost per Acre-Foot
Groundwater Replenishment System [a]	Orange County Water District	$955
Regional Recycle Water Program, Northwest Area Project [b]	Inland Empire Utilities Agency	$1,467
Southeast Water Reliability Project Phase 1 [c]	Central Basin Municipal Water District	$1,672
Widomar Recycle Water System [b]	Elsinore Valley Municipal Water District	$1,312

[a] Orange County Water District groundwater replenishment calculations are before subsidies and have a 5% annual escalation of operating costs from 2009 to 2012 (Groundwater Replenishment Systems 2010)
[b] Bureau of Reclamation 2012
[c] Central Basin Municipal Water District 2012 Southeast Water Reliability Project description

Unit costs of recycled water supplied by the projects in Table XX range from $1,000 to $1,700 per acre-foot. Other projects outside the study area but still within the State, such as the Eastside recycled water project currently being developed in the City of San Francisco, are projected to have even higher costs. The unit cost of water supplied by a recent project of the San Francisco Public Utilities Commission is expected to be in excess of $8,000 per acre-foot. Taken together, available data indicate that it is difficult to project the costs of recycled water supplies with any accuracy. The data also indicate that recycled water costs can vary widely as a function of project-specific characteristics.

Like recycled water, the costs of desalinated water depend on numerous project details. Permitting, regulatory, and planning considerations, the cost of capital, availability and costs of energy, and proximity to distribution systems are prominent among the challenges to further development of seawater desalination. Costs are also influenced by the type of feed water, as well as the available concentrate disposal options. The largest cost of seawater desalination is electrical energy, which represents 38% of total costs. The remainder of the cost is comprised of 25% capital costs, 16% labor, 11% chemicals, 5% membranes, and 5% maintenance (California Department of Water Resources 2009: Chapter 9). Costs are lowest for desalination of brackish groundwater at $1,000 to $1,500 per acre-foot, followed by seawater desalination at recent costs of $2,000 to $2,300 per acre-foot.

Table YY. Cost of Desalination Projects ($/acre-foot)

Project Title	Project Location	Estimated Cost per Acre-Foot
Carlsbad Desalination Project[a]	Carlsbad, San Diego County, CA	$2,014–$2,257
Huntington Beach Seawater Desalination Project[b]	Huntington Beach, Orange County, CA	$1,768–$1,812
West Basin Municipal Water District Desalination Project[c]	El Segundo and Redondo Beach, Los Angeles County, CA	$1,273 for brackish $1,700 for seawater
Camp Pendleton Seawater Desalination Project[d]	Camp Pendleton, San Diego County, CA	$1,900–$2,340
Oxnard GREAT Program[e]	Oxnard, Ventura County, CA	$1,680 first phase $1,191 second phase

Notes:
Poseidon Resources, LP and San Diego County Water Authority 2012
Municipal Water District of Orange County and Poseidon Resources, LP 2013. Range includes total costs before any subsidies and includes conveyance costs
University of Arizona Water Resources Center 2011
RBF Consulting 2009; Pacific Institute 2012
Wenner 2012

The costs of recycling and desalination can be compared to the value of water calculated using the SDBSIM model. Looking across the SWP urban agencies considered, the value to ratepayers of the water preserved by the WaterFix is $1,414 per acre-foot. These values are at the low end of the range of water supply alternative costs, which is understandable since the water supplies preserved by the WaterFix vary considerably between wet and dry years whereas alternatives such as recycling and desalination are more reliable. Because demand reduction is a feasible option, and because the costs of feasible water supply alternatives cannot be known with precision for any individual water agency, for planning purposes it is appropriate to measure the urban benefits of WaterFix using the water values produced by SDBSIM rather than the cost of alternatives. It should be noted, however, that for most water agencies the benefits of WaterFix will not be dramatically different under either approach.

C. AGRICULTURAL WATER SUPPLY BENEFITS

Turning to agriculture, there are in general few water supply alternatives available to growers beyond surface diversion and groundwater extraction. There have been some attempts to desalinate agricultural tailwater in the San Joaquin Valley, but these are only at the pilot stage at present. The most straightforward way to value agricultural water supplies is to calculate the value of water implicit in land prices, and on the water transfer market. Since the market value of cropland should equal the capitalized value of the stream of future agricultural profits, land values are often used to measure the implicit value of water used for crop production.

The Statewide Agricultural Production (SWAP) model is the evolution of a series of production models of California agriculture developed by the University of California at Davis and DWR, with support from Reclamation. SWAP is a regional model of irrigated agricultural production and economics that simulates the decisions of agricultural producers in California. The model assumes that farmers maximize profit subject to resource, technical, and market constraints. It incorporates project water supplies (SWP and CVP), other local water supplies, and groundwater. As conditions change within a SWAP region (e.g., the quantity of available project water supply increases or the cost of groundwater pumping increases), the model optimizes production by adjusting the crop mix, water sources and quantities used, and other inputs. It also fallows land when that appears to be the most cost-effective response to resource conditions.

For this report, SWAP was used to compare the long-run producer responses to changes in SWP and CVP irrigation water delivery and to changes in groundwater conditions associated with WaterFix. Water supply projections from the CALSIM II model, described earlier, were used as inputs into SWAP through a standardized data linkage procedure.

The analysis of agricultural economic effects of water supply changes provides benefits in the following categories:

- Change in groundwater pumping and cost
- Change in net return from crop production (excluding change related to groundwater pumping)
- Change in benefits to consumers of agricultural products through food price changes

An important feature of our analysis of agricultural benefits is that it incorporates the effects of the Sustainable Groundwater Management Act (SGMA). This modification is significant since surface and groundwater are substitutes, and groundwater limitations can be expected to increase the value of surface water used for crop irrigation.

To date, no agricultural regions or contractors within the Central Valley have yet developed quantified sustainable yield estimates for purposes of implementing SGMA. SGMA addresses a number of factors and criteria for sustainable yield, but for this analysis we address only the average volume of pumping that can be sustained over a period of time without reducing groundwater storage (designated here as safe yield, SY). The most recent calibration results from a groundwater flow model, the California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM), are used to derive an approximation of SY for purposes of this analysis. The intent is not to develop a precise or accurate estimate of sustainable pumping (which is not possible given the current state of knowledge), but rather to provide an assessment of direction and rough magnitude of change that such limits could impose on existing and future pumping. Further, this will be used to assess how pumping limits could affect the benefits or impacts of changes in surface water irrigation delivery, the marginal value of water for irrigation, and the willingness to pay for surface water supply.

The following general steps describe how the pumping limits were developed.

1. The latest C2VSim calibration results include estimates of average annual groundwater pumping and average annual change in groundwater storage for each of the 21 depletion study areas (DSAs) in the Central Valley. As a first approximation for purposes of this analysis, the average change in storage is treated as the amount by which average annual pumping exceeds safe yield. In a long-term safe yield condition, groundwater storage would trend neither up nor down. Therefore, adjusting the average annual pumping by the average annual change in storage provides such a first-cut estimate. It is recognized that reducing pumping in this way would change recharge rates and gradients that would, in turn, change the net water balances and flows. A more complete assessment would use C2VSIM to evaluate all of the effects – however, no testing of this approach has been undertaken by C2VSIM modelers. Safe yield (SY) is estimated here as the average annual pumping minus the average annual change in groundwater storage. Total SY for each region was apportioned to agricultural pumping based on its share of the total annual pumping in the calibration estimates, and the result was expressed as a percentage of average annual agricultural pumping.

