Addressing Climate Change Adaptation in Water Resource Management: A Case Study of the Sacramento Region

Sacramento River (top); Folsom Dam and American River Watershed (bottom)

Advanced Policy Analysis

A study conducted for the Capital Region Climate Readiness Collaborative, Sacramento, California

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The Capital Region Climate Readiness Collaborative
A membership-based network working to promote greater climate change resilience planning coordination in the six-county Sacramento Region. The purpose of this collaborative network is to create a forum where leaders from government, academia, environmental and community groups, the business community, and labor can come together to exchange information, identify vulnerabilities and data gaps, leverage resources, and advance comprehensive solutions in an effort to create stronger, sustainable, and economically viable communities in the Sacramento Region.

DISCLAIMER
The author conducted this study as part of the program of professional education at the Goldman School of Public Policy, University of California at Berkeley. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author, and are not necessarily endorsed by the Goldman School of Public Policy, by the University of California, or by any other agency.
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Abbreviations

BDCP       Bay-Delta Conservation Plan
CVP        Central Valley Project
DWR        California Department of Water Resources
EDCWA      El Dorado County Water Agency
EID        El Dorado Irrigation District
IPCC       Intergovernmental Panel on Climate Change
IRWM       Integrated Regional Water Management
IRWMP      Integrated Regional Water Management Plan
PCWA       Placer County Water Agency
RWA        Regional Water Authority
RWMG       Regional Water Management Group
SB         Senate Bill
SCWA       Sacramento County Water Agency
SEI        Stockholm Environment Institute
SGA        Sacramento Groundwater Authority
SLR        Sea level rise
SWE        Snow water equivalent
UWMP       Urban Water Management Plan
WRA        Water Resources Association of Yolo County
WDCWA      Woodland-Davis Clean Water Agency
YCWA       Yuba County Water Agency
Executive Summary

Climate change is posing new challenges to traditional water management practices due to changing weather patterns and natural hazard conditions. Inevitable consequences of climate change, including changes in the timing, intensity, and variability of precipitation, reduction of average annual snowpack, and long-term changes in watershed vegetation, will threaten future availability and reliability of water. As historical data become less predictive of future scenarios, water managers require new paradigms and practices to avoid high economic, social, and environmental costs from climate change-induced disasters. However, local water agencies have limited resources, capacity, and expertise to address problems that lie outside of their core responsibilities. Opportunities exist for mutual learning and cooperation to fulfill capacity gaps between water agencies, the scientific community, and other stakeholders but barriers to adaptation must first be understood and overcome. Drawing on water resource management experiences in the six-county Sacramento region (El Dorado, Placer, Sacramento, Sutter, Yolo, and Yuba counties), this report assesses knowledge and capacity needs of water agencies in order to plan and prepare for climate change as well as identifies research priorities and strategies to increase local resilience.

Key Findings:

- Water agencies are building more resilience into their systems by diversifying water supply portfolio and improving management practices, but these actions are not based on climate change considerations. It is unlikely that they can adequately adapt to climate change without overcoming barriers to adaptation discussed in this report.

Perceptions of climate change and its impacts

- Water agencies that function as public utilities rather than a strategic planning organization indicate that they are taking a “conservative and steady approach” as they feel that there is too much uncertainty regarding the magnitude and timing of the effect, and which specific supply sources would be the most at risk. In contrast, agencies whose main function is long term planning show some degree of urgency to start planning for climate change and improving the resilience of the system, but they also acknowledge that the process should be a cautious one as well.

- Knowledge about climate change reflects the agency’s interest and level of urgency. Interviewees who provide general responses about climate change impacts tend to refer to a “high level of uncertainty” often. They also tend to be less concerned about climate change than interviewees who provide detailed explanations about potential local impacts and who appear more open to discussing climate change issues.

Barriers to adaptation

- **Knowledge:** Water agencies have limited knowledge about local climate change vulnerabilities and they mainly rely on the state (e.g., Department of Water Resources) and federal government for climate change-related information. High priority information
needs include downscaled climate data for the Sacramento region and cascading effects of climate change on hydrologic parameters. (see Table 10 for a summary of information needs)

- **Funding**: Local water agencies’ actions are responsive to funding opportunities from the state and federal sources. However, in most cases these funds only become available during or after the occurrence of extreme events.

- **Human resources and institutional limitations**: An engineering-based water management tradition has been generally effective in the past. Water engineers who work with historical and real-time data often find it difficult to come to grips with long-term scale of climate impacts. Other competing, more immediate, issues such as drought, Integrated Regional Water Management (IRWM), and the Bay-Delta Conservation Plan (BDCP) take attention away from climate change. As a general practice for long-term planning, agencies hire consultants to fulfill capacity gaps.

- **Political barrier**: Climate change remains a contentious issue in certain districts. Water agencies, which operate under the direction of the elected board members who must serve their constituents, are concerned about how to justify any efforts to adapt based on the grounds of climate change because they feel that it is difficult to prove.

- **Lack of leadership**: Water agencies lack leaders to manage risks from climate change. There is little incentive for immediate action as climate change is a long-term problem and the problem may be inherited by other staff at a later stage.

- **Law and legal mandate**: There is no legal mandate to require local agencies to adapt to climate change. Agencies feel that they do not have a clear policy direction from the state regarding climate change adaptation.

### Recommendations

The scientific community plays a critical role in providing reliable and unbiased information that increases the incentives to accelerate adaptation practices. High priority research areas include *downscaled climate change impacts at the level of the watershed and local supply, impacts of climate change on groundwater,* and *an economic analysis of climate change adaptation*. The disconnect between science and practice can be mitigated through a collaborative process that allows decision makers and experts to own the problem, set common goals, and integrate their perspectives into research design (Ford et al., 2013; Dilling & Lemos, 2011). The current challenge in the Sacramento region’s water sector is how to build interest in climate change adaptation and to mainstream it into the planning process. The following strategies are recommended to build local engagement in climate change adaptation.

### Actors and Strategies

<table>
<thead>
<tr>
<th>Actors</th>
<th>Strategies</th>
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| General (e.g. adaptation leaders) | - Create the right incentives to increase local buy-in into climate change adaptation by determining a broad set of benefits from adaptation strategies and deciding how risks will be shared [ST]  
- Identify existing mechanisms that can support adaptation action (e.g. capital investment plans) and determine what institutional arrangement best fit into existing structure. These arrangements may involve information brokers, collaborative group processes, embedded capacity (training), boundary |
organizations (consultants), and knowledge networks [ST]

- Determine shared goals and perceived needs to respond to climate change.
- Increase the urgency to start adaptation planning by highlighting the costs of inaction or delay and engage in education and training programs to improve understanding about climate change and impacts [ST]
- Build trust and relationships with stakeholders by creating transparency in the decision-making process and sharing risks and responsibilities [ST, MT, LT]

Local water agencies

- Pursue a cost-effective approach to secure future water reliability and consider no-regrets strategies that have benefits beyond climate change adaptation [ST]
- Increase adaptive capacity (e.g., build awareness of potential impacts) [ST, MT, LT]
- Consider context-based approach to managing uncertainties (e.g., Robust Decision Making, see Groves et al., 2013; vulnerability and robust response, see Weaver et al., 2013; decision scaling, see Brown, 2010) [ST]

Local government (city- and county-level)

- Integrate adaptation into Climate Action Plans and apply an integrated approach to addressing impacts in various sectors (e.g., water, emergency response, agriculture, and city planning) [ST, MT, LT]
- Provide policy and funding support for local water agencies to integrate climate change considerations into planning [ST, MT, LT]
- Facilitate knowledge exchange and collaboration between stakeholders [ST, MT, LT]

Scientific community

- Provide support to local players to increase adaptive capacity (e.g., communicate climate change information in an appropriate format) [ST]
- Build trust and relationships with local agencies by communicating uncertainties, jointly producing knowledge, and providing open access to information [ST, MT]
- Align research priorities with local needs [ST]
- Estimate economic costs of adaptation options vs. delayed response [ST]
- Improve knowledge of the consequences of climate change on groundwater resources [ST, MT]
- Increase accuracy and certainty of downscaled climate change impacts [MT, LT]

State and federal government

- Provide clear policy direction for climate change adaptation [ST]
- Encourage adaptation at the local level [ST]
- Make funding available for adaptation planning and implementation [ST]
- Establish a legal mandate for local agencies to assess and prioritize climate change impacts and create an adaptation plan [ST, MT]
- Reform the water rights system, as climate change will disproportionally disadvantage water rights holder [MT, LT]

Note: brackets indicate activities that can be achieved in the short term [ST] or less than 5 years, medium term [MT] or 5-10 years, and long term [LT] or more than 10 years.
Introduction

The complexity in water resource management relates to uncertainties and risks in ensuring a reliable supply of water for a growing demand. Through high-level planning processes, water agencies assess current knowledge and capacity, identify options for long-term development of infrastructure and other projects, and determine implementation plans. Risk reduction is often achieved by system design and technical solutions that use historical data to predict future water needs and availability. This knowledge-intensive management practice has typically been effective in normal years when the supply of water is not greatly disrupted by natural disasters or other unforeseen circumstances. However, climate change is posing new challenges to traditional water management practices due to changing weather patterns and natural hazard conditions. Managers can no longer assume stationarity of their systems. The Intergovernmental Panel on Climate Change (IPCC) summarizes potential climate change impacts on water resources as change in the timing and amount of precipitation, decreased snow cover, change in the pattern of runoff and groundwater recharge, and sea level rise (IPCC, 2013). Climate change will increase the frequency and severity of natural disasters such as flooding or drought. It will also affect water quality through warmer water temperatures and rising sea level. As historical data become less predictive of future scenarios, water resource managers require new paradigms and practices to avoid high economic, social, and environmental costs from climate change-induced disasters. However, water agencies have limited resources and capacity to address problems that lie outside of their core responsibilities. Adaptation thus entails collaboration with experts and stakeholders to fulfill knowledge and capacity gaps. This transition is inevitable, but difficult due to the current mismatch in the production and usability of climate change information. Opportunities exist for mutual learning and cooperation to fulfill capacity gaps between water agencies, the scientific community, and other stakeholders but barriers to adaptation must first be understood and overcome.

This report is part of the Advanced Policy Analysis (APA) project for the fulfillment of a Master of Public Policy degree program at the Goldman School of Public Policy, University of California at Berkeley. The project client is the Capital Region Climate Readiness Collaborative, a network that aims to promote greater coordination on climate change adaptation at the regional and local levels across the six-county Sacramento region. The report assesses knowledge and capacity needs of water agencies in the client’s service area, namely El Dorado, Placer, Sacramento, Sutter, Yolo, and Yuba counties, in order to plan and prepare for climate change. It also identifies strategies and research priorities to increase local resilience.

Part 1 of the report provides background information on the six-county Sacramento region’s water supply and demand, water resource management, and potential climate change impacts. Part 2 discusses the adaptation framework and adaptation options. Part 3 clarifies the objectives of the study. Part 4 explains methods of data collection and analysis. Part 5 summarizes study results and discusses key findings. Lastly, Part 6 concludes and offers recommendations for setting research priorities and overcoming challenges in the adaptation process.
Part I: Background

Sacramento Region Water Resources and Demand

Spanning 6,300 square miles, the Sacramento region consists of El Dorado, Placer, Sacramento, Sutter, Yolo, and Yuba counties and has a total population of 2.4 million (U.S. Census Bureau, 2013). Situated in one of California’s key agricultural regions and urban areas, the region extends from the Sacramento and San Joaquin delta to the foothills of the Sierra Nevada Mountains. There are two distinct climate patterns in the region. The mountainous areas in the east have cold and wet winters and relatively mild summers and the western region’s Mediterranean climate is characterized by damp, cool winters and hot, dry summers.

Fig. 1: Six-county Sacramento region

![Map of Sacramento Region](source: SACOG, 2014 (accessed April 12, 2014))

The Sacramento, American, Yuba, and Feather rivers are the main surface water resources for the region’s urban and agricultural areas. Supplies are provided through multipurpose reservoirs, which have competing uses for water supply, electricity production, recreation, environmental protection, and flood control. Some of the major reservoirs in the region include Folsom Lake (976.9 thousand acre-feet), Bullards Bar (966.1 thousand acre-feet), and Clear Lake (313 thousand acre-feet).
Table 1 shows water storage levels in selected reservoirs supplied by the Sacramento River. Apart from year 1977 and 1983, which were very dry and wet years, respectively, water storage levels have declined in many of these reservoirs in the past six years. The California Department of Water Resources (DWR) provides a Water Year Index to characterize annual water abundance of the Sacramento River and tributary runoff (see Table 2). This Water Year Index classifies the hydrologic conditions in the Sacramento Valley for each water year (October 1 – September 30) into five categories of wet, above normal, below normal, dry, and critical. Since 2007, the Sacramento Valley has experienced below normal to critically low levels of supply, with a wet year in-between in 2011. Existing conditions can be compounded by climate change. Recent research has linked the 2013-2014 drought in California to anthropogenic warming and suggested that future droughts will be even more severe (Wang et al., 2014).

