CLIMATE CHANGE AND WATER RESOURCES IN THE SACRAMENTO-SAN JOAQUIN REGION OF CALIFORNIA

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PREFACE

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SUMMARY

The Sacramento-San Joaquin region of northern California is particularly vulnerable to changes in precipitation and temperature that might result from the greenhouse effect (or natural climate change) because of the critical role that water development has played in the region's economic development. Three key water management issues are especially sensitive to climate change: 1) water supply and flood control; 2) land use and levee maintenance in the Sacramento-San Joaquin Delta; and 3) water quality in the Delta. The management implications of climate change and the range of possible responses are described for each of these areas.

Water supplies in the California State Water Project (SWP), which provides users ranging from small irrigation districts to metropolitan Los Angeles, are sensitive even to small changes in runoff due to the close balance between current demand and supply. Recent climate impacts suggest that relatively small future changes in runoff (either amount or timing) could cause supply shortages or require changes in flood protection policies that reduce freshwater yield. Potential adjustments range from traditional responses emphasizing new or enlarged reservoirs or changes in the efficiency of water transport and use in the system.

Land use and water quality in the Sacramento-San Joaquin Delta are also threatened by decreased freshwater runoff and rising sea level. Much of the land in the Delta is below sea

level and protected by dikes of various reliabilities. The Delta's freshwater ecosystem is critical to maintaining the quality of water for both local use and export.

Theoretically feasible responses for Delta land and water protection under a changing climate range from a commitment to physical protection at any cost ("maintaining the status quo") to allowing the Delta to metamorphose into a brackish marsh (a policy of "strategic inundation"). Adjustment options in the face of climate change that reduces runoff include accepting lower Delta water quality or reducing upstream water uses.

That many interests and institutions are focused on what is, essentially, a connected constellation of climate-sensitive policy issues in Northern California suggests that near-future climate change could create new ties among resource management areas, as well as new tensions. New types of interagency cooperation have been proposed to deal with these problems, but no strategy has yet emerged to offer an integrated response to problems of water supply and quality, flooding, and Delta protection, all of which could be exacerbated by almost any nontrivial magnitude or direction of climate change. Perhaps a new form of integrated regional planning, based on climate sensitivities, is needed to deal with the emerging threat of climate change.

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INTRODUCTION

This paper examines some of the options for adjusting water resource management policies in the face of potential future climate change in California's Sacramento-San Joaquin region. We analyze the current policy landscape (the institutions and issues involved and the social mechanisms available for adjustment), examine responses to recent climate impacts, and describe a range of potential adjustments in the face of a climate change that would affect water-related resources in the area.

The Threat of Climate Change

Global climate warming predicted to accompany increasing atmospheric concentrations of greenhouse gases has become a major national and international policy issue. Increasingly credible predictions indicate that anthropogenic climate changes are likely to emerge from the noise of natural climate variability during the next decade or so. By the middle of the 21st century, global average temperatures may be 3° to 5° C warmer than present (World Meteorological Organization, 1985; National Academy of Sciences, 1983). Some analysts believe that global warming is already under way (Hansen et al., 1988; Hansen and Lebedeff, 1988), as evidenced by unusually warm temperatures in the 1980s.

In concert with increasingly reliable predictions of climate change, our ability to assess impacts has improved (Kates et al., 1985). Researchers have studied historical climate-society relationships (Parry, 1981; Bowden et al., 1981), assessed international implications of climate impacts (Kates, 1980), and predicted climate change impacts on agriculture (Parry et al., 1988), global food supplies (Liverman, 1987), water resources (Hanchey et al., 1988), and other natural resource areas.

These impact studies point to disruptive and potentially irreversible climate change effects on natural and social systems (Parry et al., 1988). The U.S. Environmental Protection Agency's (1988) report to Congress, the most comprehensive assessment of nationwide impacts to date, indicates how pervasive and far-reaching climate change effects could be--affecting water and food supply, land use, energy demand, air quality, health, and essentially all other economic sectors. Moreover, serious impacts may be associated with even the more modest climate changes likely to occur well before the oft-cited benchmark of doubled greenhouse gas concentration is reached during the mid-21st century.