2. The SY percentage was applied to the corresponding regional average annual groundwater pumping estimated by SWAP for the No Action Early Long-term condition, resulting in an average annual SY pumping limit. We did not use the absolute magnitude of the estimated SY from step 1 due to differences in the calibration land use and water

use data in the two models. Also, though the regional boundaries of the two models are mostly similar, some of the SWAP regions split a DSA into two or three sub-regions. In these cases, the same SY percentage was applied to each of the sub-regions. Figure 1 displays the SWAP regions; the C2VSIM regions and numbering are the same except that they do not split some regions into two or more sub-regions (as designated in SWAP by the suffix a, b, or c).

3. An important exception to the procedure described in step 2 is the development of safe yield for Westlands Water District (WWD). WWD has developed its own estimate of the safe yield of the confined aquifer underlying the district. Groundwater above the confining layer is subject to quality degradation and may not be usable for irrigation over the long term. WWD estimates in its 2012 Water Management Plan that the safe yield is between 135 and 200 TAF per year. We have used 200 TAF as the average annual pumping limit for this SWAP region. Ideally, other regions' SY estimate would also take account of water quality in different aquifer layers, including regions 10, 15, 19, and 21. At this time, we do not have detailed data to make such adjustments in other regions, so this analysis relies solely on the water balance-based estimates described in steps 1 and 2.

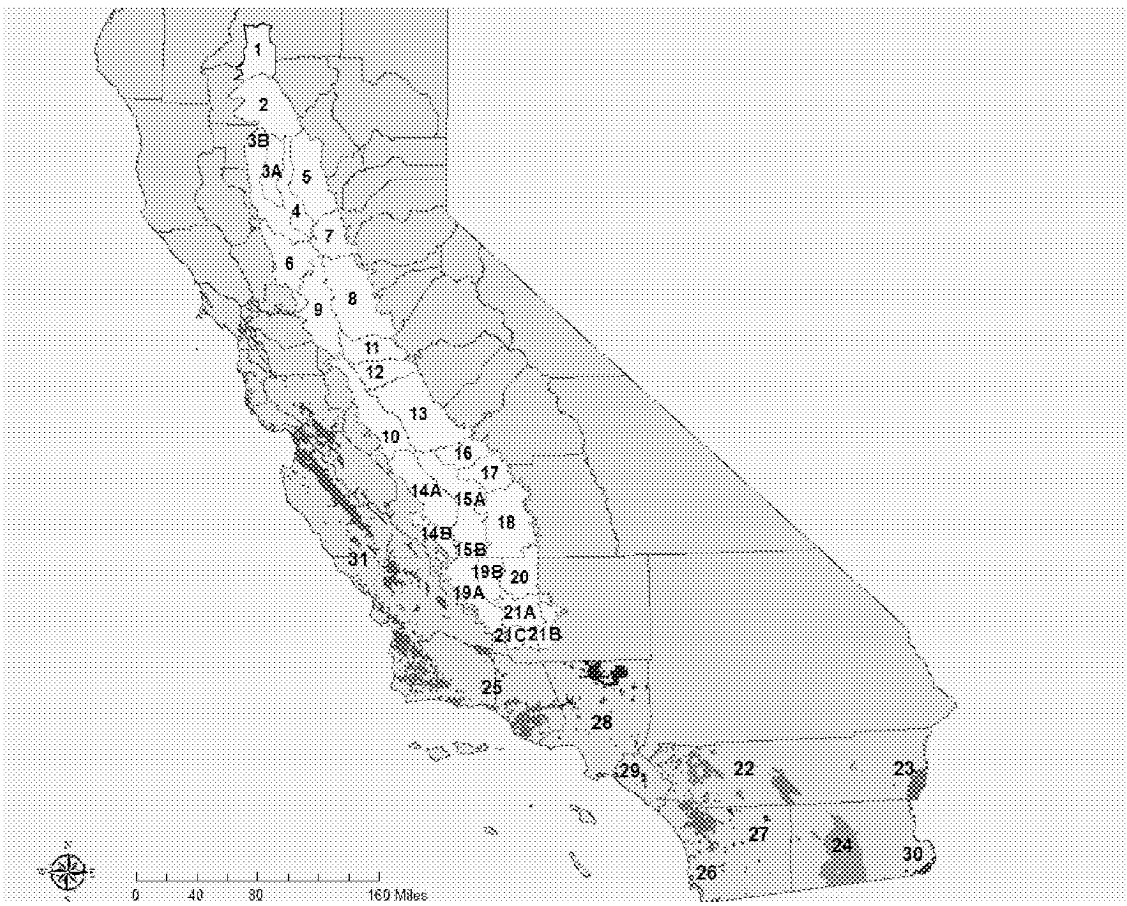
4. SY limits are unlikely to be imposed equally in every year. In future, regional groundwater management agencies implementing SGMA would likely allow greater pumping in dry and critical water years due to lower surface water availability, offset by lower pumping volumes in the other years, so that the groundwater resource is optimally allocated over time. We have not derived an optimal pattern of pumping limits by year type, but have developed a simple approach using the same No Action estimates from the 2013 BDCP analysis. The dry/critical pumping limit is increased (relative to the average annual limit) enough to offset the loss of surface water in dry/critical years versus the overall average, but subject to two constraints. First, the weighted average pumping over all year types must not exceed the average annual limit (a feasibility condition); and second, the dry/critical year pumping can be no more than twice the overall average (a reasonability condition to avoid infeasible or implausible solutions in three of the regions).

The SWAP regions are shown in Figure 1. The Delta export regions' pumping limit estimates that result from this procedure are shown in Table 5. GW SY Average is the overall average pumping SY. The next column displays that value as a percentage of the groundwater pumping from the early long-term No Action analysis prepared in 2013. The final column is the dry/critical year pumping limit.

Table 5: Estimated Safe Yield Groundwater Pumping Limits (AF Thousands)

Region	GW SY, Average	As Percentage of No Action Avg. GW Pumped	GW SY, Dry/Critical Years
V10	285.2	0.97	424.9
V14A	200.0	0.42	400.0
V14B	40.0	0.69	40.0
V15A	905.1	0.95	931.8
V15B	30.9	0.95	40.1
V19A	73.1	0.68	116.7
V19B	199.6	0.68	254.9
V20	173.5	0.49	212.2
V21A	124.8	0.73	167.8
V21B	38.4	0.73	76.8
V21C	81.0	0.73	92.9

Figure 1: SWAP Regions



D. SUMMARY OF WATER SUPPLY BENEFITS

The environmental compliance benefits of the WaterFix relative to the existing conveyance baseline with comparable operating criteria, are substantial. For SWP urban contractors, these benefits total $10.172 billion over the 50-year operating period. For the SWP agricultural contractors, environmental compliance benefits are $1.333 billion, while benefits for the CVP contractors are $1.482 billion. Thus, the total water supply benefits of the WaterFix are $12.987 billion.

