6. Water Supply Adaptations to Changes in Delta Management

"The rains of California are ample, but confined to Winter and Spring. In time, her streams will be largely retained in her mountains by dams and reservoirs, and, instead of descending in floods to overwhelm and devastate, will be gradually drawn away throughout the Summer to irrigate and refresh. For a while, water will be applied too profusely, and injury thus be done; but experience will correct this error; and then California's valleys and lower slopes will produce more food to nourish and fruit to solace the heart of man than any other Twenty Millions of acres on earth."

Horace Greeley (1868), Recollections of a Busy Life

In this chapter, we examine how water users in California might adapt to major changes in the Delta and in Delta water management. Water agencies and users have a wide range of long-term options in this regard. The exploration and integration of these options in complex water systems usually require the use of computer models. Here, we employ two computer models of water and agricultural management to examine adaptations and adaptation costs for several major, even extreme, sets of long-term Delta conditions. The CALVIN (California Value Integrated Network) model examines long-term statewide water supply adaptations to changes in Delta water availability. The DAP (Delta Agricultural Production) model examines how changes in Delta salinity might affect agricultural production within the Delta. We also briefly review the benefits of a peripheral canal water supply diversion upstream of the Delta and consider its economic value, based on the results of our modeling exercises. This analysis provides useful background for a broader discussion of alternatives for the Delta, pursued in the next chapter. We begin with a review of the direct and indirect use of water from the Delta in different parts of the state.

State and Regional Use of Delta Water Supplies

Table 6.1 presents estimates of the consumptive uses of water (water that is either consumed or evaporated and unavailable for potential reuse) in or tributary to the Sacramento–San Joaquin Delta. Because these estimates must be assembled from various sources, the particular numbers are somewhat uncertain. Nevertheless, they illustrate some important points.

First, there is little doubt that much less water flows through the Delta today than would under natural conditions.[1] In an average water year (October to September), total diversions from the Delta—about 18 million acre-feet (maf)—account for roughly 40 percent of all flows that would have naturally passed through the Delta. In addition, the seasonal patterns of Delta inflows and net outflows have been altered significantly. Today, spring Delta outflows are much lower than they would be naturally, and summer outflows are generally higher.

Second, most diversions (64% on average) occur upstream of the Delta. To the north, Sacramento Valley water users deplete Delta inflows by almost 6.7 maf per year, mostly for agricultural uses. To the south, an additional 4.0 maf per year are consumed by diversions on the San Joaquin River and its tributaries, including the Friant-Kern Canal, which exports water to the Tulare Basin (Kern and Tulare Counties). The major water projects that use the Delta as a transfer point—the Central Valley Project and the State Water Project—account for only about 31 percent of all diversions, averaging 5.4 maf per year and regularly exceeding 6.0 maf per year in recent years. The balance (4%) is accounted for by in-Delta users, primarily farmers.

Third, direct exports from the Delta have increased over time, with the exception of drought periods (Figure 6.1). This trend continues today. Although exports to the federal Central Valley Project have decreased somewhat in recent years as a result of environmental flow requirements of the CVPIA, State Water Project exports have increased in response both to growth in urban water demand in Southern California and the Bay Area and to several recent wet years.

[1]There is some dispute over the extent to which native vegetation and wetlands consumed some of these flows under natural conditions. Also, precipitation increases in recent decades might be mitigating some effects of increased water withdrawals (Fox, Mongan, and Miller, 1990).

Table 6.1

Estimated Average Consumptive Uses of Delta and Delta Tributary Waters, 1995–2005 (taf/year)

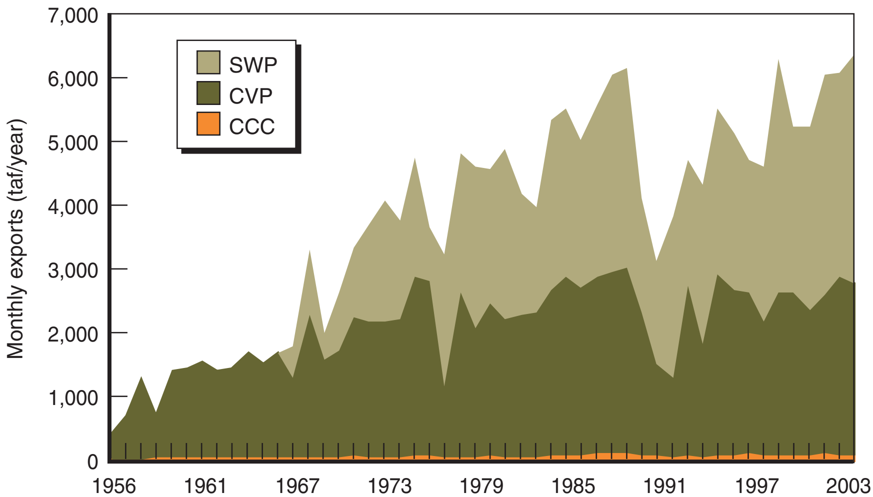
Demand Area	Agriculture	Urban	Environment[a]	Total
Net Delta outflow	—	—	22,553	22,553
Total diversions	14,090	3,235	415	17,740
Upstream diversions	9,540	1,712	138	11,390
Delta diversions	4,550	1,523	277	6,350
In-Delta	769	0	0	769
Upstream diversions	0	0	0	0
Delta diversions	769	—	—	769
North of Delta	6,000	562	138	6,700
Upstream diversions	6,000	520	138	6,658
Delta diversions	0	42	0	42
South of Delta	7,321	1,699	277	9,297
Upstream diversions	3,540	600	—	4,140
Delta diversions	3,781	1,099	277	5,157
West of Delta	0	974	0	974
Upstream diversions	0	592	0	592
Delta diversions	0	382	0	382

SOURCES: U.S. Bureau of Reclamation (2005); Jenkins et al. (2001), Appendix F; Department of Water Resources (1998, 2005c); DAYFLOW data (Department of Water Resources); San Francisco Public Utilities Commission (2005); Santa Clara Valley Water District (2005); Contra Costa Water District (CCWD) (2005); and East Bay Municipal Utilities District (2005).

NOTES: Calculations assume that consumptive use constitutes 75 percent of upstream agricultural withdrawals and 65 percent of upstream urban withdrawals. taf = thousand acre-feet.

[a]Environmental uses include net Delta outflows and water diverted to supply wetlands.

