

# **The Economics of Ending Delta Water Exports Versus the Peripheral Canal:**

## **Checking the Data of the PPIC**

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### **Summary:**

The issue of a peripheral canal has returned to the center of the debate about the future of the Delta. The case for building a peripheral canal has recently received a major boost from a report by the Public Policy Institute of California (PPIC) that endorses the peripheral canal as the best long-run solution for the Delta. The PPIC report considers alternative strategies, most notably ending Delta water exports. They find that ending Delta water exports is significantly better for the environment than a peripheral canal, but reject the strategy because it is too costly. However, the PPIC's cost estimates are exaggerated. They depend on inaccurate assumptions that utilize outdated, undocumented, or fabricated sources. When adjustments are made to their population growth, water recycling cost, and desalination cost assumptions to reflect the best, documented sources, the cost of ending Delta exports are likely to be similar to a peripheral canal. With similar costs, ending Delta exports is the best strategy due to its superior environmental benefits.

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The issue of a peripheral canal has returned to the center of the debate about the future of the Delta. The case for building a peripheral canal has recently received a major boost from a report by the Public Policy Institute of California (PPIC) that endorses the peripheral canal as the best long-run solution for the Delta. The PPIC report considers alternative strategies to a peripheral canal, most notably ending Delta water exports. It argues that the long-run choice is only between two options: ending exports and a peripheral canal. The PPIC analysis states that ending Delta water exports is significantly better for the environment than a peripheral canal, but it rejects the strategy because ending exports is too costly. However, the PPIC's cost estimates for ending Delta water exports are greatly exaggerated. They depend on inaccurate assumptions that utilize outdated, undocumented, or fabricated sources. When adjustments are made to their population growth, water recycling and desalination cost assumptions to reflect the best, documented sources, the cost of ending Delta exports are similar to a peripheral canal. With similar costs, ending Delta exports is the best strategy due to its superior environmental benefits.

The key unsupported assumptions that inflate PPIC cost estimates are:

- California population grows to 65 million in 2050.
- Water recycling costs \$1,480 per acre foot.
- Desalination costs of \$2,072 per acre foot of desalted water.

These assumptions are keys to assessing reduced Delta exports because they define the level of future urban water demand and the cost of alternative urban water supplies when Delta exports are curtailed. In both cases, the PPIC assumptions lie far beyond the highest estimates of credible sources. Their population projection assumes 5-10 million too many urban water users, their water recycling cost is about two and a half times current estimates, and their desalination cost is nearly double current estimates.

The next section provides details on the PPIC's assumptions, and documents more credible levels. This is followed by some calculations that illustrate the potential impact on the costs of reducing Delta exports. Finally, these adjusted cost estimates are compared to those for a peripheral canal, and the impact on the PPIC study's conclusion is discussed.

## **Unrealistic Assumptions and Inaccurate Data**

### *Population Growth*

The PPIC's population growth assumption is stated on page 4 of Technical Appendix F.

“The results presented here simulate the level of development in the year 2050, with a projected population of 65 million (up from 39 million in 2008) (Medellin-Azuara et. al. 2008; Department of Finance, 2008). Urban water demands were based on the year 2020 per capita demands ... scaled to the estimated 2050 population.”

The first clue that there is a problem with the data is that the current population isn't even correct. The state's current population is about 37 million according to the U.S. Census and estimated at about 38 million by the California Department of Finance, not 39 million as stated above. By giving a pair of 2008 references, it appears that the PPIC report is using the latest

data. However, the Department of Finance population reports they reference (the latest made in 2007, not 2008) estimate the 2050 population at 59.5 million, not the 65 million claimed. The second reference is another of the authors' papers (Medellin-Azuara et. al. 2008) and the true source is revealed in their *Climatic Change* article,

“data from Landis and Reilly (2002) for a ‘high’ estimate of year 2050 population (65 million) and resulting land use in California. This provided urban water demands and irrigated land areas for 2050.”

The PPIC report never refers to their estimated future population as a high growth scenario like it is described in their references. Rather than update their model with the latest data, they use old high growth estimates from previous studies, drop the statement that it is a high growth scenario, and fabricate a reference to a reputable official source.

