Introduction

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Confusion now hath made his masterpiece!

William Shakespeare, *Macbeth*

For more than 30 years, California has struggled to manage its water effectively. Numerous factors have contributed to this struggle, including changes in the value that society places on ecosystems, growing urbanization, declining state and federal financial and technical support, a shifting climate, and outdated water management systems. All of these factors make water scarcity and increasing flood risk a part of life in California, now and for the indefinite future.

Current policies have proved inadequate to meet diverse and growing demands for water supply reliability and water quality, flood protection, and ecosystem health:

- Competition for water has become intense. The state has run out of cheap "new" water sources, and agricultural and urban water users now compete both among themselves and with emerging environmental demands.
- Water quality concerns are growing, despite progress in cleaning up wastewater and industrial discharges. "Nonpoint" sources of pollution—the runoff from agricultural fields, timber harvesting, mining, and urban streets, gardens, and construction sites—are still not well managed, and California lacks adequate policies to prevent harmful new chemicals from entering the environment. The consequences are increased costs of drinking water treatment, risks to public health, lower crop yields, and harm to aquatic ecosystems.

Mount Shasta from the Shasta River.

- Flood risks are high and growing. Investments in flood protection have not been adequate to maintain existing infrastructure, and many local governments have promoted development behind weak levees, placing more lives and property at risk.
- Ecosystems and native species are in decline. Decades of harmful water and land management practices have degraded aquatic habitat, worsening conditions for native fish and other species that depend on California's wetlands, streams, lakes, and estuaries. The growing number of species listed under the Endangered Species Act reflects this decline, and ESA regulations to protect these species have, in turn, become a flashpoint in the increasing conflicts over water management.

In short, today's system of water management, developed in previous times for past conditions, is leading the state down a path of environmental and economic deterioration. Crises are brewing, waiting for the next drought, flood, or lawsuit to bring widespread or local catastrophe. In some ways, California is already in a crisis, but the crisis is moving so slowly that the state's leaders and residents often fail to recognize it. Given anticipated changes in demographic, economic, climatic, and ecosystem conditions, today's conflicts are likely to worsen unless California can quickly develop significant, forward-looking changes in water policy.

California's Failing Water Policy

Current conflicts over California's water are wide-ranging and reflect the diverse landscape, climate, economies, ecosystems, and cultures of the state. The struggles to remove four dams on the Klamath River, improve flood protection for Sacramento, find a solution to the decline of the Salton Sea, resolve aquifer overdraft in Central Coast basins, dispose of salt in the Santa Ana Basin, and manage the Sacramento–San Joaquin Delta for both water supply and ecosystem health all seem to be unique local problems. Yet they and myriad other water conflicts in California have important common, interrelated elements.

Infrastructure Limits

The elaborate 20th century water supply and flood control systems that are symbolic of what Norris Hundley, Jr., has called "the hydraulic society" made it possible for one of the world's most diverse and dynamic economies to prosper in

a semiarid region highly susceptible to floods and droughts (Hundley 2001). A network of hundreds of groundwater basins, 1,400 dams, and thousands of miles of canals, aqueducts, and levees delivers water and manages floods for more than 38 million people. This development reflects the state's dry and variable climate and the geographic distance between California's major water sources and its population and farming centers—75 percent of California's precipitation occurs north of Sacramento, and 75 percent of its water demand lies to the south (Figure A).

But California has outstripped the capacity of traditional water infrastructure to satisfy its current economic, environmental, and social demands for water. Expanding traditional water infrastructure is increasingly costly and less effective. The most accessible and productive streams have already been tapped, and there is little room left to support aquatic ecosystems.