Communities also pump groundwater for municipal consumption and agricultural irrigation. In the Sierra Nevada foothills, water may be scarce during summer and fall despite high flows in the winter and spring following snowmelt. Groundwater is also scarce in this area, and when available, it typically contains contaminants and heavy metals. Conversely, the Sacramento Valley region has abundant groundwater resources and relatively higher groundwater quality, although contamination and pollution remain a problem in some areas. Intensive use of groundwater in the past has resulted in decreased groundwater elevations. Pumping depressions were evident in northern Sacramento County as early as 1968 (SGA, 2008). Operational changes and regional collaboration through conjunctive use have reversed this decline since the mid-1990s, but population growth and climate change pose new threats to groundwater supply. The region has some opportunities for using recycled water, and many local agencies are pursuing this option to supplement surface and groundwater resources.

**Table 1: Sacramento River’s end-of-month storage in calendar year (March) in 1000 acre-feet**

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<tbody>
<tr>
<td>CVP, North</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Folsom Lake</td>
<td>977</td>
<td>628.2</td>
<td>285.3</td>
<td>651.6</td>
<td>745.9</td>
<td>562</td>
<td>634.7</td>
<td>664</td>
<td>601.1</td>
<td>436</td>
</tr>
<tr>
<td>PG&amp;E</td>
<td>144.6</td>
<td>55.1</td>
<td>25</td>
<td>31.3</td>
<td>65.6</td>
<td>29.2</td>
<td>20.7</td>
<td>87.4</td>
<td>62.9</td>
<td>87</td>
</tr>
<tr>
<td>Lake Spaulding System</td>
<td></td>
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<tr>
<td>Yuba County WA</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bullards Bar Reservoir</td>
<td>969.6</td>
<td>701</td>
<td>296.4</td>
<td>794.7</td>
<td>773</td>
<td>684.2</td>
<td>785.7</td>
<td>817.2</td>
<td>804.6</td>
<td>600.6</td>
</tr>
<tr>
<td>South Sutter Water District</td>
<td>104.5</td>
<td>101</td>
<td>11.9</td>
<td>108.1</td>
<td>93.7</td>
<td>92.2</td>
<td>96.8</td>
<td>95.7</td>
<td>92.8</td>
<td>87.8</td>
</tr>
<tr>
<td>Camp Far West</td>
<td>230</td>
<td>163.7</td>
<td>28.9</td>
<td>220.3</td>
<td>180.3</td>
<td>182.2</td>
<td>161.5</td>
<td>195.2</td>
<td>222.3</td>
<td>168.8</td>
</tr>
</tbody>
</table>

*Source: DWR, 2014*
Agricultural water is a major proportion of the overall consumption in the region. Irrigated water peaked in the 1980s and has since slightly declined or remained relatively constant due to improvements in irrigation efficiency. Water use increase in recent decades has been driven by urbanization, especially in the Sacramento metropolitan area and other cities in El Dorado, Placer, and Yolo counties. For larger urban areas, surface water diversion is a key component of the water supply portfolio but abundant groundwater supplies in the Sacramento Valley have also become a principal resource for many cities. Environmental use of water in the Sacramento region is expected to increase under fishery and wetland requirements to protect natural habitats. Water demand will continue to grow in the future as urban areas expand and the population rises to an expected 3.8 million by 2060 (Department of Finance, 2013).

\[\text{Table 2: Sacramento Valley Water Year Index}\]

<table>
<thead>
<tr>
<th>Water Year</th>
<th>Index (maf)</th>
<th>Year-type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>12.4</td>
<td>wet</td>
</tr>
<tr>
<td>1996</td>
<td>9.7</td>
<td>wet</td>
</tr>
<tr>
<td>1997</td>
<td>11.0</td>
<td>wet</td>
</tr>
<tr>
<td>1998</td>
<td>12.4</td>
<td>wet</td>
</tr>
<tr>
<td>1999</td>
<td>10.0</td>
<td>wet</td>
</tr>
<tr>
<td>2000</td>
<td>9.2</td>
<td>wet</td>
</tr>
<tr>
<td>2001</td>
<td>5.9</td>
<td>dry</td>
</tr>
<tr>
<td>2002</td>
<td>6.5</td>
<td>dry</td>
</tr>
<tr>
<td>2003</td>
<td>8.0</td>
<td>above normal</td>
</tr>
<tr>
<td>2004</td>
<td>7.7</td>
<td>below normal</td>
</tr>
<tr>
<td>2005</td>
<td>7.4</td>
<td>below normal</td>
</tr>
<tr>
<td>2006</td>
<td>13.0</td>
<td>wet</td>
</tr>
<tr>
<td>2007</td>
<td>6.2</td>
<td>dry</td>
</tr>
<tr>
<td>2008</td>
<td>5.4</td>
<td>critical</td>
</tr>
<tr>
<td>2009</td>
<td>5.5</td>
<td>dry</td>
</tr>
<tr>
<td>2010</td>
<td>6.9</td>
<td>below normal</td>
</tr>
<tr>
<td>2011</td>
<td>10.0</td>
<td>wet</td>
</tr>
<tr>
<td>2012</td>
<td>6.9</td>
<td>below normal</td>
</tr>
<tr>
<td>2013</td>
<td>5.8</td>
<td>dry</td>
</tr>
</tbody>
</table>

Notes: water year (Oct 1 - Sept 30)
Unit: million acre-feet

wet: 9.2 < x 
above normal: 7.8 < x < 9.2
below normal: 6.5 < x < 7.8
dry: 5.4 < x < 6.5
critical: x < 5.4

Source: DWR, 2013

Local Water Management

Water management structure is quite diverse between counties in the Sacramento region. Water may be locally managed by public agencies, joint power agencies\(^1\), or voluntary coalitions. Counties such as Sacramento, Placer, and Yuba have county-wide water agencies that

\(^1\) California law authorizes two or more public agencies to jointly exercise power to create a new legal entity or establish a joint approach to address a common problem. These joint power agencies may be called joint powers authority or JPA.
function as a utility provider or wholesale water supplier but the El Dorado County Water Agency mainly engages in long-term planning and coordination with independent water districts. The Yolo County does not have a county-wide water agency. Instead, the Water Resources Association of Yolo County, a non-profit organization whose members include Yolo County and city-level governments, functions as a regional forum to coordinate and facilitate decision-making on county-wide water issues. Sutter County has a relatively small population compared to its counterparts in the Sacramento region, and its water agency is part of the Department of Public Works’ Water Resources division. City-level water services are generally part of the department of utilities or department of public works. Cities may have rights to surface water or contract with wholesale suppliers and those in the Sacramento Valley typically own groundwater wells to supply needed water resources to their residents.

Water managers make decisions across different time scales to satisfy multiple objectives. Their priorities are determined by legal, regulatory, and institutional requirements, including service contracts (Raff et al., 2013). Managers may exercise discretion to achieve objectives, taking economic efficiency and environmental responsibility into consideration. Day-to-day operations depend on the system’s operating plan and operational outlook that are applicable to the coming days, weeks, or months. Important decisions must be approved by the board of directors, which often comprises of a small group of locally elected officials who represent the interests of the organization’s constituents or ratepayers.

State oversight of water agencies is limited in comparison to that of gas and electricity providers. A complex and decentralized water system creates a challenge for integrative management of water resources, storage, and distribution systems. Counties such as Sacramento have more than 20 water districts while others such as El Dorado has as few as five water and irrigation districts. As water is a finite and vulnerable resource, competing uses and benefits of water across different areas and jurisdictions must be taken into consideration. State water laws and policies provide a framework to overcome these challenges and offer guidance for decision-making (Appendix VI). In the past decade, much effort has focused on integrated regional water management (IRWM) to manage all aspects of shared water resources in a collaborative manner rather than the more traditional, fragmented approach of management. This policy direction will influence investments and guide water management in the coming years.

**Climate Change Impacts**

Climate change poses new challenges to water management. In addition to preexisting conditions that create pressure on water resources, climate change will seriously affect the long-term availability and reliability of water in the Sacramento region. The General Circulation Models (GCMs) predict large-scale changes in climate and other physical parameters under different scenarios of atmospheric greenhouse gas concentration. Global in scale, these models are too coarse to accurately assess regional or local impacts. More efforts are being made to

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2 In general, a water district is a separate local government that delivers water and other public services to a particular area. It is at a smaller jurisdictional level than a water agency.
downscale global models and produce more fine-grained output that consider local hydrologic parameters such as groundwater, evapotranspiration, flows, and other factors that may affect watersheds. Direct impacts of climate change on water resources include (1) changes in the timing, intensity, location, amount, and variability of precipitation; (2) reduction of average annual snowpack and changes in the timing of snowmelt; (3) long-term changes in watershed vegetation and increased incidence of wildfires; (4) increased water temperatures; and (5) sea level rise. As the Sacramento region is located further inland, sea level rise does not directly affect its water resources, but there is some possibility of saltwater intrusion into groundwater aquifers (Yolo County, 2005; Borcalli & Associates, 2000). The overlap of sea level rise and requirement for environmental use of water to maintain salinity standards downstream will reduce the availability of water upstream. Changes in weather patterns and more extreme temperatures will also impact urban and agricultural water demand, which may add another stress factor on vulnerable water resources.

The following subsections discuss climate change impacts on precipitation, snowpack, and temperature in the Sacramento region using Cal-Adapt, a web portal that provides downscaled climate change impacts for the state of California. Four general circulation models\(^3\) available in Cal-Adapt provide predictions on how the physical environment will change under different emissions scenarios. These responses reflect the climate sensitivity of the natural systems. As response processes and feedback mechanisms are not yet fully understood, the models provide ranges of outcomes for each emissions scenario. Two scenarios of mid-high emissions level (A2) and low emissions level (B1) are considered in this modeling exercise. As the models become more sophisticated over time, downscaled information will have higher degrees of certainty and accuracy. Details of the models and their evaluation are available in the IPCC’s Fourth Assessment Report: Evaluation of Climate Models (IPCC, 2007).

**Precipitation**

Climate change will alter the timing, amount, intensity, location, and variability of precipitation. The changing patterns of rain and snowfall, however, are generally difficult to predict at a local level due to natural variability and complex climatic and non-climatic interactions of temperature, wind, evapotranspiration rates, and other factors. The average number of precipitation events may decrease but precipitation will become more intense on average. More precipitation is also expected to fall as rain rather than snow due to the warming of average atmospheric temperatures. As shown below (Figure 2a), the annual precipitation level in 2020 is predicted to be relatively low in the Valley region, which receives about 20 inches of precipitation or less, but higher elevations will receive 80+ inches. Figure 2b illustrates the expected level of precipitation between low and high emission scenarios at a particular area in Sacramento (from a rectangle area in Figure 2a). The projected precipitation level does not vary much as this data representation is not sensitive to seasonality and there is no clear pattern of

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\(^3\) These General Circulation Models are (1) CCSM3 (2) GFDL (3) PCM1 and (4) CNRM. More details can be found here: [http://www.ipcc-data.org/sim/gcm_clim/SRES_AR4/index.html](http://www.ipcc-data.org/sim/gcm_clim/SRES_AR4/index.html)
precipitation change that emerges from two different emissions scenarios. The model requires further calibration to estimate local impacts, determine variability of precipitation, and predict timing of extreme events. However, the present state of knowledge can inform that future precipitation may look very different from the past even with little changes in annual precipitation level (Kiparsky & Gleick, 2003). It is important to note that these yearly estimates conceal precipitation events that will vary throughout the year.

