

Adapting California Water Management to Climate Change: *Charting a Path Forward*

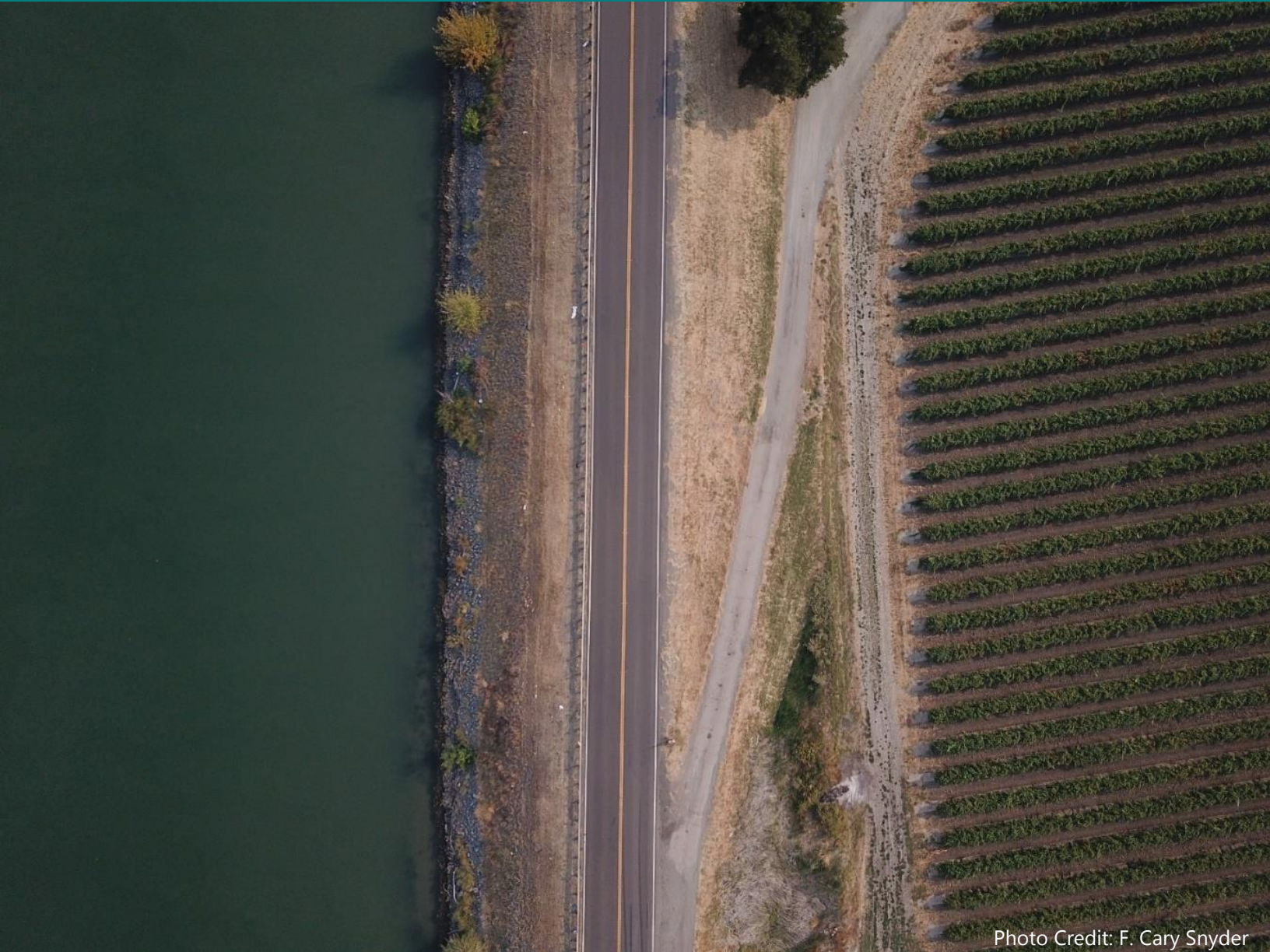


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A Report by the 2020 Water Education Foundation Water Leaders



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Overview of Water Leaders and Purpose of Report

The Water Leaders Class, sponsored by the Water Education Foundation, is an annual leadership program aimed at nurturing and enhancing the water knowledge and leadership skills of early to mid-career professionals hailing from across California and beyond. The 2020 Water Leaders Class is comprised of a diverse set of individuals who are passionate about the future of water policy, supply and quality in the state of California and who are dedicated to using their platforms to help ensure a brighter future for California water.

Each Water Leaders Class is responsible for preparing a report on a specific issue that is at the forefront of water policy in California. The 2020 Water Leaders Class was tasked with exploring both the impacts of climate change on water in California and the avenues for adapting to these impacts in ways that are technologically feasible, sustainable and inclusive of all Californians. To meet this task, each member of the 2020 Water Leaders Class was paired with and responsible for conducting an interview and developing a relationship with a mentor who is a knowledgeable water professional. Through the interview process, leaders were able to gain insight on the various impacts of climate change on water in California and the mitigation and adaptation efforts that are currently underway. Since mentors represented a wide variety of water-related professional sectors, the 2020 Water Leaders Class was able to collectively gain an understanding of the widespread impacts of climate change in most water-related sectors throughout the state. In addition to gathering knowledge from their mentors, members of the 2020 Water Leaders Class further explored water policy and history in California by participating in workshops, hearing from water experts and learning from one another.

Armed with the insight gained from the yearlong experience, the Water Leaders Class set out to create a collaborative report that utilizes the diverse backgrounds of class members to provide a comprehensive analysis of the intersection of climate change and water in California.

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Disclaimer

This report, and the opinions expressed herein, were prepared by the authors in their individual or personal capacities, and do not represent the views of the Water Education Foundation (WEF), its Board of Directors, or the authors' employers. One author, Cory Copeland, is an employee of the Delta Stewardship Council, which may make decisions regarding two projects endorsed in the report. In order to protect his and the Council's impartiality, Mr. Copeland did not discuss, participate or otherwise engage in drafting the sections 'Policy Recommendations – Infrastructure' of the report. Instead, he contributed to the report's 'Introduction - Impacts of Climate Change on Water Systems in California.'

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The Water Leaders would also like to thank the 2020 mentors who provided guidance and insights on California water issues. These mentors generously donated their time and expertise:

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Dedication to William R. “Bill” Gianelli

Bill Gianelli, the Water Education Foundation’s second president and a leading figure in California water during construction of the State Water Project, died March 30, 2020, in Monterey County. He was 101.

Mr. Gianelli was president of the Foundation from 1985-1989 and made a major financial donation that helped the Foundation create an educational program for young professionals from diverse backgrounds, which was named the William R. “Bill” Gianelli Water Leaders Class in his honor. The year-long program began in 1997 and now includes more than 400 graduates.

This year’s Water Leaders report is dedicated to Mr. Gianelli, honoring his life and his contributions to advancing leadership and solutions in the California water world.

Table of Contents

List of Abbreviations	vii
Executive Summary	1
1 Introduction	7
1.1 Projected Climate Change Impacts.....	7
1.2 Uneven Distribution of Impacts	10
1.3 A Principled Approach to Adaptation.....	11
2 Guiding Principles	12
2.1 Equity	12
2.2 Partnerships and Collaboration.....	13
2.3 Innovation Through Scientific Understanding	13
2.4 Multi-benefit Approaches	14
3 Infrastructure	15
3.1 Background.....	15
3.2 Recommended Actions	17
4 Regulations	22
4.1 Background.....	22
4.2 Recommended Actions	22
5 Data and Technology	30
5.1 Background.....	30
5.2 Recommended Actions	31
6 Conclusion	36
7 References	38
Figure 1: Map of major water storage and conveyance infrastructure in California	16
Table 1: Potential water project permitting frameworks.	24

List of Abbreviations

AF	acre-feet
AR	atmospheric river
ASCE	American Society of Civil Engineers
ASO	Airborne Snow Observatory
BARR	Bay Area Regional Reliability
CalOES	California Office of Emergency Services
CDFA	California Department of Food and Agriculture
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CNRA	California Natural Resources Agency
Delta	Sacramento-San Joaquin Delta
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utility District
FIRO	Forecast Informed Reservoir Operations
Flood-MAR	Flood-Managed Aquifer Recharge
LiDAR	Light Detection and Ranging
NASA	National Aeronautics and Space Administration
NGO	non-governmental organization
P3	Public-private partnership
Reclamation	Bureau of Reclamation
SFPUC	San Francisco Public Utilities Commission
SGMA	Sustainable Groundwater Management Act
State Water Board	State Water Resources Control Board
U.S.	United States
USGS	U.S. Geological Survey

Executive Summary

California's climate is changing. Eight of the 10 largest wildfires in California history have occurred in the last decade, with more than 4 million acres burned in just 2020, shattering the previous record (Krishnakumar 2020). Looking ahead, weather patterns are expected to become even more extreme, with flashier floods and more intense droughts (CalAdapt.org; Swain 2018). The projected change in how and when California receives precipitation has serious implications for how the state will need to manage water if both people and the environment are to be supplied equitably.