Impact projections have led to calls for concrete policy actions (White, 1988). Proposed responses are aimed mostly at reducing anthropogenic greenhouse gas emissions in order to prevent, or at least delay, global warming (Conference Statement Committee, 1988). Much less attention is given to the question of how well systems for managing climate-sensitive resources can cope with climate change. Yet global warming in the range of 1^{o} to 2^{o} C is likely to occur in the next two decades even with immediate greenhouse gas emission reductions, as accumulated gases and thermal inertia in the atmosphere-ocean system conspire to raise global temperature (Jones et al., 1987). Thus, resource managers may have to adjust to noticeable climate shifts in the near future, although the regional pattern of these changes cannot yet be predicted with much certainty.

Adjusting to Climate Change

At the most abstract level, there are essentially two types of human responses to climate change: inadvertent and purposeful. Even without recognizing that the climate is changing, people and institutions will adjust inadvertently, through existing mechanisms. Changes will occur in how people manage water, forests, agriculture, and other climate-sensitive resources, even in the absence of explicit climate change adjustment policy. Indeed, some researchers argue that inadvertent adjustment can, in most cases, absorb the impacts of the greenhouse effect with little or no social disruption. Others argue that the scale and magnitude of potential greenhouse climate changes are such that severe social impacts can only be avoided through purposeful planning and anticipatory policies.

At least in the near-term--over the next two decades or so--the most likely policy responses will be inadvertent, incidental, and reactive. Climate fluctuations that are either part of normal climate, or of the greenhouse effect (there will probably be no sound scientific basis for distinguishing between these two over the next several years), will elicit policy responses either by tripping existing response mechanisms like flood control plans and crop damage payments, or by eliciting emergency response geared to extreme events. Thus, there is reason, in any impact assessment, to examine existing policy mechanisms and contemporary trends which affect social adaptability.

More purposeful adjustment will emerge only with strong belief among decision-makers that the climate will change in the future or that climate change is actually under way. Purposeful adjustment policy might take four general forms:

- Do-nothing: recognize the change but take no action.
- Laissez-faire: let systems adjust without assistance.
- Reactive: establish or fine-tune mechanisms as impacts accumulate and adaptive pressures build, but take no action now.
- Proactive: begin a phased adjustment of resource systems now to absorb climate change.

These adjustment categories overlap, of course, and different policy mixtures will come into play in a changing climate. For example, some economic areas may simply be left to adjust without government assistance, while in other cases the threat to social well-being may be so great that active public policy intervention is called for. Both inadvertent and purposeful adjustment might proceed either incrementally or as a series of crisis responses.[1] Resource managers might, for instance, respond to climate change gradually by adjusting resource systems in small steps, or by responding chiefly to the most severe impacts or to surges of new information or dire predictions.

The Case of Climate Change and Policy in California

The goal of this study is to identify policy elements that may affect response to climate changes in California's Sacramento-San Joaquin region (Figure 1). The focus is on issues raised by climate change in terms of water resource impacts, the public and private institutions likely to play a role in adjustment (Table 1), and the theoretical and practical range of adjustments available to resource managers. Thus, this analysis does not include more speculative responses such as wholly new public programs aimed at stabilizing climate or the restructuring of resource management systems in fundamental ways. Resource management theory suggests that decision makers in an area affected by climate change will first rely on existing mechanisms, traditional approaches, and least-cost options as they respond to impacts, and will be slow to recognize and accept the need for more far-reaching change. Thus, our analysis points

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[1] This distinction was drawn by political scientist M.H. Glantz (1979) to illustrate the different responses likely to emerge if planners view CO_2-induced climate change as a slow, cumulative trend vs. a disjunct, step-like process (e.g., if they focus on a doubling of CO_2).