It is also possible to calculate the present value of water user benefits per 100,000 af of average year supply increase:

- SWP Urban Contractors: $2.882 billion
- SWP Ag Contractors: $665 million
- CVP Ag Service Contractors: $572 million

These figures can be used to approximate the water supply benefits from other WaterFix scenarios, and to calculate the implicit cost of environmental restrictions such as Scenario 6, changes in the CVP/SWP split, and the performance of the WaterFix with different assumptions about north and south of Delta storage. For instance, Scenario 6 results in the loss of roughly 500 thousand acre-feet of SWP and CVP water supplies. Assuming current rules for allocating water, Scenario 6 results in a loss of roughly $7.5 billion in producer and consumer welfare.

IV. Water Quality Benefits

Construction of the WaterFix tunnels will substantially lower the salinity of Delta water supplies. Table 6 below displays estimates of average water quality at the Banks and Jones Pumping Plants. These reductions in salinity benefit farmers and urban water users, and this section describes the methods used to value water quality improvements.

Table 6: Water Quality Changes Resulting from WaterFix

Parameter	Units	Proposed Action Without Tunnels	Proposed Action With Tunnels	Difference
Banks PP				
TDS	(mg/L)	283.51	197.67	-85.84
Chloride	(mg/L)	81.29	48.17	-33.12
Jones PP				
TDS	(mg/L)	278.45	198.39	-80.06
Chloride	(mg/L)	78.62	47.84	-30.78

The economic effects of changes in water quality of irrigation water are complex and may occur in the short term and over the long term. Numerous water quality constituents may specifically affect agricultural production, but salinity, measured as electrical conductivity or parts per million (ppm) of TDS, is the single best indicator of effect for water delivered from the Delta. Improved irrigation water quality means less water is applied to leach salts, and for purposes of this analysis, that saved water is valued at the avoided cost of additional water supply (groundwater pumping is the incremental water supply avoided). Calculations account for the different crops grown in affected delivery areas.

The long-term value of salinity changes depends upon interactions between irrigation management, crop selection, and groundwater conditions. Poor drainage conditions in many areas receiving irrigation water from the Delta indicate that costs of drainage management could be avoided or postponed by improved quality of delivered water. Changes in surface water delivered also affects the use of groundwater for irrigation, which can have up to or three times the TDS concentration as water from the Delta. Longer-term implications of salt management in areas receiving Delta irrigation water are not evaluated here. Therefore, the quantified salinity benefits should be viewed as a conservative estimate.

The salt leaching benefit provided by the improved SWP/CVP delivered water quality is calculated in two components:

- For the portion of project supply that replaces groundwater pumping, the benefit is calculated relative to the applied groundwater quality.
- For all other applied project water, the benefit is calculated relative to the baseline project water quality. For each alternative, Proposed Action and SWRCB Alternative, the baseline is the no-tunnels configuration of that alternative.

These two components affect how the overall irrigation water quality changes, especially in the context of groundwater replacement of changes in surface water delivery.

For both alternatives, the tunnels provide a substantial improvement in quality of delivered water, and also provide increased delivery of surface water. Annual water quality benefits to the SWP agricultural contractors are roughly $5.5 million, and are roughly $12.1 million to the CVP agricultural water users. Assuming an operational date of 2027, WaterFix results in water quality benefits to CVP and SWP agricultural water users of $216.5 million and $97.0 million, respectively.

Urban water quality benefits are calculated using two models. The Lower Colorado River Basin Water Quality Model (LCRBWQM) assesses the cost to water users for the MWD service area. The South Bay Water Quality model was used for the Bay Area urban agencies. These models value reduced salinity according to improvements in taste and expended appliance life, among other factors.

Both regions (South Coast and Bay Area) receive water quality improvement of delivered water. For the MWD service area, annual water quality benefits are $106.7 million, while for the Bay Area urban customers annual benefits are $14.5 million. The present value of reduced salinity to SWP urban consumers is $2.3 billion.

V. Reduction of Seismic Risks

By adding redundancy to the Delta's water conveyance infrastructure, the California WaterFix addresses the seismic risks that plague the current infrastructure. Figure 2 displays active faults and historic seismicity in the area surrounding the Delta. Of particular interest is the Hayward-Rodgers Creek Fault (H-RCF). The H-RCF is located west of the Delta and east of San Francisco Bay. Based on the USGS analysis of earthquake potential in the Bay Area, the Hayward-Rodgers Creek Fault has the highest probability (27 percent) of a magnitude 6.7 or greater event occurring in the next 30 years of all the major faults in the region. Estimates of the maximum magnitude for the Hayward-Rodgers Creek Fault vary from 6.5 to 7.3. To demonstrate the seismic risk reduction benefits of the California WaterFix, this report considers the effects of a magnitude 6.7 earthquake on the Hayward-Rodgers Creek Fault.

In the event of a future earthquake that occurs on the H-RCF, numerous levee failures could occur that leads to island flooding and significant salt water intrusion. Depending on a number of factors (e.g., the size of the earthquake, the number of levee failures), the salinity intrusion could have a major impact on California's water supply.

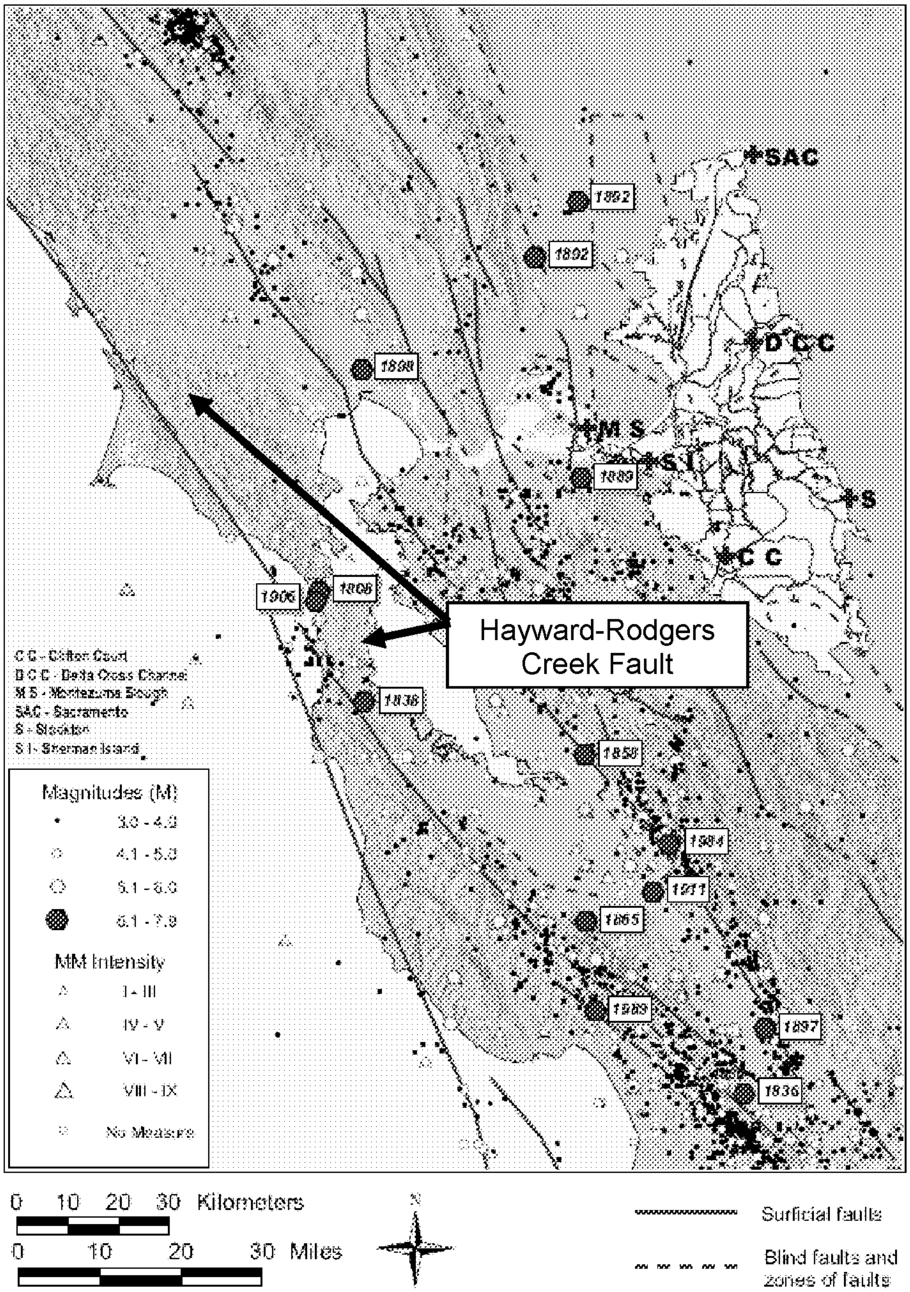
This section details the steps taken to simulate changes in Delta exports following a large earthquake near the Delta. This section also describes the IRPSIM model developed by MWD that was used to simulate changes in end use, storage and costs of operations for MWD and several other SWP contracting water agencies. The section concludes with a description of economic impacts using the impact framework detailed in the previous section.