Given anticipated population growth over the coming decades, California's urban water demand is likely to increase, although conservation programs will slow the pace of this growth. However, agricultural water uses are likely to decline somewhat in reaction to market forces, including land development (Department of Water Resources, 2005c). Some agricultural lands south of the Delta also will be coming out of production because the soils are becoming too saline to farm profitably. Some growth



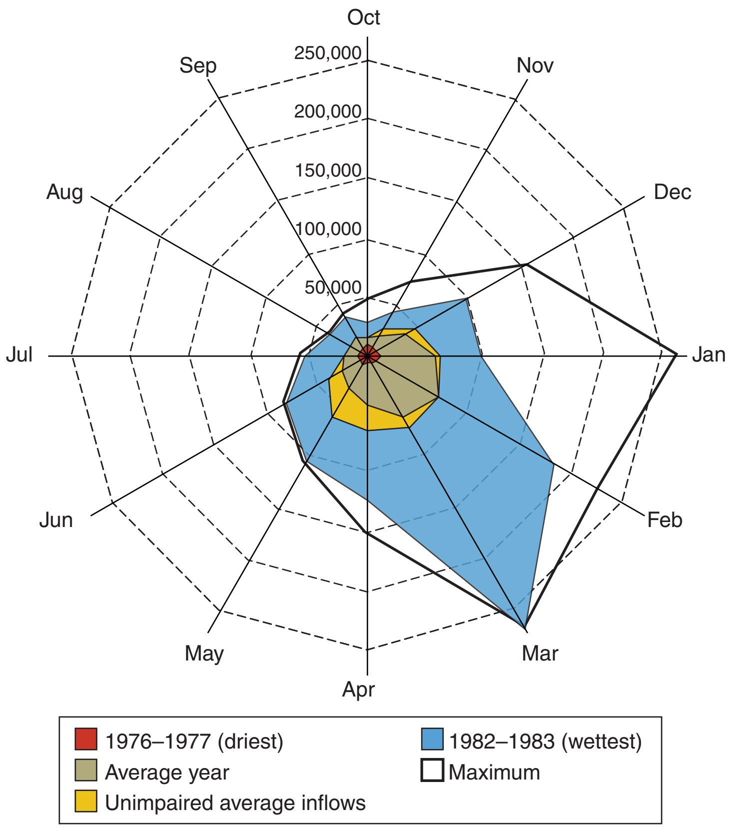
SOURCE: DAYFLOW data (Department of Water Resources).

NOTES: Totals are for water years (October to September). Exports include the Central Valley Project at Tracy (Delta-Mendota Canal), the State Water Project at Banks (California Aqueduct), and diversions for the Contra Costa Water District through the Contra Costa Canal (CCC). Five-year gap between first two years, six-year gap between others.

Figure 6.1—Major Direct Water Exports from the Delta, 1956–2005

in urban water demands can be offset by these declines in irrigation, as well as by improvements in water conservation. On balance, only small increases in total water demands are likely for urban and agricultural uses.

Delta water supplies remain highly variable, despite substantial management of flows through reservoir storage and releases. Inflows to the Delta from upstream sources vary greatly across seasons and years (Figure 6.2). The driest year of record (1976–1977) had little inflow, averaging only 2,800 cfs for the year, and little absolute seasonal variability, ranging from 1,600 to 5,000 cfs. The wettest year of record (1982–1983) had an average inflow of 89,000 cfs, ranging from 23,000 to 267,000 cfs of monthly average flows. Other years of record had higher individual monthly flows, usually associated with floods. We estimate that on average, the inflows that would have occurred if the Delta had been in its natural



SOURCE: DAYFLOW data (Department of Water Resources).

Figure 6.2—Seasonal and Annual Variability of Delta Inflows, 1956–2005 (cfs)

state (shown as "unimpaired" flows in Figure 6.2) tended to be greater than current inflows, especially during spring.[2]

Direct water exports from the Delta are also variable (Figure 6.3), although to a lesser extent than inflows. There are two distinct seasons of

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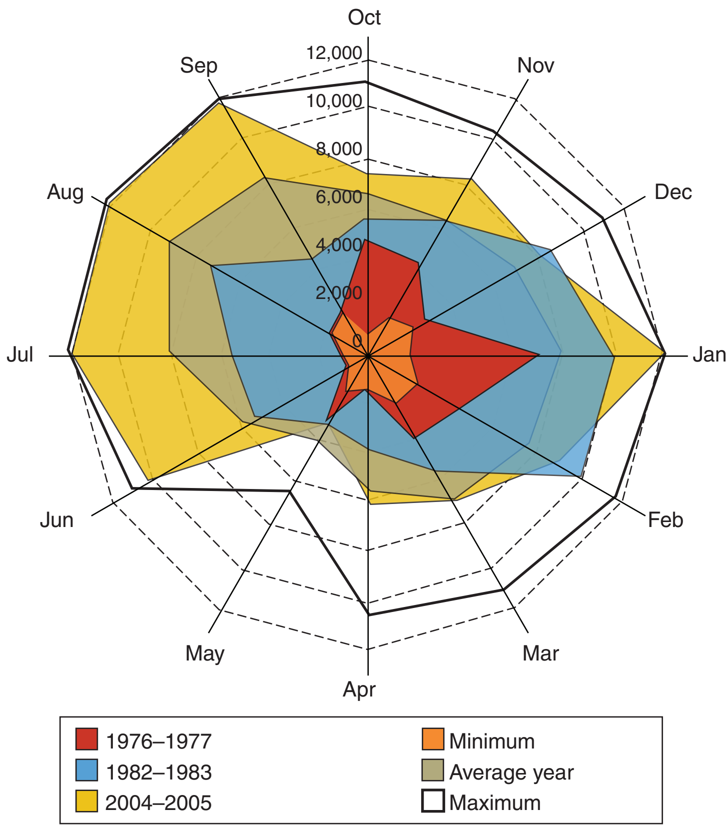
[2]Unimpaired flows are estimated using two DWR data series for the period 1956–2005: (1) DAYFLOW estimates of Delta inflows and exports and (2) estimates of unimpaired or natural Central Valley inflows.



SOURCE: DAYFLOW data (Department of Water Resources).

Figure 6.3—Seasonal and Annual Variability of Delta Pumping, 1975–2005 (cfs)

pumping, winter and summer, with historically less pumping in spring and fall months. This pattern is a result of the high demand for irrigation water during the summer months and the filling of off-stream storage in San Luis Reservoir in winter. It also reflects efforts to minimize pumping during the spring and fall months when fish are spawning. Annual export pumping since 1975 has ranged from 3,100 cfs (1976–1977) to 8,900 cfs (2004–2005).

Statewide Adaptations to Delta Water Availability and Management

The reliability of the Delta as a water source is of great concern to water managers, particularly those whose agencies rely on direct diversions of Delta water. At issue are both regulatory reliability (given continued concerns over the needs of fish species) and physical reliability (given the threats to the integrity of the levee system). In response, many users of exported water have made strides to reduce their dependence on the Delta in recent years. Urban water agencies have been developing interties—or connectors between aqueducts—to enable water sharing in the event of emergencies, such as a massive levee failure. Both urban and agricultural water agencies have developed underground storage (or "groundwater banking"), water use efficiency, water markets, transfers and exchanges, wastewater reuse, and other activities. Indeed, much can be done to reduce the dependence of water users on Delta supplies, although such actions always come at some cost, in terms of financial expense or water scarcity (i.e., using less than the desired amount of water).

If water supplies from the Delta were abruptly cut off and water users were both unable to draw on alternative supplies and unprepared to reduce water use, the results would be catastrophic for many users. Costs for such scenarios, arising from multiple levee failures, are estimated to be as high as $10 billion per year (Illingworth, Mann, and Hatchet, 2005). In contrast to these scenarios, this chapter examines a "soft landing" approach to adaptation, in which reasonable preparations would be made for any major changes in Delta conditions and management.