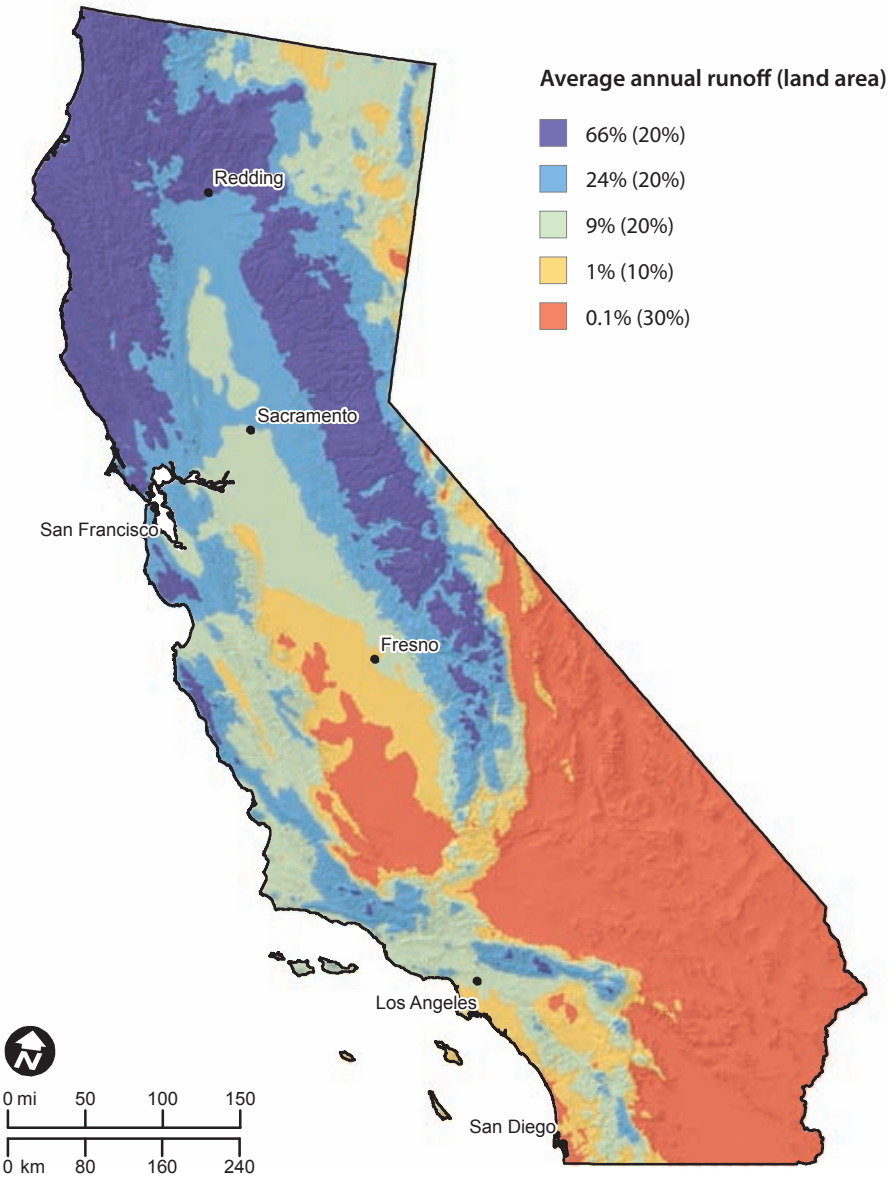
Funding Limits

The great expansion in water supply and flood control infrastructure in the 20th century relied on financial and technical support from federal and state governments. Over the past 30 years, diminishing institutional support (particularly federal funding for large water projects) has failed to keep pace with expanding needs. The state's financial contributions to water management have largely been funded by general obligation bonds that must be paid back with state tax revenues. Given the current and prospective fiscal climates in Washington and Sacramento, increased federal and state largesse is unlikely in the near future. At some point, reliance on state borrowing will no longer be viable, as the public begins to realize that dedicating tax revenues to pay off water bonds means reduced funding for other public services supported by the state's general fund. The legislature's 2010 decision to postpone an $11.1 billion water bond initiative for at least two years may be a tacit admission of this financial limit.

A Changing Climate

Most of California's water management infrastructure was designed during the first half of the 20th century. Yet the climate in California (and in much of the American West) has changed in the past 60 years—and will continue to change. A more volatile climate now appears to be the norm, with an increasing frequency and intensity of droughts, floods, extreme high tides, and heat waves. An overwhelming body of science suggests that this current trend will continue and intensify in the future, further testing the resiliency of water management systems designed for the past (Hanak and Lund 2008).