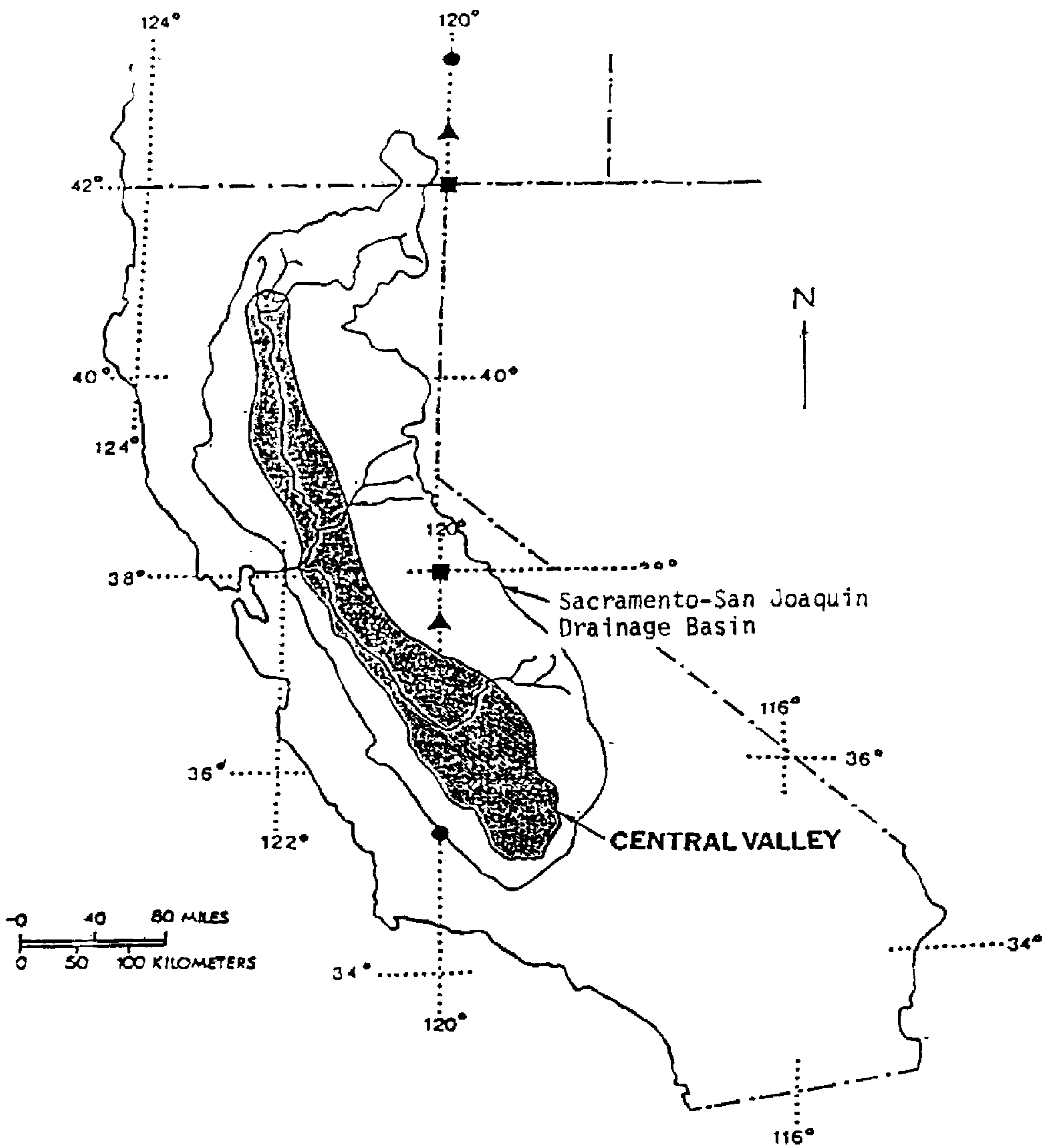

FIGURE 1
CALIFORNIA'S SACRAMENTO-SAN JOAQUIN BASIN

TABLE 1

INSTITUTIONS MOST LIKELY TO PLAY A ROLE IN
RESPONDING TO CLIMATE CHANGE IN NORTHERN CALIFORNIA

- U.S. Army Corps of Engineers - (FC, ER)
- U.S. Bureau of Reclamation - (WS)
- Federal Emergency Management Agency (FEMA) - (FC, DL, ER)
- State Federal Resource Control Board (SWRCB) - (WS, WQ)
- Department of Water Resources (DWR) - (WS, FC, DL, ER)
- The Reclamation Board - (FC, DL)
- Office of Emergency Services (OES) - (FC, DL, ER)
- Bay Conservation and Development Commission (BCDC) - (LU)
- California Department of Fish and Game - (RE)
- Suisun Resource Preservation District - (LU)
- State Water Contractors - (WS)
- State Lands Commission - (LU)
- Delta municipalities - (LU)
- Delta Advisory Planning Council (DAPC) - (FC, LU)
- Local reclamation districts - (DL)
- Bay Institute, Environmental Defense Fund, Other Non-governmental organizations (NGOs) - (NG)
- East Bay Municipal and Utility District - (WS, WQ)
- Metropolitan Water District of Southern California - (WS)
- Association of California Water Agencies - (WS)

Key to table codes:

WS - water supply	WQ - water quality
FC - flood control	DL - delta levee maintenance
LU - land use/zoning	ER - emergency response
RE - recreation	NG - non-governmental organizations

out policy responses that might emerge over the next several years while the climate future remains uncertain but public pressure to mitigate future impacts grows.