It is important to note that U.S. Census Bureau population figures are consistently below recent Department of Finance (DOF) population estimates, which themselves are 5.5 million below the PPIC assumption. As DOF estimates are eventually revised and benchmarked to the Census, it is highly likely that they will be revised lower in the future. For example, the latest Census estimate of California's population is 36.6 million on July 1, 2007. The DOF estimate for the same date is 37.8 million, about 1.2 million people higher than Census figures that were released after DOF released its estimates. In 2030, the Census projects the state population at 46.4 million, about 2.8 million lower than the Department of Finance projection of 49.2 million. The Census has not published 2050 numbers for California, but their earlier estimates project to 55 million for California in 2050. As a result, a much more defensible estimate of 2050 California population is 55 to 59 million, not the 65 million assumed in the PPIC report. The PPIC itself has a demographic research group that projects population in this range, and it isn't clear why the PPIC would assume population figures in this study that far exceed the estimates of their own in-house demographers.

### *Desalination and Water Recycling Costs*

The PPIC's water recycling and desalination cost figures are also described on page 4 of Technical Appendix F.

“Urban coastal areas were assumed to have access to desalted seawater at a cost of \$1,400 per acre-foot (in 1995 dollars, or \$2,072 per acre-foot in 2008 dollars) and all urban areas were assumed to have access to up to 50 percent of their wastewater flows as recycled water, at a cost of \$1,000 per acre-foot (in 1995 dollars, or \$1,480 per acre-foot in 2008 dollars).”

A few sentences earlier, the PPIC explains their approach to getting current cost figures.

“economic data are in 1995 dollars, but for this report all costs have been updated to 2008 dollars using the Engineering News-Record multiplier of 1.48.”

They provide no references for their cost estimates. Rather than gathering the most recent cost estimates based on the latest technology and experience, the PPIC study uses 1995 estimates and inflates them based on a generalized construction cost index. This is an inaccurate approach even with constant technology, but is especially problematic in this case due to significant cost decreases as desalination and water recycling technology has improved in recent years.

Prior to this study, the PPIC released other reports (Lund et. al. 2007, Hanak 2005) by the same authors that give much lower cost estimates for both technologies. For example, in the 2005 PPIC report Water for Growth, Ellen Hanak uses California Department of Water Resources estimates that water recycling costs of \$600 per acre-foot (af) for treatment and delivery, and desalination is \$800 to \$1500 per acre-foot. It is curious that such references disappeared in their most recent report when its controversial conclusion that the economics supports a peripheral canal critically hinge on higher assumed costs (\$1480af for recycling and \$2072af for desalination).

There are numerous other references that show costs are consistently well below the figures used in the PPIC report. Most notably, Orange County opened a wastewater to drinking water recycling plant about a year ago that is operating at \$550 per acre foot (Los Angeles Times, 1/2/2008). In May 2008, the National Research Council of the National Academy of Sciences published an assessment of current desalination technology in the United States from a panel of a dozen leading experts. The report generally cites desalination costs of approximately \$1000 per acre foot. Similarly, the California Coastal Commission (2004) notes the significant declines in desalination costs, estimating average costs for several proposed southern California plants in an approximate range of \$800-\$1000 per acre-foot with costs rising to about \$1200 per acre-foot with high electricity costs. Over time, recycling and desalination costs are likely to decrease further as technology continues to advance.

A frequent comment is that desalination and, to a lesser extent, water recycling use high amounts of energy, so these assumed costs will increase significantly if the electricity prices were to increase substantially. This is true, but it is important to note that higher energy costs will have the same or greater impact on the cost of pumping water south from the Delta. The energy cost of pumping Delta water hundreds of miles south and over mountains to Southern California is about the same as desalination (about 3,000 kWh per acre-foot), and greatly exceeds the energy use of water recycling (Cohen, Nelson and Wolff 2004, Voutchkov 2007). If Delta exports are eliminated, some of it will be replaced by desalination (similar energy use), some by water recycling (less energy use), and some will be replaced by conservation and reductions in irrigated agriculture (no energy use). Thus, higher future energy costs will have a greater effect on the costs of a peripheral canal option than on ending Delta exports.