Figure A
Most of California's precipitation falls far from cities and farms



SOURCE: Calculations by J. Viers using data from PRISM, CIMIS, and the U.C. Davis Soil Resource Laboratory (see the notes).

NOTES: The map shows the distribution of runoff—the amount of local precipitation that flows into streams and recharges groundwater. Relative runoff is depicted as a percentage of annual runoff, calculated by adjusting average monthly precipitation (PRISM 1970–2000) by losses to soil storage capacity (U.C. Davis Soil Resource Laboratory, Beaudette, and O'Geen) and average monthly reference evapotranspiration (CIMIS 2000–2005, Hart).

Environmental Failures

Perhaps the most important factor affecting California's efforts to meet current demands for water management is the historical failure to adequately protect the environment. Ever since the Gold Rush, the environment has borne the brunt of the tremendous changes in land, water, and infrastructure development that have shaped California. The hydraulic mining industry—the state's first large-scale use of water—discharged vast quantities of mine tailings and mercury-laden wastes into Northern California's rivers. The hard rock mining industry proved equally destructive, leaving behind a legacy of more than 47,000 abandoned mines, many discharging the most toxic fluids known to mankind into the state's rivers and streams. The rapacious logging practices of this era laid waste to salmon habitat in California's North Coast rivers, which, coupled with overharvesting at sea, led to precipitous declines in salmon and steelhead populations. Rapid expansion of hydropower—damming and redirecting the flow of many Sierra Nevada and Coast Range rivers—damaged the ecosystems of native fish and amphibians. Sprawling urbanization in the South Coast and the San Francisco Bay Area converted rivers and streams into flood control channels carrying tainted storm runoff. The tremendous growth in grazing and agriculture in the late 1800s through the mid-1900s transformed California's native landscape, eliminating roughly 95 percent of the state's wetlands that were both vital components of the natural flood control systems and home to a diverse range of fish, birds, and other species (Mount 1995; Isenberg 2005).

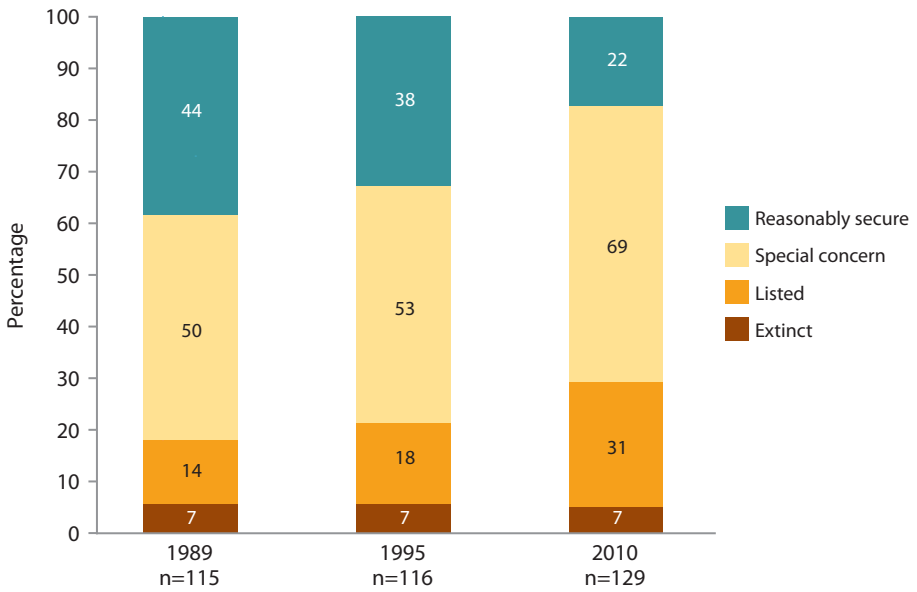
Large water and flood control projects also created widespread and lasting changes in the environment. The Central Valley Project, the State Water Project, the Sacramento–San Joaquin Flood Control Project, San Francisco's Hetch Hetchy Project, Los Angeles's Owens Valley Project, and hundreds of other local and regional projects imposed extensive costs on the environment. When these projects were designed and constructed, they reflected the general thinking of the time. Environmental costs were either ignored or viewed as a necessary tradeoff. The only significant attempt at mitigation was the widespread introduction of hatcheries to offset the effects of dams that prevented the access of salmon and steelhead trout to spawning grounds. Ironically, even fish hatcheries have become an additional burden on the environment.