Adapting to climate change requires state and local leaders to take greater steps to protect Californians who live in flood-prone areas, restore the functionality of aquatic ecosystems and ensure water supply reliability for all Californians. While California has led the nation in climate change impact assessment and planning (CNRA 2018), we must take further action to increase our resilience and ensure a reliable water supply moving forward, through efforts such as developing and maintaining an integrated system of infrastructure, updating regulations and statutes to reflect best available science and improving the collection, sharing and application of data. Solutions that promote equity and collaboration, leverage science and data for innovation and offer multiple benefits will result in the most successful and sustainable outcomes for our environment and communities.

The 2020 Water Leaders Class comprises 23 individuals from diverse backgrounds with a shared interest of exploring both the impacts of climate change on water in California and the avenues for adapting to these impacts in ways that are technologically feasible, sustainable and inclusive of all Californians. This report presents three key policy recommendations identified by the Water Leaders with 14 implementable actions that can help achieve a more robust and flexible system for managing California's water supply under an ever-changing climate.

Collectively, the following recommended actions present a strategy to guide California policymakers and water managers in adapting our water system to a changing climate.

Recommendation 1: Develop and maintain an integrated system of infrastructure to promote resilience, sustainability and operational flexibility.

California's aging water infrastructure needs new investments to improve its performance under changing hydrologic regimes.

Action 1: Diversify local and regional water supply portfolios.

Many water systems across the state rely on imported water, and these traditional sources have become increasingly unreliable with climate change. Regional resilience can be enhanced through alternative water supplies, including potable and non-potable water reuse, stormwater capture, seawater and brackish water desalination, water transfers and water conservation and efficiency measures. Providing pathways and incentives to diversify water portfolios will enable water agencies to implement more alternative supplies. For example, energy credits to offset the pumping that will be necessary to artificially recharge and extract groundwater will enable water agencies to blend local groundwater sources with traditional surface water supplies. Incentives can also be in the form of local ordinances.

Action 2: Incentivize urban stormwater recharge projects.

Urban stormwater capture programs are an important approach for increasing decentralized groundwater recharge, enhancing stormwater quality and diminishing localized flooding during large rainfall events. Public-private partnerships and rainwater harvesting programs can effectively incentivize and advance urban stormwater management.

Action 3: Develop regional infrastructure networks capable of operating as an integrated system.

California will need sustainable, flexible water conveyance and storage options to adapt to climate change. One critical component of this is updating and expanding regional infrastructure to be integrated with the State Water Project and Central Valley Project. The proposed Sites Reservoir north of Sacramento, the expansion of Los Vaqueros Reservoir in Contra Costa County and conjunctive use projects like the Sacramento Regional Water Bank in the American River watershed are examples of infrastructure projects with the potential to provide both regional and inter-watershed water supply solutions.

Action 4: Restore and build conveyance capacity.

Restoring and increasing California's water conveyance capacity allows water to be moved to areas of need more readily, improving adaptation capacity for extreme events like floods and droughts. Examples of intertie operations include the network of existing and proposed interties under the Bay Area Regional Reliability project, the Delta Mendota Canal/California Aqueduct intertie and the proposed Delta Conveyance Project.

Action 5: Invest in projects that create, reconnect and expand floodplains and wetlands.

Two promising multi-benefit approaches to increasing California's water resilience are restoring wetlands and creating more groundwater recharge opportunities through managed aquifer recharge using floodwater. For example, flooding rice fields in the winter is a multi-benefit project because it can create habitat for birds, recharge the groundwater system, decompose rice for future agricultural use and mitigate flood risk.

Recommendation 2: Update regulations and statutes to allow California's water systems to be flexibly managed concurrent with changing conditions.

Regulations need to be updated to consider climate change and to offer new frameworks encouraging adaptive management.

Action 1: Identify opportunities to align permit requirements and enable more flexibility.

Review of existing permit requirements would help identify opportunities to align elements, improve efficiency and avoid overlapping requirements across different permitting agencies. Additionally, new frameworks for permitting such as adaptive management, performance-based permitting and protocol-based permitting could allow greater flexibility for permit applicants with similar or greater protections in place.

Action 2: Update local land use rules.

Planning and other land use decisions have traditionally been made in California at the local level. However, there is a pressing need for more regional coordination and state assistance to help plan ahead for the impacts of climate change to water supply and flooding. Taking steps to designate more low-lying areas as floodplains, flood zones, bypasses and overflow zones and limiting development in such areas can mitigate the potential impacts of catastrophic flooding and improve groundwater recharge.

Action 3: Support local agencies with fiscal resources for climate adaptation planning.

In order to address climate needs, the state must require local agencies to incorporate climate risk assessments and adaptation plans within local land use and water supply planning processes. One way to encourage local governments to develop and implement climate adaptation plans is to incorporate matching funds from the state or federal government for local governments taking proactive measures. Such a model can be found in California's Senate Bill 1 transportation tax funding.

Action 4: Exempt water agencies from Proposition 218.

Many features of Proposition 218, the Right to Vote on Taxes Act, have improved transparency and public accountability. However, they also impose restrictive cost recovery requirements for public utilities. Water infrastructure is underfunded, and Proposition 218 limits water agencies' ability to increase rates to fill existing funding gaps, provide lifeline rates to disadvantaged customers and adjust rates to compensate for droughts. Exempting water utilities from Proposition 218 would provide local water districts with a tool to locally fund sustainable water projects, encourage conservation and support equity in their communities.

Action 5: Make groundwater recharge a beneficial use.

California law allows the diversion of water for recharge or storage when the water will be used for a designated beneficial end use, but the law does not recognize leaving recharged groundwater in an aquifer or "non-extractive uses" as a beneficial use (California Water Code Section 1242). This lack of regulatory clarity can hinder implementation of recharge projects that would provide broad basin benefits and promote groundwater basin sustainability. Clarifying guidance from the State Water Resources Control Board and/or new legislation may be necessary to broaden the definition of "beneficial use" to fully realize the benefits of groundwater recharge.

Recommendation 3: Improve the collection, sharing and use of data, compatible with appropriate technology, to address flooding, water supply and ecosystem management.

California needs to invest in improved data and technology to reduce uncertainty and inform investment decisions and management practices.

Action 1: Improve the use of climate data in water decision-making.

California needs to build upon the water data framework established under Assembly Bill 1755, the Open and Transparent Water Data Act. Having a centralized and integrated data platform with relevant resources on how to use the data would enable water managers to better utilize climate modeling tools, particularly for local water agencies with limited resources and capacity.

Action 2: Develop partnerships to improve accessibility of climate modeling for water stakeholders.

Partnerships among government agencies, non-governmental organizations and private institutions can increase transparency and make climate data and models more accessible to local water agencies, tribes and other users. Partnerships allow multiple stakeholders to leverage shared resources and overcome barriers to finding and utilizing data and tools. For example, partnerships can help smaller agencies build the necessary funding and technical capacity to implement climate modeling tools that may otherwise be inaccessible.

Action 3: Standardize climate modeling tools, technologies, datasets and approaches.

California's water managers rely on several tools, technologies and datasets to manage the state's water resources. However, managers lack guidance on which tools to use and how to apply them. California needs a comprehensive resource that provides guidance on vetted tools, technologies and datasets and the associated approaches, parameters and other considerations to apply datasets to local and regional water management.

Action 4: Incorporate the latest technology into water operations, such as Airborne Snow Observatory and Forecast Informed Reservoir Operations.

Airborne Snow Observatory and Forecast Informed Reservoir Operations are examples of harnessing the latest technology to improve water operations through enhanced data collection. The Airborne Snow Observatory program maps and analyzes the distribution of snow water equivalent (i.e., the amount of water contained in the snowpack) and snow albedo (reflectivity) in

mountain basins using aircraft with LiDAR (Light Detection and Ranging) technology and an imaging spectrometer to fly over each watershed, providing a true representation of the snowpack. Forecast Informed Reservoir Operations enables more effective management of reservoirs by leveraging improvements in weather and water forecasting.

With California already experiencing impacts of climate change, policymakers and water managers cannot afford to delay action. The forthcoming severity, duration and increased frequency of both drought and flood suggest all aspects of life in California will be impacted. Sustainable and flexible water management strategies will become increasingly difficult, controversial and paramount. Californians need leaders to act now in strengthening our water management policies and practices to ensure an equitable future for our state's diverse communities, industries and environment.



Photo Credit: Jon Flobrant, Unsplash.

1 Introduction

California's changing climate has serious implications for how we manage water. Climate modeling projects an increase in precipitation in Northern California and a decrease in precipitation in the dry southern part of the state. Overall, annual precipitation is expected to occur over a shorter time span, with increased likelihood of extreme rain events (Swain 2018). Warmer temperatures have, and will continue to, magnify impacts of normally occurring droughts (Grow 2015). California's water management strategies will have to adapt to our changing climate in order to reduce flooding, provide reliable water supply and restore ecosystem functionality.

1.1 Projected Climate Change Impacts

Flood Risk

California has a history of massive flooding. A week of continuous rain in November 1861 started what would turn out to be the most significant flood in the history of the state. By early 1862, as the wet season hit its peak, much of California's Central Valley was under as much as 15 feet of water. On January 22, 1862 a levee near B Street and 28th Street in Sacramento was breached by flood waters that quickly overtook the city. To avoid future catastrophe, California made it a priority to invest in local and statewide flood control systems (Kelley 1998).