Water suppliers and users can be remarkably adaptable. Studies of how California's water supply could adapt to major climate, population, and infrastructure changes indicate that considerable adjustment is physically possible at reasonable cost (Tanaka et al., 2006; Jenkins et al., 2004). Furthermore, adaptations may be facilitated by the highly intertied nature of the state's water system and the decentralized nature of water management. State and federal agencies manage the large water projects, but many planning decisions are made at the local level. Local and regional water agencies commonly have the political, financial, and technological wherewithal to make long-term changes in their water supplies and water use. Although institutional conflicts can limit short-term actions, cooperation has increased considerably in recent decades in such areas as water marketing, groundwater banking, and emergency sharing agreements.

Table 6.2 summarizes many of the options available to water managers seeking to balance supplies and demands. In addition to traditional methods to expand usable water supplies, such as surface storage, conveyance, and water treatment, the list includes more contemporary methods, such as improvements in operational efficiencies and wastewater reuse. Water demand management measures include improving water use efficiency ("more crop per drop") as well as water scarcity (reducing water use beyond desired levels by rationing urban water use, fallowing some farmland, or curtailing recreational activities). Various general tools (pricing, water markets, exchanges, and taxes or subsidies) may be used to motivate local users to implement both supply- and demand-side options.

Modeling Water Supply and User Adaptations

A similarly wide range of alternatives exist for managing Delta water supplies. As seen in Chapter 2, numerous alternatives have been proposed in the past, and Chapter 7 will consider others. Various Delta outflow regulations, policies on Delta exports, changes in physical pumping, conveyance, and storage capacities would be reasonable elements to examine, both individually and in combinations. If one also considers a reasonable set of adaptations by water users and managers, estimating the performance of alternatives becomes a complex exercise Here, we draw on two computer models to examine the ability of California water users to adapt to changes in water supply available from the Delta. The CALVIN model explores how California's larger water supply system could respond to changes in water supplies and demands resulting from different Delta management strategies. The DAP model explores how in-Delta agriculture would be affected and would respond to changes in Delta land and water management.

All model results are based on imperfect assumptions and limited information. Nevertheless, for such complex systems as the Delta and California's water supply, these types of analytical aids are indispensable for exploring, developing, and evaluating new alternatives. Computer models

Table 6.2

Water Supply System Management Options

Demand and Allocation Options

General

Pricing[a]
Subsidies, taxes
Regulations (water management, water quality, contract authority, rationing, etc.)
Water transfers and exchanges (within or between regions/sectors)[a]
Insurance (drought insurance)

Demand Sector Options

Urban water use efficiency[a]
Urban water scarcity[a] (water use below desired quantities)

Agricultural water use efficiency[a]
Agricultural water scarcity[a]

Ecosystem restoration/improvements (dedicated flow and nonflow options)
Ecosystem water use effectiveness
Environmental water scarcity

Recreation water use efficiency
Recreation improvements
Recreation water scarcity

Supply Management Options

Operations Options (Water Quantity or Quality)

Surface water storage facilities (new or expanded)[a]
Conveyance facilities (new or expanded)[a]
Conveyance and distribution facility operations[a]
Cooperative operation of surface facilities[a]
Conjunctive use of surface and ground waters[a]
Groundwater storage, recharge, and pumping facilities[a]

Supply Expansion Options (Water Quantity or Quality)

Supply expansions through operations options (reduced losses and spills)
Agricultural drainage management
Urban water reuse (treated)[a]
Water treatment (surface water, groundwater, seawater, brackish water, contaminated water)[a]
Desalting (brackish and seawater)[a]
Urban runoff/stormwater collection and reuse (in some areas)

[a]Options represented in the CALVIN model.

allow us to precisely represent current knowledge and explore the implications of uncertainties in a standardized evaluation of a wide range of solution alternatives. Although there are obvious pitfalls to quantitatively analyzing such complex systems, decisionmaking without such aids has shown itself to be risky, even dangerous. Model results provide insights based on our best knowledge of the system and a relatively transparent way to compare policy and management alternatives for complex systems.

Delta Agricultural Production Model

The DAP model specifically focuses on agricultural land, water, and cropping decisions for the Delta region. It is calibrated on four years of recent agricultural land use data for Delta lands and crop production as well as on cost data for nearby regions. DAP allows cropping and water use decisions, and their associated revenues and profits, to be estimated for 35 Delta subregions (individual islands and groups of islands) for a set of salinity conditions (see Appendix D). We use the DAP model below to examine how Delta cropping patterns and profitability might change under Delta management alternatives that alter salinity.

Statewide Economic-Engineering Water Supply Model (CALVIN)

The CALVIN economic-engineering optimization model represents California's vast intertied water supply and demand system. The model was developed with state funds over the past eight years (Jenkins et al., 2001; Draper et al., 2003) and has been applied to a variety of water management problems, including problems of climate change (Jenkins et al., 2004; Pulido-Velázquez, Jenkins, and Lund, 2004; Null and Lund, 2006; Tanaka et al., 2006). This model is used below to examine the effects of changes in water exports on all major agricultural and urban water users that depend on the Delta. The model includes a wide range of adaptation options (Table 6.2). The scenarios are based on water demand for the year 2050, with a projected state population of 65 million (up from 37 million in 2005). They also assume that water agencies will complete currently planned infrastructure enhancements. Although fixed and construction costs are not included, the modeled results put the water supply costs and responses of each management alternative in perspective. Appendix C contains more detailed information on the model as well as additional model results for the cases discussed here. CALVIN is intended as a strategic screening model to identify promising operations and management alternatives and to provide preliminary water supply cost estimates of these alternatives.

Delta Management Alternatives

We focus on three Delta management alternatives that illustrate the water management and performance implications of a wide range of Delta policies and show how modeling analysis can provide insights for crafting and evaluating Delta alternatives. The three alternatives are an abandonment of water exports, a substantial increase in minimum net outflow requirements from the Delta into the San Francisco Bay, and a shift to allowing parts of the Delta to become more saline. We employ the CALVIN model to better understand major water supply consequences and potential water management responses to the first two alternatives, and we employ the DAP model to assess the consequences to Delta agriculture of the third alternative.

Effects of Ending Delta Exports

An extreme policy alternative would be to completely abandon all exports from the Delta. Although extreme, such an alternative could be imagined if the Delta proved to be an excessively unreliable or expensive part of California's water supply system. To model responses without Delta exports, we assumed that this change is not sudden, as might occur in the case of an unforeseen, catastrophic levee failure. Rather, we assume that water agencies would become well prepared for the change, by constructing reasonable interties, wastewater reuse, and desalination facilities and fashioning institutional agreements to cooperate, such as water marketing and exchanges.