Fig. 2a: Annual precipitation level in 2020  Fig. 2b: Modeled historical average and projected precipitation levels

Snowpack

Snowpack in the Sierra Nevada Mountains serves as critical year-round water storage for California, providing a steady supply of snowmelt to rivers and downstream reservoirs. But as precipitation falls as rain instead of snow, snowpack will diminish in size, thus greatly reducing freshwater runoff for spring and summer consumption. During the twentieth century, the average snowpack size in early spring has already decreased by approximately 10% (DWR, 2008, p.3). Local climate snapshots (Figures 3a & 3b) show the projected difference in snow water equivalent (SWE), or amount of water contained within the snowpack in April. Even in a low-carbon emissions scenario (B1), there is a clear impact on snowpack. The baseline “climate normal” time period of 1961-1990 is compared to the end of century period of 2070-2090. Green areas suggest high levels of snow water loss, especially in the high mountainous areas of the Sierra Nevada. An example of Placer County’s snow moisture average indicates a clear decrease in the amount of snow over time. By the end of the century, April snowpack could decline by as much as 53.7% even in a low emissions scenario, from a modeled historical average of 18.77 inches in snow depth. In a high-emission scenario, this loss could be up to 70.3%. In addition, snow-covered areas are expected to decrease over the next few decades. Figure 4 compares decadal averages of snowpack in December 2010 and December 2060. The projection uses
average values from the four climate models and data layers were downscaled using a bias correction and spatial downscaling approach. The decrease in snow-covered areas may be explained by a decrease in total snowfall or a shorter snow season. These changes can translate into a series of undesirable outcomes such as increased frequency and magnitude of droughts and floods and long-term decline in renewable water supplies (Solomon et al., 2007). Reductions in seasonal and inter-annual runoffs can have serious economic impacts, especially in agricultural and water-intensive industrial sectors. Changes to surface water hydrology may also decrease groundwater recharge.

Fig. 3a: Projected changes in April snow water equivalent for a low emissions scenario (Placer County)

Fig. 3b: Modeled historical average and projected snow moisture levels

Fig. 4: Projected December snow water equivalent in 2010 and 2060 under a low emissions scenario
Temperature

An increase in average global temperature will have different impacts at the local and regional levels. Some areas may experience a dramatic increase in temperatures while others may see a decrease or very little change. The biggest increases in temperature are occurring at high elevations (DWR, 2008). Increases in temperature will cause precipitation to become more variable and affect the predictability of stream flows (Hayhoe et al., 2004). Early melting of the snowpack will cause the peak flow of rivers to occur earlier in the spring (DWR, 2008). These changes will have important implications for water rights holders as withdrawals are specific to a particular time period.

The following figures illustrate changes in average temperature between the baseline (1961-1990) and end-of-century periods (2070-2099) for Placer and Sacramento counties. The maps depict a low emissions scenario, but a comparison with the high emissions scenario is shown in figures 5b and 6b. Temperature increases are comparable between the two counties, though greater changes are expected in the higher altitude areas in the Sierra Nevada foothills. Other counties in the Sacramento region (not shown) are predicted to have similar increases in temperature in the same period. Areas shown in red, which indicate a high increase in temperature, also expect greater snowpack loss as discussed above. At the same time, warmer water temperatures can potentially affect water quality due to algal growth and reduction of dissolved oxygen levels.

Fig. 5a: Projected changes in annual average temperature for a low emissions scenario

![Projected changes in annual average temperatures for the low emissions scenario](image)

Fig. 5b: Observed and projected average temperatures (Placer County)

![Observed and Projected Temperatures](image)
Warmer temperatures will increase the evapotranspiration rate, leading to greater moisture loss from the watershed and a higher risk of wildfire. The greatest impacts are predicted to be in the dense vegetative areas of Yuba, Placer, and El Dorado counties. Although in normal conditions, wildfires promote vegetation and plant diversity and release nutrients into the soil, climate change will increase the duration of wildfire season, expand the areas vulnerable to wildfire, as well as heighten the intensity of individual fires, creating major health and environmental hazards. Wildfires also have the potential to change watershed conditions, reducing the infiltration rate of water and sometimes resulting in dramatic changes in annual and peak stream flows (Neary et al., 2004). Figure 7 displays projected wildfire risks over time based on the CNRM model, which uses temperature, northward and eastward wind, specific humidity, ozone concentration, and surface pressure variables. The ratio of additional risk relative to 2010 levels was calculated as a 30-year average for periods ending in 2020, 2050, and 2085. Darker orange and red areas indicate up to a ten-fold increase in fire risk. This risk is based on climate projections and does not include landscape and fuel sources parameters. In a low emissions scenario, wildfire risk in El Dorado County may increase by 1.36 times in 2050 and by 1.43 times in 2085. Placer County may face up to 1.02 increase in 2050 with a slight decrease in risk to 0.83 in 2085. The risk in Yuba County may increase by 1.4 times by 2050 and by 1.47 times in 2085.
While there is still uncertainty regarding the accuracy of downscaled models, it is certain that water resources will be greatly affected by the decrease in snowpack and spatial and temporal changes in other climatic factors. These impacts will increase the vulnerability of the current water supply system, especially in high-growth areas projected to experience the fastest increase in water demand. Future risks in water supply management can be mitigated if actions are taken at the local and regional level to increase the sector’s adaptive capacity. The following section discusses a climate change adaptation framework and outlines adaptation options for water management.
Part II: Adaptation Framework

Climate change adds complexity and risks to the long-term planning of water supply. Water agencies have traditionally relied on statistical models based on past data to estimate future supply and demand, which are never free from measurement errors and model uncertainty. Despite that models have generally been reliable in predicting changes in water resources, climate change presents specific challenges for local institutions as future conditions lie beyond historical experience, impacts are local and heterogeneous, and a higher level of capacity is required to address impacts (Huntjens et al., 2012). The situation in the past 30 years is no longer representative of what will happen in the next 30 years, and water management must adapt to the new context of a changing climate.

According to the Intergovernmental Panel on Climate Change (IPCC), adaptation is “[t]he process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities” (IPCC, 2013). Moser and Ekstrom (2010) expands this definition to broaden the timescales of adaptation action (i.e. short-term coping and longer-term transformations) and to recognize that action may not be justified by climate change alone but may be a response to non-climatic factors such as land-use plan updates, infrastructure replacement, and changes in population. It may be premature to assume that all adaptation will have positive effects on intended outcomes as some action can become maladaptive when the situation changes. To fit this concept into the context of water resource management, this report defines adaptation as a collaborative, self-organizing, and iterative process of adjustment to actual or expected climate or other non-climatic factors that ultimately increases the resilience of the system to climate change impacts. Some actions may not be undertaken in direct response to climate change but are considered as adaptation if they can improve the adaptive capacity of the system (e.g., water transfer agreements) or allow organizations to incorporate new information to adapt to climate change (i.e., vulnerability assessments). The process of adaptation will ultimately lead to a more resilient system, which can cope with a hazardous event or trend of disturbance that allows the system to maintain its essential function, identity, and structure (Arctic Council, 2013; IPCC, 2013).

Incremental and transformative adaptations are two broad adaptation categories that reflect different timescales and magnitudes of change. The former aims to maintain the present system in scenarios where changes occur only at a small scale for a short time span. In contrast, transformative adaptation involves proactive management of drivers of change to attain desired outcomes in both short and long terms (Park et al., 2012). Incremental adaptation is often based on limited capacity and data to inform decision-making, while transformative adaptation places greater emphasis on costs and benefits of planning and immediate action. Taking into account the drivers, goals, and potential outcomes of adaptation, the U.S. Agency for International Development (USAID) offers a typology of the adaptation concept, which has evolved to differentiate adaptation measures and to characterize adaptation themes (USAID, 2010). These concepts provide a useful framework for designing adaptation strategies that fit into the existing system. For example, the no-regrets adaptation approach (e.g. conservation and improvements in
water use efficiency) is best suited where there is high political distrust of predictions concerning climate change.

Table 3: Key adaptation concepts defined

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned adaptation</td>
<td>Adaptation that is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change, and that action is required to return to, maintain, or achieve a desired state.</td>
</tr>
<tr>
<td>Autonomous adaptation</td>
<td>Spontaneous adaptation to address a specific vulnerability element, taken by the individuals or private entities uniquely impacted by climate change.</td>
</tr>
<tr>
<td>No-regrets adaptation</td>
<td>Adaptation options (or measures) that would be justified under all plausible future scenarios, including the absence of manmade climate change.</td>
</tr>
<tr>
<td>Maladaptation</td>
<td>An adaptive response, made without consideration for interdependent systems that may inadvertently increase risks to other systems sensitive to climate change.</td>
</tr>
<tr>
<td>Climate-proofing</td>
<td>Enhancing resilience to, and reducing the risks posed by, climate change; for example, improving the ability of infrastructure to withstand floods and cyclones.</td>
</tr>
<tr>
<td>Climate resilience</td>
<td>The capacity of a system, community, or society potentially exposed to hazards to adapt by resisting or changing in order to reach and maintain an acceptable level of functioning and structure.</td>
</tr>
<tr>
<td>Mainstreaming</td>
<td>The full and systematic incorporation of a particular issue into the work of an organization so that it becomes an accepted and regular part of the organization’s policies and practices.</td>
</tr>
</tbody>
</table>

Source: USAID (2010)

Adaptation is fundamentally a “local” response, as water is managed at the local or regional level and local actors play important roles in addressing climate change impacts. The conceptualization of the adaptation process generally reflects the key stages of the decision-making framework (Willows & Connell, 2003; Moser & Ekstrom, 2010, EPA, 2012). It is a circular, iterative, and tiered process, which allows for reprioritization, performance evaluation in light of new information, and refinement of adaptation options. This report adopts the ideal-type stages of the adaptation decision-making process of Moser and Ekstrom (2010). Although the model does not depict a real world decision-making process and should not be followed in a linear order, it provides a simple and straightforward model to identify adaptation challenges along different stages. A breakdown of the stages is outlined below.

In the “understanding” stage, actors first learn to detect and become aware of the problem, resulting in the initial problem definition and framing. Information gathering leads to
an increase in knowledge and deepen problem understanding, after which the problem definition may be refined or strengthened. Once the problem has been clearly determined, the actors move to the next stage of “planning”, which involves a development of adaptation options, assessment of these options where trade-offs are considered, and selection of options. Finally, the “management” stage begins with implementation of the selected option. Outcomes are then monitored to determine whether the option is successful in mitigating the problem. The monitoring and evaluation stages are very critical for adaptive management as new information is processed and used to improve adaptation activities.

FIGURE 8: IDEAL-TYPE STAGES OF THE DECISION MAKING PROCESS

Adaptation Options

Climate change adaptation includes any change in operations, management, and infrastructures to improve the resilience of water systems. This improvement can be viewed in multiple ways, including an increase in future reliability of water supply or a better way to respond to uncertainties. Based on assessments of the impacts on climate change across temporal and spatial scales, adaptation options require integrating demand-side and supply side strategies and may change existing operational framework and planning. Adaptation in water management may appear similar to traditional water supply management strategies such as development of additional or alternative supplies, implementation of best practices to encourage more efficient use of water, and use of multi-objective decision support systems. However, adaptation planning also makes use of climate change information and scenarios to develop a more flexible and responsive management system to expected changes. Accordingly to Brekke et al. (2009), climate change adaptation options can be divided into three groups, namely:
(1) Adaptation options involving operational changes. These changes include actions to increase flexibility in operational plans. For example, some reservoirs are used for multiple purposes such as flood control, water supply, and hydropower generation. Updated hydrologic records and future projections can be integrated into operational plan to make storage space variable to the expected precipitation level. Conjunctive use of water also helps to increase the flexibility of water management through coordinated use of groundwater and surface water.

(2) Adaptation options involving water-demand management. As climate change can increase water consumption through the increased use of electricity for heating or cooling and higher evapotranspiration rates for agriculture, water-demand reduction is one way to enhance water system resilience. It also has the co-benefit of reducing energy demand, which reduces greenhouse gases. Water conservation programs such as high-efficiency toilet rebates, education and training, and water efficiency for landscaping may involve interagency collaboration for program funding and implementation.

(3) Adaptation options involving infrastructure modifications. This type of adaptation requires an integration of climate change information to gauge the extent to which existing infrastructures would remain effective under future climate scenarios. Increases in the severity, frequency, and duration of a drought will put pressure on water agencies to diversify water supply portfolios or construct new infrastructures to boost water production. However, there is also a risk of maladaptation if structures increase climate vulnerability in other systems.