Over the 20th century, California built levees, bypasses, sea walls, stormwater systems and dams to control flooding, and more recently turned to restoring natural features such as wetlands and floodplains to help absorb flood waters. Despite these investments, floods still pose a significant risk in California. The last major flood in 2017 caused an estimated \$1.5 billion in damage and killed five people (Rice et al. 2017). Unfortunately, the 2017 flood and even the 1862 flood are much smaller than the largest floods seen in California's paleontological record (Ingram and Malamud-Roam 2013). Climate change further complicates California's flood risk; even paleontological estimates may be conservative for California's risk of future flooding. Extreme precipitation events are expected to increase under climate change (Huang et al. 2020). Flood managers in California are preparing plans that will incorporate this increased risk, though more can be done statewide (California Department of Water Resources [DWR] 2017).

Climate change will require cities to create new stormwater solutions, coastal areas to deal with new flooding from sea level rise and increased storm surges, and flood managers to offer greater protection to the one in five Californians who live in areas at risk from flooding (Mount 2017). Developing solutions that provide multiple benefits offering flood protection, water supply reliability and ecological resilience will require California to align investments in data and information, infrastructure and regulations.

While many solutions have been explored and planned, resources for flood control have not increased commensurate with increased risk. The unfortunate reality is that climate change will require California to invest more resources to receive the same flood protection outcomes California receives today. Delaying investments will compound risk and future damages. By taking action today, we can both decrease existing risk of flooding and begin to pay down on our long-term adaptation needs for future resilience.

Timing and Availability of Water Supply

The Sacramento-San Joaquin Delta (Delta) is the hub of California's water supply network. The Delta is fed by the Sacramento and San Joaquin Rivers and flows out to the San Francisco Bay. It is the largest estuary on the West Coast of the continental United States. The Delta is crucial to the vitality of California's people, economy and environment. The Delta is the entry point for salmon to return from the sea to spawn in the cool rivers of the Sierra Nevada and is home to a variety of unique plant and fish species. Large metropolitan areas (San Francisco Bay Area, Los Angeles and San Diego) and agricultural regions (San Joaquin Valley) rely on the Delta as a water conveyance network. It also supports power transmission, car and rail transportation, recreation, urban land use and much more (Lund 2007).

Shifting precipitation patterns caused by climate change and increased salinity will alter water management by limiting the time when water quality will allow exports. Peak flows will happen earlier in the spring due to timing of snowmelt. Dam releases upstream control the peak flow in the Delta, and reservoir releases are timed to meet downstream demand, control flooding and provide environmental flows. If downstream demand shifts (e.g., if farmers start growing crops earlier), then peak flows in the Delta would shift and may not coincide with environmental needs. Increased temperatures could also increase demand for water exports (Wang 2011). Increasing air temperatures will also reduce water exports from the Delta. By mid-century, a two-degree Celsius increase in temperature would reduce exports by 350,000 to 500,000 acre-feet (AF) of water, as provided in a pre-publication copy of *Delta Adapts* by the Delta Stewardship Council.

Water deliveries to the Bay Area, Los Angeles, San Diego and San Joaquin Valley will be impacted by salinity. To maintain water quality for urban and agricultural uses, Delta exports are halted when water reaches a certain salinity level. As sea level rises, reservoir operators will need to release more water upstream to allow water supply deliveries to continue. A 60-centimeter (about 24-inch) increase in sea levels will result in a 40 percent chance that one or more reservoirs would reach “dead storage” level (i.e., not provide any use) by the end of the century (Wang 2011). This would cause water shortages in many metropolitan areas, reduce agricultural production and negatively impact the environment.

In addition to the Delta, significant water supplies for California come from the Colorado River and resources developed by local water districts. Climate change will also stress the Colorado River system by shifting snowmelt to earlier in the year, causing more frequent and intense droughts and reducing water deliveries because of increased evaporation from warmer air temperatures (Clow 2010; Udall & Overpeck 2017). Climate change will reduce surface water deliveries across the state and water managers must adapt and plan for that future reality.

Stresses on Ecosystems

Climate change poses a significant threat to California’s embattled ecosystems. Hundreds of threatened and endangered plant and animal species live across the state (California Department of Fish and Wildlife [CDFW] 2020a; CDFW 2020b), and efforts to manage habitats to help them recover and to improve overall environmental quality require vast amounts of water.

Californians have consistently supported environmental policies that require improving the state’s ecosystem as investments are made into its flood control and water supply system, and these priorities are unlikely to change anytime soon. A poll conducted in

the summer of 2020, during the heart of an economic downturn, asked the state's residents which statement they agree with: stricter environmental laws and regulations in California cost too many jobs and hurt the economy, or stricter environmental laws and regulations in California are worth the cost. The poll showed that 61 percent of Californians agreed with the statement that environmental laws are worth the cost (Baldassare et al. 2020). Based on this response, most Californians want policymakers to make progress on environmental issues affecting the water system.

Unfortunately, rising temperatures and other climate change impacts will harm species and complicate ongoing restoration. In the Delta, climate change will increase temperature, shift flow regimes, change the tidal prisms and affect water quality, further stressing the system (Delta Stewardship Council 2018). Statewide critical aquatic species like Pacific salmon and steelhead are threatened by climate change (Crozier et al. 2019). Reports on the threats to the many bird species that California supports are similarly concerning (Audubon n.d.). To mitigate the stress on California's ecosystems from climate change, California's water supply and flood control managers must continue to look for multi-benefit solutions and invest in green infrastructure (e.g., wetland and floodplain restoration, rainwater capture and horizontal levees) where feasible. Furthermore, new permitting frameworks may be needed to allow projects flexibility to adapt to new conditions, as climate change gives environmental managers moving targets for restoration. Savvy climate adaptation can support the needs of California's water system while furthering California's desire for strong environmental programs.

1.2 Uneven Distribution of Impacts

California's history, though filled with optimism and triumph, is also mired with discriminatory practices that have directly impacted access to and quality of drinking water for disadvantaged communities in California. Today, approximately one million Californians do not have access to safe drinking water (Cowan 2019). This inequity has the potential to be exacerbated by climate change (CNRA et al. 2020).

When climate change increases water salinity, for example, small drinking water systems serving disadvantaged rural communities may not have the capacity to implement groundwater treatment for their systems. Similarly, climate change will likely have a detrimental impact on surface water quality. For instance, changes to water temperature caused by climate change will impact oxygen levels in surface water reservoirs, and changes to industrial wastewater and agricultural runoff will directly impact surface water bodies (CNRA et al. 2020). These impacts to surface water bodies may require more robust treatment systems. With the expected costs to treat surface water systems only growing more expensive, even larger water systems may not have the capacity to keep up with surface water treatment techniques needed to deliver safe drinking water

to residents. Any major changes to groundwater and surface water will invariably impact drinking water systems and disproportionately burden small, disadvantaged communities.

1.3 A Principled Approach to Adaptation

Adapting to climate change will be a task that challenges generations of Californians. This report proposes a series of practical policy options to begin the process of adaptation in California to ensure that the water supply, flood protection and environmental quality that Californians desire are being provided even as the climate changes. This report highlights three major areas of focus for adapting California's water management to climate change. First, California's aging water **infrastructure** needs new investments to improve its performance under new hydrologic regimes. Second, **regulations** need to be updated to consider climate change and to offer new frameworks encouraging adaptive management. Third, California needs to invest in improved **data and technology** to reduce uncertainty and inform investment decisions and management practices.

While each of these areas of adaptation will be necessary for improving the water system's ability to meet the needs of Californians, the recommendations in this report are only a small representation of what will be required to adapt to climate change. Therefore, in addition to a series of practical policy recommendations, this report offers a list of principles that inform the adaptation actions: equity, partnerships and collaboration, innovation through scientific understanding and multi-benefit approaches.



2 Guiding Principles

The guiding principles below reflect an overarching vision for improving and adapting California’s water management to a changing climate. Actions must promote equity, partnerships and collaboration, innovation through scientific understanding and multi-benefit approaches. The combination of these principles allows for a broad and comprehensive vantage of the challenges facing water management. These principles create a common foundation for the policy recommendations presented in this report.

2.1 Equity



Ensure water management solutions are prioritized and implemented in an equitable manner.

Policymakers and water managers must understand the social and environmental implications of water legislation, regulations and management decisions. In many communities throughout California, environmental hazards are closely tied to decades of racial and economic injustices. Low-income communities of color are disproportionately affected by the impacts of climate change (Office of Environmental Health Hazard Assessment 2010). Progress has been made through Assembly Bill 685 (2012) and Senate Bill 200 (2018) to enforce and fund the human right to safe and affordable drinking water and to encourage equality for those lacking access to clean drinking water. However, much work remains to be done to achieve equal access to water and sanitation for all Californians. Any efforts to adapt to climate change must be

implemented in an equitable manner by engaging and empowering vulnerable communities rather than furthering environmental injustices.