Economic and water delivery results under 2050 demand conditions appear in Table 6.3. "Target delivery" refers to estimates of the annual water deliveries that would eliminate shortages for each water service area, irrespective of costs. "Delta exports" assume cost-effective (optimized) operations with current levels of access to Delta pumping. This assumption results in an average 2.9 maf per year of shortages (as indicated by the "water scarcity" column, which shows "target" minus "delivery"). "Scarcity cost" is the economic cost to local water users of these shortages. This includes lost agricultural production and the costs to households

Table 6.3

Average Annual Water Scarcity Costs Without Delta Exports

		Delta Exports			No Exports			Net Change	
Region	Target Delivery (taf)	Delivery (taf)	Water Scarcity (taf)	Scarcity Cost ($ million)	Delivery (taf)	Water Scarcity (taf)	Scarcity Cost ($ million)	Delivery (taf)	Scarcity Cost ($ million)
Statewide	42,016	39,066	2,950	210	34,055	7,961	1,041	–5,011	831
Urban	12,809	12,749	60	44	12,461	347	321	–287	277
Agriculture	29,208	26,317	2,891	166	21,594	7,614	720	–4,723	554
Sacramento Valley	10,935	10,617	318	3	10,798	137	1	181	–2
Urban	1,662	1,662	0	0	1,662	0	0	0	0
Agriculture	9,274	8,956	318	3	9,137	137	1	181	–2
San Joaquin Valley	8,025	7,405	620	10	6,129	1,896	138	–1,276	128
Urban	1,634	1,634	0	0	1,605	29	34	–29	34
Agriculture	6,391	5,771	620	10	4,524	1,866	104	–1,247	94
Tulare Basin	11,679	10,667	1,012	24	7,010	4,669	486	–3,657	462
Urban	1,406	1,406	0	0	1,406	0	0	0	0
Agriculture	10,272	9,260	1,012	24	5,603	4,669	486	–3,657	462

Table 6.3 (continued)

Region	Target Delivery (taf)	Delta Exports			No Exports			Net Change	
		Delivery (taf)	Water Scarcity (taf)	Scarcity Cost ($ million)	Delivery (taf)	Water Scarcity (taf)	Scarcity Cost ($ million)	Delivery (taf)	Scarcity Cost ($ million)
Southern California	11,378	10,377	1,001	173	10,118	1,260	415	–259	242
Urban	8,107	8,047	60	44	7,788	318	286	–259	242
Agriculture	3,271	2,330	941	129	2,330	942	129	0	0

SOURCE: CALVIN model.

NOTES: The table reports results for projected water demands in the year 2050. Regional numbers might not sum to the statewide total because of rounding. Bay Area urban users and Delta agriculture are included in the San Joaquin Valley, and Central Coast urban contractors of the SWP are included in the Tulare Basin.

and industries of water conservation and other reductions in use. For the first case, statewide scarcity cost averages $210 million per year.

The no-export case precludes all Delta exports from the CVP, the SWP (except the small North Bay Aqueduct), and the CCWD. Infrastructure is the same as the first case, except that additional intertie capacity would be constructed, mostly where some aqueducts currently cross or are nearby (Appendix C).

Sectoral and Regional Effects

The CALVIN analysis demonstrates that California's economy as a whole would not suffer catastrophic consequences if direct Delta exports were ended in a well-planned manner. Without water exports, annual costs to water users would be on the order of $831 million, less than one-tenth of one percent of the state's current $1.5 trillion per year economy. This contrasts with much higher costs (on the order of $10 billion per year) if Delta exports were ended abruptly (Illingworth, Mann, and Hatchet, 2005). But even under a well-planned abandonment of Delta exports, the economic costs to water importing regions of the state would be substantial, including roughly $554 million per year in reduced agricultural production and $277 million per year in increased water scarcity for urban areas. Overall, water deliveries would fall by five maf per year, and the brunt of this loss would be felt by agricultural water users within and south of the Delta (in the San Joaquin and Tulare regions), who would lose about a third of their deliveries.[3]

With so many changes in water supply deliveries and operations, operating costs for the water supply system would also change significantly. These costs would include pumping, water and wastewater treatment, and costs for additional wastewater reuse (at $1,000 per acre-foot) and seawater desalination (at $1,400 per acre-foot).[4] The costs of expanding wastewater

[3]For details, see Appendix Figures C.2 through C.5. Such large reductions in output might also raise the price of some commodities, particularly those for which San Joaquin Valley farmers have a large market share, such as some fruits and vegetables. This shift would augment revenues for farmers who can remain in production (in California or elsewhere) and generate some additional costs for consumers (in California and elsewhere).

[4]These are conservative cost estimates for these new sources. The most recent California Water Plan Update (Department of Water Resources, 2005c) assumed a range

reuse and desalination (over $1 billion per year) would be largely offset by reductions in pumping and treatment costs for export-based water deliveries, leaving an overall increase in operating costs of only $157 million (Table 6.4). Thus, the overall water scarcity and operating cost of ending direct Delta exports would be about $1 billion per year.

Table 6.4

Average Annual Operating Costs Without Delta Exports ($ million)

	Delta Exports	No Exports	Cost Increase
Statewide	3,154	3,311	157
Sacramento Valley	195	206	12
San Joaquin Valley and Tulare Basin	998	974	–24
Southern California	1,961	2,131	169

SOURCE: CALVIN model results for water demands in the year 2050.

Without exports, urban areas that rely on Delta exports would initially lose important supplies, but they would be able to compensate with various alternative sources. Water deliveries from the Delta to urban Southern California would decrease by about 2.2 maf per year, but water purchases and recycling investments would reduce this gap nearly tenfold, to 258 taf per year. Urban water users in the Bay Area would be able to adapt with increased intertie capacity, more wastewater reuse, and seawater desalination. Central Coast cities supplied by the SWP would also be shorted, and they would need to increase wastewater reuse and seawater desalination.

Agricultural water users south of the Delta would also make considerable use of water markets, conjunctive use, and increases in water use efficiency. However, the net water delivery and economic effects would still be substantial, particularly for farmers on the west side of the San Joaquin Valley and Tulare Basin, who depend most on Delta pumping. Agricultural areas dependent on San Joaquin River diversions at Friant Dam and Tulare Basin inflows would also be affected, because these would remain the

of $300 to $1,300 per acre-foot for recycled water and $800 to $2,000 per acre-foot for seawater desalination.

only transportable surface waters that could serve regions whose exports have been cut off. Tulare Basin agricultural production would be particularly affected by the end of Delta water exports, although many farmers with rights to Friant-Kern and local Tulare surface waters would be likely to do well financially through sales of this scarce water to cities in Southern California.

Meanwhile, other agricultural areas in the state would be largely unaffected by ending water exports from the Delta. Agricultural areas on the east side of the San Joaquin Valley that depend directly on streams flowing from the Sierra Nevada would be much less affected, because they do not depend on the Delta and they cannot transfer water to other regions without sending water through the Delta. Inland Southern California agricultural users, who rely predominantly on Colorado River water supplies, would be unaffected because the Colorado River Aqueduct has no available capacity to transport additional water to Southern California cities. (The "Delta exports" case assumes that enough transfers would have already taken place to keep this aqueduct full.) The end of Delta exports would cut Sacramento Valley farmers off from transfer opportunities; instead, their water deliveries and agricultural profits would increase slightly because they would no longer need to contribute to Delta outflows. Sacramento Valley cities would be unaffected.