The earthquake scenario considered in this report is evaluated using the tools developed as part of the California Department of Water Resources Delta Risk Management Strategy (DRMS) project (URS/JBA, 2009). Specifically, the DRMS Seismic Risk Analysis (SRA), Emergency Response and Repair (ERR) and the Water Analysis Module (WAM) tools (software packages) are used to evaluate the water supply impact of seismically initiated levee failures in the Delta.

Earthquake Scenario - The first step in the analysis is to define the earthquake scenario to be evaluated. An earthquake scenario is defined for a specific seismic source (e.g., fault), a specified earthquake size (magnitude), and a location. The size of the earthquake is typically selected as the estimated maximum magnitude that can be generated by the fault. The earthquake location is defined by the closest approach of the fault to the site or region of interest.

Seismic Risk Analysis (SRA) - Given the occurrence of an earthquake on a fault of a specific magnitude (an earthquake scenario), the DRMS seismic risk analysis software evaluates the earthquake ground motions that may be generated and the performance of the levees on each island in the Delta. Empirical studies of earthquake ground motions demonstrate the ground motions that can be generated are random, even for an event that occurs on a specific fault of known magnitude. Similarly, the response of Delta levees to earthquake shaking cannot be predicted exactly and as a result how many and which levees may fail during an earthquake is also random. The DRMS seismic risk analysis code evaluates the randomness of ground motions and levee performance and generates sequences of flooded islands. A sequence is a specific list of which levees have failed and which islands are breached as a result of an earthquake. Since the ground motions that can occur and the performance of the levees are random, there are many possible combinations of flooded islands that can occur as a result of single earthquake. As a result, the SRA calculates thousands of sequences (each representing a different combination of flooded islands) that quantify the randomness in levee performance.

Figure 2: Earthquake Faults near the Delta



Emergency Response and Repair (ERR) - Following an earthquake that results in levee failures, repairs are made to close levee breaches and damaged levee sections and to dewater flooded islands. The ERR is a simulation code that models the repair of levees that were damaged or breached in a sequence. It takes into account the rate of quarry production, rock placement, and the potential for levee interior erosion that can occur on flooded islands (e.g., such as occurred on Jones Tract in 2004). The ERR model produces a time series of breach closures and island dewatering that serves as input to the WAM model. In addition, ERR estimates the cost of levee repairs.

Water Analysis Module (WAM) - The Water Analysis Module simulates direct, water-quality-related consequences of levee breach sequences. Specifically, WAM incorporates initial island flooding, upstream reservoir management response, Delta water operations, water quality (salinity) disruption of Delta irrigation, Delta net losses (or net consumptive water use), hydrodynamics, water quality (initially represented by salinity), and water export. The module receives the description of each breach scenario (e.g., resulting from a seismic or other event) and details of the levee repair process from the ERR. The model produces hydrodynamic, water quality, and water supply consequences for use in the economic and ecosystem modules. The water quality consequences of levee failures (i.e., salinity) are dependent, not only on the initial state of the Delta at the time of failure, but also on the time series of tides, inflows, exports, other uses, and on the water management decisions that influence these factors. Thus, WAM tracks water management and the Delta's water quality response starting before the initial breach event and proceeding through the breach, emergency operations, repair, and recovery period.

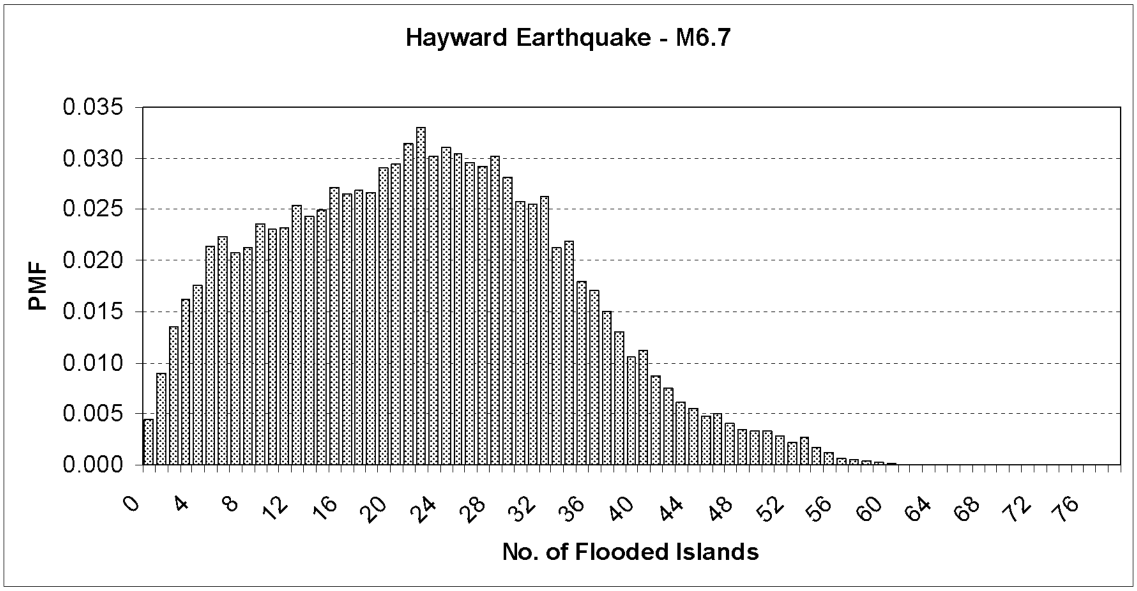
As described above, this report examines the consequences of a magnitude 6.7 earthquake on the H-RCF. The DRMS study team generated thousands of levee failure sequences for each earthquake simulated. Figure 3 shows the distribution of the number of flooded islands for the 6.7 earthquake scenario on the H-RCF. As seen in the figures, the randomness in ground motions and levee performance provides a wide range in terms of the number of islands that are flooded as a result of levee failures.