THREE WATER RESOURCE POLICY PROBLEMS IN CALIFORNIA

Though climate affects essentially all social and economic aspects of water resources in the region, future policy response will probably focus on three areas particularly vulnerable to climate change:

1) Water Supply Management

Water supply management represents a central and linking issue in California, where water supply is the basis for most economic development: agricultural, industrial, recreational, etc. Water links climate, other natural resources, and society. The chief problem is to accommodate rising demand, short-term climate fluctuations, the need to export water from the water-rich north to southern California, flood hazard mitigation, and the potential for long-term climate change.

2) Delta Islands Land Use and Maintenance

The delta at the confluence of the Sacramento and San Joaquin rivers acts as the focus of water supply, wetland habitat, and other environmental protection issues, and represents a critical natural hazard and land-use problem centered on protecting areas threatened with inundation. Much of the land, the so-called "Delta islands," is protected by a system of levees of various ages and reliabilities. Devoted mainly to agriculture, the Delta islands are also very important in helping prevent saltwater intrusion into the river system. Subsidence of the islands below sea level has led to an increasing rate of levee failure in recent years, and sea level rise or changes in quantity and/or timing of freshwater runoff would exacerbate this problem.

3) Water Quality

Another major component of the "Delta problem" relates to the intrusion of saline waters eastward from San Francisco Bay into the riparian system, due to four factors: levee deterioration, freshwater consumption and transfer above and within the Delta, short-term wind surge, and sea level rise. This issue is intimately related both to water supply and Delta levee maintenance.

Of course, there are other resource management issues in the region that will likely prove sensitive to climate change, including the estuarine functions of San Francisco Bay and bay-shore land use, forestry, dry-land agriculture, recreation, transportation, and energy use. But, the pivotal importance of water development, plus the ability to model the cascade of impacts associated with runoff in a credible way, makes water a logical focus for an initial impact assessment.

The goal of this paper is not to prescribe response policy. The policy implications raised here are meant to guide later analysts who will translate better predictions of climate change and impacts into policy responses if a consensus emerges, due to new predictions or to actual climate impacts, that climate change warrants overt public policy response.

Water Supply Management

The underlying problem in managing California's water resources is the natural spatial and temporal maldistribution of supply and demand in the state. More than two-thirds of the state's surface water supply originates north of about Sacramento, while 70% of the state's population and 80% of the total demand for water lie to the south. Another problem is the seasonality of runoff; most of the runoff occurs during November-April while peak demand occurs during June-August. Finally, as population has grown, demand has increased, and supply reliability has been stressed in some areas, while conflict over use and allocation is growing in others. The study area is also subject to flooding during the runoff season, and substantial public investment has been devoted to flood control, especially along the American River near Sacramento.

Water resource management policy in the region has been changing over the last decade, and California is today at a critical juncture in water development that makes the region particularly sensitive to climate uncertainty. The salient management change has been a swing away from building large storage and conveyance facilities to more flexible and efficient operations of existing facilities. Wolman and Wolman (1986) observed that this trend is evident throughout the country. In California, environmental and economic factors have slowed the development of physical facilities over the past decade, reducing the buffer of "excess" capacity and creating marked water supply and flood control vulnerabilities to climate and other perturbations.

The Policy Environment of Water Supply

Northern California's Sacramento-San Joaquin Basin is the setting for two of the largest and most elaborate water management systems in the world: the Bureau of Reclamation's Central Valley Project (CVP), and the State Water Project (SWP) planned and operated by California's Department of Water Resources (DWR). These two agencies lie at the focus of a complex set of social institutions including the water users (ranging from small irrigation companies to the Metropolitan Water District, which has call on almost half of the SWP's total supply for delivery in southern California), other state and federal agencies with regulatory power over water-related issues (e.g., the Corps of Engineers, which sets flood control policy, and the State Water Resources Control Board (SWRCB), which regulates water quality and sets water rights), and environmental advocacy groups, which are particularly powerful and visible policy players in California.