By the late 1960s, the aggregate degradation of the nation's air, water, lands, and natural resources gave rise to the modern environmental movement. This shift in societal values is reflected in a welter of statutes passed from the late 1960s through the 1970s that dominate water management in California today, including

the National Environmental Policy Act, the Clean Water Act, and the Endangered Species Act, as well as their state counterparts. In the decades that followed, the environment would become a central consideration in debates over water.

Although environmental considerations have become integral to all water management and planning, progress in improving environmental conditions has been mixed. As noted above, the Clean Water Act has led to substantial improvements in water quality from "point" sources, including wastewater and industrial plants, but it has been less effective in managing polluted runoff from various agricultural and urban areas. And, although the Endangered Species Act appears to have reduced the overall rate of species extinction in the United States (Scott et al. 2006), it has not protected all species whose populations or habitats are in peril. In California, many native fish species ("fishes") continue to decline (Figure B). As scientists and regulators learn more about the needs and sensitivities of these species, the share of water that must be allocated to the environment usually increases. This trend seems unlikely to change soon.

Figure B
California's native fishes are in sharp decline



SOURCE: Moyle, Katz, and Quiñones (2010).

NOTES: Extinct = extirpated from California; listed = listed as threatened or endangered under state or federal Endangered Species Acts; special concern = species in decline that could qualify for listing in the future; reasonably secure = widespread, abundant species according to current knowledge.

Absence of Consensus

Growing recognition of environmental failures and disagreements about solutions (and how to pay for them) are central to the conflicts that characterize California water management today. The state also faces profound conflicts on other difficult issues, including how to regulate development in flood-prone areas, whether to regulate groundwater use, and how to allocate the costs of new infrastructure between direct beneficiaries and the general public. The decentralized, and often fragmented, nature of water management and decisionmaking in California has contributed to the current policy deadlock.

Although state and federal agencies built and operate some of the largest water projects in California, the state's water management system is highly decentralized, involving many hundreds of local and regional agencies responsible for water supply, wastewater treatment, drainage management, flood control, and land use decisions. This decentralization across scales and functions of government has created many responsive but narrowly focused stakeholders who drive most water policy today. Having many self-interested stakeholders in a system of decentralized governance encourages each party to hold out for a better deal. The result is often a game of "chicken," where the management of a declining resource becomes deadlocked. Each faction, while acknowledging the growing problems of decline, fears policy change and seeks only those changes that serve its own interests, thus collectively preventing anything but small changes in management despite growing prospects for catastrophe.

This deadlock is particularly prominent in the management of the Sacramento–San Joaquin Delta—the fragile hub of the state's water supply network—which is experiencing an ecological collapse and faces the prospect of a major physical collapse as well. Consensus processes over almost 15 years have been unable to develop effective long-term policies for reversing environmental decline and improving water supply reliability (Lund et al. 2010; Hanak et al. 2010; Madani and Lund 2011). Searching for consensus seems only to have continued the deteriorating status quo.

Scientific and technical work has become embroiled in the advocacy of stakeholders engaged in what can be called "combat science," where scientific work is sponsored or employed primarily to advocate or attack particular interests, rather than to gain better insights into problems and solutions. The lack of independent scientific and technical assessments of California's water problems and solutions has given rise to many popular and politically useful myths that hinder serious discussions and negotiations of water policy (Hanak et al. 2010).