The end of direct Delta exports would reduce some pressure on environmental flows in the Sacramento Valley and Trinity River. However, wetland water deliveries south of the Delta would become much more expensive in terms of additional scarcity costs to other uses.[5]

Storage Versus Conveyance

Without Delta exports, the value of water storage capacity would decrease in most locations. South of the Delta, surface water storage sites would tend to be emptier because there would be less water to keep in storage. North of the Delta, reservoirs would tend to have more water but would no longer be able to help alleviate water problems in the southern part of the state. The only exceptions would be modest increases in the value of storage capacity at Millerton on the San Joaquin River and

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[5]For details, see Appendix Table C.3.

in reservoirs on inflows to the Tulare Basin (especially on the Kaweah and Tule Rivers). For no reservoir would the average economic value of increasing storage capacity exceed $100 per acre-foot per year.[6]

Instead, conveyance capacity would become much more valuable, reflecting the value of moving available water sources to places that lose export supplies.[7] For instance, the average economic value of expanding the Hayward-EBMUD intertie would increase from $178 per acre-foot to $588 per acre-foot. The value of expanding the Hetch Hetchy Aqueduct would rise to $608 per acre-foot. Expansion of both facilities would replace some lost State Water Project supplies. Expansion of Colorado River Aqueduct capacity would rise in value from $169 per acre-foot to $488 per acre-foot, reflecting increased water scarcity and operating costs in Southern California. Capacities along the Cross Valley Canal in the Tulare Basin would also merit consideration for expansion, with economic values averaging $151 per acre-foot. This expansion would allow more San Joaquin and Tulare Basin inflows to be diverted to the California Aqueduct for Southern California water users. The value of increasing Mokelumne River Aqueduct capacity, to allow greater diversions from the Mokelumne River or the Sacramento River (through the Freeport Project), would average $186 per acre-foot. The value of a small peripheral canal—allowing continued exports of Northern California water—would be roughly the same.

Effects of Climate Change

With climate warming, the costs of eliminating Delta exports could increase substantially. This increase could arise in two ways. First, decreases in precipitation—predicted by some climate models—may reduce overall water availability. Second, the diminished storage capacity of the Sierra Nevada snowpack—foreseen by all climate models—will reduce the ability to move water from surplus times and locations (winter in Northern California) to surface and groundwater storage locations elsewhere in the

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[6]In other words, users would not be willing to pay more than $100 per acre-foot for additional storage—a lower value than the per acre-foot cost of most, if not all, surface storage programs. See also Appendix Table C.4.

[7]The costs of such conveyance facilities are not available and would vary greatly with local conditions, but are commonly $1 million to $3 million per mile of length.

state. Available climate warming adaptation studies indicate that these conditions would increase the value of using direct Delta exports to move water from wetter to drier seasons and locations (Tanaka et al., 2006; Lund et al., 2003; Medellin et al., 2006). Therefore, the loss of Delta exports could constitute a more significant loss to the state as the climate changes over time.

Soft Versus Hard Landings

Even with tremendous preparation and forethought, ending all exports from the Delta would have substantial regional economic effects on California, averaging $1 billion per year in increased water scarcity and operating costs. Although this is a large effect, it is much smaller than the economic consequences of a sudden loss of the Delta because of catastrophic levee failure, an effect estimated at up to $10 billion per year. However, a series of infrequent Delta catastrophes, or hard landings, each entailing Delta failure, severe shortage, and rebuilding, might be less expensive overall than the permanent ending of all exports. In any event, either a series of hard landings or the ending of direct Delta exports would have very substantial and probably unacceptably high economic and political costs. However, the development of a soft landing strategy will require state and local leadership and preparation, as well as the negotiation of major changes in institutions, regulations, contracts, and finance (see Chapter 9).

Effects of Increasing Minimum Delta Outflow Requirements

Allowing greater levels of net Delta outflows into the San Francisco Bay is the traditional method for reducing seawater salinity in the Delta. It is not surprising, therefore, that those interested in preserving the Delta as a freshwater body—including Delta farmers, local urban diverters, and some environmentalists—often call for increases in net Delta outflows. This objective might gain more support in light of concerns over levee stability. If many island levees fail, or if the sea level rises substantially, increased Delta outflows might be needed to maintain the freshness of the western Delta. Because increasing net Delta outflows reduces the amount of water available for direct water exports and upstream diversions, it poses a threat to many water users, particularly south of the Delta.

We used the CALVIN model to examine the effects of increases in minimum Delta outflow requirements on water operations in California. Although this strategy has some similarities to the prohibition of Delta exports, the water operations and economic consequences are considerably different. Whereas export prohibition effectively excludes upstream diverters in the Sacramento Valley and some eastside San Joaquin Valley communities from participating in adjustments (because they have no way to send their water to exporters if Delta exports are prohibited), increases in minimum Delta outflows allow all regions that use Delta water to participate in adaptations.

The most cost-effective way to increase net Delta outflows would use a dual strategy that reduces both upstream water diversions and direct exports from Delta pumping plants (Figure 6.4). Assuming that the regulatory burden for these reductions would fall on export water users south of the Delta, who have lower priority water rights, this strategy would require a substantial increase in water sales moving through the Delta. For example, these water users, including urban agencies and farmers in the western San Joaquin Valley and the Tulare Basin, would be willing to pay Sacramento Valley and eastside San Joaquin water users to reduce their own use and allow more water to flow into the Delta via the Sacramento and San Joaquin Rivers; from there, much of it would be pumped south of the Delta to urban agencies and farms in the western San Joaquin Valley and the Tulare Basin. Water users would also make greater use of wastewater reuse, cooperative operations, and water conservation. In contrast to the no-export scenario examined above, seawater desalination would be used only in extreme circumstances.[8]

The economic cost of water scarcity for agricultural and urban sectors in each region and overall is shown in Figure 6.5. In contrast to the earlier no-export case, a strategy of increasing net Delta outflows would mean that burdens and incentives for cost-effective water management were spread

[8]For details, see Appendix Figures C.8 to C.10.

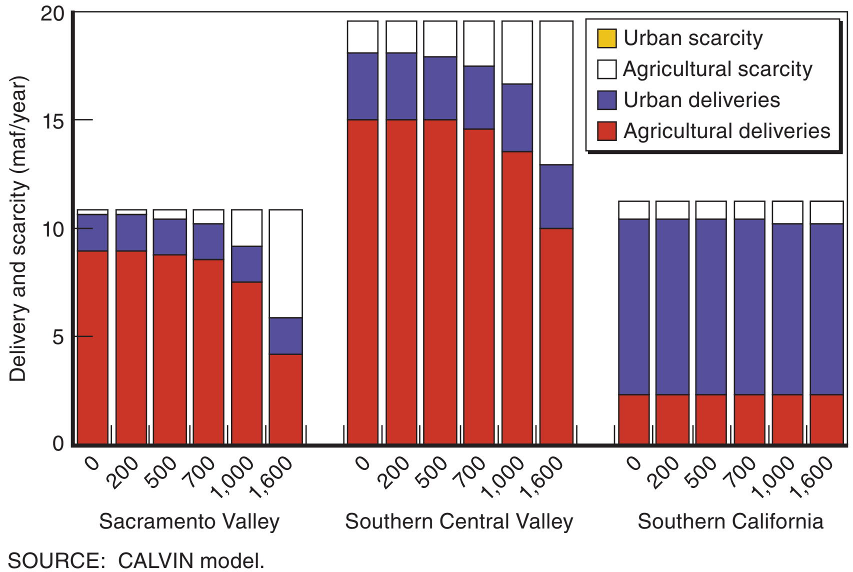
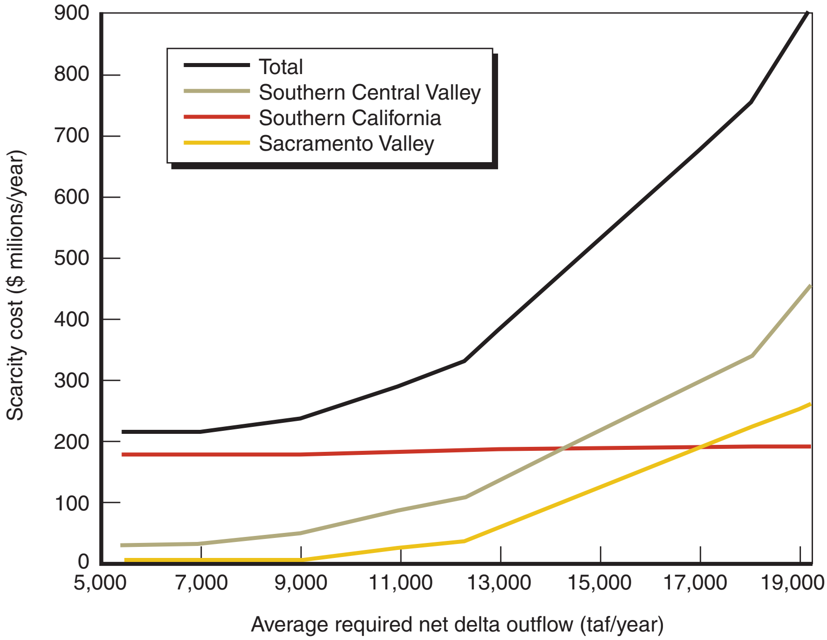