Brekke et al. (2009) provide the federal government’s perspectives on climate change, suggesting that adaptation often requires a partnership between federal, state, and local stakeholders and may take advantage of the existing Integrated Regional Water Management (IRWM) planning process. As climate change information is limited at the local and regional levels, the California Department of Water Resources (2009) offers decision-making approaches, such as Robust Decision Making (RDM), and the decision-scaling model, to build adaptive management capacity. In addition, Hanak & Lund (2008) suggest adaptation options that water managers in California can employ to improve water supply service through demand- and supply-side strategies. All of these options have been used in California in varying degrees.
<table>
<thead>
<tr>
<th>Method</th>
<th>Operational pros and cons</th>
<th>Illustrative cost range ($/acre-foot)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demand and reallocation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water transfers</td>
<td>Pros: Flexible tool for lowering costs of dry-year shortages and enabling long-term reallocation of supplies as economy shifts</td>
<td>50–550</td>
</tr>
<tr>
<td></td>
<td>Cons: Potential economic harm to selling regions</td>
<td></td>
</tr>
<tr>
<td>Agricultural water use efficiency</td>
<td>Pros: Reduces total stream diversions and pumping; enables farmers to raise yields and limit polluted runoff.</td>
<td>145–675 (per acre-foot of net use reduction)</td>
</tr>
<tr>
<td></td>
<td>Cons: May not generate net savings that make water available for other users; net use reductions often require fallowing</td>
<td></td>
</tr>
<tr>
<td>Urban water use efficiency</td>
<td>Pros: Savings can often occur without loss of quality of life; high net savings possible in coastal areas and with landscape changes; some actions also save energy</td>
<td>225–520 (per acre-foot of gross use reduction)</td>
</tr>
<tr>
<td></td>
<td>Cons: Requires implementation by large numbers of consumers; can be especially difficult for outdoor water uses, which depend on behavior as well as technology</td>
<td></td>
</tr>
<tr>
<td><strong>Supply management</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conjunctive use and groundwater storage</td>
<td>Pros: Flexible source of storage, especially for dry years</td>
<td>10–600</td>
</tr>
<tr>
<td></td>
<td>Cons: Slower to recharge and harder to monitor than surface storage</td>
<td></td>
</tr>
<tr>
<td>Recycled municipal water</td>
<td>Pros: Relatively reliable source in urban areas</td>
<td>300–1,300</td>
</tr>
<tr>
<td></td>
<td>Cons: Public resistance can preclude potable reuse</td>
<td></td>
</tr>
<tr>
<td>Surface storage</td>
<td>Pros: Flexible tool for rapid storage and release</td>
<td>340–820+ (state projects)</td>
</tr>
<tr>
<td></td>
<td>Cons: Potential negative environmental impacts; small value of additional storage with a drier climate</td>
<td></td>
</tr>
<tr>
<td>Desalination, brackish</td>
<td>Pros: Can reclaim contaminated groundwater for urban uses</td>
<td>500–900</td>
</tr>
<tr>
<td></td>
<td>Cons: Brine disposal can be costly</td>
<td></td>
</tr>
<tr>
<td>Desalination, seawater</td>
<td>Pros: “Drought-proof” coastal urban supply tool, especially useful in areas with few alternatives</td>
<td>1,000–2,500</td>
</tr>
<tr>
<td></td>
<td>Cons: Potential environmental costs at intakes and for brine disposal; sensitive to energy costs</td>
<td></td>
</tr>
</tbody>
</table>


Notes: Please see Hanak & Lund (2008) for details regarding sources of information. Costs are illustrative and vary widely with local conditions. For conjunctive use, the costs of water for banking may be additional. For most options other than water use efficiency, cost estimates do not include delivery. For water transfers, conjunctive use, and surface storage, cost estimates do not include treatment. For agricultural use efficiency, cost estimates are for subsidies needed to implement measures that are not locally cost-effective and refer only to actions yielding net water savings. Many costs from DWR sources are from studies in the early to mid-2000s and may have increased with inflation. Some figures are rounded.
Part III: Objectives

The objectives of this study are to assess the information needs of local water agencies in the six-county Sacramento region, determine barriers to climate change adaptation, and provide recommendations on how experts and different groups of stakeholders can contribute to overcoming these challenges. The consequences of climate change may not be clearly discernible in some regions but early adaptation will increase the ability to effectively respond to extreme events and minimize costs to the local economy and the environment. Integration of climate change information into planning will limit activities that may irreversibly constrain future adaptation. Given water agencies’ limited resources and capacity in terms of funding, staffing, climate-related knowledge, and expertise, climate change adaptation requires a collaborative effort and support from the local, state, and federal governments. Guidance on how such collaboration can be achieved will help to translate knowledge into action.

Part IV: Scope of Study and Methods

The study was conducted during the period of January – May 2014. It is based on water supply management in six-county Sacramento region, namely, El Dorado, Placer, Sacramento, Sutter, Yolo, and Yuba counties, which is under the service area of the Capital Region Climate Readiness Collaborative, the project client. The report relies on secondary research and interviews with key informants including water managers, planners, and a consultant. The secondary research provides general overview of current water management mechanisms for long term planning and identifies current adaptation efforts or the lack thereof. The materials consulted include agency-level water management plans, the Urban Water Management Plans (UWMPs), and Integrated Regional Water Management Plans (IRWMs), as well as academic literature and policy papers on climate change adaptation concepts, practice, and barriers in the adaptation process. Existing information available online provides background for this report and is used to determine the state of knowledge on climate change both at the state and local levels of governance.

Prior to conducting in-depth interviews, 12 preliminary interviews were conducted with staff in local planning departments to understand the general perception and level of concern of climate change impacts in each county. These interviews also helped to determine the scope of this report and to identify key informants for the second phase of interviews.

Eleven semi-structured interviews were conducted by the author over one month. Six interviews were held in-person and the remainder by phone. A list of interviewees is provided in Appendix I. Interviews began with an explanation of the research, goals, and confidentiality agreement. Prompts for interview questions allowed interviewees to highlight their key understandings and ideas related to water management and climate change.
Additional, more specific questions were prepared in advance and were used selectively depending on responses (see Appendix II). This interview guide allowed for consistency in data collection, while maintaining flexibility for interviewees to address topics of their concern. Each interview took approximately 30 minutes to one hour. Prompts for questions include:

1. What are your agency's existing mechanisms (e.g. tools, collaboration, policies) to respond to different future scenarios of oversupply or shortage of water?
2. How might climate change impact water management in your jurisdiction?
3. What are your agency’s needs (e.g. information, tools, capacity) to better plan and manage water supply under uncertainty?
4. What are some of the challenges you have faced in order to fulfill these needs?

Interview data were transcribed and analyzed after responses have been organized systematically into themes. Keywords with highest frequency were noted. The analysis (Part V) focuses on local agencies’ perception of climate change impacts and their relevance to water management, information needs, and barriers to adaptation.

Part V: Results and Discussions

This section synthesizes and discusses responses from semi-structured interviews with key informants. Within the limited timeframe, none of the planners from Sutter County Water Agency were available for interviews, and their perspectives are omitted from this analysis. Interviews with County planners were used to supplement understanding of local perspectives on climate change. Subsections are divided into five key areas: perceptions of climate change and impacts, existing adaptation strategies, barriers to adaptation, windows of opportunities, and limitations on interpreting results.

Perceptions of Climate Change and its Impacts

Overall, there is a broad recognition of climate change and potential impacts to water management within each interviewee’s jurisdiction. Interviewees, however, have mixed views about the level of threat and relevance to their current operations. Climate change is generally viewed as an “added risk” in planning and management but it is a long term problem that takes time to understand and address.

Among possible impacts to the water sector, the reduction of snowpack and change in seasonality and timing of snowmelt have been identified as the greatest concern. Snowpack plays an important role within the region’s reservoir system, serving as a large reservoir with a flow release mechanism. An increase in temperature and change in the pattern of precipitation will diminish snowfall and threaten the region’s source of freshwater. Changes in the timing and amount of snowmelt brought about by climate change will decrease water availability in the summer and impact water management drastically within the region. This concern is greatest for water agencies that rely solely on surface water or a combination of surface and groundwater.
Other concerns include higher frequency and severity of drought, change in precipitation, and change in timing and quality of river flows. Districts that use groundwater as their only water source have relatively low levels of concern on climate change, as it can take 2-3 drought years to seriously reduce groundwater resources, but they are also seeking to expand surface water access. Although climate change is viewed as a challenge to management, it is perceived as a long-term issue, for which there is still time to plan and prepare. Most water agencies interviewed agree that climate change ultimately translates to concerns over the reliability and availability of water, especially in the summer peak season when the demand for water is highest.

Climate change-induced wildfires have been identified as a serious concern by the El Dorado County Water Agency (EDCWA). The 2013 Rim Fire in the central Sierra Nevada region was the third largest wildfire in California’s history, highlighting potential impacts of climate change, especially for water districts located near the foothills of the Sierra Nevada. The causes of concern are watershed degradation, increase in vegetative growth which provides fuel for larger wildfires, and change in soil chemistry that may cause soil to be nonabsorbent and to repel water. Despite potential impacts on water resources below the watershed, other interviewees do not appear to share the same level of concern as the EDCWA.

Beyond the direct impacts of climate change on water supply, interviewees point out that an overlay of climate change on regulatory policies such as the Delta Plan and the forthcoming Bay-Delta Conservation Plan may seriously impact management within their jurisdictions. They are concerned that climate change will make compliance even more difficult, especially for maintaining water quality and salinity standards. However, there is a divergence in opinion over how sea level rise (SLR) may indirectly affect water management in the Sacramento region if Folsom Dam is required to release water to maintain quality standards. Some interviewees think that this indirect impact could be high with policy stationarity, but others feel that the effects, if any, will be insignificant.

Local vulnerabilities in water supply dominate the discussion on climate change impacts. The recognition of demand-side impacts (e.g., an expanded use of water for urban and agricultural irrigation) seems minimal for most local water agencies interviewed. Part of the reason may be that they do not think these impacts are significant or they are more concerned about how climate change relates to their direct responsibilities. While agencies recognize the potential impacts of climate change, at least qualitatively, they think that there is too much uncertainty regarding the magnitude and timing of the effect, and which specific supply sources would be the most at risk. Interviewees who provide general responses about climate change impacts tend to refer to a “high level of uncertainty” often. They also tend to be less concerned about climate change than interviewees who provide detailed explanations about potential local impacts and who appear more open to discussing climate change issues.

As local water agencies generally feel unsure about the extent of local climate change impacts, they appear less concerned and less willing to alter their plans and operations until impacts become more evident. Water agencies that function as public utilities rather than a
planning organization indicate that they are taking a “conservative and steady approach” as they feel that planning and decision-making to adapt to climate change must be a slow process. In contrast, agencies whose main function is long-term planning show some degree of urgency to start planning for climate change and improving the resilience of the system, but they also acknowledge that the process should be a cautious one as well.

Table 5: Ranking of climate change concerns in Sacramento region’s water management sector

<table>
<thead>
<tr>
<th>Potential impacts**</th>
<th>Level of concern*</th>
<th>Frequency of response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of snowpack</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Change in timing and seasonality of snowmelt</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Drought</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Reduction or change in precipitation</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Change in timing and quality of flows</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Wildfire</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Climate change and policy interactions</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Demand-side impacts</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

* Comparisons among climate change impacts rather than with other priorities

** Flood was not mentioned because the discussion focused on water management

Existing Adaptation Strategies

Local water agencies acknowledge that current planning activities and project implementation are not responding to climate change. Their main focus is on increasing the reliability of water supply and enhancing the flexibility of the system in anticipation of population growth or for emergency preparedness, which may include drought, flood, or terrorist attack\(^4\). Although agencies have not integrated adaptation into planning nor developed strategies to specifically respond to climate change, they are already engaging in climate change adaptation to some extent because strategies, such as water conservation and conjunctive use, ultimately improve the system’s resilience to external shocks. Public utilities that have less diversified water resources have a long term plan to expand surface water rights, secure redundant supply, and pursue conjunctive use or groundwater banking. The City of Davis, in collaboration with the City of Woodland, has successfully acquired water rights from the Sacramento River and established the Woodland-Davis Clean Water Agency (WDCWA), a joint power authority, to implement and oversee regional surface water supply projects. Other efforts to obtain water rights and engage in groundwater banking are being pursued by agencies such as the El Dorado County Water Agency (EDCWA).

\(^4\) Terrorism is not a concern but it has been cited to illustrate that a robust water system should work adequately in times of emergency.
Interviewees also discuss a regional effort within Sacramento County and parts of Placer, El Dorado, and Yolo counties to improve the reliability of water by enhancing system redundancy. The Regional Water Authority (RWA) is commencing a study to assess the efficiency of the distribution systems and interties between water agencies and to test the systems against multiple scenarios of water shortage to reveal key vulnerabilities. The study is part of the RWA’s regional reliability plan. It does not focus on the cause of the shortage but considers what should be done if certain areas cannot access water under an atypical condition. For example, if Folsom Lake loses the ability to supply water to the region, how can local agencies access alternative sources of water and would these sources be sufficient under the assumed conditions? The process of thinking through some of these scenarios has already resulted in new ideas about diversion projects, facilities, and strategies such as water exchange. However, this long term plan is expected to take years to reach an agreement.