### *Other Assumptions*

The PPIC makes a number of other questionable assumptions that are not included in the revised cost estimates that follow. The most troubling of these is an implicit assumption about the value of Delta fisheries, recreation, endangered species and other environmental values. Even with their own high cost estimates of ending Delta water exports, the PPIC must impose their own subjective assumption that these environmental benefits are worth less than \$1 billion annually to

conclude that the peripheral canal is the best strategy. Rather than attempt to value these benefits in monetary terms, the PPIC report notes that such estimates are controversial. This is true, so if the PPIC team does not wish to use existing methodologies to put a value on the environmental services, their report should simply illustrate the water supply cost vs. environment trade-off rather than endorse a particular course of action. By recommending the peripheral canal because ending Delta exports may cost about \$1 billion more, the PPIC implicitly imposed their own subjective, low value on these environmental services, an action which is far more controversial than valuing environmental benefits.

Some other PPIC assumptions further inflate the estimated costs of restricting exports, but are likely to be less important than water recycling, desalination and population growth. First, they do not consider how increases in water conservation using both existing and future technologies are likely to reduce demand. In addition, they assume that the composition of the economy is fixed over time, while the reality is that the industrial share of the economy has declined since they fixed the proportions and is likely to continue in the future. The PPIC produces a forecast of the structure of the state economy, and (similar to the PPIC's population forecasts) these could be used to more accurately estimate future demand. Finally, there is uncertainty about the costs of constructing the peripheral canal itself. The estimates are extremely uncertain. The PPIC assumes the costs are less than \$10 billion, but the Delta Vision report cites estimates as high as \$26 billion.

### **Estimating the Impact on the Cost of Ending Delta Exports**

What would be the impact of lower population levels, water recycling costs and desalination costs on the PPIC estimates? Using the tables and figures from the PPIC report, a rough estimate shows that the cost of eliminating Delta exports decreases to about one-third the PPIC's estimates, from a range of \$1.5 to \$2.5 billion per year to about \$0.4 to \$1.0 billion per year.

The costs of reduced exports come from two sources: scarcity costs and operating costs of the water system. When Delta water exports are eliminated, southern water users either bear the scarcity costs of doing without the water (e.g. decreased agricultural profits, reduced benefits from urban water uses) or bear the cost of replacing Delta water from higher cost sources (e.g. recycling wastewater, desalination).

The PPIC study estimates these costs with the CALVIN model developed at UC-Davis. Table F.3 in the PPIC report (displayed below) details how these costs break down at different levels of water restrictions. BC is the base case, and represents current Delta exports of 5.9 million acre-feet (maf) annually. 50%R is a 50% reduction in pumping capacity, which translates into a 1 maf (18%) reduction in water delivery. 75%R is a 75% reduction in pumping capacity, which leads to a 3.4 maf (58%) reduction in delivery. NE is the no export case, a 5.9 maf (100%) reduction in water deliveries. RT represents restricted transfers, a special case of no exports that causes increased costs on urban users by limiting their ability to purchase water from agricultural users.

An argument can be made against considering the RT case in evaluating the costs of reducing Delta exports. The extra cost from restricting transfers is essentially a water subsidy for

agricultural users at the expense of urban users (if imposed by the government) or a decision by farmers to forego the economic benefit of selling water to urban areas (if voluntary). In either case, it is not a cost required by reducing Delta exports, but results from separate decisions to allocate water inefficiently. Despite this argument, this analysis considers the RT case to be consistent with the PPIC report.

Table F.3. reprinted from PPIC report.

**Table F.3 - Annual average statewide net operating costs with export restrictions**

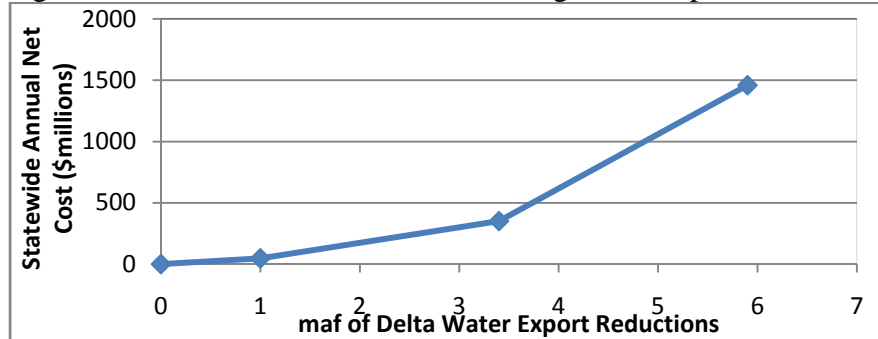
	Statewide Annual Average Costs (\$M/year)				
	RT	NE	75%R	50%R	BC
Groundwater	771	736	773	806	818
Surface Water Treatment	1143	1492	2044	2060	2061
Desalination	1933	541	55	55	55
Recycled Water	1446	1452	354	348	347
Surface Water Pumping	449	981	1669	1784	1832
Hydropower Benefits	2476	2605	2746	2745	2749
Total Net Operating Costs <sup>a</sup>	3266	2596	2151	2308	2365
Statewide Scarcity Cost	1573	1540	877	416	312
Total Statewide Net Costs <sup>a</sup>	4839	4136	3028	2724	2677

