RECLAMATION

Managing Water in the West

SECURE Water Act Section 9503(c)—Reclamation Climate Change and Water 2016

Chapter 1: West-Wide Overview

U.S. Department of the Interior
Bureau of Reclamation

March 2016

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

On Cover: Map of the 17 Western States showing locations and typical scenes representing the eight major Reclamation river basins listed in the SECURE Water Act.

SECURE Water Act Section 9503(c), 2016 Report to Congress

Chapter 1: West-Wide Overview

Prepared for

United States Congress

Prepared by

U.S. Department of the Interior
Bureau of Reclamation

U.S. Department of the Interior
Bureau of Reclamation
Policy and Administration
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Acronyms and Abbreviations

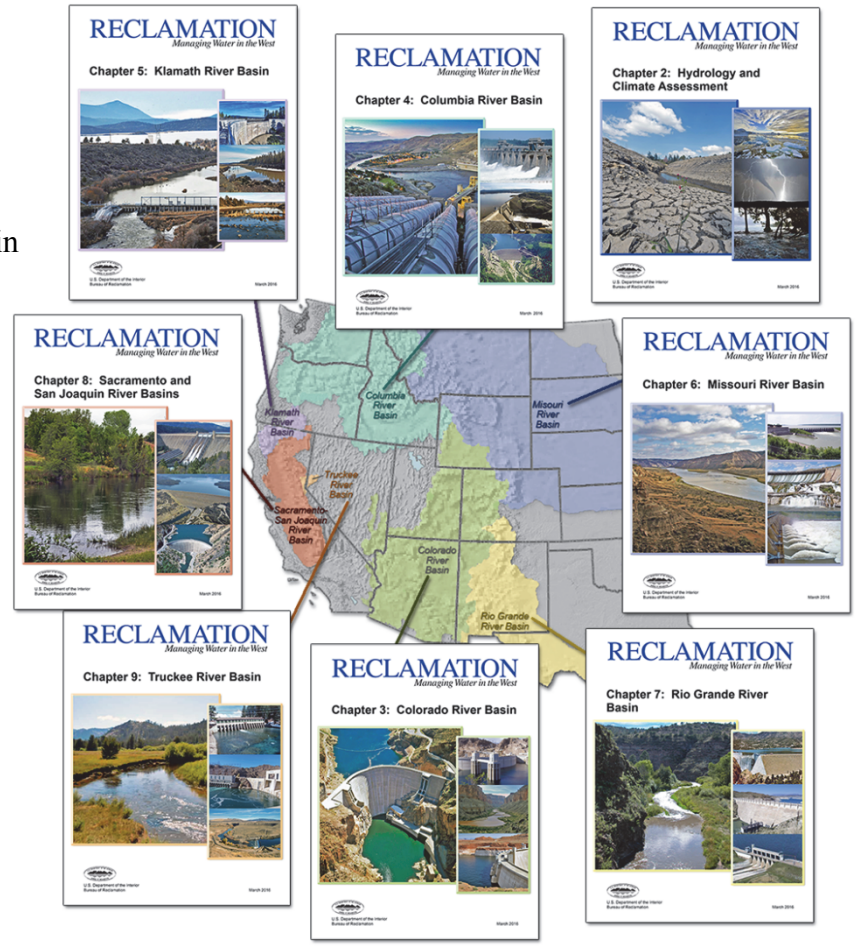
°C	degrees Celsius
BGNDRF	Brackish Groundwater National Desalination Research Facility
CCAWWG	Climate Change and Water Working Group
CMIP	Coupled Model Intercomparison Project
DOE	Department of Energy
DOI	Department of the Interior
DWPR	Desalination and Water Purification Research
LCC	Landscape Conservation Cooperatives
NOAA	National Oceanic and Atmospheric Survey
Reclamation	Bureau of Reclamation
Title XVI	Title XVI Water Reclamation and Reuse Program
U.S.	United States
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WaDE	Western Data Exchange
WaterSMART	Sustain and Manage America's Resources for Tomorrow
WCRP	World Climate Research Program
WestFAST	Western Federal Agency Support Team
WSWC	Western States Water Council
WWCRA	West-Wide Climate Risk Assessment

About this Chapter

This overview chapter is part of the 2016 SECURE Water Act Report to Congress prepared by the Bureau of Reclamation (Reclamation) in accordance with Section 9503 of the SECURE Water Act (Subtitle F of Title IX of P.L. 111-11). The 2016 SECURE Water Act Report builds upon the first SECURE Water Act Report, submitted to Congress in 2011,[2] which characterized the impacts of warmer temperatures, changes to precipitation and snowpack, and changes to the timing and quantity of streamflow runoff across the West by identifying additional impacts of climate change and adaptation strategies throughout western river basins. These strategies are developed in coordination with Reclamation stakeholders and customers through the Sustain and Manage America's Resources for Tomorrow (WaterSMART) Basin Studies and additional programs and activities.

This chapter provides a West-wide summary of the information presented in Chapters 2 through 10 of this SECURE Water Act Report to Congress, including highlights in the following areas:

- Identification of the key climate change risks and anticipated impacts to western water resources—those relevant West-wide, as well as those specific to certain western basins;
- Discussion of strategies being considered and implemented to mitigate and adapt to these climate change impacts; and



An overview of Reclamation's coordination activities with western partners to address emerging water-management challenges associated with climate change.

[2] The first SECURE Water Act Report, submitted to Congress in 2011 is available on the Reclamation website: http://www.usbr.gov/climate/SECURE/docs/SECUREWaterReport.pdf.