In addition to the regional reliability plan, discussions within the water sector have focused on a reoperation of Folsom Dam. Constructed in 1955, the Folsom Dam is operated by the U.S. Bureau of Reclamation to supply water for the Central Valley Project (CVP). The multipurpose dam and reservoir provide flood control, hydroelectricity, drinking water, and agricultural water. To improve dam management, the Army Corps of Engineers is developing a new water control manual that has variable flood control space instead of a fixed, specified storage level. This approach will take into account water availability in the storage upstream, basin wetness, and weather forecast before determining the amount of water to maintain inside the dam. The reoperation of Folsom Dam is an adaptive management, which takes real time conditions, including weather, into consideration. Despite local support of this new approach, there are some concerns over the effectiveness of the forecast-based operations. The reoperation project is currently underway.

Another effort is being pursued by the Water Forum, which is developing a flow standard for the Lower American River. This process has taken over a decade because of regional politics but the Water Forum has begun to investigate a new option called a Carryover Storage Alternative. Instead of draining Folsom reservoir every water year to prevent flooding, the new management approach will allow water to be carried over the water year, which helps to maintain water supply. The option receives support from areas that are more dependent on Folsom reservoir and it may have co-benefits of preventing riverine degradation in a drought year as water can be released to maintain water level and river flow. Although this option has been categorized as a drought-proof strategy, it could be also thought of as a climate change adaptation because it increases the resilience of the system to droughts. On the other hand, this adjustment could make the system more vulnerable to flooding in years of high, early rainfall.

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5 RWA is a joint powers authority that serves and represents the interests of over 20 water providers in the Sacramento County and parts of Placer and El Dorado counties.
6 The Water Forum was created by the City and County of Sacramento to provide platform for solving water conflicts in the region. It comprises of diverse groups of business and agricultural leaders, citizens groups, environmentalists, water managers, and local governments.
7 Water year is a 12-month period from October 1 to September 30 of the following year.
combined with warm winter temperatures as projected by climate change models. Balancing between drought proofing and flood prevention is a challenging task and operational decisions need to rely on the best information available.

Water conservation has been part of many cities and water agencies’ program in the past. The state mandate to reduce 20% of per capita water consumption by 2020 also pushes these efforts forward. These programs have led to a decrease in consumption over time, especially in areas that have minimal urban growth such as the cities of Davis and Citrus Heights. Interestingly, the City of Davis is also aiming to reduce an additional 20% of water use to increase consumption efficiency and put less pressure on water resources. As a result of California’s drought crisis, agencies are encouraging users to cut back on water use voluntarily but the long-term effect of the drought on water conservation is still unclear. Interviewees’ responses have been mixed regarding how the current drought crisis will help to accelerate adaptation action.

Regional collaboration also plays an important role in adaptation planning and enhancing local adaptive capacity. Seeking local partners such as the El Dorado County Water Agency (EDCWA), the Bureau of Reclamation is exploring climate change adaptation measures for the San Joaquin-Sacramento River systems and bringing together local and statewide perspectives relating to Folsom Dam and the Central Valley Project. Research institutions such as the Sierra Nevada Research Institute, the University of California at Merced, and the Stockholm Environment Institute have been referred to several times to provide information support on the impacts of climate change or the development of a better monitoring system. Other efforts include the Placer County Water Agency’s collaboration with Sacramento Municipal Utility District (SMUD), Sacramento Area Flood Control Agency (SAFCA), the U.S. Army Corps of Engineers, and the Bureau of Reclamation to add additional monitoring devices in the American River watershed to improve water level forecasts based on real-time flow conditions. By combining information on existing flows in the major tributaries and snow-level conditions throughout the watershed, agencies can better anticipate runoff in real time to improve flood control in Folsom reservoir and optimize water storage capacity.

Lastly, the integrated regional water management (IRWM) planning process provides another avenue for local agencies to work together on climate change adaptation. Local water agencies are eligible to apply for state funding for IRWM plan and project implementation. The IRWM guidelines require that the region examines climate change impacts, prioritizes regional vulnerabilities, and include a program or methodology to further understand climate impacts and plan for adaptation. Interviewees suggest that IRWM is a useful document to “start” thinking about climate change and adaptation but some feel that the climate change chapter is only informational and does not push agencies to think critically and act.
Summary of existing adaptation strategies identified in the interviews

- Supply expansion and enhancement
  - Purchase or contract surface water rights
  - Well conversion
- Flexible supply system
  - Redundant water supply
  - Conjunctive use or groundwater banking
  - Folsom Dam reoperation (variable water storage level and carryover storage alternative)
- Demand-side management
  - Water conservation program
- Regional collaboration:
  - Integrated Regional Water Management (IRWM)
  - Research
  - Monitoring projects

Given the broad definition of climate adaptation adopted by this report, water agencies have undertaken an adaptation process whether or not climate change was the driver of their actions. This recognition does not imply that local agencies have or have not sufficiently adapted to climate change. As science progresses, agencies can adopt specific tools to help plan and implement better adaptation options. Agencies that are farther along the process in terms of using climate forecast and modeling may be able to respond faster when new information becomes available. On the other hand, agencies that have relatively high water supply flexibility appear to be slowest in adapting to climate change.

Barriers to Adaptation

Knowledge

Climate change lies outside of water managers and engineers’ area of expertise. Agencies mainly rely on the state (e.g. Department of Water Resources: DWR) and federal government for climate change-related information. The state has taken a lead role in climate change issues and provided some directions for local agencies to follow. The majority of past and current efforts have focused on climate change mitigation but adaptation is becoming an issue of concern. A few interviewees also access climate change information from research institutes such as the Sierra Research Institute, the University of California at Merced, RAND Corporation and the Stockholm Environment Institute through project collaboration.

Amongst the organizations interviewed, only the Regional Water Authority (regional planning organization for Sacramento county and part of Placer and El Dorado counties), El
Dorado Irrigation district (EID), and Yuba County Water Agency (YCWA) have employed climate modeling. However, the RWA’s model is relatively simple and has only hydrologic and climate parameters. The EID does not rely very much on their climate model, which was developed in early the 2000s and YCWA is in the process of reviewing their results.

Gaps in knowledge about climate change impacts and how water system can become more adaptive appear to be one of the most significant barriers to adaptation. Interviewees show hesitation and doubt when asked to discuss vulnerabilities and implications for local water management. Some of the responses are as follows:

- “This is getting into my personal speculation in a lot of ways. I think this year is a good indicator [of climate change]”
- “I don’t have a deep understanding here and I’ll be talking almost as a layperson in this regard”
- “Climate change... and again, I’m not familiar with that”
- “[Climate change] is an awfully big issue to take and bite up”
- “The challenge is the enormity of the impacts”
- “I only think about [climate change impacts] because you’re sitting here asking questions”

As mentioned in the Perceptions of Climate Change and its Impacts section, local water agencies think of climate change as a long term issue that adds uncertainties and risks to future operations. They do not have a clear understanding of climate change scenarios in the next 20-30 years and what they need to do now. To some extent, these agencies are still at the stage of understanding and are trying to define the problems posed for their operations (see Part III on Adaptation Framework). However, interviewees also express their need for information to think more critically about climate change and adaptation options, and potentially to guide future decision-making. These information needs range from a broad set of questions on local impacts to specific types of data to aid current and future planning. In addition to climate information, there are suggestions for the research community to evaluate long-term economic models to compare the costs of adaptation strategies against the costs of future catastrophes in a business-as-usual (no adaptation response) scenario. Interviewees also question current modeling efforts that assume policy stationarity in different climate scenarios. For example, the Delta is a large mixing zone of fresh- and sea water. With sea level rise, this mixing zone is bound to change, and it would be unrealistic to maintain the same salinity standard for the Delta area. Most of the water in the reservoir would need to be released to preserve such water quality standard as a result.
### Table 6: Information needs

<table>
<thead>
<tr>
<th>Types of knowledge</th>
<th>Information needs</th>
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<tr>
<td><strong>Climate change modeling and forecasts</strong></td>
<td>Downscaling of climate data to better predict how climate change will manifest locally</td>
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<tr>
<td></td>
<td>Improvements in water modeling and forecasting</td>
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<td></td>
<td>Anticipated precipitation (amount and timing for a particular location)</td>
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<td></td>
<td>Aquifer recharge and recovery</td>
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<td></td>
<td>Policy change (e.g. salinity and water quality standards) under different climate scenarios</td>
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<td></td>
<td>Timing of climate change impacts</td>
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<tr>
<td><strong>Understanding impacts</strong></td>
<td>Cascading effects of climate change-induced wildfire on watershed health and the ability of soil to hold moisture</td>
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<td></td>
<td>Urban heat islands and impacts on water use</td>
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<td></td>
<td>Potential effects from an increase in evapotranspiration rate</td>
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<tr>
<td><strong>Data collection</strong></td>
<td>Information from weather stations and LiDAR</td>
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<td></td>
<td>More accurate data on stream flows and snowpack in the Sierras</td>
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<td></td>
<td>Soil moisture conditions in the watershed (historical and projected)</td>
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<tr>
<td><strong>Adaptation options</strong></td>
<td>Different tools to plan and types of adaptation options available</td>
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<tr>
<td><strong>Economic</strong></td>
<td>Costs of adaptation compared to costs of catastrophes under a business-as-usual scenario</td>
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<tr>
<td></td>
<td>Local economic impacts of climate change (e.g. industries move to other water abundant areas)</td>
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### Funding

The lack of funding is one of the most mentioned barriers to climate change adaptation. Water agencies that function as utility providers earn revenue from the sale of water and, in some districts, electricity. Their operations are thus susceptible to both economic and natural resource shocks. Local water agencies’ actions are responsive to funding opportunities from the state and federal sources. In most cases, these funds only become available during or after the occurrence of extreme events. The attention on IRWM allows many water agencies to work together and apply for state funding but smaller agencies also have to compete with projects from other resource-rich counties. Frequently, these small agencies do not have the capacity to successfully develop applications and secure funds. The lack of resources limits the types of activities that
agencies can engage in and reduces their ability to seek information, integrate climate models into their planning process, and ultimately become more adaptive. A selection of the responses is highlighted below:

- “In most cases, funding becomes responsive to some extreme events”
- “The challenge of water agencies in the operating system is that they have many things to worry about [and] to raise their own money”
- “[For the] IRWMP, now we have to compete with other big projects from other big counties”
- “How can Flood Control and Water Irrigation District earn in this situation? They’re not able to deliver water to their farmers at all. That means very small income from water. They also use that water for hydroelectricity. It’s a big impact on their operation.”
- “Part of the reason we haven’t done modeling is because it’s expensive.”

Human Resource and Institutional Limitations

Specific roles and responsibilities of local water agencies constrain the types of activities that they can engage in. An engineering-based water management tradition has been generally effective in the past. Water engineers who work with historical and real-time data often find it difficult to come to grips with long-term scale of climate impacts. This constraint may be one reason why local agencies emphasize that climate change information must have a sufficient level of certainty before they can start to plan for adaptation. However, they themselves are not in a position to gather data and look more deeply into climate change issues.

More immediate, competing issues such as drought, IRWM, and the Bay-Delta Conservation Plan (BDCP) take attention away from climate change. These issues directly impact water agency operations as they link to revenue generation or funding access. These agencies typically have a 10-20 year operational plan or capital investment plan. It would be difficult to push climate adaptation up the list of priorities, especially when the information about local climate change impacts is still limited. At the same time, agencies with more financial resources and greater flexibility in water supply management also delay adaptation efforts. Institutional inertia or the natural tendency to resist change could be one of the forces at play. According to one response, “water agencies are doing their own planning to make themselves in a good position... [But] water management is self-correcting up to a point and it may require more disasters to change”. Agencies that focus on long-term planning may be more equipped to think about climate change and adaptation. Their capacity is, however, limited by human resources. These agencies often have less than five people working on a number of long-term planning issues and must work with consultants to fulfill this capacity gap.
Political Barrier

Political support is a necessary component to motivate adaptation but climate change remains a contentious issue in certain, rural districts. Water agencies operate under the direction of the elected board members, who must serve their constituents. These water agencies are concerned about how to justify any efforts to adapt based on the grounds of climate change because they feel that it is difficult to prove. Even with available funding from the state or federal government, ratepayers will ultimately bear some costs. Unpopular actions have resulted in political backlash such as past outcry from a water rate increase. This is another reason why the focus is often on water supply enhancement or drought preparedness projects, which are relatively apolitical.