2.2 Partnerships and Collaboration



Promote partnerships and collaboration among diverse stakeholders to implement innovative, sustainable and transparent solutions.

Given the complex and interconnected challenges facing the water management community, partnerships are essential to achieve sustainable and financially feasible solutions. When multiple stakeholders with different goals work together—such as local and state agencies, businesses and institutions, community organizations and environmental groups—greater benefits may be achieved. One major benefit of partnerships is the ability to match projects with alternative funding sources. Funding can be one of the largest hurdles when implementing projects and making decisions as insufficient funds can limit decision-making power and inhibit project implementation. Bringing together the correct group of stakeholders for funding and implementation can help achieve success. In addition, multi-stakeholder collaboration helps ensure that all voices are heard and that solutions are equitable.

Transboundary cooperation, such as between watersheds and adjacent aquifers or within watersheds that cross county or state lines, is also necessary for effective water management. Achieving cooperation among all or most stakeholders can help reduce conflicts and enable greater climate resilience for California’s water systems.

2.3 Innovation Through Scientific Understanding



Promote use of the most current and widely accepted scientific approaches and models to guide water management decisions.

Scientific understanding must form the basis for water management strategies to adapt to a changing climate. Additionally, addressing new challenges requires new ways of thinking. Leveraging the best available science to inform innovative approaches will enable water managers to adapt to changing conditions.

Building on the themes of equity and partnerships and collaboration, stakeholders need to be engaged in a feedback loop: data must be made available for models to be created, allowing for decisions to be made. Data has the power to help a large population of water managers and stakeholders. The water management community can come together to benefit from a deeper understanding of the environmental

changes occurring and use best available science and data to navigate the challenges effectively and efficiently.

2.4 Multi-benefit Approaches



Promote solutions that offer social, economic and environmental benefits and engage multiple stakeholders.

California's water management history is marked by stiff competition among water users and projects that benefit select user groups. There is growing recognition that water management solutions can and must provide multiple benefits, improving outcomes in multiple facets of a connected water system. For example, projects to expand floodplains can provide flood control, groundwater recharge and habitat benefits. Where possible, projects should be designed to achieve multiple benefits for our environment, business and communities.



Photo Credit: US Bureau of Reclamation.

3 Infrastructure

Policy Recommendation: Develop and maintain an integrated system of infrastructure to promote resilience, sustainability and operational flexibility.

3.1 Background

The increasing intensity of major storm events coupled with aging and deteriorating infrastructure in California will likely exacerbate flooding and damage to existing infrastructure. Levees, bypasses and floodplains that constitute the majority of California's flood control system are in desperate need of modernization and repair. Storage and conveyance systems (shown in Figure 1) need to be updated and integrated and regional coordination must become a mainstay of operations. Sustainability is paramount when considering updated infrastructure to ensure longevity of the system, with a focus on using data to drive identification, scope and scale of these projects. The study and coordination of groundwater and surface water reliance on existing systems will be critical in developing a diversified water source as well as a recharge and flood control benefit. We must build smarter systems while repairing existing infrastructure, focusing on conveyance, conservation and supply in order to adapt to climate change.

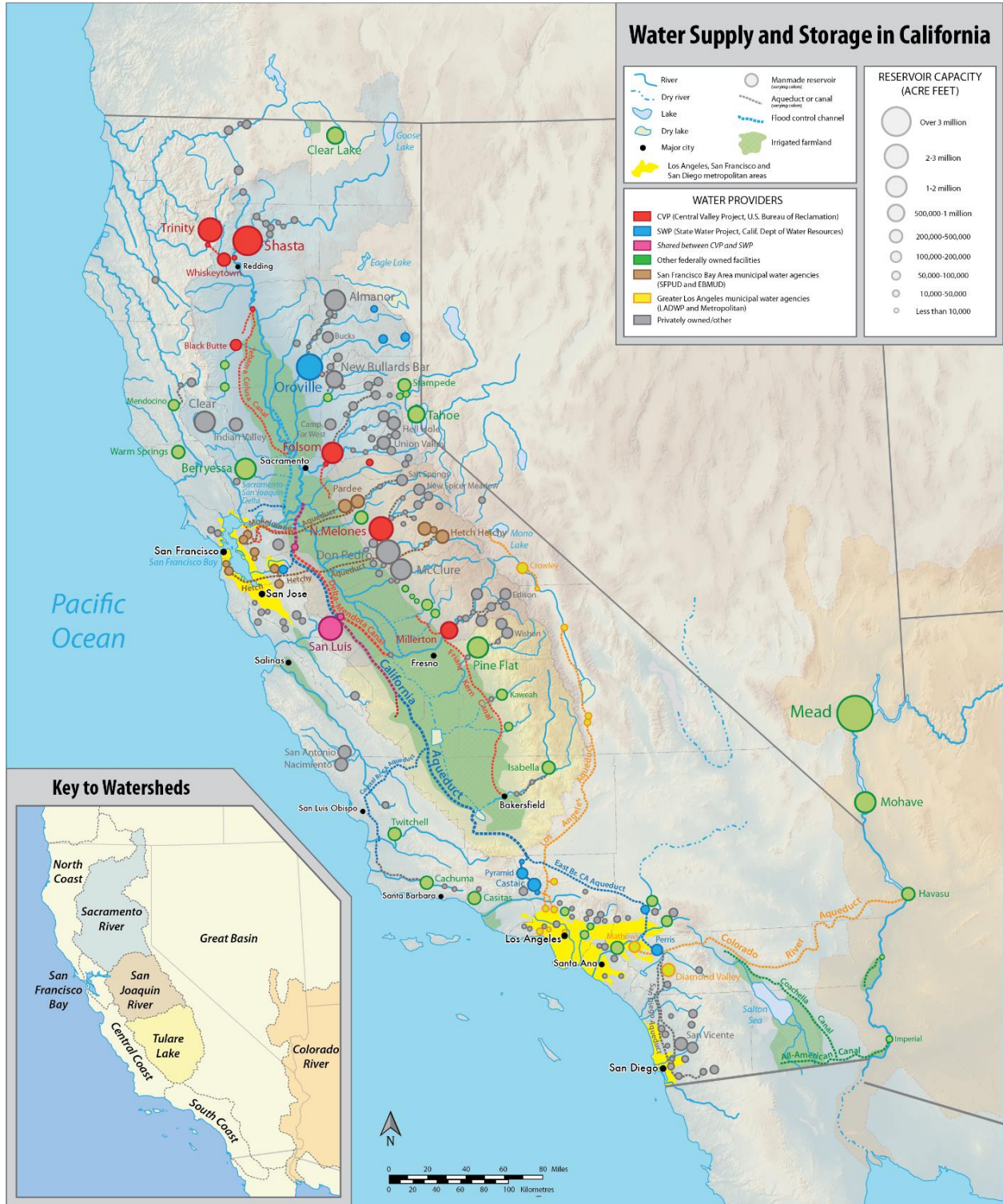


Figure 1: Map of major water storage and conveyance infrastructure in California. Source: Wikipedia.

3.2 Recommended Actions

Action 1: Diversify local and regional water supply portfolios.

Reduce dependence on imported supplies by investing in economically and environmentally sustainable alternative water supplies and demand management measures to increase resilience.

Many water systems across the state rely on surface reservoirs to store upper watershed runoff and hundreds of miles of conveyance infrastructure to deliver that water to where it is needed. However, with climate change, these traditional sources have become increasingly unreliable, leading to water shortages in significant portions of the state during periods of extreme drought (Sedlak 2015). Regional resilience can be enhanced through alternative water supply solutions, including potable and non-potable water reuse, stormwater capture, seawater and brackish water desalination, water transfers and water conservation and efficiency measures. The benefits and costs of these options differ significantly, from financial costs to energy intensity and other co-benefits. For example, the levelized cost of water from these sources ranges from up to \$3.50 per cubic meter (desalination) to cost *savings* up to \$4 per cubic meter (efficiency) (Pacific Institute 2018). There are also different energy implications of alternative water supply options, ranging from energy savings (hot water conservation) to high energy intensity (seawater desalination). Many of these considerations are site-specific and vary by agency, depending on local conditions and accessible resources (California Urban Water Agencies 2017).

There are examples of water agencies committing to diversifying their water portfolios across the state, such as the East Bay Municipal Utility District's (EBMUD) goal of augmenting their water supply portfolio by 50 million gallons per day with conservation and recycling by 2040 (EBMUD 2012). While some local agencies have sufficient funding to diversify their water portfolios, funding remains a significant barrier to most water agencies. For example, the City of Antioch's Brackish Water Desalination Project has taken decades to build up financial resources and ratepayer approval for the project.

Providing incentives to diversify water portfolios will enable water agencies to invest more in alternative water supplies. For example, energy credits to offset the pumping that will be necessary to artificially recharge and extract groundwater will enable more conjunctive use of groundwater and surface water supplies. Incentives can also be in the form of local ordinances. The City and County of San Francisco adopted an ordinance (San Francisco Public Utilities Commission [SFPUC] 2016) that established a threshold whereby projects were required to install and operate an onsite non-potable water system to treat and reuse available graywater, rainwater and foundation drainage for

irrigation and toilet and urinal flushing. Public concerns regarding the safety of non-potable water systems have been raised in multiple communities. For example, non-potable supply projects in Redwood City and San Diego have faced significant public opposition before being built. This barrier can be overcome by focused community outreach and by designing projects that provide the public with alternatives (Sedlak 2015).