The Key Issue is Long-Term Water Supply Adequacy

Both the CVP and SWP employ large surface water storage to capture winter and spring runoff for use during the summer peak demand period. Elaborate systems of canals, aqueducts, pumping plants, and other control structures deliver water to agricultural, municipal and industrial users.

The foremost concern vis-a-vis climate change is the system's overall adequacy in the face of changes in total runoff or the timing of runoff. The SWP's supply reliability is defined in its statutes and contracts with users as the ability to meet requests in all but the most "extraordinary conditions." Until 1977 this reliability was supported by a large buffer between supply and delivery (Figure 2), which not only assured long-term supply, but made seasonal deliveries more reliable. If the rains stopped early in the wet season, managers could still meet projected demand by drawing on the large buffer supply.

Because the project was in many respects a response by the state legislature to severe drought in 1928-34 (when the need for droughtproofing was first voiced), managers acted very conservatively, tending to treat every dry spell as if it were a recurrence of this historical event. Thus, the worst drought on record became the project's design target, a water planning practice common throughout the country. The logic of planning for such multiple-year droughts was further supported by the occurrence of several back-to-back dry years in the mid-1950s.

The project's overall goal is to meet user demands and fulfill the actual and implied contract that the SWP will not fail to deliver at least a predetermined minimum supply. Such risk-averse planning and operation creates a situation in which actual supply exceeds firm yield (the amount of water available in all but the driest years, usually calculated to allow shortages damaging to users only once in one hundred years) most of the time. SWP managers deal with this by declaring the excess for delivery as surplus rather than contract water. Contract amounts are tied to estimates of minimum project yield, while surplus water is not guaranteed from year to year, and thus acts as a flexible buffer to contracted supplies. This situation is good for users, who can place great confidence in basic SWP supply reliability and can benefit from the sale of cheaper, "surplus" water.