Climate change adaptation implies a fundamental change in how agencies operate. Both internal and external politics can prevent change from taking place. Projects related to long-term investments have taken years to reach fruition, partly because of the politics surrounding water in California. Coupled with the unpopularity of climate change in certain rural regions and its implications on water availability (e.g. for the agricultural sector), there is very little political will to start adaptation planning. Yet if water agencies do not start now, they may not be able to respond effectively to long-term changes in the water supplies. Even in water districts that have consulted climate modeling to inform long-term planning activities, maintaining the political will within the adaptation process continues to be a challenge.

Lack of Leadership

The lack of leadership also links to political and institutional constraints. As climate change is a long term problem, there is little incentive for immediate action as the problem may be inherited by other staff at a later stage. One interviewee jokes, “I’ll be retired by then; it’s somebody else’s problem,” but this point highlights an important sentiment that may be shared by higher level staff at different water agencies. Some other responses include:

- “[climate change] is not something that somebody is beating on a drum to say [adaptation] must be done”
- “We’re not dealing with [climate change] well. We’re not dealing with that at all. I don’t know anybody who is trying to deal with that question. There is no leadership on climate change [at our agency]”

Law and Legal Mandate

Apart from Executive Order S-13-08, which urges state agencies to develop strategies to identify and prepare for expected climate change impacts, there is no legal mandate to require local agencies to adapt to climate change. The IRWM planning process, which requires a climate change assessment, has not translated into local planning for adaptation. When asked why very little or no effort has been made to integrate climate change into high-level plans, interviewees
indicate that they do not know what the state’s direction is, how they would determine potential impacts, and how information could ultimately translate into action. From a public policy perspective, the state has multiple important priorities to address, including crime, education, healthcare, and the economy, among others. What limited attention water issues receive is currently focused on drought, the Delta water tunnel project, and integrated water resources management, where climate change and adaptation have been marginally addressed.

**Windows of Opportunities**

Interviewees recognize some opportunities to work on climate change adaptation through Water Master Plan and other planning updates, which occur approximately every five years. In the past, these updates have been driven by land-use change but they could potentially become more responsive to climate and policy changes. Awareness of climate change impacts has been increasing in recent years, and the state’s new General Plan guidelines (2014) to address climate change mitigation and adaptation may put more pressure on local water agencies to increase their participation in the adaptation process. As one interviewee explains:

“Right now, the information is not firm enough to make a decision on. It’s not to say that you can’t prepare, that you can’t talk about it, that you can’t start incorporating those concepts into your document, so that the conversation continues. But ultimately at some point in time, you say, yes I can make a decision based on everything that we’ve seen and can make a good case in front of your board, whether we need to increase rates or we need to do this or that to be able to generate enough money to do it.”

Interagency collaboration to generate such information would help to bridge understanding of climate change and create more opportunities to accelerate the adaptation process. The IRWM is one platform for interagency and regional cooperation and there are other opportunities for cooperation with research institutes and the state and federal agencies. Through the interviews, information sharing of best practices has been suggested as a key strategy for climate change adaptation as water agencies are quick to respond to information about successful options and investment tools.

The following subsections describe local water agencies’ key plans for water management and explore opportunities for climate change adaptation. The state plays a critical role in increasing local adaptive capacity and providing guidance for adaptation planning. Three key planning documents are available for long-term water resource management: the agency-specific Water Master Plan, Urban Water Management Plan (UWMP), and the Integrated Regional Water Management Plan (IRWMP).
Agency-specific Water Master Plan

The Water Master Plan is a planning tool that water agencies use to assess current and future water supply reliability and demands. It provides a roadmap for the development of future infrastructure and maintenance of existing facilities. These long-term planning documents typically extend for 20 years and may be developed in conjunction with the county or city’s General Plan. The update cycle thus depends on growth and land development. The state does not require local water agencies to create Water Master Plans, although they may be mandated by the local government. These plans may be used in conjunction with other planning documents as discussed below. As water agencies have more flexibility in designing and developing the Water Master Plan, it is less likely that they will consider climate change impacts and adaptation options until they feel the necessity to do so. However, the new General Plan guidelines\(^8\) will require cities and counties to address climate change (OPR, 2014). This progress toward mainstreaming climate change into local plans may trigger relevant agencies to incorporate mitigation and adaptation into their long-term plans. In addition, if more trusted information about impacts in their service area becomes available, it is highly likely that agencies will incorporate it into their planning process. For example, the Stockholm Environment Institute (SEI) under a contract from the National Oceanic and Atmospheric Administration (NOAA) developed a hydrologic and climate change model that was later applied to the El Dorado Irrigation District’s water supply analysis. The District also partnered with researchers from the RAND Corporation to apply new planning tools and approaches that consider growing water needs, potential climatic changes, fire risks, and other challenges. As a result, water supply alternatives were evaluated based on their ability to capture and store seasonal runoff and respond to climate change impacts and a climate change element has been incorporated into the District’s Water Master Plan.

Urban Water Management Plan

Through the California Water Code (Division 6), otherwise known as the Urban Water Management Planning Act, every urban water supplier that provides over 3,000 acre-feet of water annually or serves more than 3,000 or more connections is required to develop its water reliability assessments over a 20-year planning horizon. The assessment must be prepared every five years and submitted to the Department of Water Resources for review. Urban Water Management Plans are usually due on December 31 of years ending in 0 and 5 with a possible 6-month extension period. The most updated version of the UWMPs is from 2010 and new updates are planned for 2015.

State laws and policies are integrated into these plans, which set direction for local agencies’ operations. For example, SB X7-7 (the 2009 Water Conservation Act) requires urban water agencies to reduce per capita water use by 20 percent by December 31, 2020. The Act also

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\(^8\) In drafting process, as of May 3, 2014.
promotes expanded development of sustainable water supplies at the regional level and requires efficient water management practices for agricultural water supplies.

The Department of Water Resources’ 2010 UWMP guidebook does not require local agencies to address climate change impacts on water supplies but urges urban water providers to consider these impacts, which “are very likely to intensify within the 20-year UWMP planning horizon” (DWR, 2011). Similar to the Water Master Plan, the Urban Water Management planning process provides another opportunity to incorporate climate change considerations into the selection of project alternatives to increase overall system resilience. A summary of existing UWMPs in the Sacramento region is included in Appendix IV. Among the 18 UWMPs reviewed, four discuss climate change in a general way, one focuses on local impacts and management strategies, and the rest have not considered climate change or do not anticipate that climate change will affect local resources. However, a number of strategies to improve system reliability have been identified in the UWMPs, including conjunctive use, water conservation target, recycled water, new well development, and Sacramento River diversion. In order to adapt better to climate change, these strategies require further analysis to test their ability to respond to different future climate scenarios.

**Integrated Regional Water Management**

In 2002, the state passed the Integrated Regional Water Management Planning Act (SB 1672) to establish a regional collaboration to manage all aspects of water resources for a particular region or watershed. The amendment of the IRWM Planning Act in 2008 strengthened the development process of IRWMPs and improved the bond funding mechanism (Spanos, 2012). The Department of Water Resources also published a white paper on climate change adaptation strategies that year, identifying the IRWMP as the basis for broader community climate change adaptation (DWR, 2008). Through Propositions 50 and 84, the state released funding for IRWM efforts and provided new guidelines for developing IRWMPs, which require a minimum of a 20-year planning horizon, a five-year update, and inclusion of a climate change element that discusses adaptation and mitigation responses.

In the latest 2012 guideline, the climate change element in the IRWMP must include:

1. A discussion of the potential effects of climate change on the IRWM region, including an evaluation of the IRWM region’s vulnerabilities to the effects of climate change and potential adaptation responses. The evaluation must at least be equivalent to the vulnerability assessment in the Climate Change Handbook for Regional Water Planning 2011.
2. A selection process of project alternatives that considers greenhouse gas emissions.
3. A list of prioritized vulnerabilities based on a vulnerability assessment and the IRWM’s decision making process.
4. A plan, program, or methodology for data gathering and analysis of the prioritized vulnerabilities.
In addition, the guideline provides a direction for the steps that regional water management groups (RWMGs) should take to integrate adaptation into the existing planning process, including resource management strategies, project review process, relationship to local water planning and local land use planning, plan performance and monitoring, and coordination between member agencies. The IRWMP allows involved parties to develop projects in response to the prioritized climate change risks and access IRWM-eligible funding. Opportunities also exist for local water agencies to take the IRWMP’s regional-level climate change information and examine vulnerabilities locally. The IRWM guideline is being updated but the current 2014 draft does not have any changes in the climate change element.

Other Adaptation Efforts

In 2009, the State of California adopted a State-wide Adaptation Strategy and developed a set of guiding principles for climate adaptation in water resource management. The state’s resource management agencies took the lead in identifying sector-specific strategies, some of which may be adopted locally. The state is currently developing an update to this strategy document. More recently, the Governor’s 2014 California Water Action Plan suggests pursuing water projects that “plan for Climate Change” while “achieving multiple benefits”. Ten action items were recommended to achieve the goals of reliability, restoration, and resilience. Actions that relate to water supply reliability and resilient systems include (1) make conservation a California way of life; (2) increase regional self-reliance and integrated water resources management across all levels of government; (3) manage and prepare for dry periods; (4) expand water storage capacity and improve groundwater management; (5) increase operational and regulatory efficiency; and (6) identify sustainable and integrated financing opportunities. Although the Water Action Plan applies to state agencies rather than local players, it recognizes the significance of partnerships between federal, state, local, and tribal governments and sets a direction that will influence local water agencies’ decisions to integrate adaptation into their current operations.

Limitations on Interpreting Results

The results from the interviews should be interpreted with care as they represent the views and perspectives of individuals within a complex institutional framework and objectives. Responses have been analyzed overall to understand the water sector’s approach to climate change but the level of interest and concern may vary widely across geographic and institutional settings, position within the organization, and exposure to climate change information. The results are snapshots of water agencies’ views and may not fully capture the heterogeneity of opinions and needs within the Sacramento region. In addition, the timing of the interviews coincided with California’s drought crisis. Interviewees were under pressure to respond to this immediate problem and may not be prepared to address long-term impacts of climate change.
Part VI: Conclusion and Recommendations

Overall, local water agencies in the six-county Sacramento region are working toward insuring the future reliability of water through water agreements, improved flexibility of the supply system, and demand-side management. To some extent, they are building more resilience into their systems by diversifying water supply portfolio and improving management practices. Because the planning horizon for new developments, water rights purchase, or other contracts can take up to a decade or more (Adger et al., 2005; Hanemann, 2012), early incorporation of climate adaptation can prevent practices that will increase future climate change vulnerability. Current efforts may not be sufficient to adapt to new conditions of a changing climate and growing pressures from population growth, environmental degradation, and regulations. Planned adaptation to avoid maladaptive responses (e.g., surface water storage that changes the flow regime and increases the risk of water shortage in downstream areas) can minimize economic, social, and environmental costs of climate change-induced disasters. Local water agencies need clear policy directions and incentives to implement on-the-ground solutions to these challenges. At the same time, this report has identified knowledge gaps as one of the most important barriers to climate change adaptation. The scientific community plays a critical role in providing reliable and unbiased information that increases incentives to accelerate adaptation practices, given that a delayed response may be very costly compared to planned adaptation or a no-regrets approach. Water agencies need guidance on what they should plan for. Research priorities should be determined by the scope of research impact, likelihood to accelerate action (e.g., fits planning timeline), political support, and availability of funding (details of some funding opportunities are provided in Appendix III).

The following research areas are recommended to support adaptation in water resource management at the local level:

Downscaled climate change impacts at the level of the watershed and local supply
To water managers, the present state of knowledge about localized climate change impacts has a high degree of uncertainty, and information is available at a coarse scale. The need for watershed-level analysis that can be translated into the impacts on the local water supply has been around for decades (see Waggoner, 1990; Gleick et al., 2000) but attempts at downscaling still do not provide sufficient level of reliability that allows planners to determine an appropriate course of action. The timing of impacts is exceedingly critical to decisions to plan new infrastructure or engage in other adaptation options. It may be technically infeasible to produce such information at this time. However, climate change modeling efforts that aim to inform adaptation practices in the water sector should focus on a shorter timeframe (e.g., 20-30 years) to imitate the same planning timescale of water agencies. Projections, thus far, evaluate impacts up to the end of the century to motivate mitigation efforts, but adaptation requires more precise estimates that fit into the local context and water management needs. This information includes
the timing and variability of rain and snowfall. Much of the interest is also in how climate change will impact hydrologic parameters (e.g., flows, evapotranspiration rate, and soil moisture) and the implications for watershed and local supplies. Downscaled climate change scenarios may be simplifications of reality but modeling exercises should take into account policy change and relevant regulatory standards such as salinity level. The strengths and weaknesses of various models should be communicated clearly to determine relevance and suitability for the local context.