For purposes of estimating economic consequences, the mean number of flooded islands was used. For the M 6.7 event, the mean number of flooded islands is 22. To estimate economic impacts, a sequence with the mean number of islands was selected. These sequences were used in the ERR and WAM calculations to estimate the water conveyance impacts.

The impact of levee failures to water conveyance in the Delta depends on the time of the year the event (Start Time) occurs and the hydrologic conditions at the time. For instance, does the event occur in the middle of a long drought or during a period of above normal precipitation and snow? To model the impact of hydrologic conditions on water conveyance following the random occurrence of earthquake in or near the Delta, a set of alternative hydrologic conditions were selected from the historic hydrologic record for California.

Calsim II input and output for the no breaches case defines the baseline including reservoir storages, reservoir releases, Delta salinity, inflow, outflow, pumping, and project deliveries – namely, the Calsim Run for 2005 Level of Development, extended hydrology, D-1641, and B-2 (the most current, available 2005 version from the Common Assumptions Model Package). Water delivery deficits reported by the WAM are calculated relative to this baseline.

Figure 3: Probability Density of the Number of Flooded Islands for a Magnitude 6.7 Earthquake on the Hayward Fault



Calsim input and output have been computed for the entire 82-year hydrologic sequence derived from the historic record. WAM has the flexibility to use the beginning of any Calsim month as the levee breach initiation time and uses the Calsim state-of-the-system at that time as its starting condition. WAM then uses the Calsim hydrologic conditions for the next several years as the input hydrology for the duration of the event.

To characterize the variability in economic impacts across hydrologic conditions, this report displays ten scenarios that are broadly representative of the hydrologic record over the period 1922-2004. The method of sequential analysis captures the operation of storage resources that are drawn upon and refilled based on supplies and demands. The specific years and the hydrologic conditions considered in this analysis are as follows:

- Wet year followed by 2 wet years -- 1969
- Wet year followed by 2 normal years -- 1971
- Wet year followed by 2 below normal or dry years-- 1958

- Normal year followed by 2 above normal or wet years -- 1972
- Normal year followed by 2 normal years -- 1936 (Note – There was no sequence in the historic record that matched this condition; 1938 is a wet rather than normal year)
- Normal year followed by 2 below normal or dry years -- 1946
- Dry year followed by 2 above normal or wet years -- 1939
- Dry year followed by 2 normal years -- 1949
- Dry year followed by 2 below normal or dry years -- 1947
- Dry followed by two dry or critical years -- 1987

There exists uncertainty about the exact number and location of failed levees, optimal repair methods and times, and daily natural inflow following a particular earthquake. All of these factors result in uncertainty about the exact pattern of water supply outages. To model this uncertainty, the DRMS post-earthquake water supply scenarios were modified as follows. The DRMS water supply runs for the 10 hydrologies specified above list a unique recovery date after which the post-earthquake and baseline water supplies converge. Water supplies may be available to some degree prior to this recovery date, but not in all cases. The study team defined four partial outage scenarios for this analysis. These partial delivery scenarios specify no Delta exports for some fraction (25, 50, 75 and 100 percent) of the DRMS-specified recovery time. The average recovery time across the 10 hydrologies was 30 months, meaning that the average cessation of Delta exports in the 25 percent scenario is 7.5 months, 15 months for the 50 percent scenario, etc.

An additional dimension to the analysis is that we consider two scenarios for the allocation of end-use shortages. In the first scenario, all losses are absorbed by the residential sector. While this common approach preserves businesses and protects jobs, it can also lead to large economic losses for residential consumers. For this reason, we also consider an optimal reduction scenario where the residential, commercial, industrial and agricultural sectors are targeted to minimize welfare loss.

Delta export losses are translated into changes in end-use with an augmented version of the SDBSIM model that incorporates MWD wholesale agencies and several non-MWD urban contractors. SDBSIM is based on MWD's IRPSIM model and is implemented using a Monte Carlo simulation approach that integrates projections of water demands and imported water supplies for each forecast year and adjusts each projection according to weather conditions based on assumed hydrologies. For agencies within the MWD service area, the SDBSIM model integrates retail urban water demand projections (MWD-MAIN), local supply and imported water projections (MWD Sales Model), SWP imported water supplies (CALSIM/DWRSIM), and Colorado River Aqueduct (CRA) imported water supplies (CRSS) and results in a set of supply and demand conditions over the 10 year period 2010-2019 that are indexed to various hydrologies. For non-MWD agencies, similar information on demands, imported water and storage is provided directly.

At the time of the analysis, SDBSIM included the following agencies:

- Alameda County Flood Control and Water Conservation District, Zone 7
- Alameda County Water District
- City of Santa Maria
- Castaic Lake Water Agency
- Metropolitan Water District of Southern California
- Mojave Water Agency
- San Bernardino Valley Municipal Water District

Water supply losses vary widely by hydrology, as does recovery time. It bears repeating that these water supply losses are entirely caused by changes in the salinity that make it impossible to export water during some months. Recovery times are defined as the number of months following the earthquake necessary for baseline and post-earthquake water quality profiles to converge.

Table 6 reports urban losses from a major earthquake on the Hayward-Rogers Creek Fault. In the 25 percent outage case, roughly corresponding to an outage lasting 7.5 months, average impacts are $499 million when allocated to the residential sector and $419 million when allocated across all sectors to minimize welfare loss. In the latter case, however, job losses average 3,419, with a minimum of 0 and a maximum of 18,123 (again in the 1987 case).

Assuming a 50 percent duration outage, which is around 15 months, economic impacts of a magnitude 6.7 earthquake are larger. Welfare losses average $2.1 billion when shortages are all allocated to the residential sector, and $1.4 billion when allocated to minimize welfare loss in which case job losses average 17,523 but can be as large as 71,271 in the 1987 hydrology.

These two cases (25 percent and 50 percent) represent the most likely outage scenarios. There is considerable work underway at both DWR, MWD and elsewhere on post-earthquake repair times, and many experts believe that Delta water supplies can be recovered within a period as brief as 6 months. In consideration of this fact, DWR has asked urban water agencies to assume a 6 month Delta outage when preparing water supply reliability analyses as part of their Urban Water Management Plans.

Nonetheless, it is instructive to examine cases of longer-duration outages. Such cases may not be as likely as the three described above, but they are still possible. In the case of a 75 percent duration outage, average impacts are $6.0 billion in the all-residential case and $3.2 billion when the shortage can be allocated to all sectors. Job losses average 47,800 in this case, but can be as high as 157,657 were the earthquake to occur in 1987 hydrologic conditions. In the 100 percent outage case (with an elimination of Delta exports averaging 30 months), impacts average $8.1 billion in the all-residential shortage case and $4.4 billion when spread across residential and non-residential demand segments. Job losses average 65,793 in this case, and range as high as 231,330 in the 1987 hydrology.