Consequences of Inaction

These five factors—increasingly obsolete design of its water management system, reductions in federal and state funding, changing climate, the challenge of incorporating environmental protection and sustainable management of the state's aquatic ecosystems, and lack of consensus on the options for future reform—have led California water management into a dysfunctional impasse. As we describe in later chapters, continuing the current policies will lead to many environmentally and economically costly outcomes. These include:

- Continuing deterioration in the ecosystem of the Sacramento–San Joaquin Delta, with a corresponding deterioration in the region's ability to supply water to farms within the Delta and in the southern Central Valley and to cities from the Bay Area to San Diego;
- Growing conflicts over groundwater use in overdrafted aquifers;
- Declining crop yields and soil quality as a result of salinity in the southern Central Valley;
- Continuing damage to habitat for native fish and other aquatic and riparian species statewide, as a result of invasive species, deteriorating water quality, and unfavorable land and water management, leading to additional listings under the Endangered Species Act and disrupting water delivery and flood management systems;
- More frequent suspensions of recreational and commercial salmon fishing;
- Growing numbers of poorly understood and inadequately regulated chemicals entering the state's waterways, posing risks to public health and the environment;
- Higher drinking water treatment costs for urban dwellers and declining water quality for rural water users who depend on wells;
- Increasing flood risks for existing and new urban development in the Central Valley and coastal regions of the state;
- Inadequate funding for environmental regulation and protection; and
- Increasing fragmentation and dissipation of scientific effort and growing use of science in debilitating adversarial processes.

Many of these problems are likely to grow worse in light of continuing changes in the physical environment, including climate warming and sea level

Without new policies, flood risks will increase in many parts of the state. Photo by Monica M. Davey/epa/Corbis.

rise, which will bring increasing stress to aquatic ecosystems and the state's current systems for managing water supply and floods.

In the past, California water policy has changed to meet the needs of the times, albeit often by responding fitfully and imperfectly to controversies and crises. Today, California has arrived at a point once again where, given the circumstances, it *must* adapt its water management to changing conditions—perhaps through controversy and crises but perhaps with forethought and careful consideration as well.

From Conflict to Reconciliation

This book outlines an ambitious reform agenda to help put California water management on a more constructive and hopeful path. In this vision, California moves beyond the current Era of Conflict and continuing deterioration toward an Era of Reconciliation, in which water is managed more comprehensively and more flexibly for the benefit of the economy *and* the environment, meeting broad social goals of balance, efficiency, and fairness (see Box A). Water management in this new era seeks to promote reliability, at a reasonable cost, while being capable of adapting to changing conditions. The system is more integrated, more transparent, and better able to support decisionmaking and enforce compliance with the law. Conflicts will remain, but they will be less debilitating.

A

Goals for a modern California water policy

In developing a new water policy, California should seek to attain five broad societal goals:

Public health, safety, and welfare. Water management should support the well-being of the state's residents.

Ecosystem health. Ecosystems are not just a source of water for direct human uses; they are also a source of broader social and economic well-being and must be protected.

Balance. In recognition of environmental values, new policies must explicitly consider and balance tradeoffs between ecosystem benefits and traditional management of water supply and flood protection.

Efficient allocation and use. California water policy and law, embodied in Article X, § 2, of the state constitution, reflect the importance of efficient allocation and use of water and the need to adapt water uses to changing economic conditions. Policies supporting this goal need to be strengthened in response to unmet environmental demands and changing climatic conditions.

Fairness. New policies must be perceived as fair, not selectively supporting one interest at the expense of others. Efforts should be made to ease the costs of policies that harm disadvantaged groups.

Although conflicts among these goals are inevitable, all elements of society have a long-term interest in achieving a balance among them rather than adopting extreme solutions that are unsustainable in environmental, economic, or social terms.

These societal goals translate into five objectives for water system management:

Reliability and sustainability. Some degree of stability and predictability in water policy is essential to support continuing economic well-being.

Reasonable cost. Where possible, water management must reduce the costs of delivering services to the state's residents, without neglecting social and environmental costs.

Adaptability to changing conditions. Effective water policy must incorporate mechanisms for anticipating change and incorporating scientific projections and uncertainties into management.

Integration. Modern policy must continue current trends toward integrating water management for diverse purposes, linking policies that govern water supply and quality, flood management, and ecosystem health.

Transparency, clarity, and enforceability. New policies need better legal mechanisms to enforce compliance and better information systems to support decisionmaking and enforcement. Transparency is essential to support the societal goal of fairness.