Figure 6.4—Average Agricultural Water Scarcity by Region with Increasing Minimum Monthly Net Delta Outflow Requirements (maf/year)

more uniformly across all regions using waters tributary to the Delta.[9] Although urban water scarcity would increase as the regulations on Delta outflows became stricter, average scarcity levels would never exceed 100 taf per year (an amount too small to be seen in Figure 6.4). With stricter regulations, Sacramento Valley water might be sold in greater volumes to users south of the Delta.

As seen in Figure 6.5, small increases in minimum net Delta outflow would lead to fairly small cost increases as long as water resources were managed cost-effectively. However, as these requirements increase further, water scarcities would affect more highly valued crops and a few more urban water users. At the highest feasible levels of required minimum net Delta outflows (19.2 maf per year), water scarcity costs would approach those for ending water exports entirely ($900 million per year versus

[9]As before, Southern California agricultural users are unaffected, because their Colorado River supplies are isolated from Delta effects because of the limited capacity of the Colorado River Aqueduct.



SOURCE: CALVIN model.

Figure 6.5—Average Annual Water Scarcity Cost by Region with Increasing Minimum Monthly Net Delta Outflow Requirements

$1,041 million per year, respectively). However, annual statewide water deliveries would be much lower (29 maf versus 34 maf, respectively). This comparison illustrates the economic value of being able to share water deliveries across the state; moving water across the Delta substantially diminishes the economic effects of any reductions in total water deliveries.

The greater flexibility of the increased minimum outflow plan would make it less costly than the no-export alternative to maintain existing wetland wildlife refuges in the San Joaquin Valley. Both the no-export and the increased minimum outflow alternatives have the potential to offer additional benefits in terms of increasing terrestrial ecosystem habitat restoration on the western side of the San Joaquin Valley. Some reductions in irrigated land area might serve this purpose, provided that these lands are not too salinized from years of agricultural use.

Adapting Delta Agriculture to Salinity Changes

In-Delta agriculture depends on the availability of land and water supply. As seen in Chapter 2, the salinity of Delta water supplies has been a primary concern for Delta agricultural interests for at least a century. The DAP model can estimate changes in cropping patterns as well as farm revenues and profits that would occur under various management strategies that may increase the salinity of some parts of the Delta. Figure 6.6 shows the estimated distribution of farm revenues (per acre of agricultural land) for each Delta island for typical, current summer salinity conditions. Currently, the economic value of agricultural production is not uniform throughout the Delta, and agricultural production in much of the western and central parts of the Delta is quite low. Total agricultural revenues for this base case scenario—intended to simulate current conditions—are $381 million per year, with profits estimated at $196 million per year.

Figure 6.7 shows the economic value of agricultural production revenues for each Delta subregion when salinities are 10 times higher than in the base case conditions. This tenfold increase in Delta salinity would reduce overall agricultural revenues to $285 million per year, a decline of $95 million per year or roughly 25 percent. Profits would be reduced by almost 30 percent ($58 million per year) to $138 million per year and irrigated land area would be reduced by about 8 percent (less than 30,000 acres). The model suggests that these higher salinities would end production on three islands. The agricultural effects of any Delta salinity scenario can be estimated in this way.[10]

Certainly, much higher salinity scenarios are possible. The DRMS examined a many-island levee failure that resulted in much higher salinities far into the Delta for one year. The DAP model may be adapted to estimate the agricultural economic effects of such emergency scenarios as well as

[10]See Appendix Figure D.4 for the corresponding results for a twentyfold salinity increase. Relative to the base case, a twentyfold increase in salinity reduces overall annual crop revenues to $153 million per year (–60%) and profits to $66 million (–66%).