Table 7: Urban Losses from Earthquake-Induced Reductions of Delta Water Supplies ($ Thousands)

Scenario	Category		Mean		Low		High
25% Outage Duration	Total Case 1 Impacts	$	499,010	$	30,577	$	1,736,164
	Total Case 2 Impact (less jobs)	$	419,713	$	30,599	$	1,395,254
	Case 2 Lost Jobs		3,419		0		18,123
50% Outage Duration	Total Case 1 Impacts	$	2,053,101	$	239,680	$	7,540,172
	Total Case 2 Impact (less jobs)	$	1,415,804	$	239,623	$	4,847,254
	Case 2 Lost Jobs		17,523		76		71,271
75% Outage Duration	Total Case 1 Impacts	$	6,028,504	$	554,495	$	24,518,967
	Total Case 2 Impact (less jobs)	$	3,170,458	$	534,435	$	10,337,506
	Case 2 Lost Jobs		47,600		462		157,857
100% Outage Duration	Total Case 1 Impacts	$	8,089,637	$	811,003	$	33,211,210
	Total Case 2 Impact (less jobs)	$	4,403,388	$	790,107	$	14,315,895
	Case 2 Lost Jobs		65,793		555		231,330

This analysis indicates that while expected losses from an earthquake-induced cessation of Delta water supplies may not be large, there are realistic cases where losses can be serious. For example, even in the conservative 25 percent outage scenario, losses can exceed $1.4 billion if the earthquake is followed by a series of dry years (such as California is experiencing at present). Further, if the outage is total during the period of recovery (averaging 30 months), then average losses can exceed $4.4 billion across the historic hydrology. If the worst occurs and a 100 percent outage is followed by a series of dry years, then urban losses can exceed $33.2 billion if all mandatory conservation is placed on the residential sector. If this proves to be infeasible and water shortages must be allocated across all sectors, then job losses balloon to as much as 231,330, which is equivalent to a 1.2 percent increase in the state's unemployment rate.

Seismic risk reduction benefits to ag are negligible (DRMS concluded this).

VI.Summary of Quantified Direct Benefits and Costs

This part of the report has presented the benefits and costs of the WaterFix from the perspective of ratepayers in the agencies whose water supplies will be affected by its implementation. Impacts are expected to result from four basic types of effects: more efficient environmental compliance, improved water quality, reduced seismic risks and mitigation of the effects of sea level rise caused by climate change. These categories of impacts correspond to the major types of risk facing the Delta's water infrastructure at present and over the coming decades.

Table 8 summarizes the discussion of direct benefits to three categories of water users: SWP urban, SWP agricultural and CVP users.

Table 8: Summary of WaterFix Direct Benefits and Costs ($ Thousands)

Benefits	**SWP Urban**	**SWP Ag**	**CVP**	**Total**
Environmental Compliance	$ 10,172,400	$ 1,333,326	$ 1,481,990	$ 12,987,716
Water Quality Improvements	$ 2,301,324	$ 96,935	$ 216,489	$ 2,614,748
Avoided Seismic Risks	$ 499,010	$ -	$ -	$ 499,010
*Avoided Seismic Risks - Upper Bound	$ 8,089,637	$ -	$ -	$ 8,089,637
Cost Allocation	$ 5,337,967	$ 2,012,283	$ 2,688,678	$ 10,038,928
Net Benefits	$ 7,634,767	$ (582,022)	$ (990,199)	$ 6,062,547

Taken together, the benefit and cost figures show that the WaterFix easily passes a benefit cost comparison in aggregate. Costs allocated to the SWP and CVP contractors have a present value of $10.038 billion, and produce benefits of $16.100 billion, for a net benefit of $6.062 billion. There are a number of factors that could influence the cost-benefit comparison, and some are discussed below. Further, note that if one considers the higher figure for seismic risk reduction benefits resulting from an earthquake coinciding with a drought, the cost-benefit comparison becomes even more favorable.

However, looking at the results more closely, under the currently negotiated operating criteria the level of direct benefits for state and federal agricultural contractors is not sufficient to justify investing in the project. For the SWP agricultural contractors as a whole, the net benefits of the

WaterFix are -582 million, and for the CVP agricultural service contractors are -990 million. By comparison, the WaterFix passes a cost benefit comparison for urban agencies by a factor of well over 2 to 1, using the more conservative figure for seismic risk reduction benefits and not counting the benefits of mitigating sea level rise. Urban benefits may be even larger if one considers the higher levels of seismic risk that occur should an earthquake coincide with a dry period, and the effects of mitigating sea level rise over a longer time horizon.

The cost allocation shown in Table 7 assumes that there are third party contributions to cover costs allocated to the exchange contractors and refuges. The present value of this contribution is roughly $3.9 billion. Should these funds not materialize and the contractors be forced to absorb these costs, the project would not be as attractive in aggregate, or to the urban contractors.

To conclude this section, it should be noted that there are additional relevant factors and risks that are difficult to quantify at present. Whether the WaterFix ultimately turns out to be a sound investment for all groups of contractors depends on how these issues are resolved.

It is assumed that the WaterFix construction can be completed within the assumed budget. While the WaterFix construction cost estimate includes provisions for overruns in most cost categories, there is no guarantee that the project will be completed on budget. Of course, if costs are higher than anticipated, the cost-benefit comparison may not be favorable, depending on the magnitude of the overrun.

Another significant consideration is future environmental outcomes in the Delta, such as the level of future populations of listed species. The WaterFix will be permitted under Section 7 of the Endangered Species Act (whereas the Bay Delta Conservation Plan would have been permitted under Section 10) and a new Biological Opinion will be issued that will govern operations of the tunnels and other Delta export facilities. Should environmental conditions continue to deteriorate even after construction of the tunnels, it is possible that the fish agencies could re-initiate consultation and issue a new Biological Opinion. It is an open question whether some degree of regulatory assurances, or similar mechanisms, can be built into the WaterFix permit and governance structure.

While Section 7 does not contain the same level of regulatory assurances as Section 10, and thus the current permitting structure carries additional risks that may not exist with a Habitat Conservation Plan issued under Section 10, it should be borne in mind that the tunnels result in additional water deliveries under a wide range of environmental outcomes. That is, if smelt populations continue to decline after construction of the WaterFix, the relevant question for investment analysis becomes what would have been the level of deliveries without the tunnels? Viewed this way, future environmental outcomes may affect the *level* of deliveries more than the *difference* between deliveries with and without tunnels. It is, of course, the difference in yields that results from the tunnels that is relevant for cost-benefit analysis.

Show water supply results under a range of operating criteria. WaterFix with same operating criteria as at present would produce average deliveries of 5.9 maf. This would increase aggregate benefits by roughly $15 billion and result in positive returns above allocated costs for all major user groups.

Another factor that may be relevant in the future but is difficult to fully analyze at present is the possible construction of future storage projects. Storage north or south of the Delta is complementary to the WaterFix since the yield benefits of such projects can be larger with more conveyance possibilities across the Delta.