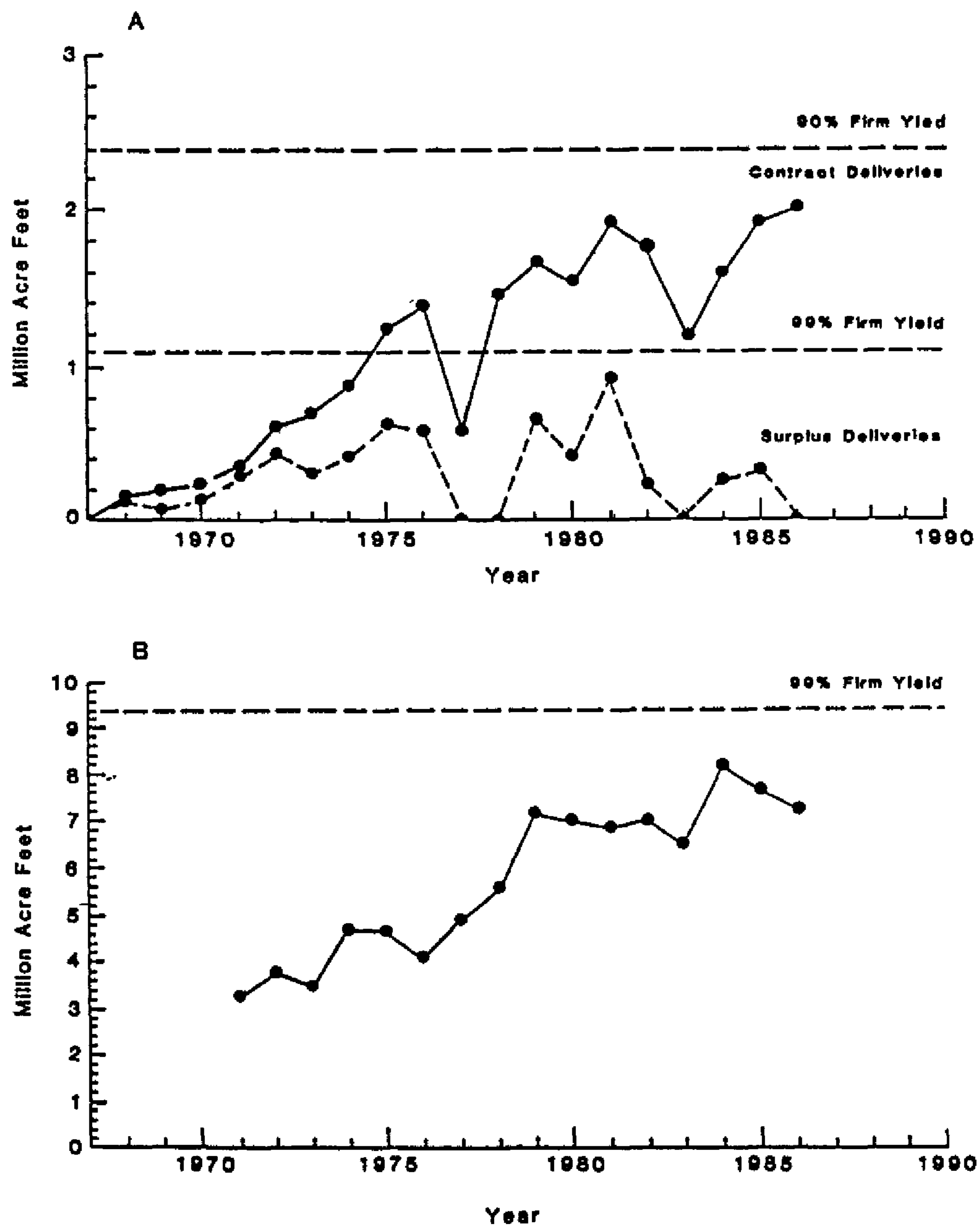

Figure 2. Water deliveries and firm yield levels for (a) the State Water Project and (b) the Central Valley Project.

SWP development is guided by a long-term plan which projects a total demand of 3.6 million acre-feet (maf) by the year 2010 (California Department of Water Resources, 1983). Users set the demand projections by providing DWR with their capital investment plans. Phased facilities development was planned to keep firm yield larger than projected demand, but projects (such as the proposed Auburn Dam and Delta Peripheral Canal) have been delayed due to environmental and economic constraints. In concert with larger-than-expected water requirements for meeting Delta water quality standards (discussed below), these delays have made the SWP quite sensitive to climate impacts in the last decade. This fact was noted in the Coordinated Operations Agreement (U.S. Bureau of Reclamation, 1986) in which CVP and SWP supplies are shared.

> The CVP, for an interim period of time, has water for which it has no facilities to fully deliver that water to Federal contractors. The SWP, on the other hand, has conveyance capacity available but an insufficient water supply with which to fully utilize its system. (U.S. Bureau of Reclamation, 1986)

That is, the CVP has a surplus of water and the SWP is short, especially in relation to users' projected requirements. These different sensitivities are seen in the two water systems' relative capacities. The CVP has a reliable or firm yield of roughly 9.4 maf while the SWP has a equivalent firm yield of roughly .9 maf, and a 90% firm yield (i.e., the amount that can be delivered in nine out of ten years) of 2.4 maf (Figure 2).

The CVP has delivered between 7 and 8 maf to users over the last several years, while the SWP has been making contracted deliveries of up to 2 maf in recent years and delivering an additional 1 maf in "surplus" water.

Growing Climate Sensitivity Raises User Concerns

SWP planners faced growing constraints on adding new facilities during the 1970s (see Sudman, 1983, and Franceschi and Sudman, 1983). Storage capacity increased little while contract water requests quadrupled (from .3 maf to 1.3 maf) between 1970 and 1975 (exceeding the project's .9 maf 99% firm yield) and approached 2.4 maf 90% firm yield in the early-1980s (Figure 2). The system was becoming more sensitive to climate fluctuations, and users could reasonably ask whether it would protect them from future drought if new facilities were further delayed.

The 1976-77 drought created a crisis that highlighted the system's growing climate sensitivity and illustrated the nature of managerial response to climate impacts. The drought produced the driest rainy season on record, causing deliveries to fall below firm yield targets in 1977. Managers curtailed deliveries to avoid eventual storage depletion. Firm agricultural water deliveries in 1977 were shorted by 60%, and municipal/industrial supplies were reduced by 10% (California Department of Water Resources, 1978). Total deliveries declined from 2.05 maf in 1976 to .9 maf in 1977.