Action 2: Incentivize urban stormwater recharge projects.

Provide resources to new and existing stormwater projects to green communities, manage urban floods and increase local water supply.

Urban stormwater capture programs are an important approach for increasing decentralized groundwater recharge, enhancing stormwater quality and diminishing localized flooding during large rainfall events. Public-private partnerships (P3) will be critical for effectively incentivizing and advancing urban stormwater management. Rainwater harvesting programs can provide incentives and promote stormwater capture, which helps to reduce peak season pumping demand on aquifers, reduces stormwater runoff and provides an alternative water supply source that in turn improves stormwater quality and reduces erosion. One study estimated that stormwater capture has the potential to increase water supplies in urbanized San Francisco Bay Area and Southern California by 420,000 to 630,000 AF per year (Pacific Institute & Natural Resources Defense Council 2014). Another study estimated that implementation of local stormwater capture projects in the Los Angeles Basin could alone provide approximately 31,000 AF of additional water supplies per year (Bureau of Reclamation [Reclamation] 2016).

Examples of these existing stormwater capture programs are numerous, with the SFPUC Rainwater Harvesting Rebate program being the most prominent in Northern California. Examples of severe urban flooding due to overdevelopment without adequate stormwater collection are clear from case studies of Houston's experience during Hurricane Harvey in 2017. One of the top recommendations put forth by the American Society of Civil Engineers (ASCE) Texas Section following the disaster was to "[e]mploy alternative flood mitigation strategies" consisting of permeation and localized collection of stormwater or stormwater runoff (ASCE Texas Section 2018). The Texas Commission on Environmental Quality stated in court documents that, "permeable surface loss will contribute to flooding problems," referring to development in floodplain regions of Houston. The local county (Harris) has since taken steps to implement new development requirements of stormwater retention and detention (Satija et al. 2017). It is imperative that urban centers, prone to flood risk, increasingly implement stormwater recharge

programs funded through incentivizing collection, reuse and recharge while ensuring that overdevelopment does not occur.

Action 3: Develop regional infrastructure networks capable of operating as an integrated system.

Provide spatial and temporal flexibility in managing our water supplies to reliably meet the needs of diverse water users and increase resilience to climate change.

Local regions across California will need sustainable, flexible water conveyance and storage options to adapt to climate change impacts on water supply reliability. One critical component of this is updating and expanding regional infrastructure that can be integrated with statewide projects like the Central Valley Project (CVP) or the State Water Project (SWP). Off-stream reservoirs can help bridge the gap between wet and dry periods and provide flexibility in managing our water supplies while minimizing the environmental consequences associated with on-stream reservoirs. The proposed Sites Reservoir north of Sacramento and the expansion of Los Vaqueros Reservoir in Contra Costa County are good examples of infrastructure projects that can provide both regional and inter-watershed solutions as well as reliable water supplies for agricultural, urban and environmental partners. Both are off-stream reservoirs that can be co-managed for providing water to meet human and agricultural needs while securing reliable water supplies for wetlands to create wildlife and waterfowl habitat.

New water storage options must go beyond traditional surface water reservoirs to include more innovative options such as groundwater banks. Investing in conjunctive use opportunities can help supplement existing large-scale infrastructure by offsetting and complementing surface water supplies with groundwater and creating flexibility in the system. Some prominent examples include conjunctive use projects proposed under the Water Storage Investment Program like the Chino Basin and Willow Spring water banks in Southern California and the Sacramento Regional Water Bank in Northern California (California Water Commission 2020; Regional Water Authority 2019).

Action 4: Restore and build conveyance capacity.

Develop a more robust and integrated water system to help prepare for more extreme precipitation patterns.

Water conveyance and flood protection structures are important links to a diversified, flexible system that is resilient in the face of changing precipitation patterns and more extreme events. Much of California's water conveyance infrastructure is aging and in need of repair. In some cases, conveyance infrastructure has been damaged by land subsidence due to groundwater overdraft. For example, according to the Friant Water Authority (FWA), the conveyance capacity on the Friant-Kern Canal in the San Joaquin

Valley is forecasted to drop to 30 percent of its original design, from 4,000 cubic feet per second to 1,200 cubic feet per second (FWA 2019). Restoring and increasing California's water conveyance capacity allows water to be moved to areas of need more readily, improving adaptation capacity to extreme events like floods and droughts. Restoring conveyance must happen in tandem with addressing the root causes of conveyance loss (e.g., groundwater overdraft) for long-term improvements.

Interties help develop local regional networks, maximize benefits from surface water and groundwater storage investments and provide spatial flexibility in managing water supplies, especially during emergencies. Some examples of intertie operations include the network of existing and proposed interties under the Bay Area Regional Reliability (BARR) project, the Delta Mendota Canal/California Aqueduct intertie and the proposed Delta Conveyance Project. BARR is aimed at increasing water supply reliability and resilience in the Bay Area, while the Delta Mendota Canal/California Aqueduct intertie and the proposed Delta Conveyance Project focus on ensuring reliable inter-basin conveyance. Because funding requirements will be significant, project beneficiaries must be considered a critical partner in cost-sharing.

Action 5: Invest in projects that create, reconnect and expand floodplains and wetlands.

Collaboratively increase beneficial habitat and develop additional groundwater recharge opportunities, in addition to accounting for flood risk severity.

Two promising multi-benefit approaches to increasing California's water resilience are restoring wetlands and creating more groundwater recharge opportunities through managed aquifer recharge using floodwater.

Wetlands are natural relief valves in the system during flood events. They help manage flood risk during wet periods, capturing and replenishing groundwater basins with floodwaters that can then be used during droughts. Where opportunities for restoring natural wetlands are limited, rural and agricultural landscapes can be temporarily converted into seasonal floodplains. For example, flooding rice fields in the winter is a multi-benefit project because it creates habitat for birds and food for fish, recharges the groundwater system, decomposes rice for future agricultural use and can mitigate flood risk. Federal and state programs have created 350,000 acres of winter-flooded rice fields in California. These flooded rice fields also provide critical temporary waterfowl habitat in addition to the 200,000 acres of managed wetlands in the Central Valley. Pilot projects like the California Rice Commission Salmon Pilot Project further expand the multi-benefits from flooding post-harvest rice fields to grow fish food, benefitting the struggling salmon populations in the Sacramento Valley (Northern California Water Association 2020).

Flood-Managed Aquifer Recharge (Flood-MAR) involves harnessing flood water from rainfall or snowmelt and redirecting it onto agricultural landscapes and managed natural lands to recharge the underlying aquifers. This is a multi-benefit solution that can simultaneously address flood management, water management and sustainability issues. For example, as discussed above in Action 4, land subsidence contributes to major losses of conveyance capacity for both supply deliveries and flood protection. Certain regions, such as Red Top in Madera and Merced Counties, have had success in controlling subsidence by implementing Flood-MAR (Water Education Foundation 2017).

Although a novel concept and a promising solution, there are uncertainties surrounding the operational and regulatory viability of Flood-MAR. These include differences in flow rates between flood releases and percolation of recharged water, availability of conveyance and agricultural lands to spread floodwaters, ownership of the stored water, loss of crop productivity, environmental consequences of diverting excess instream flows and possible effects on groundwater quality, particularly in small community systems. DWR is currently conducting a study in the Merced River watershed, in collaboration with the Merced Irrigation District, to address some of the operational concerns surrounding the implementation of Flood-MAR projects (DWR 2020). Terranova Ranch in the Kings River Basin is another prominent example, a 1,000-acre pilot study for assessing the feasibility and effects of Flood-MAR on agricultural landscapes (Bachand et al. 2016).



Photo Credit: Barb Canalē, Unsplash.

4 Regulations

Policy Recommendation: Update regulations and statutes to allow California's water systems to be flexibly managed concurrent with changing conditions.

4.1 Background

California has a complex overlay of statutes, regulations and policies from governments at the federal, state and local level. The structure of water oversight within the state provides for environmental review and stakeholder input through public commentary. Given the impacts of a changing climate, policymakers and water managers will need to adapt and implement new strategies that may not be easily achieved under the existing regulatory framework. By building adaptation strategies into its statutory and regulatory structures, California will be able to respond to and plan for the shifting patterns in water supply and environmental flows.

4.2 Recommended Actions

Action 1: Identify opportunities to align permitting requirements and enable more flexibility.

Perform a comprehensive review of existing permitting requirements to identify opportunities to align elements, avoid overlapping requirements and enable more regulatory flexibility for permit applicants in a changing climate.

Environmental permits serve a critical role in the California regulatory structure. They protect public health, environmental quality, cultural resources, property and more. As currently conceptualized, permits attempt to provide certainty about the level of protection afforded to the environment. For example, they may provide a bright-line for the amount of water in a stream or the amount of habitat that must be restored. The underlying assumption of this permitting structure is that the value of the actions required by the permit are well understood. Often, assumptions are made about the continued efficacy of an action over the course of decades. Climate change complicates this assumption because it is well known that climate change will alter ecosystem functions, social priorities and natural processes.