To take one example, consider Sites Reservoir, a contemplated offstream storage project west of the Sacramento Valley and north of the Delta. Assuming the current conveyance infrastructure in the Delta, Sites would produce water supplies of 246 thousand acre-feet on average and 383 thousand acre-feet in an average dry or critically dry year. With construction of the WaterFix, the average water supply produced by Sites would be 344 thousand acre-feet in an average year, and 510 thousand acre-feet in an average dry or critically dry year. Thus, the WaterFix increases the productivity of an investment in Sites Reservoir by 98 thousand acre-feet in an average year and by 127 thousand acre-feet in an average dry or critically dry year. Using the approximate water values discussed earlier in this section, it follows that implementing the WaterFix would increase the present value benefits of the Sites Reservoir project by roughly $1.5 billion.

The WaterFix can create additional opportunities for water transfers, thereby increasing the benefits from the project. By making it easier to convey water across the Delta, the WaterFix could allow for additional water to move from the Sacramento Valley to the state and federal contractors in the San Joaquin Valley, the Bay Area, and Southern California. More detail?

Water trading *among* south of Delta users also has the potential to increase the aggregate benefits from the WaterFix. By allowing users to sell their available supplies to other contractors, establishing more robust markets within the state and federal projects can put each group of contractors in a position where their net benefits are positive. This outcome could be accomplished at minimal facilities cost, although it would be important to consider the impact of supply reallocation on areas of origin, including local labor markets and groundwater resources. As shown in Section III, every 100 thousand acre-feet that is reallocated from the average SWP agricultural contractor and CVP water service contractor to the average SWP urban agency creates roughly $2.0 billion in net direct benefits. Allowing agricultural water contractors to sell their water allocations for more than their cost share of the WaterFix also helps alleviate concerns about the affordability of the project to all users.

VII. Adaptation to Climate Change

Sea level rise poses a significant threat to the Delta's water supply infrastructure. The current intakes are close to sea level, and any rise in the ocean's surface level means that the state and federal pumps are inundated with salt water more frequently, resulting in a loss of project deliveries. The WaterFix is expected to mitigate the impacts of sea level rise due to the construction of a second set of intakes on the Sacramento River upstream of the Delta and at a higher elevation than the current intakes. Indeed, the water supply tables presented in Section III show that the WaterFix maintains SWP deliveries through the Delta at roughly their current levels. Without north Delta intakes, yields fall significantly. This result makes adaptation to climate change one of the strongest arguments in favor of WaterFix, although it is a difficult one to quantify with certainty.

For the SWP, WaterFix preserves 1,220 thousand acre-feet of Delta supplies annually that would otherwise be lost due to sea level rise and other climate impacts. Absent construction of the Delta tunnels, urban contractors would lose over 900 thousand acre-feet of supply across all water year types. MWD alone would lose an average of 641 thousand acre-feet of supply annually, an amount of water equivalent to over 11 Carlsbad desalination projects. For the CVP, WaterFix preserves 61 thousand acre-feet annually.

This report does not monetize the value of these climate change mitigation benefits of the WaterFix. There is substantial uncertainty about how climate change will evolve over the coming decades, and the results presented here should be considered as illustrative. Second, there is uncertainty about the exact timing of climate impacts. While the model results correspond to 2100 levels of development, sea level rise may occur more rapidly or slowly than expected. Nonetheless, the water supply results for 140-cm of sea level rise should be of concern to water district managers and policy makers, and show that the WaterFix can be an important part of California's overall strategy to mitigate the effects of climate change on the state's economy.

VIII. Indirect and Public Benefits of Cal WaterFix

The analysis to this point has focused on benefits and costs from the perspective of the water users. WaterFix provides benefits to a much larger cross-section of Californians, however, even though the current financing plan has no provision for any group other than the water users to pay for the new facilities.

A. FOOD PRICES AND CONSUMER IMPACTS

Stabilizing Delta supplies with WaterFix will increase California farm output and benefit consumers through reduced food prices, primarily for fresh fruits, nuts and vegetables. The food price reductions resulting from improved conveyance are especially large in light of SGMA's restriction of groundwater overdraft.

Using the SWAP model described earlier, I calculated the annual and present value of food price reductions resulting from WaterFix, as compared to the existing conveyance and tighter environmental regulation baseline. Table AA below displays the results of the calculations.

Implementing WaterFix will provide annual consumer benefits of $78 million in the form of reduced food prices. Most of these benefits come as a result of stabilizing SWP deliveries at roughly their current levels. In present value terms, WaterFix provides over $1.7 billion in consumer benefits over the life of the project. For certain SWP agricultural contractors, the consumer benefits of WaterFix are nearly as large as the grower benefits.

It should be pointed out, however, that the food price decreases resulting from implementation of WaterFix actually harm California growers operating in other regions of the state as they are forced to sell their output at lower prices. According to the SWAP model output, these losses amount to roughly $1.2 billion in 2015 dollars. Thus, the WaterFix has important distributional implications within California agriculture.

Further, most of the consumer gains from the WaterFix are realized by outside of California.

B. JOB GAINS FROM CONSTRUCTION OF NEW CONVEYANCE FACILITIES

Estimates of job impacts from the construction and the operation and maintenance of the water facility are based on employment multipliers generated by the IMPLAN model. IMPLAN is an input-output model that is used to calculate employment impacts based on the amount of dollars spent in a particular industry.[2] We partition the facility construction and O&M costs into different categories of spending (i.e. labor, materials, equipment, design and project management, subcontractors, and O&M).[3,4] We run the category-specific costs through IMPLAN using industry-specific multipliers to get direct, indirect, and induced impacts under each category. In cases where there are detailed manning tables on employment associated with costs, such as direct labor, direct design and project management, and direct O&M, we use the manning table employment numbers rather than the IMPLAN results (described in more detail in the next section). We then combine all the employment impacts by category into aggregated direct, indirect, and induced impacts as seen in Table 9 below.[5]

Table 9: Job Impacts from the Construction and O&M of New Delta Conveyance[6]

Type	FTE Impacts		
	Construction	O&M	Total
Direct	19,973	3,200	23,173
Indirect	64,479	967	65,446
Induced	34,319	1,642	35,961
Total	**118,771**	**5,809**	**124,580**

2 IMPLAN is widely used by federal and state government agencies when assessing economic impacts of large scale projects. Official IMPLAN website: https://implan.com/

3 These costs do not include land acquisition costs. Costs are taken from November 2013 Bay Delta Conservation Plan, Public Draft, Chapter 8, Table 8-5. Available at: www.BayDeltaConservationPlan.com

4 Roughly $2.0 billion of these costs are assumed to be spent out-of-state on tunnel boring machine equipment, large valves and pumps, and out-of-state administrative costs. Out-of-state costs do not generate job impacts for California and are therefore left out of this analysis.

5 Direct employment impacts are related to expenditures on construction and design & project management. Indirect impacts are associated with purchases of materials and equipment necessary for project implementation. Induced employment impacts are associated with fluctuations in spending by households experiencing income changes resulting from direct and indirect impacts.

6 These figures do not include induced employment impacts associated with household income increases from payments received for the land acquisition necessary for the facility construction.