<sup>a</sup> Totals may not sum due to rounding, RT is no exports with restricted transfers, NE is no exports, 75%R is 75% reduction in export pumping capacity, 25%R is 25% reduction in export pumping capacity, and BC is base case (2050 demands).

The PPIC cost estimate of \$1.5-\$2.5 billion annually is calculated directly from Table F.3. The cost of each level of water restriction is found by subtracting the total costs for that scenario from the cost of the base case. Thus, the total cost of restricting all exports is \$4,136,000,000 - \$2,677,000,000 = \$1,459,000,000. This is how they arrive at the \$1.5 billion lower bound cost of reducing Delta exports. The upper bound figure of \$2.5 billion is calculated by looking at the difference between the RT (restricted transfer) case and the base case, then arbitrarily adding another \$300 million for assumed additional inefficiencies in the system (\$4,839,000,000 - \$2,677,000,000 + \$300,000,000 = \$2,462,000,000). The CALVIN model definitely underestimates the transactions costs of operating the water transfer system, but the PPIC authors don't explain why these costs would be substantially higher without Delta exports. The \$300 million in additional costs for the RT case is not adequately supported.

For this analysis, there are two important points to be made from Table F.3. First, the costs of reducing exports are driven up by three lines that show large increases in costs going from the BC to NE and RT cases; desalination, recycled water, and scarcity costs. Second, the cost of the last 2.5 maf of water taken out of the system (moving from 75%R to NE) is much higher than the first 3.4 maf of export reductions (the difference between 75%R and BC). Figure 1 shows the cost of reducing Delta water exports at different levels. It's only in this final step that the reductions affect higher value urban users and force expensive investments in wastewater recycling and desalination. These costs are reduced dramatically when slower population growth reduces urban water demand and recycling and desalination costs are lower.

Figure 1. PPIC Cost Estimates of Reducing Delta Exports



What would be the impact of changing these three assumptions (population growth, water recycling costs and desalination costs) to more current and justifiable levels? The next section considers the potential impact of lowering the cost of alternative supplies, then the more complex question of lower population estimates is considered.

#### *Impact of Reduced Water Recycling and Desalination Costs*

Table 1 adjusts the PPIC cost estimates for lower water recycling and desalination cost estimates. The first scenario sets costs at the midpoint of the current cost ranges listed in the California Department of Water Resources 2005 State Water Plan. These costs were estimated at \$300-\$1300 per acre foot for recycling, and \$800-\$2000 per acre foot for desalination. The second scenario is more optimistic about technology and sets costs at the level of the new Orange County water recycling facility, \$550af, and desalination at the projected cost of the recently approved Carlsbad desalination plant, \$950af. This scenario is somewhat optimistic about 2008 costs, but is conservative for 2050 as technology will continue to advance.

Under the first scenario, the total costs of reducing Delta exports drops roughly in half from the PPIC's original range of \$1.5 to \$2.5 billion annually to \$0.8 to 1.05 billion annually. Under the slightly optimistic technology assumption, the costs drop further to about \$0.5 billion annually. In the first case, the costs of reducing exports are close to the high range of peripheral canal costs. In the more optimistic technology case, the cost of ending Delta exports is slightly less than a peripheral canal. In both cases, these costs are still calculated with the PPIC's high 65 million population scenario. The next section shows that the estimated costs drop further when lower population growth cuts demand.