**Impacts of climate change on groundwater**

Much of the Sacramento region is located within a groundwater basin that serves as a primary water source for a number of growing cities. Groundwater resources have proven to be quite reliable during past drought periods and the conjunctive use approach has been successful in conserving groundwater for dry years and in optimizing water demand and supply balance. However, there is very little understanding of how climate change may impact these groundwater-dependent regions. As dry periods become longer and more frequent due to climate change, it is unclear how groundwater recharge will be affected. In addition, the Sacramento region may lie further inland, but sea level rise may potentially lead to saltwater intrusion into deep aquifers. Opportunities exist for collaboration with local groundwater agencies, and funding for these types of studies is available through the California Department of Water Resources.

**Economic analysis of climate change adaptation**

Climate change will increase the frequency and severity of natural disasters, which have negative short-run impacts on the local economy. Delayed adaptation will result in high economic loss, especially for water agencies that are financially reliant on the sale of water, electricity, and other water-related services. Comprehensive estimates of adaptation costs and benefits are currently limited. The comparison of the costs of delayed response and implementation of adaptation options may increase an agency’s incentives to undertake an adaptation process. The economic analysis should investigate different adaptation strategies and possible co-benefits under multiple climate change scenarios. The study may also consider water needs by industrial and agricultural sectors, short-term loss if those needs are unmet, and long-term implications on sector development in a region that lacks water reliability. At the same time, social and environmental externalities from adaptation options (e.g., reservoir construction to increase surface water storage can change river hydrology and affect natural habitats) should be taken into account. An economic analysis ranks high in potential research impact and likelihood to accelerate adaptation. It may garner support from water-intensive sectors but public funding resources appear to be limited.

Large quantities of climate change information already exist but disconnect between science and practice continues to be a barrier to adaptation (Kiem & Austin, 2013). Information should be at a locally relevant scale while uncertainties should be characterized and
communicated clearly. Attention should also be given to improving data collection methods as the robustness of climate modeling and subsequent analyses depends on high quality data that is valid, complete, accurate, and consistent. Researchers need to work with local authorities to ensure practical use of climate change information and direct technology transfer. Ford et al. (2013) suggest that more science does not necessarily lead to better decision-making. However, the usability of science should be enhanced through a collaborative process that allows decision makers and experts to own the problem, set common goals, and integrate their perspectives into research design (Ford et al., 2013; Dilling & Lemos, 2011). This collaboration can also help to reduce gaps in capacity at the agency level. Key features of usable science include (1) pertinence or the degree of relevance of research to decision makers’ own operations; (2) quality or the extent to which research is trusted and valued by decision makers; and (3) timeliness or the extent to which the information will be available in time for decision making (Ford et al., 2013). Knowledge that draws on collaborative research experience will increase inside knowledge of the system and the likelihood of informing policy and decision-making (Serrao-Neumann et al., 2013).

As adaptation will eventually occur in response to changes, the key is how well organized the process will be, how costly the responses are, and how effective and comprehensive adaptation is in offsetting negative impacts (Hanemann et al., 2012). There are differing views on the pace of adaptation and where to focus adaptation efforts (for example, see Adger et al., 2007, on marginal changes and Hanemann et al., 2012, on early reform of California water rights). This report takes on the view that adaptation should be context-based, and transformative adaptation should be pursued when projected incremental changes are insufficient to avoid the high costs of climate change impacts. The current challenge in the Sacramento region’s water sector is how to build interest in climate change adaptation and to mainstream it into the planning process. Knowledge alone does not lead to action and collaboration may not occur unless common interests are identified. It is also important to address other barriers to adaptation as discussed in the previous section. Water agencies and stakeholders must undergo a political process to establish a shared vision, negotiate costs and benefits, overcome cognitive challenges, build internal capacity, and reach an agreed outcome. Targeting various groups of stakeholders, recommended strategies to engage local water agencies in climate change adaptation are described below.

Note: brackets indicate activities that can be achieved in the short term [ST] or less than 5 years, medium term [MT] or 5-10 years, and long term [LT] or more than 10 years.

<table>
<thead>
<tr>
<th>Actors</th>
<th>Strategies</th>
</tr>
</thead>
</table>
| General (e.g. adaptation leaders) | • Create the right incentives to increase local buy-in into climate change adaptation by determining a broad set of benefits from adaptation strategies and deciding how risks will be shared [ST]  
• Identify existing mechanisms that can support adaptation action (e.g. capital investment plans) and determine what institutional arrangement best fit into |
existing structure. These arrangements may involve information brokers, collaborative group processes, embedded capacity (training), boundary organizations (consultants), and knowledge networks [ST]

- Determine shared goals and perceived needs to respond to climate change.
- Increase the urgency to start adaptation planning by highlighting the costs of inaction or delay and engage in education and training programs to improve understanding about climate change and impacts [ST]
- Build trust and relationships with stakeholders by creating transparency in the decision-making process and sharing risks and responsibilities [ST,MT,LT]

**Local water agencies**

- Pursue a cost-effective approach to secure future water reliability and consider no-regrets strategies that have benefits beyond climate change adaptation [ST]
- Increase adaptive capacity (e.g., build awareness of potential impacts) [ST, MT, LT]
- Consider context-based approach to managing uncertainties (e.g., Robust Decision Making, see Groves et al., 2013; vulnerability and robust response, see Weaver et al., 2013; decision scaling, see Brown, 2010) [ST]

**Local government (city- and county-level)**

- Integrate adaptation into Climate Action Plans and apply an integrated approach to addressing impacts in various sectors (e.g., water, emergency response, agriculture, and city planning) [ST,MT,LT]
- Provide policy and funding support for local water agencies to integrate climate change considerations into planning [ST,MT,LT]
- Facilitate knowledge exchange and collaboration between stakeholders [ST,MT,LT]

**Scientific community**

- Provide support to local players to increase adaptive capacity (e.g., communicate climate change information in an appropriate format) [ST]
- Build trust and relationships with local agencies by communicating uncertainties, jointly producing knowledge, and providing open access to information [ST, MT]
- Align research priorities with local needs [ST]
- Estimate economic costs of adaptation options vs. delayed response [ST]
- Improve knowledge of the consequences of climate change on groundwater resources [ST,MT]
- Increase accuracy and certainty of downscaled climate change impacts [MT, LT]

**State and federal government**

- Provide clear policy direction for climate change adaptation [ST]
- Encourage adaptation at the local level [ST]
- Make funding available for adaptation planning and implementation [ST]
- Establish a legal mandate for local agencies to assess and prioritize climate change impacts and create an adaptation plan [ST,MT]
- Reform the water rights system, as climate change will disproportionately disadvantage water rights holder [MT,LT]
References


## Appendices

### Appendix I: Information of Interview Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brian Keating</td>
<td>Placer County Flood Management and Water Conservation District</td>
<td>District Manager</td>
</tr>
<tr>
<td>David Eggerton*</td>
<td>El Dorado County Water Agency</td>
<td>General Manager</td>
</tr>
<tr>
<td>Darrell Eck*</td>
<td>Sacramento County Water Agency</td>
<td>Senior Civil Engineer</td>
</tr>
<tr>
<td>Dianna Jensen*</td>
<td>City of Davis, Water Division</td>
<td>Principal Civil Engineer</td>
</tr>
<tr>
<td>Donna Gentile*</td>
<td>Water Resources Association of Yolo County</td>
<td>Administrative Coordinator</td>
</tr>
<tr>
<td>Edmund Sullivan</td>
<td>Placer County, Planning Department</td>
<td>Senior Planner (Natural Resources)</td>
</tr>
<tr>
<td>Einar Maisch*</td>
<td>Placer County Water Agency</td>
<td>Director of Strategic Affairs</td>
</tr>
<tr>
<td>George Booth</td>
<td>Sacramento County Water Resources Department</td>
<td>Senior Civil Engineer</td>
</tr>
<tr>
<td>Jim Abercrombie*</td>
<td>El Dorado Irrigation District</td>
<td>General Manager</td>
</tr>
<tr>
<td>Lisa Bay*</td>
<td></td>
<td>Consultant – Yuba County IRWMP, climate change chapter</td>
</tr>
<tr>
<td>Max Stevenson</td>
<td>Yolo County Flood Management and Water Conservation District</td>
<td>General Manager - Resources</td>
</tr>
<tr>
<td>Robert Swartz*</td>
<td>Regional Water Authority</td>
<td>Principal Project Manager</td>
</tr>
<tr>
<td>Scott Matyac*</td>
<td>Yuba County Water Agency</td>
<td>Water Resources Manager</td>
</tr>
<tr>
<td>Steve Geiger</td>
<td>Sutter County, Planning Services</td>
<td>Senior Planner</td>
</tr>
<tr>
<td>Terrance Davis*</td>
<td>City of Sacramento, Department of Utilities</td>
<td>Program Manager</td>
</tr>
<tr>
<td>Tom Gohring*</td>
<td>Water Forum</td>
<td>Executive Director</td>
</tr>
<tr>
<td>Wendy Hartman</td>
<td>Yuba County</td>
<td>Planning Director</td>
</tr>
</tbody>
</table>

* recorded interviews
Appendix II: Sample Interview Questions

Introduction

The purpose of this research is to assess existing mechanisms and identify stakeholders’ needs for information and expertise to improve water management in the context of climate change. Responses will be analyzed overall and your responses will be kept confidential, unless permission is granted. The interview will be recorded for the sole purpose of data collection and analysis. Findings from this assessment will be available in May 2014 and will be used to inform and enhance the Capital Region Climate Readiness Collaborative’s work on climate adaptation in the Sacramento region. Do you have any questions before I begin?

1. What are your agency’s existing mechanisms (e.g. tools, collaboration, policies) to respond to different future scenarios of oversupply or shortage of water?
   a. Is there a mechanism for ensuring coordination, information exchange, and effective policy implementation? Please explain
   b. How effective has inter-agency or regional collaboration been?
   c. What are some tools that your agency is using to aid decision making? (e.g. modeling, GIS, etc.)
      i. Is your agency planning to expand this technical capacity?

2. How might climate change impact water management in your jurisdiction?
   a. What are key vulnerabilities in your jurisdiction?
   b. What is the level of concern?
   c. How have these concerns been addressed?
   d. Has political commitment and support for climate adaptation been demonstrated? How so?
   e. What triggered these responses?

3. What are your agencies’ needs (e.g. information, tools, capacity) to better plan and manage water supply under uncertainty?
   a. What has already been/is being done to increase the understanding of climate change impacts on water resources?
   b. Who/where do you look to in order to gain more understanding? [identify sources of information]
   c. **Probing question on what they have or have not done and why** (e.g. policies, strategies, projects, collaboration with other organizations)
   d. What type of information has been/is being collected, discussed, or used to plan for adaptation? [probe to identify types of sources of information and who was involved in data collection]
   e. What additional capacity (resources) and/or expertise do you need to develop plans to prepare for these uncertainties?
4. What are some of the challenges you have faced in order to fulfill these needs?
   a. What do you see as the main gaps that hinder your agency from [start planning for adaptation, preparing strategies, implementing]? For example, the interest of the agency, financial constraints, political considerations, lack of leadership?
   b. How do you think these gaps can be overcome? [e.g. knowledge sharing, partnerships, change in leadership, etc.] What do you think are some strategies to accelerate adaptation efforts?
   c. What do you see as the biggest challenges as you continue through this process of adaptation or in dealing with the impacts of climate change?