The approach to permitting by state, local and federal regulators in California prioritizes certainty about the level of environmental protection by making project designs take into account increased temperature, sea level rise or other changes resulting from climate change. This approach will not be successful given the deep uncertainty presented by climate change. How much climate change will occur and how it will express itself in California's water system are still topics of major scientific and political debate that are unlikely to be resolved soon. The best available science on climate change continually evolves. For permitting agencies, chasing certainty under these conditions may feel like raking leaves in the wind. For regulated entities that already believe permitting is slow and cumbersome, the increased burdens of navigating these uncertainties can be frustrating.

This presents a serious problem for the California water system moving forward. Climate change adaptation will require the California water sector to be nimble. Delays and redundant or overlapping requirements that create inefficiencies will have consequences on our ability to adapt. A comprehensive review of existing permitting processes is recommended to identify opportunities where permit requirements can better align among and within local, state and federal agencies—to advance permitting processes that allow for quicker project implementation and operations, in a manner with similar or greater protections in place.

There is a critical need for consistent tools and frameworks across permitting agencies to allow for greater clarity from project proponents. Three frameworks to consider are adaptive management, performance-based permitting and protocol-based permitting. An adaptive management-based permit would require the project to be run using a formal scientific process to ensure the project targets are being met. A performance-based permit would approve projects that achieve certain standards, regardless of the mechanism by which those standards are achieved. Finally, permitting agencies must consider developing ministerial permits based on protocols established using the best available science for critical actions such as ecosystem restoration that are necessary to

implement to provide long-term resilience. Table 1 offers some additional description of the frameworks with associated advantages, disadvantages and considerations.

Table 1: Potential water project permitting frameworks.

Framework	Advantages	Disadvantages	Considerations
<p>Adaptive Management-Based Permitting.</p> <p>The permitting agency issues permits more readily while enforcing adaptive management plans as needed.</p>	<ul style="list-style-type: none"> • Long-term project commitment. • Science based, experimental management. • Permit based on hypothesis, allowing new flexible management actions. 	<ul style="list-style-type: none"> • Requires monitoring. • Requires ongoing funding, no “set it and forget it” projects. • Requires ongoing engagement from regulator to track implementation of adaptive management plans. 	<ul style="list-style-type: none"> • How long should a plan be on the hook for monitoring and adaptive management? • Bond funding requirements have made implementing adaptive management plans difficult in the past.
<p>Performance-Based Permitting.</p> <p>A permit framework where a target for performance is defined by the permitting agency, agnostic about how it is achieved.</p>	<ul style="list-style-type: none"> • Proponents can focus on meeting the desired project outcome. • The method of achieving the outcome, while not permitted, must still be demonstrated. 	<ul style="list-style-type: none"> • Regulators have less control over the mechanisms and, in some cases, this could have consequences. • Requires ongoing monitoring until targets are achieved. 	<ul style="list-style-type: none"> • Proving achievement of an outcome is complicated in complex ecological systems.
<p>Protocol-Based Permitting.</p> <p>A permit where an action’s value is determined upfront based on a model project that is studied, allowing future actions to be taken without discretion from the permitting agency.</p>	<ul style="list-style-type: none"> • Can provide framework for easy permitting of common project types. • In some instances, these projects may be California Environmental Quality Act (CEQA) exempt if permits are ministerial. 	<ul style="list-style-type: none"> • Requires a lot of upfront science. • Will not be helpful for unique projects. 	<ul style="list-style-type: none"> • These protocols may need to evolve as climate science improves.

The state of California can serve as a model of cooperation by improving inter-agency coordination and streamlining permitting processes to make multi-partner, multi-benefit projects easier to plan and complete. Evaluating the permitting system in California to ensure that it can support adaptation and the development of resilience is a necessary step to help achieve California’s goals for our environment and water.

Action 2: Update local land use rules.

Develop land use designations and controls that align with water supply and flood management goals.

Planning and other land use decisions have traditionally been made in California at the local level by political subdivisions, such as cities and counties, under the authority provided by state statute (per California Government Code, Section 65000). While there is statewide engagement through the Sustainable Groundwater Management Act (SGMA) and the CEQA process, there is a pressing need for more regional coordination and state assistance to help plan ahead for the impacts of climate change to water supply and flooding.

Local governments and the state must adopt new standards that develop comprehensive mapping to 500-year floodplains and apply controls to residential and commercial developments away from such areas. The increased frequency of rainfall and intermittent flooding due to climate change will dramatically increase the threat of flooding beyond existing projected floodplain models (Dettinger 2011). Those controls could include limitations on all development or special requirements such as raising ground levels or creating local assessment districts to address flood risk through infrastructure improvements. Taking steps to designate more low-lying areas as floodplains, flood zones, bypasses and overflow zones can mitigate the potential impacts of catastrophic flooding and work towards lessening the impact of catastrophic droughts through groundwater recharge. These areas or designations would prevent development for any residential, commercial or industrial purpose and focus instead on seasonal agriculture or environmental use (DWR 2020). This has the additional benefit of providing water that can go toward replenishing overdrafted groundwater basins identified in the SGMA process.

Other requirements for land use designations could include identifying a maximum water-per-square-foot allotment or surcharge per acre for development on a particular parcel as part of the state's environmental review process. Setting a more stringent minimum standard for water—based on a particular land use designation—would encourage local governments and developers to adequately plan for long-term water needs and would discourage exemptions for land use designations before local planning commissions.

The state's appropriate agencies, such as the Governor's Office of Planning and Research and the California Department of Housing and Community Development, must provide guidance to local governments on how to transition land use designations from residential, commercial, irrigated agricultural or industrial to those that are climate resilient, such as dryland farming, habitat restoration and green energy zones.

Since local sources of funding are tied to development in the form of sales, use and property taxes, it is appropriate to use backfill state funding for areas identified for limited development due to climate needs. Appropriate state funding sources could include the state General Fund, Greenhouse Gas Reduction Fund or appropriate state bond funding.

Action 3: Support local agencies with fiscal resources for climate adaptation planning.

Require and provide funding for local agencies to develop climate risk assessments and adaptation plans that include stakeholder engagement.

The California Governor's Office of Emergency Services (CalOES) has developed a guide to support local governments and others in planning for climate adaptation, and other agencies such as DWR have developed their own vulnerability assessments of climate change to the State Water Project (CalOES 2020; DWR n.d.). These guides and overviews are supplementary to local development standards.

In order to address climate needs, the state must require local agencies to incorporate climate risk assessments and adaptation plans within local land use and water supply planning processes. These could include:

- Implementing holistic sustainable groundwater basin management plans, with requirements for engagement across local government political designations;
- Identifying water supply, storage, treatment and distribution system improvements to strengthen reliability and resilience;
- Requiring parcels at greater risk of fire, flood, erosion or other hazards to meet higher building standards for development, or;
- Creating state requirements for local governments to increase building densities in climate-safe parcels of land and reduce or eliminate development of parcels at high risk of damage from climate change.

Allocation of most state General Fund and federal fiscal resources have been predicated on per capita spending (Murphy & Danielson 2018). Such distributions ensure even funding regardless of political division, such as city, regional, special district or county governments. However, such allocations do not encourage local governments to take proactive policy steps with funding predicated on policy adoption.

In order to encourage local governments to develop climate adaptations, one model may incorporate matching funds from the state or federal government for local governments taking proactive measures. Such a model can be found with California's

Senate Bill 1 transportation tax funding, which provides matching Special Fund resources to communities that have placed their own tax or local surcharge to meet infrastructure demands (California Transportation Commission 2020). Additional funding resources may come from a state climate adaptation bond or from the Greenhouse Gas Reduction Fund, either as a grant resources or through a matching fund program.

Action 4: Exempt water agencies from Proposition 218.

Amend the California Constitution to remove the Proposition 218 restrictions that limit a water utility's options for promoting equity and adapting to climate change.

In 1978, California voters passed Proposition 13, which placed limitations on property taxes based on assessed property value. This caused local governments to have to find alternate revenue sources, such as benefit-based assessments, special taxes and user fees. Voters responded by passing Proposition 218, the Right to Vote on Taxes Act, in November 1996. Some of the features of Proposition 218 include voter approval on taxes, limits on use of general taxes, stricter rules on benefits assessments, restrictions on use of fees and others.

Many of Proposition 218's features have improved transparency and public accountability. However, they also impose restrictive cost recovery requirements (Hanak et al. 2018). Proposed fee increases must undergo public approval, including a protest vote if there is enough opposition (Pitzer 2012). Given the public's general resistance to higher taxes and the reluctance of elected officials to vote for a rate hike, increasing water rates can be difficult. In 2014, it was estimated that between \$2 billion and \$3 billion would be needed annually to fill gaps in funding for the following: safe drinking water for small disadvantaged/rural communities, flood protection, stormwater management, freshwater ecosystem management and integrated management (Hanak et al. 2018).