Looking closely at the results in Table 1 and Table F.3, it is important to note that only about 1/3 of the reduced Delta exports (about 2 maf in the RT case, 1.25 maf in the NE case) are estimated to be replaced by water recycling and desalination combined. Reductions in pumping and treatment costs for Delta exports offset most of the costs of recycling and desalination even in the PPIC's high cost estimates. Using lower costs, the pumping and treatment cost reductions exceed the cost of additional recycling and desalination, resulting in a net reduction in operating cost. Thus, the cost of reducing Delta exports is entirely made up of scarcity costs.

**Table 1. PPIC table F.3 data adjusted for lower water recycling and desalination costs. Units are 2050 annual costs in millions of 2008 dollars.**

	Recycling \$800af, Desal. \$1400af			Recycling \$550af, Desal. \$950af		
	RT	NE	BC	RT	NE	BC
Groundwater	771	736	818	771	736	818
Surface Water Treatment	1143	1492	2061	1143	1492	2061
Desalination	1305	365	37	886	248	25
Recycled Water	782	785	188	537	540	129
Surface Water Pumping	449	981	1832	449	981	1832
Hydropower Benefits	2476	2605	2749	2476	2605	2749
<b>Total Net Operating Costs</b>	1974	1754	2187	1311	1392	2116
Statewide Scarcity Costs	1573	1540	312	1573	1540	312
<b>Total Statewide Net Costs</b>	3547	3294	2499	2884	2932	2428
<b>Cost Difference from Base Case</b>	1048	796		455	503	

If the CALVIN model were solved with lower recycling and desalination costs, it would predict more investment in these sources (shrinking the operating cost advantage), and reduced water scarcity (reducing scarcity costs).<sup>1</sup> Total costs of reducing exports would be even lower, but these costs would almost entirely fall on agricultural users to the south.

#### *Impact of Lower Population Growth*

Given the urban water demands assumed in the PPIC study, reducing 2050 population estimates by 6-10 million people would decrease statewide water demand by approximately 1.5 to 2.5 maf in 2050. Assuming that about two-thirds of that urban demand reduction occurs in areas south of the Delta implies a reduction of 1 to 2 maf of demand from the region served by Delta exports.

This 1 – 2 maf reduction in demand essentially replaces some of the lost Delta water. A 1.25 maf reduction in urban water consumption would move the costs of the no export (NE) case halfway between the original NE and 75%R cases, dramatically lowering the cost of the NE solution. The reduction in urban water consumption would also reduce the cost of the base case

<sup>1</sup> This is reflected in the unusual result in Table 1 that the cost of the RT case is lower than the NE case under the optimistic technology assumption. Restricting transfers should always result in higher costs. This strange result stems from the fact that the estimates in this paper assumes the quantity of desalination, recycling, scarcity and water transfers are the same as the original PPIC solutions even when desalination and recycling costs are lower. The RT results from the PPICs original model solutions had much larger investments in desalination that were sub-optimal at \$2072af, but are much closer to the optimal level at \$950af. The PPICs RT scenario allocation with more investment in urban recycling and desalination and less transfers from agriculture to urban uses is therefore closer to what the CALVIN model is likely to predict if it were solved with lower costs.



(BC). Table 2 adjusts the values in Table F.3 so that NE (no export) values are between the current NE and 75%R values (due to lower population levels). The BC (base case) adjusts also, but the change is small because it is a flat segment of the cost curve. The BC cost is reduced by ½ the change between BC and 50%R which assumes a constant slope to this curve around the original base case level. Table 2 also uses the same water recycling and desalination costs as Table 1.

Table 2 shows the total cost of reducing Delta exports considering both lower population growth and lower recycling and desalination costs. The key impact is that lower population growth reduces scarcity costs by about \$250 million, from slightly over \$1.2 billion to a little below \$1 billion annually. This result follows from reduced water demand, particularly from high-value urban users. The savings from lower cost water recycling and desalination are reduced somewhat, because less water is needed from these sources with lower demand. Overall, the estimated costs of eliminating Delta exports ranges between \$425 million and \$722 million annually.