These shortages provoked calls by users and policy makers for an evaluation of dry-year delivery policies--the key management criteria in any water system. Recognizing that they might not be able to increase project supplies in the near future, SWP managers were being forced to make a strategic choice between operating the system to protect its long-term supply or to keep operations flexible. By keeping as much water in storage as possible, a strategy that calls for occasional delivery curtailments early in developing droughts, managers could increase the probability of making future deliveries even under dry conditions. Alternatively, they could accept greater risks of storage depletion by maintaining full contract deliveries as future droughts develop, rather than saving water in storage. The choice, made in the midst of the severe 1976-77 drought, was to protect long-term supply by giving priority to end-of-year storage. This choice meant risking shortages in current-year deliveries that later may have proven to be unnecessary because an incipient drought failed to intensify (California Department of Water Resources, 1977).

This water allocation policy was codified in a "rule curve" which determined deliveries and carry-over storage during periods of short supply (see California Department of Water Resources, 1977 and 1978). Users, who had become skeptical of informal, intuitive water allocation decisions used in the past, supported the more rigid approach at first. Because many users were still making long-term capital investments in the use of contracted water, they approved of the strategy aimed at maintaining the project's ability to deliver even reduced water amounts over the long-term, rather than maintaining full deliveries at the risk of eventual supply depletion (Snow, 1976; and Robie, 1976).

The new rule curve was not invoked again for several years. Yet, due to continued demand growth, tightened water quality standards in the Delta, and a referendum blocking construction of the Peripheral Canal (which would have increased firm yield by perhaps 1 maf), SWP managers estimated in 1983 that, even with conservative supply management, contract requests would only be satisfied in normal or above-normal runoff years by 1986, and met in only very wet years by 1990, when requests were expected to reach 2.9 maf (California Department of Water Resources, 1983). Given this squeeze on supply, managers and users again called for additional storage facilities to augment dry year supplies (as well as to provide more flood control capacity that might allow a relaxation of flood control rules in other reservoirs--see below). They were guardedly optimistic that a major new reservoir could be operating by the year 2000 (California Department of Water Resources, 1983, p. 250).

Readjusting Allocation Policies

Conservative supply management and growing demand were thus both in effect during the sharp drought of 1985, when the "rule curve" called for significantly curtailed current year deliveries in order to meet minimum needs if the drought continued into the next year. Users reasoned that unnecessary delivery shortages--a frequent problem with rigid allocation criteria in a variable climate--might be worse than simply running out of water further into a multi-year drought.

This attitude change is evident in SWP documents. Noting that the 1977 rule curve "emphasized credibility at the expense of usability--probably due to the unprecedented drought conditions prevailing at the time it was designed" (California Department of Water Resources, 1985a, p. 2), SWP managers began to question its usefulness given the growing inadequacy of average supply. The situation had, perhaps, been anticipated two years earlier in the 1983 update of the state's water plan:

> Uncertainty regarding the capability of increasing developed supplies over the next several decades may justify and in fact may require taking greater risks in delivering water to customers.... Some water projects (could) take greater risks by delivering a higher annual supply, leaving less carryover storage in case of drought. This would allow growing needs to be met in normal years.... (E)xisting facilities may be operating in a more conservative manner than is necessary. (California Department of Water Resources, 1983, p. 255)

This analysis, reflecting poor prospects for increasing raw supply and recent large short-term swings in runoff, set the stage for re-evaluating the dry-year operating procedures. It suggested that:

> The objective reliability of the Rule Curveprocedure (99%) may be more restrictive than intended in Water Supply Contracts, so that the (seasonal) forecast magnitude of available supply has been more limited and (SWP) approval of delivery schedules further delayed during the runoff season than may be warranted. (California Department of Water Resources, 1985a, p.15).

A new policy emerged: adjust the rule curve each year given current conditions and attempt to maintain full contract deliveries early in a drought by drawing more liberally on reservoir storage (thus accepting greater risk of failing to meet subsequent year demands). This "variable risk" approach would help managers avoid imposing unnecessary shortages during short dry spells and would make seasonal supply projections less likely to be revised downward.

Thus, the SWP followed a complex, crisis-driven policy process that shifted from rigid allocation criteria to more flexible rules as the project became more sensitive to climate impacts. Flexible operations, in lieu of further physical facilities and/or increased raw supply, can help a water system adjust to some climate change. But the problem remains to assess the "absorptive capacity" provided by variable-risk allocation rules.