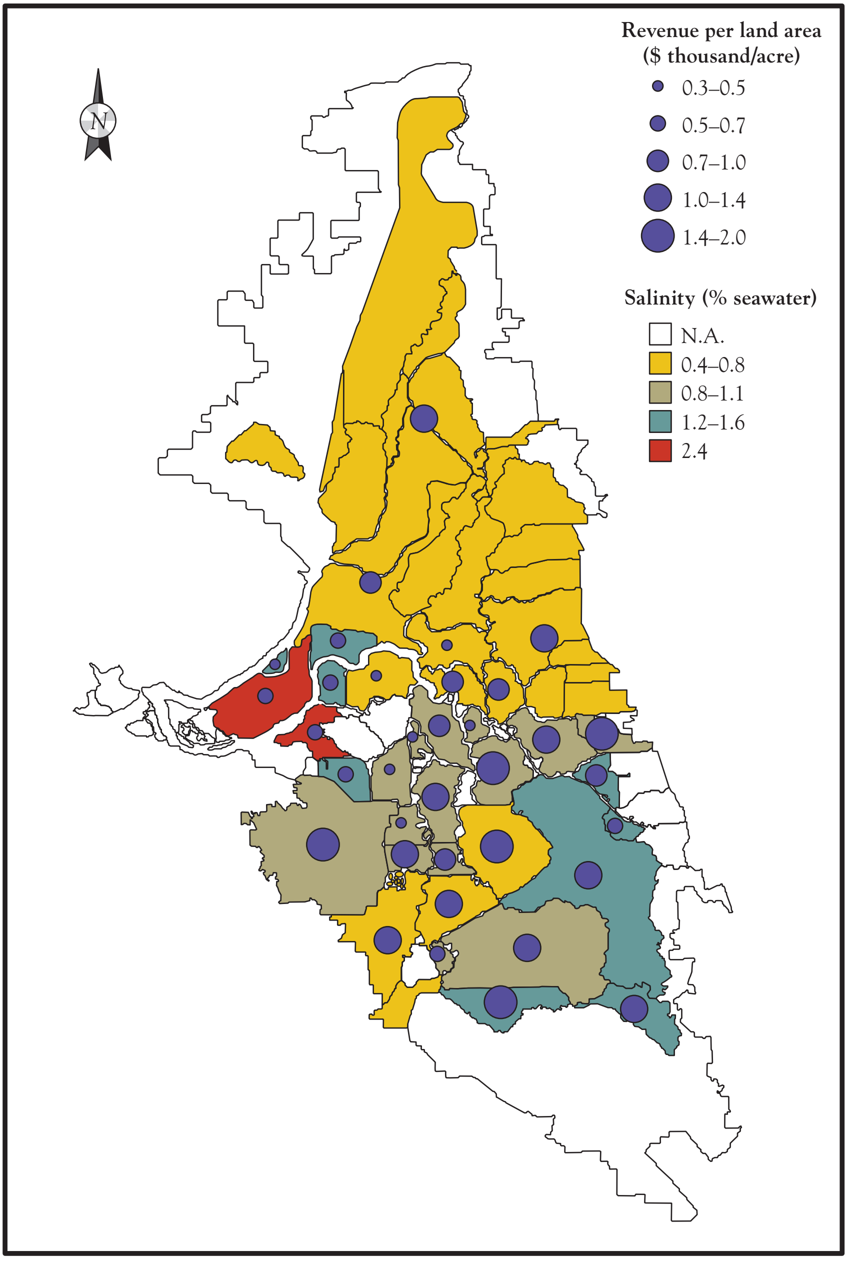


Figure 6.6—Current Agricultural Revenues by Delta Island for Typical Current Salinity Levels

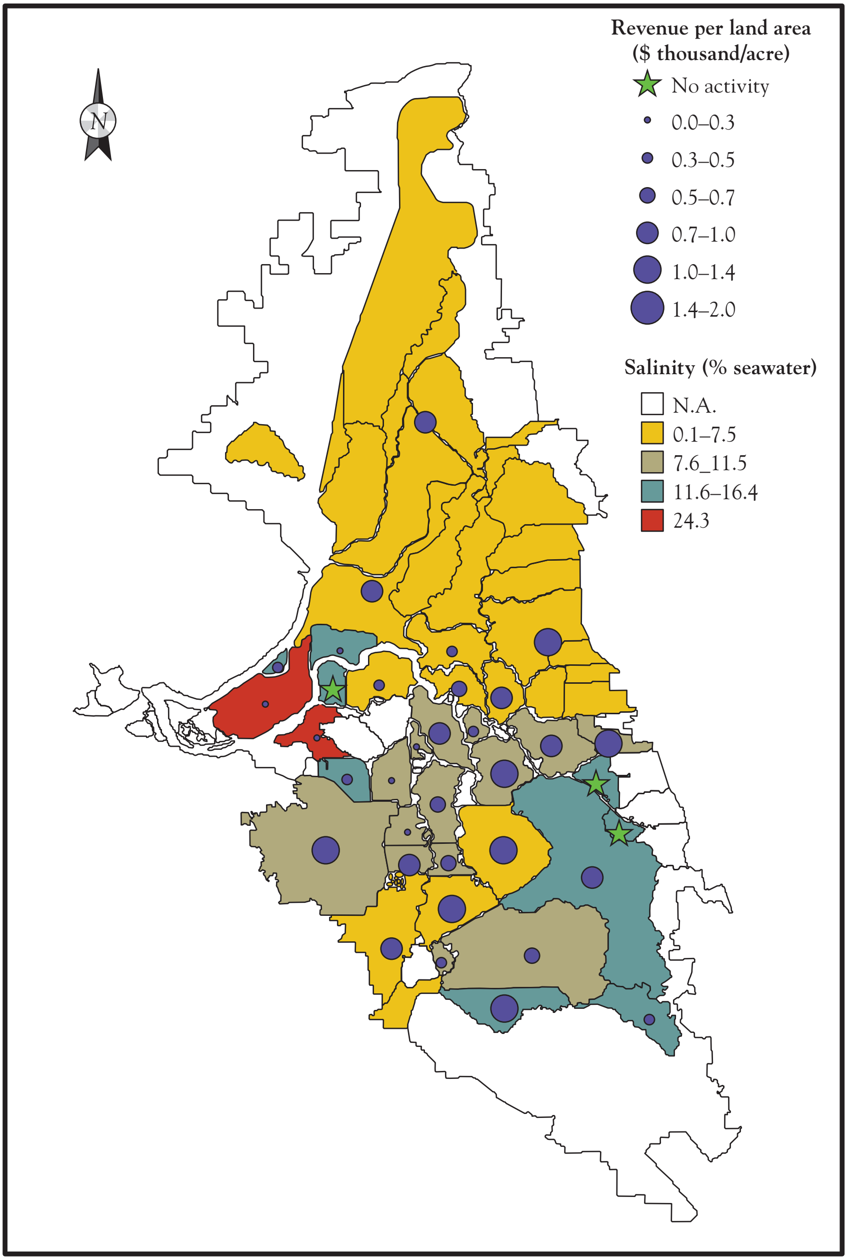


Figure 6.7—Total Agricultural Revenue with a Tenfold Increase in Delta Salinity Levels

more typical salinity patterns that might be expected under scenarios with managed salinity fluctuation. A well-managed salinity fluctuation regime for the Delta should be able to avoid catastrophic scenarios.

Even today, salinity is not uniform throughout the Delta; substantial amounts of salt are introduced with the tides and with the agricultural drainage in San Joaquin River flows. If salinities in some parts of the Delta are allowed more variability to support desirable species, only some parts of the Delta are likely to be affected. In particular, western, central, and southern parts of the Delta would see the greatest effects. However, the large freshwater inflows likely from the Sacramento River would keep northern areas of the Delta rather fresh and unaffected by salinity from seawater or from San Joaquin Valley drainage under almost any conditions.

The ability of Delta farmers to support local levees is already severely limited by the profitability of this land use. The least profitable islands tend to be those in the western and central Delta, the most desirable areas for reintroducing salinity fluctuations. Reductions in profit from higher salinity in these areas would further reduce farmers' abilities to support levee improvements, requiring either additional state subsidies or eventual abandonment of these levees.

Modeling can be used to estimate the effects of changes in salinity on agricultural production and profitability within the Delta, and to help design mitigation strategies. As seen in Figure 6.7, the costs of a tenfold increase in salinity are not evenly distributed across Delta islands but are instead concentrated in areas of the Delta that already have higher salinities from tidal seawater mixing and San Joaquin River drainage. More detailed hydrodynamic modeling studies would be required to estimate salinity conditions specific to various water management alternatives. Models such as DAP can then be used to estimate the effects of management strategies for in-Delta water users in ways comparable to the economic and management evaluations modeled with CALVIN for areas outside the Delta.