**Table 2. PPIC table F.3 data adjusted for lower population growth, water recycling and desalination costs. Units are 2050 annual costs in millions of 2008 dollars.**

	Recycling \$800af, Desal. \$1400af			Recycling \$550af, Desal. \$950af		
	RT	NE	BC	RT	NE	BC
Groundwater	772	755	824	772	755	824
Surface Water Treatment	1594	1768	2062	1594	1768	2062
Desalination	671	201	37	456	137	25
Recycled Water	486	488	187	334	336	129
Surface Water Pumping	1059	1325	1856	1059	1325	1856
Hydropower Benefits	2611	2676	2751	2611	2676	2751
<b>Total Net Operating Costs</b>	1972	1861	2215	1604	1644	2144
Statewide Scarcity Costs	1225	1209	260	1225	1209	260
<b>Total Statewide Net Costs</b>	3197	3070	2475	2829	2853	2404
<b>Cost Difference from Base Case</b>	722	595		425	448	

Lower population growth could reduce overall demand by less than estimated above if it results in more agricultural demand. The net impact on water demand is small if new urban growth is developed on previously irrigated farmland. The 1.25 maf reduction in demand assumed here is on the low end of the range of demand reductions expected from lower population growth, so it may roughly approximate the agricultural effect. However, the best approach would be to adjust the CALVIN model to fully model reduced urban demand and any predicted increases in agricultural demand from reduced urbanization. The difficulty in estimating the net impact on total water demand from lower population is one reason for considering the effect of water recycling and desalination costs without lower population growth in the previous section.

## Conclusion: Impact on the PPIC Decision Analysis

The PPIC considers several alternatives, but argues that in the long-run the real choice is between a peripheral canal and ending Delta exports. The first two rows of Table 3 reproduce the bottom-line results of the PPIC report. Ending Delta exports is better for fish, but much more costly. Their conclusion is that the peripheral canal is the best alternative, because ending Delta exports is too costly. They note that the peripheral canal is better than current Delta pumping operations for fish, and advocate for additional funds for environmental remediation to help fish.

This paper finds that the PPIC's cost estimates for ending Delta exports are highly inflated by inaccurate and unsupported assumptions about key parameters. More realistic values for future water recycling and desalination costs reduce the annualized costs of ending Delta exports to between \$500million and \$1billion. Adjusting for lower population growth decreases the cost by an additional \$100-250 million. This is a significant cost, but it is comparable to the cost of a peripheral canal. With comparable costs, ending Delta water exports is clearly the best choice because of its superior environmental benefits.

**Table 3. Annual Costs and Fish Population Viability**

Alternative	Average Cost (\$ billion/year)	Delta Smelt Population Viability	Chinook Salmon Fishery Viability
Peripheral Canal (PPIC study)	0.25-0.85	10-40%	20-50%
No Delta Exports (PPIC study – high pop. Growth, recycling and desalination costs)	1.50-2.50	30-60%	40-80%
No Delta Exports (lower recycling and desalination costs)	0.45-1.05	30-60%	40-80%
No Delta Exports (lower population growth, recycling and desalination costs)	0.40-0.75	30-60%	40-80%

This criticism does not take issue with the general approach or model used in the PPIC study. The problem is the inaccurate data input into an otherwise sound model. The estimates in this paper are rough approximations, but they clearly demonstrate that the errors in the PPIC analysis are substantial, most likely large enough to change the study's conclusion. The best way to calculate the impact is to estimate the CALVIN model with lower, more realistic parameter values. Thus far, the UC-Davis/PPIC researchers have responded to this and other criticisms of their study by defending their assumptions rather than solving the model for more realistic scenarios. As demonstrated earlier in this review, the PPIC report does not support their assumptions with any valid references, and every reputable source of cost and population estimates has values well below those used by the PPIC.

The decision to construct a peripheral canal will have long lasting impacts for the state. The project will impose significant financial and environmental costs. The primary benefits of the

peripheral canal (avoiding the costs of reducing and ending Delta water exports) are likely to be much less than claimed by the PPIC and others recommending a peripheral canal. Statements such as “Without water conveyed through the Delta ... California’s economy will run dry,” (Delta Vision Strategic Plan Executive Summary, page ES-1) are less credible than previous predictions that the nation’s economy would collapse with gas at \$3 per gallon. The cost of ending Delta exports is about 0.03% of the current state economy (only about 0.1% under the PPICs assumptions), and is similar to the costs of building a peripheral canal. Similar to reducing our dependence on cheap fossil fuels, reducing our dependence on cheap water conveyed through the Delta will generate increased efficiency, stimulate alternative supplies as technology increases, and leave future generations with a healthier environment.