**Closing.** Is there anything else we might have missed that you would like to add (about the adaptation process in your jurisdiction)?
Appendix III: Possible Sources of Funding

- Groundwater related financial assistance programs
  - The Department of Water Resources provides grant funds and low-interest loans for local groundwater management and monitoring programs. Local Groundwater Assistance Act of 2000 (AB 303) provide funding for local agencies to manage groundwater resources effectively. Eligible projects include groundwater studies, groundwater monitoring, and groundwater basin management. Proposition 13 Groundwater storage/recharge program authorized DWR to provide grants for feasibility studies and construction projects to facilitate conjunctive management of surface water and groundwater to improve supply reliability. A total of $200 million was authorized by Groundwater Storage Program. The sum of $30 million was authorized for Groundwater Recharge Program.
  - DWR’s funding information: http://www.dwr.water.ca.gov/nav/nav.cfm?loc=t&id=103
  - Applicants must be local public agencies with authority to manage groundwater resources

- U.S. Bureau of Reclamation supports Climate Change Variability (CCV) projects under the Science and Technology program. CCV is part of the Bureau’s program priorities. Research on long-term climate change impacts, short-term climate variability from floods to droughts, developing data, tools, and training resources and scoping efforts. Research advances the Bureau of Reclamation and community capabilities in climate change preparedness. Since 2011, the Science and Technology Program has provided 1.5 to 2 million dollars annually for Climate Change and Variability research and projects. Annual call for proposals is from April to June. http://www.usbr.gov/research/programs/science-technology/process.cfm
  - Other partnering opportunities http://www.usbr.gov/research/partnering/index.cfm

- The NOAA’s Climate Program Office provides grants for climate and atmospheric research. Topics include data sets and indicators, research to advance understanding, monitoring, and prediction of drought, climate extreme event preparedness, and planning and adaptation. http://cpo.noaa.gov/GrantsandProjects.aspx

- Environmental Protection Agency (EPA) provides funding opportunities through the Science to Achieve Results (STAR) program for water and watersheds research. Request for application opens every summer. http://epa.gov/ncer/rfa/
Appendix IV: Urban Water Master Plans (Climate Change and Adaptation)

<table>
<thead>
<tr>
<th>County</th>
<th>Organization</th>
<th>Date published</th>
<th>Climate change element</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>El Dorado</td>
<td>El Dorado Irrigation District</td>
<td>Jul-11</td>
<td>Y</td>
<td>For planning purposes, in conjunction with EDCWA and neighboring water purveyors, the EID developed a regional drought model that simulates district system response under dry year conditions, output shortfall, and incorporates switches to integrate potential water supply projects, potential demand cutbacks, and climate change factors. As part of the plan update process, the EID partnered with researchers from RAND Corporation and Stockholm Environment Institute (SEI) to apply new planning tools and approaches for accommodating growing water supply needs, potential climatic changes, fire risk and other challenges. However, future supply projections assume persistence of normal rainfall patterns and stable water quality characteristics based on past observations and moderate promulgation of water quality regulations (pp. 5-7).</td>
</tr>
<tr>
<td></td>
<td>South Tahoe Public Utility District</td>
<td>Jul-11</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Placer</td>
<td>Placer County Water Agency</td>
<td>Jun-11</td>
<td>N</td>
<td>The plan indicates that the City would consider water transfer opportunities in the context of improving dry year reliability and climate change may have some effects on current and future resources.</td>
</tr>
<tr>
<td></td>
<td>City of Lincoln</td>
<td>Jul-11</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td></td>
<td>City of Roseville</td>
<td>Aug-11</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Sacramento</td>
<td>Sacramento County Water Agency</td>
<td>Jul-11</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td></td>
<td>California American Water, Sacramento District</td>
<td>Oct-11</td>
<td>Y</td>
<td>The organization considers an adaptive management process to prepare for climate change uncertainties, although it is unclear the extent to which adaptive management has been practiced.</td>
</tr>
<tr>
<td></td>
<td>City of Galt</td>
<td>May-13</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elk Grove Water District</td>
<td>Jun-11</td>
<td>N</td>
<td>The plan notes that climate is subject to a great deal of debate and is not addressed in this UWMP. In anticipation of new information becoming available within the next five years, EGWD expects to discuss the topic in its 2015 UWMP.</td>
</tr>
<tr>
<td></td>
<td>Sacramento Suburban Water District</td>
<td>Jul-11</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>City of Sacramento, Department of Utilities</td>
<td>Oct-11</td>
<td>Y</td>
<td>Strategies for climate adaptation were driven by GHG emissions reduction and to achieve co-benefits of becoming more resilient. Strategies in Phase 1 focus on water conservation (e.g. water pumping efficiency measures and system optimization, low-maintenance/drought-tolerant landscaping at city facilities, centralized weather-sensitive irrigation systems at golf courses and other city facilities, watering reductions in city parks). Phase 2 considers community-wide GHGs reduction and adaptation strategies related to water supply management and conservation. Currently, the city implements projects as indicated by the Water Forum Agreement and the CA Urban Water Conservation Council (CUWCC), which include water metering, automated infrastructure and pricing, water conservation ordinance enforcement, incentive and rebate programs, public education and information campaign, conjunctive use program to utilize more groundwater to supply demand in drier years and more surface water in wetter years.</td>
<td></td>
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</tr>
<tr>
<td>Citrus Heights Water District</td>
<td>Jun-11</td>
<td>N</td>
<td>The city considers water transfers and exchanges to improve dry year reliability. However, based on future water demand requirements, the City of Folsom does not anticipate that climate change will affect current and proposed water supplies. Determining the exact implications of climate change at this time is speculative. None of the climate change impacts are currently foreseeable but it will assess trends in snowpack, runoff patterns, and consumer use.</td>
<td></td>
</tr>
<tr>
<td>City of Folsom</td>
<td>Jun-11</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sutter</td>
<td>Yuba City</td>
<td>Jun-11</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>City of Davis</td>
<td>Jul-11</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>City of West Sacramento</td>
<td>Oct-11</td>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yolo</td>
<td>City of Woodland</td>
<td>Jul-11</td>
<td>Y</td>
<td>Climate change is addressed in a general way, noting many potential interconnections as well as serious effects on water supply reliability. The city will continue to include adaptive management principals in water supply and infrastructure planning.</td>
</tr>
<tr>
<td>Yuba</td>
<td>California Water Service Company, Marysville District</td>
<td>Jun-11</td>
<td>Y</td>
<td>The company intends to prepare a Climate Assessment Report in 2013 that will examine regional impacts on water supply for each of its 24 service areas. They will review any supply changes that may occur due to climate change and outline mitigation and adaptation methods.</td>
</tr>
</tbody>
</table>
## Appendix V: Integrated Regional Water Management Plans (Climate Change Element)

<table>
<thead>
<tr>
<th>Name of IRWMP</th>
<th>Members</th>
<th>Date published</th>
<th>Comments on climate change element</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Water Basin IRWMP (ARB IRWMP)</td>
<td>Sacramento, Placer, and El Dorado Counties</td>
<td>2013</td>
<td>The plan provides a vulnerability checklist for climate change impacts and includes quantitative analysis of climate change impacts using a number of models and modeling techniques such as the Global model (MPI-ECHAMS), regional downscaling, rainfall-runoff modeling, impact analysis, and local integrated hydrologic modeling. However, it is unclear how this information will be used to increase local capacity for adaptive management or address climate change.</td>
</tr>
<tr>
<td>Cosumnes, American, Bear, Yuba IRWMP (CABY IRWMP)</td>
<td>EDCWA, EID, PCWA, NID, as well as conservation groups, city and county agencies, tribes, regional entities, watershed groups, and recreation</td>
<td>2013</td>
<td>The plan addresses climate change by employing adaptive management and other strategies. IRWM uses Robust Decision Making approach (RDM) in the development of goals and objectives.</td>
</tr>
<tr>
<td>Northern Sacramento Valley IRWMP (NSV IRWMP)</td>
<td>Sutter, Butte, Colusa, Glenn, Shasta, Tehama counties</td>
<td>2014</td>
<td>The NSV region encompasses a large rural area with few prominent population centers. Almost all urban areas are supplied solely with groundwater. Rural residential needs are met by groundwater. Also, the region has high water rights priority for its surface water supplies. NSV members are compelled to rely on federal and State operators to offset potential impacts of climate change. The plan indicates that “given uncertainty of climate change models, the effectiveness of the resource management strategies in mitigating impacts may not be known for decades” (Ch. 4, pp. 5).</td>
</tr>
<tr>
<td>Westside IRWMP</td>
<td>Yolo, Lake, Napa, Solano, Colusa counties</td>
<td>2013</td>
<td>The plan identifies the need to increase understanding of climate change and its impacts on supply, quantity, and flood control. It gives more focus on climate change mitigation and indicates opportunities in the Bear Creek watershed project to supply energy from various sources and reduce GHG emissions.</td>
</tr>
<tr>
<td>Yolo County IRWMP</td>
<td>Yolo County and local agencies/purveyors</td>
<td>2007</td>
<td>There is no climate change element. Its 2011 update focuses on the implementation of projects in the priority list. Yolo county now participates in the Westside IRWMP and may shift their efforts to regional management.</td>
</tr>
<tr>
<td>Yuba County IRWMP (draft update)</td>
<td>Yuba County and local agencies/purveyors</td>
<td>2014</td>
<td>The county is in the process of updating and reviewing this document. The draft IRWMP applies the Robust Decision Making approach, prioritizes strategies that perform well across these scenarios, and allows for adaptive strategies for changing conditions. WEAP model is employed to determine future water resources and rich visualization of possible future are created using Tableau, a business intelligence and analytics.</td>
</tr>
</tbody>
</table>

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## Appendix VI: Relevant Legislature and Plans

<table>
<thead>
<tr>
<th>Year</th>
<th>Name</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>AB 1493: Clean Car Standards</td>
<td>Directing the California Air Resources Board to develop standards to achieve the maximum feasible and cost-effective reduction of GHGs from motor vehicles.</td>
</tr>
<tr>
<td>2002</td>
<td>California Climate Action Registry</td>
<td>Procedures and protocols for project reporting carbon sequestration in forests.</td>
</tr>
<tr>
<td>2002</td>
<td>Integrated Regional Water Management Act</td>
<td>Law to encourage local agencies to work cooperatively to manage local and imported water supplies.</td>
</tr>
<tr>
<td>2002</td>
<td>Proposition 50 (the Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002)</td>
<td>Provides $500 million dollars to fund competitive grants for projects under IRWM.</td>
</tr>
<tr>
<td>2002</td>
<td>Proposition 84 (the Safe Drinking Water, Water Quality, and Supply, Flood Control, River and Coastal Protection Bond Act)</td>
<td>Provides one billion dollars for IRWM planning and implementation.</td>
</tr>
<tr>
<td>2006</td>
<td>AB 32: Global Warming Solutions Act</td>
<td>California’s GHGs emissions cap at 1990 levels by 2020 and mandatory reporting system to monitor compliance.</td>
</tr>
<tr>
<td>2006</td>
<td>SB 107</td>
<td>Requires PG&amp;E, Southern California Edison, and San Diego Gas &amp; Electric to produce at least 20% of electricity using renewable sources by 2010.</td>
</tr>
<tr>
<td>2007</td>
<td>AB 162</td>
<td>Requires flood hazard information to be included in local general plans.</td>
</tr>
<tr>
<td>2008</td>
<td>Executive Order S-13-08</td>
<td>Calls on state agencies to develop California’s strategy to identify and prepare for expected climate impacts.</td>
</tr>
<tr>
<td>2009</td>
<td>SB X7-7</td>
<td>Requires 20% reduction in urban per capita water use in California by 2020.</td>
</tr>
<tr>
<td>2009</td>
<td>California Water Plan</td>
<td>Central to this plan is the full implementation of the Integrated Regional Water Management (IRWM) plans that address regional management practices. It plans to evaluate and provide comprehensive, economical and sustainable water use strategy at the watershed level.</td>
</tr>
<tr>
<td>2009</td>
<td>California Climate Adaptation Strategy (CAS)</td>
<td>The document sets guiding principles for adaptation: (1) use of best available science; (2) understand that data continues to be collected and that knowledge about climate change is still evolving. As such, an effective adaptation strategy is “living” and will itself be adapted to account for new science; (3) involve all relevant stakeholders in identifying, reviewing, and refining the state’s adaptation strategy; (4) establish and retain strong partnerships with federal, state, and local governments, tribes, private business and landowners, and non-governmental organizations to develop and implement adaptation strategy recommendations over time; (5) give priority to adaptation strategies that initiate, foster, and enhance existing efforts that improve economic and social well-being, public safety, and security, public health, environmental justice, species and habitat protection, and</td>
</tr>
<tr>
<td>Year</td>
<td>Plan/Update</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>2014</td>
<td>General Plan Guideline Update</td>
<td>The update provides guidance to cities and counties in the preparation of their local general plans. It now requires an inclusion of a climate change element but details about this update is not yet available.</td>
</tr>
<tr>
<td>2014</td>
<td>California Water Action Plan</td>
<td>The Plan was developed to meet three broad objectives of more reliable water supplies, restoration of important species and habitat, and a more resilient, sustainably managed water resources system that can better withstand pressures in the coming decades. Actions include (1) make conservation a California way of life; (2) increase regional self-reliance and integrated water management across all levels of government; (3) achieve the co-equal goals for the Delta; (4) protect and restore important ecosystems; (5) management and prepare for dry periods; (6) expand water storage capacity and improve groundwater management; (7) provide safe water for all communities; (8) increase flood protection; (9) increase operational and regulatory efficiency; and (10) identify sustainable and integrated financing opportunities.</td>
</tr>
</tbody>
</table>