Water Supply Aspects of a Peripheral Conveyance System

One of the most discussed "solutions" for the problems of export water supplies from the Delta is the so-called peripheral canal. As we saw in

Chapter 2, since the 1940s, various alternatives have been proposed to construct an isolated canal from the Sacramento River to south of the Delta, as a way to bypass the operational, water quality, and environmental problems associated with conveying exports through the Delta itself. During the 1960s and 1970s, one such proposal was promoted as a component of the State Water Project, but it was soundly rejected by voters in 1982. In light of concerns over the fragility of Delta levees, some exporters have recently revived the idea of a canal, and a Bay Area legislator has formally proposed such a facility (see Chapter 5). Benefits often cited in regard to a peripheral conveyance facility include:

Increased water export reliability. In earlier proposals for a peripheral canal, a key objective was greater operational flexibility, which would permit increased export quantities under many conditions. More recently, the peripheral canal proposal has resurfaced as a way of maintaining export capability without depending on fragile and seismically vulnerable levees or necessarily increasing export levels.

Improved export water quality. A peripheral conveyance facility would avoid contaminants that appear in Delta flows, which arise from in-Delta agriculture and urban activity, San Joaquin River drainage, and seawater. This objective is particularly important for urban water agencies, which face increasingly stringent requirements for drinking water treatment and regulation of disinfection by-products.

Reduced fish loss from Delta pumping. As early as the 1970s, some biologists saw such a peripheral canal as a way to reduce entrainment of pelagic fish and other organisms and to decrease confusion in the fish migrations that result from in-Delta pumping (Arnett, 1973). Recent work on pelagic organism decline indicates that Delta pumping may play a significant role in the decline of delta smelt (William Bennett and Wim Kimmerer, 2006, personal communication).

More natural in-Delta circulation and mixing. Recently, other ecological benefits of a peripheral conveyance system have been recognized. Such a system would allow water flow and quality in the Delta to vary more naturally. As discussed in Chapter 4, this change in circulation could be important for some native fish species in the Delta.

Overall, the primary benefit of a peripheral canal is the flexibility it would provide for combining water supply and ecological operations, which are currently antagonistic. Such a facility would break the connection between water exports and the maintenance of a homogeneous freshwater Delta. Greater operational flexibility would be available to manage diversified habitat in various parts of the Delta. With a peripheral canal, it would become easier to allow water flow and quality to vary in different parts of the Delta, perhaps increasing the overall suitability of the Delta for desirable species. With variable water conditions in the Delta, it is also possible to envisage continued use of occasional direct pumping from the Delta, for instance, during wet conditions.

There are many possible peripheral canal alternatives, with a wide range of details, including flow capacity, fish screening, inlet locations, outlet locations, routing, environmental mitigations, operation policies, ownership, and finance. Unfortunately, most analytical capability for water management in California is not currently suited to examining these alternatives, particularly if the goal is to manage variable conditions in the Delta. Current Delta hydrodynamics modeling capability is not suited to the study of significant changes from current Delta island configurations and conditions. The CALVIN model does not represent environmental and water quality aspects in enough detail to examine most peripheral canal alternatives.

However, analysis of adjustment costs under the management alternatives examined above does permit approximations of the value of a peripheral canal for water exporters. For the no-export case, the value of allowing a small amount of exports averages almost $1,300 per acre-foot, permitting reduction or elimination of expensive seawater desalination in the Bay Area. For cases in which environmental restrictions limit direct exports from the Delta, the value of a peripheral canal could be a few hundred dollars per acre-foot. Additional benefits would accrue in terms of export water quality. The DAP model results provide some indication that the costs to Delta agriculture need not be catastrophic, even if the canal resulted in some increases in Delta salinity levels. As seen above, a tenfold increase in irrigation season salinity throughout the Delta results in an estimated 10 to 11 percent decrease in crop revenues and profits within the Delta. A twentyfold increase in salinity reduces revenues and profits by about one-third (Appendix D).

Conclusions

Most of California's urban and agricultural water users depend on the Delta for much of their water supply. This broad dependency makes the health of the Delta a major common concern for almost all major water users. Nevertheless, water users and managers generally have substantial capacity to respond to changes in Delta management, including such extreme strategies as the elimination of the Delta as a water source. Model results suggest substantial ability to adapt if preparations, such as conveyance interties and coordinating agreements, are made. Comparisons of our model results with results from the DRMS indicate that abrupt unprepared changes, or hard landings, are much more expensive for water users than are well-prepared changes, or soft landings. Many agencies are already taking steps to reduce their vulnerability to short-term and long-term losses of Delta water supplies. Most water management decisions are made by local agencies and water users, and a productive role for the state is to facilitate the use of local decisions and resources for common state and local purposes. In the current era, local agencies and users often have greater flexibility and financial resources, and greater expertise about local management options, than state and federal agencies.

Maintaining a freshwater Delta in the face of accumulating permanent or semipermanent levee failures and sea level rise would likely require additional net Delta outflows. Delta farmers and urban agencies that draw water directly from the Delta (notably the South and Central Delta Water Agencies and the Contra Costa Water District, respectively) are likely to call for such outflows to preserve fresh water in the Delta. This chapter explored two extreme management changes to achieve this goal: elimination of all direct Delta exports and great increases in minimum Delta outflows. Although these alternatives result in high regional economic costs and inconvenience, the costs are not catastrophic relative to the state's overall economy. The costs of planned elimination of Delta exports are large, but not catastrophic, for urban water users in Southern California and the Bay Area. However, eliminating exports would greatly reduce agricultural activity in the western San Joaquin Valley and Tulare Basin, with likely catastrophic results for some agricultural communities in these regions. The costs of increasing net Delta outflows are much lower, but this alternative would require considerable re-operation of groundwater and surface water storage south of the Delta, with some reductions in agriculture in the San Joaquin Valley and Tulare Basin as well as sales of water (and reduced agricultural production) in the Sacramento Valley.

Under any of these scenarios, the loss of water supplies to agriculture south of the Delta would change the character of many rural agricultural communities in that region. Many farmers with senior water rights or contracts may do well financially by selling water, but other farmers and local workers and businesses are likely to do less well. In this case, mitigations and compensations (discussed in Chapter 9) seem appropriate to ease the transition.

Delta farmers were among the earliest major water diverters in California. Many of the changes suggested in Chapter 4 could increase water salinity for farmers in some parts of the Delta. But farms are businesses. The DAP model provides a way to estimate the effects of changes in salinity patterns, allowing benefits to be compared with costs and potential mitigation expenses to be estimated.

Although existing analytical capabilities for evaluating the operation and performance of peripheral canal alternatives are poor, some qualitative observations can be made. These are not based on CALVIN modeling but on observations and understanding of system behavior. Foremost is that many forms of a peripheral canal would break the connection between moving water to southern communities and maintaining the Delta as a homogeneous freshwater environment, thereby allowing for more dynamic and spatially varied management of the Delta. Models such as DAP could be useful in assessing the likely effects of various spatially varied management solutions for in-Delta agriculture or other uses. Initial results indicate that Delta agriculture would not be eliminated by some increase in salinity, although it would face significant additional costs.

This examination of the water supply consequences of some extreme alternatives for Delta water management provides a useful contribution to a broad discussion of alternatives for the Delta, to which we turn in the following chapter. These modeling efforts also illustrate the potential of modern mathematical models for evaluating and identifying promising solutions to large-scale problems such as those facing the Delta. Without the use of computerized models, the systematic exploration, development, and comparison of integrated solutions are severely handicapped.