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## Appendix: The PPIC Response

The previous version of this paper generated a response from Jay Lund of UC-Davis and Ellen Hanak of the PPIC, two of the PPIC report's principal authors. The response was emailed to numerous people. The PPIC has not published their response and would not grant permission to me or others to post it. The PPIC response's main arguments are paraphrased below in italics. Before commenting on what the PPIC response does say, it is even more important to point out what it does not say. A convincing response from the PPIC should include

1. New cost estimates from resolving the CALVIN model using more realistic assumptions.
2. A justification for the low value they place on the Delta environment including fisheries.
3. An explanation for the missing and fabricated references.

To date, the PPIC has not provided any of these, and instead offers the following less convincing rebuttals.

*It doesn't matter if our population estimate is too high, it just makes our analysis a 2060 or 2070 analysis.*

This argument is invalid, because it means all the other tenuous assumptions, such as desalination, water recycling and conservation technology stays frozen at 1990s level, would have to hold up for another 10 to 20 years. Even if it were a valid argument, it would still be nice to consider some assessment dates when most of the state's current population is alive.

*The demand reduction from lower population growth would be offset by higher agriculture demand as less agricultural land is lost to urbanization.*

This argument has some merit, but is unlikely to be a major factor. Nevertheless, this revision separates the effects of recycling/desalination costs from population growth to allow for the possibility of minimal population effects. The estimated costs fall enough to change the PPIC's conclusion without even incorporating the revised population assumption. On net, lower population growth will still decrease costs.

*This type of analysis inherently includes a lot of uncertainty. The PPIC lists sources of uncertainty with the direction of their likely impact on the cost estimates. The scenarios described in this review are described as an "improbable confluence of one-sided errors."*

Uncertainty is why researchers are careful to select parameter values from the center of the probability distribution, and if possible include sensitivity analysis with high and low values of the most important or most uncertain parameters. As discussed in this review, the PPIC selects extremely high values for key parameters. In fact, it is the PPIC study that models an "improbable confluence of one-sided errors." Finally, it is important to note that the PPIC report already makes an arbitrary \$300 million upward adjustment to costs for the only item in their list

(transactions costs) thought to have a significant positive effect on costs, but makes no adjustments for the longer list of items they acknowledge would decrease cost estimates.

*The model is complicated and includes millions of numbers. You can't just adjust a few numbers in the results, they need to be fed through the entire model.*

No disagreement here. It's a great argument for why they should get busy with these new CALVIN model estimates. It shouldn't take the computer long to make the millions of calculations.

However, the complicated model argument is overstated, some parts are pretty simple (i.e. the total cost of desalination is the number of acre feet of desalination times the assumed cost per acre foot). The calculations in this review are "rough", because they assume the supply of water from various sources doesn't change when the costs change. They are not a substitute for complete model runs, but they are a perfectly valid way to estimate the potential error and motivate the importance of revised model estimates. Of course, if some alternative water supplies are assumed to have lower costs, the optimization model will change its solution to take advantage of the lower costs. If this is the case, the total costs will be even lower than the rough estimates presented in this paper.

*If ending Delta exports is cheaper, then why are some people so interested in a peripheral canal.*

This paper doesn't argue that Delta exports are cheaper, only that the total costs are comparable to a peripheral canal. Of course, ending Delta exports is more costly for certain southern California interests (particularly south Valley agriculture) than a peripheral canal. These same interests are further removed from the environmental benefits of the Delta that would be enhanced by ending exports.

### **About the Author**

Dr. Jeffrey Michael is Director of the Business Forecasting Center and Associate Professor in the Eberhardt School of Business at the University of the Pacific. His research forecasting regional economic performance includes work assessing the long-range economic impacts of various aspects of climate change. Other work has examined the effect of environmental regulations and policy on property markets and land use decisions. He has received several grants, published in scholarly journals such as *Energy Policy*, *Journal of Law and Economics*, and *Ecological Economics*, and his work has been covered extensively in the press including the *Wall Street Journal*, *New York Times Magazine*, *Washington Post*, *Sacramento Bee* and the on-line magazine *Slate*. Before coming to Pacific, Dr. Michael spent nearly nine years at Towson University in Maryland where he was an award-winning teacher while serving as faculty, Associate Dean, and Director of the Center for Applied Business and Economic Research. Jeff received his Ph.D. from North Carolina State University, M.S. from the University of Maine, and B.A. from Hamilton College (NY).