Direct employment impacts from the construction of the water facility are comprised of direct labor (i.e. tradesman, craftsmen, and machine operators) and design and project management employment. The direct labor employment is taken from the manning tables outlined in the 5RMK estimates.[7] Direct labor employment is broken down into specific job types and categorized into sub-projects (the intakes, forebays, different tunnel reaches, etc.). We aggregate the employment impacts for the sub-projects by county (Sacramento, San Joaquin, and Contra Costa) according to the location of the specific sub-project. The direct design and management employment figures are taken from a manning table provided by the DHCCP.[8] Design and project management jobs are not grouped by county as it is not yet determined where this work will be based. The resulting impacts can be seen in Table 10.

Table 10: County-Level Job Impacts from the Construction of New Delta Conveyance

County		FTE Impacts
Sacramento County	Intake 2	804
	Intake 3	666
	Intake 5	709
	Forebay	191
	Total Tunnels & Shafts Jobs	3,429
	TOTAL	5,798
San Joaquin County	Total Tunnels & Shafts Jobs	5,529
	TOTAL	5,529
Contra Costa County	Byron Forebay	1,599
	Total Tunnels & Shafts Jobs	1,507
	TOTAL	3,105
Across All Counties	Remaining Jobs Along Entire Alignment	583
Location TBD	Design and PM Jobs	4,958
Total Impacts		**19,973**

The direct employment detailed breakdown is taken from the manning tables described above. Table 11 shows the aggregate direct FTE impacts by job type.

[7] 5RMK estimates were provided by DHCCP on January 30, 2013.

[8] Design and PM manning tables were provided by DHCCP on April 9, 2014.

Table 11: Direct Job Impacts by Profession from the Construction of New Delta Conveyance

Job Type	FTE Impact
Machine Operator	2,613
Design & Management	4,958
Trade & Craft	12,402
Total	**19,973**

It is important to note that there will be employment gains associated with water supply alternative investments that will occur in urban areas should the WaterFix not be implemented. It is not possible to calculate the precise magnitude of such job gains at present since it is not known exactly what types of alternatives will be constructed in areas receiving SWP and CVP supplies. However, it is reasonable to assume that the location of such newly created jobs will be different than under WaterFix. In particular, jobs created by heavier investment in desalination and water reclamation will tend to be located in the Bay Area and Southern California, and not primarily in the Delta region. Thus, failing to implement WaterFix will shift some degree of economic activity out of the Delta counties and toward the Los Angeles and San Francisco metropolitan areas. Again, like many large infrastructure projects, the WaterFix has important distributional implications within the State.

It is also important to note that if urban agencies invest in the WaterFix or replace lost Delta supplies with more expensive water supply alternatives (albeit ones under local control) that water rates will rise, creating a drag on economic activity in the State. More detail from earlier report.

C. FALLOWING AND FARM JOB IMPACTS

The SWAP modeling described earlier indicates that without WaterFix in place, more restrictive environmental regulations in the Delta will result in the fallowing of 179 thousand acres of farmland in the San Joaquin Valley. Of this amount, 115 thousand acres will be in the CVP service area (mainly on the west side of the Valley), and the remaining 64 thousand acres in the SWP service area (primarily in Kern County).

Farmland losses of this magnitude will cause significant impacts to the farm labor market. Describe statistical analysis.

Using these estimated coefficients together with data on average compensation among agricultural workers compiled by the California Employment Development Department, it follows that the WaterFix preserves 10,106 farm jobs each year providing approximately $193 million in annual wages. The present value of this farmworker income is $6.1 billion evaluated over the 100-year life of the project.

D. INDIRECT AND INDUCED ECONOMIC ACTIVITY FROM FALLOWING

Value added and revenue multipliers imply roughly 2x the farm-level impacts.

IX. Alternative Versions of CalWater Fix

Critics and commentators have suggested several alternatives to CalWater Fix proposed project. These include reinforcing existing levees (i.e., creating an "armored Delta"), building smaller capacity tunnels (e.g., 6,000 and 3,000 cfs) and building a single bore tunnel. All of these alternatives reduce construction and operating cost, but result in lower levels of species protection, water quality and water supply benefits as well. All of these alternatives have been studied extensively, and all have been demonstrated to be less desirable than the proposed project.

Reinforcing existing levees was included as an EIR alternative, and was also studied as a take alternative in the BDCP. This alternative involves through-Delta conveyance with Delta channel modifications and different intake locations than the proposed project. The total costs of this project are significantly lower than the proposed project at a present value of $5.2 billion. Water supplies would average 4.2 maf. While these tradeoffs appear to be reasonable as compared to the proposed action, through Delta conveyance does not produce acceptable environmental outcomes.

The BDCP examined 6,000 and 3,000 cfs tunnels. These alternatives also result in lower construction and operating costs: the 6,000 cfs tunnels reduce costs by $1.2 billion and the 3,000 cfs tunnels lower costs by $3.2 billion. Water supplies under these alternatives are 4.5 and 4.2 maf, respectively.

To understand why these alternatives are inferior to the proposed project, consider that moving to the 6,000 cfs version saves $1.2 billion but costs 0.2 maf of project deliveries. Put another way, moving from 6,000 cfs to 9,000 cfs produces 0.2 maf of additional supply for an annual cost of only $300 per acre-foot, which is far less expensive than any available water supply alternative. Similarly, moving from 3,000 to 9,000 cfs produces an additional 0.7 maf of supply at a cost of

$230 per acre-foot per year. These results demonstrate the huge economies of scale associated with tunnel construction. They also indicate that the contractors have already made a significant concession by moving from a 15,000 cfs facility to a 9,000 cfs one.

Lastly, some commentators have suggested saving construction cost by building a single bore tunnel. This alternative would not produce the same level of benefits as the proposed dual bore tunnels. With a single bore tunnel, the facility would need to be off-line for routine maintenance. It would also need to be shut down in the event of a failure requiring repair. Both types of events reduce the water supplies that would ultimately be produced by the project, and would not be worth the associated cost savings.

This discussion has another important implication with respect to cost allocation and financing. If there are concerns about whether the project makes economic sense to the agricultural contractors, it is economically preferable to reallocate the supplies produced by a 9,000-cfs project, than it is to reduce the size of the project. There are certainly urban and agricultural contractors that are willing to pay more for water than the incremental cost of increasing the size of the tunnels from 3,000 or 6,000 cfs to 9,000 cfs. Thus, keeping the project at its current size and allowing contractors to trade the incremental benefits of the WaterFix is more efficient and produces a higher level of aggregate benefits than reducing the tunnel capacity to solve the cost allocation problem.

X. Conclusions and Implications for Cost Allocation and Financing

Project passes a benefit cost test but not for all groups under the operating criteria being considered at present. Yields being considered now are significantly lower than those contemplated in Chapter 9, and thus the cost-benefit comparison is not as favorable. Have also lost some degree of certainty with respect to project outcomes now that the permitting has migrated from Section 10 to Section 7.

Can implement different operating criteria and increase project yields

State can contribute to the project in recognition of the indirect economic benefits from agricultural production, reducing seismic risks and mitigating the long term effects of climate change.

State can allow users to trade available SOD supplies

State can go broader and acquire water from willing sellers north of the Delta, thus enhancing SWP and CVP deliveries.

These approaches, or a combination of them, could improve the attractiveness of the project to virtually all users and allow the state to proceed with the WaterFix.

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