In this new era, California will need to reconcile human and environmental uses of water in the face of chronic water scarcity, growing flood risk, and changing social, economic, and environmental conditions. Key elements of the reform agenda include the following:

- **Ecosystem reconciliation.** To reconcile human and ecosystem uses of water, the historical approach of desperate actions to preserve single species must give way to approaches that more broadly and systematically aim to restore ecosystem functions.
- **Integrated management portfolios.** To promote adaptive capacity, managers should use diversified and integrated water management portfolios, rather than traditional single-investment approaches, and should strive to better integrate California's fragmented networks of infrastructure and operations for managing surface and groundwater supplies, flood risk, water quality, and aquatic habitat.
- **Water as a public commodity.** To more efficiently manage water for the economy and the environment, the state should build on current efforts to manage water as a public commodity, promoting reasonable use and flexibility in the face of changing conditions. This will require developing more robust fee-based funding to support public aspects of the water system, including environmental management.
- **Decision-capable and adaptive governance.** To lead reconciliation under changing conditions, California needs more adaptive, responsive, and technically capable water governance institutions. This includes better integration of local, regional, and state efforts and state agencies with more streamlined authority and better mechanisms for protecting the public trust in water. California also needs to rebuild the capacity of state institutions to collect, analyze, and disseminate scientific and technical information necessary to the development of a forward-looking, balanced water policy.

Many of the changes we propose build on existing efforts and can be implemented within existing legal authority; some will require changes in laws and institutions. Most will require strategic shifts, including new forms of collaboration among California's myriad local and regional water and land use agencies, as well as new forms of leadership by both the state and federal governments.

This ambitious agenda can put California on a sustainable path for water management that serves the state's residents well for decades to come and that protects its environmental riches for generations. Changes to the status quo are never easy, and many of the reforms we propose will meet resistance from stakeholders who fear the loss of autonomy or the potential costs of change. We suggest ways to lessen this resistance and lower the costs of reform, by employing cooperative federalism approaches that allow local agencies and water users to develop detailed solutions under general direction from the state, phasing in some reforms and using other strategies to lessen the costs to affected parties. But even with these cooperative approaches, reforms will require bold leadership at all levels. The alternative—continuing deterioration of a system increasingly ill-suited to changing conditions—is bleak and unacceptable.

Overview of This Book

In this book, we take a broad, future-oriented look at water.[1] Today, all forms and uses of water in California are linked statewide—whether directly by rivers and canals or indirectly through markets, the economy, management institutions, and law. To address the complexity of California water and the need for integrated approaches, we bring together perspectives from biology, economics, engineering, geology, and the law. We draw information from many sources, including our own research and new modeling and data analysis. We also benefitted from the wisdom and insights of an advisory board of prominent policymakers and from interviews with more than 100 individuals with expertise in many facets of California water.[2]

The book consists of three parts. Part I reviews past, present, and future conditions of water management in California. It highlights the historical origins of many aspects of today's water system, the complexity and fragility of the current system, and key drivers of change that will exert increasing pressure on this system in the future. Part II focuses on major challenges and promising approaches for managing water in the future. We presume, perhaps

1. Many excellent books have been written on water management in California. Most focus on some specific aspect, such as water supply (Pisani 1984; Bain, Caves, and Margolis 1966), flood control (Kelley 1989), or particular regions (Arax and Wartzman 2005; Kahrl 1982), generally from a historical perspective and occasionally from a public policy perspective (Bain, Caves, and Margolis 1966). In his excellent overall history, Hundley (2001) examines a wide range of water management perspectives.

2. For a summary of the results of these interviews, see Null et al. (2011), available as an online technical appendix to this book at www.ppic.org/content/pubs/other/211EHR_appendix.pdf.

optimistically, that California can emerge from today's era of debilitating conflict into one of more adaptive, if imperfect, reconciliation. We summarize the major water management challenges facing the state and examine promising approaches for (1) reconciling human and environmental uses of water, (2) integrating a portfolio of water management tools to more effectively manage water supplies, water quality, and floods, and (3) managing water more flexibly and responsively as a public commodity. Part III explores strategies for implementing policy reforms. We suggest ways to reorganize and reform state and regional water institutions to meet current and future challenges, offer strategies for reducing the costs and raising the acceptability of reform to stakeholders, and propose the key elements of a water reform agenda.