Summary: Potential Future Adjustments in Water Supply

Options for adjusting California water supplies to climate change (see Table 2) range from continuing the traditional approach of building more and larger physical facilities (at least until all available supply is controlled) to what might be called "softer" options, including a mixture of behavioral (e.g., conservation), institutional (e.g., water marketing) and technical options (e.g., water re-use, groundwater banking, and smaller, specialized physical facilities like the Auburn "dry dam" for flood control). There is, of course, the possibility

TABLE 2

OPTIONS FOR WATER SUPPLY AND FLOOD CONTROL ADJUSTMENTS IN CALIFORNIA

1) **The traditional option:** build larger facilities/increase supplies. Given sufficient public will and financing, new and larger reservoirs and water conveyance facilities could be built to reduce the impacts of climate change. Ultimately, however, the last drop of water available in the state or already allocated for importation from the Colorado River would be utilized, or new facilities would be blocked by economic and environmental constraints, and new options--like waste water reclamation, cloud seeding, desalinization, or imports from beyond the Colorado basin--would be required. Many of these options have been mentioned in recent water plan updates. There has been a large interest in weather modification in the past, and this adjustment would most likely re-emerge in any future supply shortage.

2) **A broad range of incremental adjustment:** The most likely response to climatic and other threats to reliable, quality water supply is a mixture of incremental behavioral and institutional changes, including conservation, water re-use, enhanced joint-system management, and reallocation of supplies via some form of water marketing. The 1987 update of the state's water plan promotes a form of broad-range adjustment, yet it still evinces a bias toward new, but smaller, physical facilities and structural improvements.

3) **The draconian alternative:** If climate conditions were to worsen dramatically in the next few years in the area, and given the growing climate sensitivity already exhibited by present water systems, decision makers might be pressed to instigate dramatic water-use restrictions, essentially implementing permanently, the "emergency" measures taken during recent droughts. These adjustments could include prohibiting most "non essential" uses, and permitting quicker transfers of agricultural water to municipal and industrial uses.

that a rapid deterioration of climate, imposed on an already sensitive system, could lead to drastic measures which, in the past, have been needed only in extreme years.

A "wild-card" in this list of broad alternative responses is the real and perceived need for flood control--which conflicts with supply management. If there is pressure to increase flood protection by decreasing reservoir storage in the basin, say if spring runoff increases due to the greenhouse effect, then the ability to meet demand will decrease. The trade-off between water supply and flood control in northern California represents a potentially serious policy conflict affecting all levels of government in the region. While some climatic shifts (e.g., a smoothing of the area's marked precipitation seasonality) would ease this tension, even small shifts toward earlier runoff or more extreme rainfall events would make the supply/flood-control trade-off even more difficult. Given that similar tensions exist in other water systems that provide both flood control and water supply (e.g., the Colorado River), there is a need for a broad assessment of this issue vis-a-vis changing water demands and potential climate change.

The overarching trend in water resource development policy in northern California over the last decade has been a de-emphasizing of large physical facilities. Project planners recognize a need to re-establish a buffer between supply and demand, but have been constrained by institutional forces (e.g., water law and existing water user charters) not to turn to economic or other strategies (i.e., through competitive bidding or water right sales--water marketing--which might yield more efficient allocation) to achieve a supply less sensitive to climatic inputs. Thus, their plans continue to include new physical facilities despite growing financial and environmental constraints on this traditional approach to water system development.

Without having explicitly considered potential climate change as a rationale, the recently revised development plan for the SWP (California Department of Water Resources, 1987a) includes several actions and facilities that would allow the system to absorb at least small climate changes. Spurred by success of coordinated operations with the CVP (aimed mostly at meeting Delta water quality requirements and dry-year demand), the state and federal governments are discussing further sharing (probably additional water purchases from the CVP) and further "optimizing" of joint project management. Indeed, the 1987 plan actually suggested the possibility of state management of both SWP and CVP facilities. Completely joint management could produce more than 1 maf additional firm yield in the system.

Besides operational adjustments, the 1987 plan calls for construction of off-stream storage at Los Banos Grandes south of the Delta (an approach and site less likely to draw serious environmental opposition than, say, Auburn Dam), and improvements in Delta pumping and conveyance facilities. Through these strategies, the SWP plans to achieve a 90% firm yield of roughly

3.3 maf by 2010 (Figure 3), just short of expected demand (which tends to be over-estimated) of 3.6 maf. Thus, supply and demand will still be closely balanced, but there will be more safety margin than presently exists. This will allow for more flood control space in reservoirs, as well as minimization of the threat of supply depletion during the driest years. Thus, the project adjustments suggested in the 1987 plan would help the SWP absorb at least some of the greenhouse climate change possible over the next few decades.