Water infrastructure has historically been underfunded; aging infrastructure poses significant risks that will worsen with time. If water utilities' financial gaps are not addressed, their ability to provide safe, reliable water service may be compromised. Additionally, the cost of treating and delivering drinking water is exacerbated by climate change, due to changes in precipitation patterns, long-lasting droughts and increased fires in key watersheds. If rate increases are consistently voted down, water utilities will struggle to maintain their systems and comply with safe drinking water standards.

Under Proposition 218, water rates must be tied to the cost of service, which limits utilities in their ability to offer lifeline rates or charge higher prices during drought to encourage conservation. Section 106.3 of the California Water Code states that "every human being has the right to safe, clean, affordable, and accessible water adequate for

human consumption, cooking, and sanitary purposes.” However, California’s water systems require extensive resources to operate, and revenue is lost if water cannot be turned off when a customer cannot pay. Proposition 218 makes it difficult to recoup lost revenue from other customers, and ratepayer funds cannot be used for rate assistance programs to support low-income customers. The spread of COVID-19, which prompted a global pandemic in 2020, has further exacerbated affordability concerns while simultaneously impacting utility revenue from water sales in many communities.

Water agencies must provide support and a reason for rate increases or they risk facing legal liability. For example, the City of San Juan Capistrano was sued for failing to adequately relate its four-tiered conservation cost structure with the cost of serving each tier (*Capistrano Taxpayers Association v. City of San Juan Capistrano*). This limited the city’s ability to incentivize conservation, an important measure for ensuring water supply reliability during drought and other emergencies (East Valley Water District n.d.).

In summary, water infrastructure is underfunded, and Proposition 218 limits water agencies’ ability to increase rates to fill existing funding gaps, provide lifeline rates to disadvantaged customers and adjust rates to compensate for droughts. Proposition 218 also indirectly restrains innovation and new technology, as there is inadequate funding for research and development. Exempting water utilities from Proposition 218 would provide local water districts with a tool to locally fund sustainable water projects, encourage conservation and support equity in their communities.

Action 5: Make groundwater recharge a beneficial use.

Expand the definition of beneficial use to include groundwater recharge projects promoting groundwater basin sustainability.

Many groundwater basins in California are overdrafted. Adopted in 2014, SGMA addresses this problem by requiring local water users to bring groundwater use to sustainable levels by the 2040s (Jezdimirovic et al. 2019). SGMA has spurred widespread interest in expanding recharge to replenish groundwater basins (State Water Resources Control Board [State Water Board] 2019). However, state law presents a hurdle for water rights holders interested in groundwater recharge projects.

California law allows the diversion of water for recharge or storage when the water will be used for a designated beneficial end use, but the law does not recognize leaving recharged groundwater in an aquifer—or “non-extractive uses”—as a beneficial use (California Water Code Section 1242). In the water rights context, beneficial use refers to a useful purpose to which water is applied (State Water Board 2020). Currently, there is a wide variety of well-established beneficial water uses (e.g., for domestic use or irrigation); however, the relationship between beneficial use and groundwater recharge

is often unclear, hindering implementation of recharge projects that could provide substantial benefits in groundwater basins throughout the state (Berkeley Law 2018).

Groundwater management is a complex issue involving diverse watersheds and stakeholders, and whether groundwater recharge qualifies or should qualify as a beneficial use has been discussed and debated at great length. With increasing pressure on our state's water resources from climate change and societal shifts, there is an urgent need to revisit this conversation as an opportunity to improve water management and climate adaptation.

In California, most non-extractive uses are not explicitly listed as beneficial uses in statutes or regulations; instead, the State Water Resources Control Board (State Water Board) determines, on a case-by-case basis, whether a non-extractive use amounts to a beneficial use of surface water (Berkeley Law 2018). The lack of regulatory clarity can discourage potential applicants interested in applying for a surface water right or water right change for non-extractive use from considering important groundwater recharge projects (Berkeley Law 2018). Broadening the definition of beneficial use to include groundwater recharge projects would remove the uncertainty and confusion surrounding this legal issue.

Categorizing groundwater recharge as a beneficial use would help to prevent land subsidence, seawater intrusion, degraded water quality and other "undesirable results" defined by SGMA (California Water Code Section 10721[x][1]-[6]). Recharge projects provide broad basin benefits and promote groundwater basin sustainability. Beneficial use has traditionally referred to water extraction, but the current interpretation of beneficial use fails to create space in water law for flexibility and adaptation as we move closer to reaching our sustainability goals. Clarifying guidance from the State Water Board and/or new legislation may be necessary to broaden the definition of "beneficial use" to fully realize the benefits of groundwater recharge.



Photo Credit: DWR.

5 Data and Technology

Policy Recommendation: Improve the collection, sharing and use of data, compatible with appropriate technology, to address flooding, water supply and ecosystem management.

5.1 Background

Information is the foundation of water management in California. This information starts as data, which is collected, stored and used by a mosaic of public, private and non-profit entities. Data is then used to inform models and decision-making tools on how to manage the state's water resources. In the face of climate change, it is important that relevant information is accessible, transparent and reliable.

New technologies and modeling tools have improved the ability of California's water managers to adapt real-time water operations, as well as plan for future climate scenarios and hydrologic conditions. Recent legislation has helped fill data gaps and streamline how data is collected and accessed. For example, SGMA fills data gaps in groundwater supply and quality through mandatory annual reporting and development of Groundwater Sustainability Plans. The 2016 Open and Transparent Water Data Act establishes a centralized repository for available water and ecological data.

However, barriers remain in establishing an accessible and equitable suite of data and technology for adapting California's water systems to the effects of climate change. Data

is currently collected by multiple agencies with differing standards, regulatory mandates and objectives. While there are currently already efforts to compile and standardize this data, there remains a great deal of work to be done. Furthermore, many agencies and stakeholders lack the long-term funding mechanisms necessary to make use of the tools available. As a result, “data silos” have formed, data gaps are difficult to identify and fill, and new technologies may be slow to be adapted.

To address these challenges, California needs to continue to build upon its water data and technology efforts to improve the collection and application of water and climate data and to provide consistent guidance on vetted tools and protocols.

5.2 Recommended Actions

Action 1: Improve the use of climate data in water decision-making.

Build upon implementation of the Open and Transparent Water Data Act to improve standardization of and trust in climate data.

There is a great opportunity to build upon the water data framework established under Assembly Bill 1755, the Open and Transparent Water Data Act. Implementing agencies under that legislation have recently leveraged two existing state-hosted open data portals, the California Natural Resources Agency (CNRA) Open Data Platform and the California Open Data Portal, to provide greater access to water and ecological data. As of August 2020, datasets from five federal agencies named in the legislation (Reclamation, United States [U.S.] Fish and Wildlife Service, National Oceanic and Atmospheric Administration [NOAA], U.S. Geological Survey [USGS] and the U.S. Forest Service) have been made available on those two data portals. The centralization of the datasets and the search functionalities available on the portals have allowed users to locate and utilize relevant data for their needs more easily. The implementing agencies have also been working to create a unified inventory of state-held water and ecological datasets as well as datasets from other federal agencies.

In addition to the steps already taken, California must continue to build upon these efforts and consider how to incorporate datasets from local agencies and non-governmental organizations (NGOs). As additional datasets are incorporated, the variety and complexity of the data will increase, making it crucial to continue to ensure its integrity and reliability while also maintaining its accessibility and usability. In particular, the CNRA Open Data Platform portal can serve as a repository of different resources available on how these datasets can be used. The centralization of both the datasets and the relevant resources on how to use them would lower the barriers for accessing and utilizing climate modeling tools, particularly for local water agencies with limited resources and capacity.

Action 2: Develop partnerships to improve accessibility of climate modeling for water stakeholders.

Develop partnerships among government agencies, NGOs and private institutions to increase transparency and make climate data and models accessible for local water agencies, tribes and other stakeholders.

Utilizing data and modeling can often prove to be a daunting task, especially for those new to the field or with limited resources. Partnerships allow stakeholders to leverage shared resources and overcome barriers to finding and utilizing data and tools, making them more accessible to a broad range of end users. For example, partnerships can help smaller agencies build the necessary funding and technical capacity to implement climate modeling tools that would otherwise be inaccessible. Forming partnerships that collect and use similar data will keep stakeholders personally invested in data and models, which in turn will help overcome common feelings of mistrust in some governmental data and allow for more ready acceptance of the use of climate models.

Senate Bill 19 of 2019 (California Water Code Section 144), which addresses information gaps in stream gauge information, is an example of promoting partnerships to improve collection and use of data. As noted in the legislation, “The largest individual sponsor of stream gauges in California is the USGS, which works largely in partnership with a variety of state and federal agencies that provide funding to support gauges, and at least 57 percent of USGS-funded gauges are also funded by a local agency” (Senate Bill 19, Section 1(e)). In particular, the legislation promotes the creation of new partnerships by first inventorying the location and funding agency of existing stream gauges. In turn, this inventory record allows for easier identification of funding gaps and opportunities for new partnerships to install new stream gauges or restore gauges that were discontinued due to lack of funding.

Action 3: Standardize climate modeling tools, technologies, datasets and approaches.

Develop further guidance on vetted modeling tools, technologies and datasets and the associated approaches, parameters and other considerations to apply datasets to local and regional water management.

California’s water managers rely on several tools, technologies and datasets to manage the state’s water resources. However, managers lack guidance on which to use and how to apply them. In some cases, a single agency uses multiple tools and datasets to inform its decision-making. California needs a comprehensive resource that provides guidance on vetted tools, technologies and datasets and the associated approaches, parameters and other considerations to apply datasets to local and regional water management.

The new California Water Data Consortium is well-positioned to undertake this task. The Consortium was recently formed as part of the efforts under the Open and Transparent Water Data Act to serve as a nonprofit organization to “amplify efforts to improve water data infrastructure by creating a neutral organizational space to build trust and facilitate collaboration across sectors.” The Consortium, or a similar entity, must develop an independent technical working group composed of public, private and academic experts in water resource management and environmental stewardship to vet and develop best practices on water management tools, technologies and datasets.

As an initial task, the technical working group must develop public reviewed criteria and protocols for vetting water and climate modeling tools and technologies. The working group could then use the criteria to evaluate new and emerging tools and technologies on a regular basis. The vetting criteria and list of vetted tools and technologies, and applicable assumptions, parameters and limitations could be stored in a single, publicly accessible website to ensure accessibility and transparency.

In addition, the working group must identify guidance on which data, tools and technologies to use and how to use them under a range of climate scenarios. A standardized approach to which tools and technologies to use and how to apply them will be essential to building trust around informed decision-making and adapting California’s water resources to the impacts of climate change.

Action 4: Incorporate the latest technology into water operations.

Advance research, adoption and implementation of the best available technology to improve California’s water management, including flood control, water supply and ecosystem health.

Many water agencies utilize outdated technology due to a lack of regulatory flexibility or failure to embrace new technology. Partnerships between federal, state, local, private, academic and non-profit entities can strengthen development and adoption of new technology in all aspects of California water management. Two examples that showcase how California can work towards better management practices and adapt to climate change are atmospheric river (AR) research and Airborne Snow Observatory (ASO) snow survey technology.

First, the study of ARs has shown tremendous promise in recent decades and will play a key role in California’s ability to adapt to climate change. ARs are long, narrow regions in the atmosphere where high levels of water vapor travel over a body of water. Once they make landfall, ARs release water vapor in the form of snowfall and rain. In California, 40 to 60 percent of all water supply comes from these events. Similarly, 85 percent of floods result from ARs. A better understanding of these events is crucial as California’s

climate changes and storms become flashier and fall more often as rain instead of snow (NOAA 2015).

ARs are observed using a variety of methods, including satellites, and collected data is used by models that yield real-time information available to water system operators. However, not all water agencies have the flexibility to incorporate this real-time data into their operations. Most reservoirs in California today operate on rigid rule curves embodied in outdated flood control manuals adopted in the 1970s. AR research is providing the ability to modify reservoir operations safely using Forecast Informed Reservoir Operations (FIRO). The goal of FIRO is to develop, demonstrate and implement tools and science that enable more effective management of reservoirs by leveraging improvements in weather and water forecasts. FIRO creates a natural linkage between research, applications, technology, reservoir operations and water control manuals to enable continuous improvement based on state-of-the-art science (Center for Western Weather and Water Extremes 2020).

Some water agencies that are not part of the state or federal water projects can use this technology in their operations. With additional funding and research, operators can learn where ARs are going to land and insert that data into specific watershed operations models for tailored information unique to a specific water system. For other water systems with more complex operating agreements, the ability to operate reservoirs and conveyance infrastructure before an AR landing will require modification to flood control rule curves.

Second, ASO technology is another example of how using the latest data and technology can assist California water managers in adapting to climate change. California's largest reservoir is its snowpack; therefore, accurate measurements must be provided and incorporated into water supply models. California pioneered snow survey technology in the 1950s, utilizing snow-core measurements and snow measurement sensors in limited locations across hundreds of miles. However, the state had not seen many improvements over the last half-century until the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory developed the ASO program in 2012 (NASA 2020). The ASO program maps and analyzes the distribution of snow water equivalent (i.e., the amount of water contained in the snowpack) and snow albedo (reflectivity) in mountain basins using aircraft with LiDAR and an imaging spectrometer to fly over each watershed, providing a true representation of the snowpack. Therefore, ASO technology provides water managers with a valuable resource as they adapt to a changing snowpack.

Water agencies in the Tuolumne River Watershed were the first to partner with NASA on ASO technology in 2013, and their partnership demonstrated successful results. The

Tuolumne River Watershed spans more than 1,500 square miles. Before the ASO program, water agencies had 17 points of measurement in the entire watershed, or one every 88 square miles. These consist of remote measurement sites and snow pillows that measure the mass of the snow, which often fail to provide a reliable measurement of the overall snowpack. By comparison, the ASO program utilizes images every square meter, allowing it to provide a more granular and accurate view of the available snowpack than the historical snow survey process.

This improved information has directly translated to more informed decision-making. In 2017, snowpack runoff estimates from DWR and the California Nevada River Forecast Center led Tuolumne River operators to increase releases into the river to near maximum channel capacity. Following this increase, more granular ASO data was acquired that gave operators the information and confidence to decrease the release, thereby conserving valuable water while still maintaining safety. Using ASO data allows water agencies to make releases that are better for the environment and public safety. For example, in 2018, Tuolumne River water operators used ASO data to save 150,000 AF of water in Don Pedro Reservoir that would have otherwise been released for flood control (Turlock Irrigation District 2020).

Moving forward, DWR is well poised to lead the charge to embrace widespread ASO adoption. The agency has a major role in the current snow survey program (which ASO would enhance) and considerable institutional experience with SGMA, Flood-MAR and the State Water Project. Additionally, the images and data collected during ASO flights are posted online and are made available to many other agencies that can use them to improve the accuracy of their respective products and programs, including the California Department of Forestry and Fire Protection, the National Park Service, the National Weather Service, U.S. Army Corps of Engineers and others.

FIRO and ASO are terrific examples of harnessing the latest technology to improve data collection and improve water operations. Considering the urgent challenges that climate change presents, California would benefit from working quickly to eliminate barriers to their implementation and continue to incorporate them into water management.



Photo Credit: Niklas Veenhuis, Unplash.

6 Conclusion

It is critical that California adapts water management to climate change. Impacts to the water system—including water supply, flooding and ecosystems—are some of the most pronounced consequences of climate change. Water is the backbone of California, providing drinking water for nearly 40 million people, supporting \$50 billion in agricultural revenue and contributing to a diverse ecosystem (California Department of Food and Agriculture [CDFA] 2019). Any adverse impact on water resources would have not only fiscal impacts but would harm health and livelihoods.

Failing to adapt water management to climate change has severe consequences. Extreme precipitation events are expected to intensify under a changing climate, which increases flood risk. The last major flood resulted in the loss of five lives and \$1.5 billion in damage, and climate scientists predict that future flooding events will be more extreme. In addition to flood risk, climate change could increase water demand and reduce water supply. Increased temperatures result in higher crop evapotranspiration rates and shifts the irrigation season. Meanwhile, surface water deliveries will be stressed by more extreme precipitation events, which cannot be captured by existing reservoirs. Surface water exports to the south are also reduced by increasing salinity in the Delta. Climate change further strains ecosystems. In addition to competing with agricultural users for water resources, critical aquatic species would be harmed by higher temperatures and changing flow patterns.

The policy recommendations in this report outline actions to address gaps in infrastructure, regulations and data and technology to effectively address climatic stresses. Although these policy strategies vary in their specific actions and scope, they share a few common themes: promoting equity, stakeholder collaboration, developing innovative solutions through science and advancing multi-benefit projects. These shared themes stress the importance of collaboration to climate change adaptation as well as spotlighting potential barriers to success.

It must be acknowledged, though, that these actions face significant implementation challenges. The biggest of these challenges has been and will continue to be funding. Bond funds tend to be awarded on a competitive basis, which pits these projects against many other environmental and public-benefit projects. COVID-19 has also created funding strains, which adds to the current funding gap of \$250 million for operations and maintenance and the \$12 billion needed in capital projects for California's water infrastructure over the next few decades (DWR 2017). Long-term funding for investments in new and existing infrastructure as well as existing and emerging technologies will be vital to this overall effort.

Coordination will also be a challenge. There are not many incentives for local, state and federal agencies to coordinate with water rights holders and managers—or each other. Often, the complexity of laws and regulations makes baseline compliance take priority over innovation or coordination for these projects. Yet, coordination in data standardization, water supply deliveries and mitigating inefficiencies within existing regulatory frameworks will be necessary across all stakeholder groups. Remembering that progress takes compromise, agencies must work together and find creative ways to work through the complicated challenges they face. To make these projects implementable, and to source the necessary funding, creativity will be required. One of the most important components will be to incentivize stakeholders before looking to regulation or control as the pathway to implementation.

While complex, these barriers are not new to water management in California. These discussions must continue, and the recommendations laid out in this report are merely a starting point in this effort. Successfully adapting California water management to a changing climate will be a monumental effort and will require a shared sense of urgency and purpose from all Californians in order to meet this moment.

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