This chapter is organized as follows:

- **Section 1** provides relevant background information on the implementation of the SECURE Water Act by the Department of the Interior (DOI) and Reclamation.
- **Section 2** summarizes information on the projected effects of climate change on the hydrology of the Western United States.
- **Section 3** addresses the effects of, and risks resulting from, global climate change in terms of anticipated impacts on water supplies and water operations. This includes a discussion of impacts to water deliveries; hydropower; recreation; flood management; water quality; groundwater management; watershed integrity; and fish, wildlife, and ecological resources.
- **Section 4** addresses mitigation and adaptation strategies considered by Reclamation and its western partners to address the anticipated impacts of climate change on water resources.
- **Section 5** highlights accomplishments in implementing Reclamation's Climate Change Adaptation Strategy. Relevant examples are included to summarize coordination activities conducted by Reclamation with fellow Federal agencies, State water resource agencies, and other western stakeholders. In particular, this section focuses on activities undertaken since delivery of the SECURE 2011 Report to Congress.

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1 Introduction

1.1 About Reclamation

The Bureau of Reclamation (Reclamation), established in 1902, is best known for the dams, powerplants, and canals it constructed within the 17 Western United States (U.S.). Today, Reclamation is the largest wholesaler of water in the Nation. It provides more than 10 trillion gallons of water each year for municipal use and provides water to approximately 10 million acres of irrigated farmland that collectively produce 60 percent of the Nation's vegetables and 25 percent of its fruit and nuts. Reclamation also is the largest producer of hydroelectric power in the Western U.S. Its 53 powerplants generate more than 40 billion kilowatt-hours of electricity annually, enough to serve some 3.5 million households and produce nearly a billion dollars in power revenues.

Reclamation's mission is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. As the largest manager and wholesaler of western water, Reclamation has a responsibility to consider potential risks to western water supplies, and to help implement measures that ensure water will be managed as effectively and sustainably as possible.

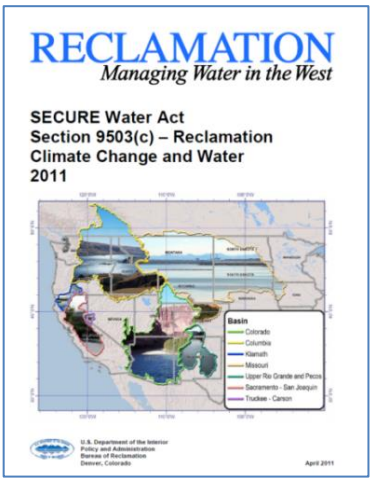
A growing risk to effective western water management is climate change. In recent decades, climate science has highlighted a broad suite of future challenges for managing western water, in addition to risks already posed by natural variations in climate and pressures associated with growing populations. This includes impacts to water supplies, water demands, and environmental conditions that have the potential to affect Reclamation's ability to fulfill its mission. In light of these challenges, Reclamation is working with its western partners to identify appropriate forward-looking adaptive actions that add resiliency and reliability to water-management planning and practices.

1.2 About Section 9503 of the SECURE Water Act

The Omnibus Public Land Management Act of 2009 (Public Law 111-11) was enacted on March 30, 2009. Subtitle F of Title IX of that legislation, known as the SECURE Water Act, recognizes that climate change poses a significant challenge to the protection of adequate and safe supplies of water, which are fundamental to the health, economy, security, and ecology of the United States. Section 9503 of the SECURE Water Act authorizes Reclamation to coordinate and partner with others to ensure the use of best available science, to assess specific risks to water supply, to analyze the extent to which water supply risks will impact various water-related benefits and services, to develop appropriate mitigation strategies, and to monitor water resources to support these analyses and

assessments.[3] The SECURE Water Act also directs Reclamation to submit reports to Congress, 2 years after enactment and every 5 years thereafter, describing progress in carrying out those activities.

1.3 The 2011 SECURE Water Act Report to Congress



In 2011, Reclamation published the *SECURE Water Act Section 9503(c) – Reclamation Climate Change and Water 2011 Report to Congress*. That report assessed climate change risks and how those risks could impact water operations, hydropower, flood control, and fish and wildlife in the Western U.S. It represented the first consistent and coordinated assessment of risks to future water supplies across eight major Reclamation river basins, and identified several increased risks to Western U.S. water resources during the 21st century. Specific projections cited in the report include:

- A temperature increase of 5–7 degrees Fahrenheit (°F) during the 21st century;
- A precipitation increase over the northwestern and north-central portions of the Western U.S., and a decrease over the Southwestern and South-central areas; and
- A decrease across much of the West in April 1st snowpack.

The 2011 SECURE Water Act Report to Congress used the World Climate Research Programme (WCRP) global climate projections developed through its Coupled Model Intercomparison Project (CMIP), which are released roughly every 5 to 7 years. The 2011 SECURE Water Act assessment was developed using hydrologic projections featured in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment and developed as part of the WCRP CMIP Phase 3, referred to here as CMIP3 Projections (i.e., the contemporary projections available in 2011). The report noted that projected changes in temperature and precipitation are expected to impact the timing and quantity of streamflows in all western basins, which would impact water available for farms and cities, hydropower generation, fish and wildlife, and other uses such as recreation.

This 2016 SECURE Water Act Report to Congress was developed using the most current hydrologic projections featured in the IPCC Fifth Assessment and developed as part of the WCRP CMIP Phase 5, referred to here as CMIP5 Projections. The difference between CMIP3 and CMIP5 projections is relatively minor when assessing the range of basin-scale potential future climatic and hydrologic conditions.

[3] The SECURE Water Act also authorizes the Department of Energy (Section 9505) and the Department of Interior's United States Geological Survey (Sections 9507 and 9508) to assess and report on the impacts of climate change on national hydropower production and water data enrichment, respectively.

Figure 1–1 illustrates the relative similarity of CMIP3 and CMIP5 projections when assessing the full range of future conditions for key water supply indicators assessed in this report.

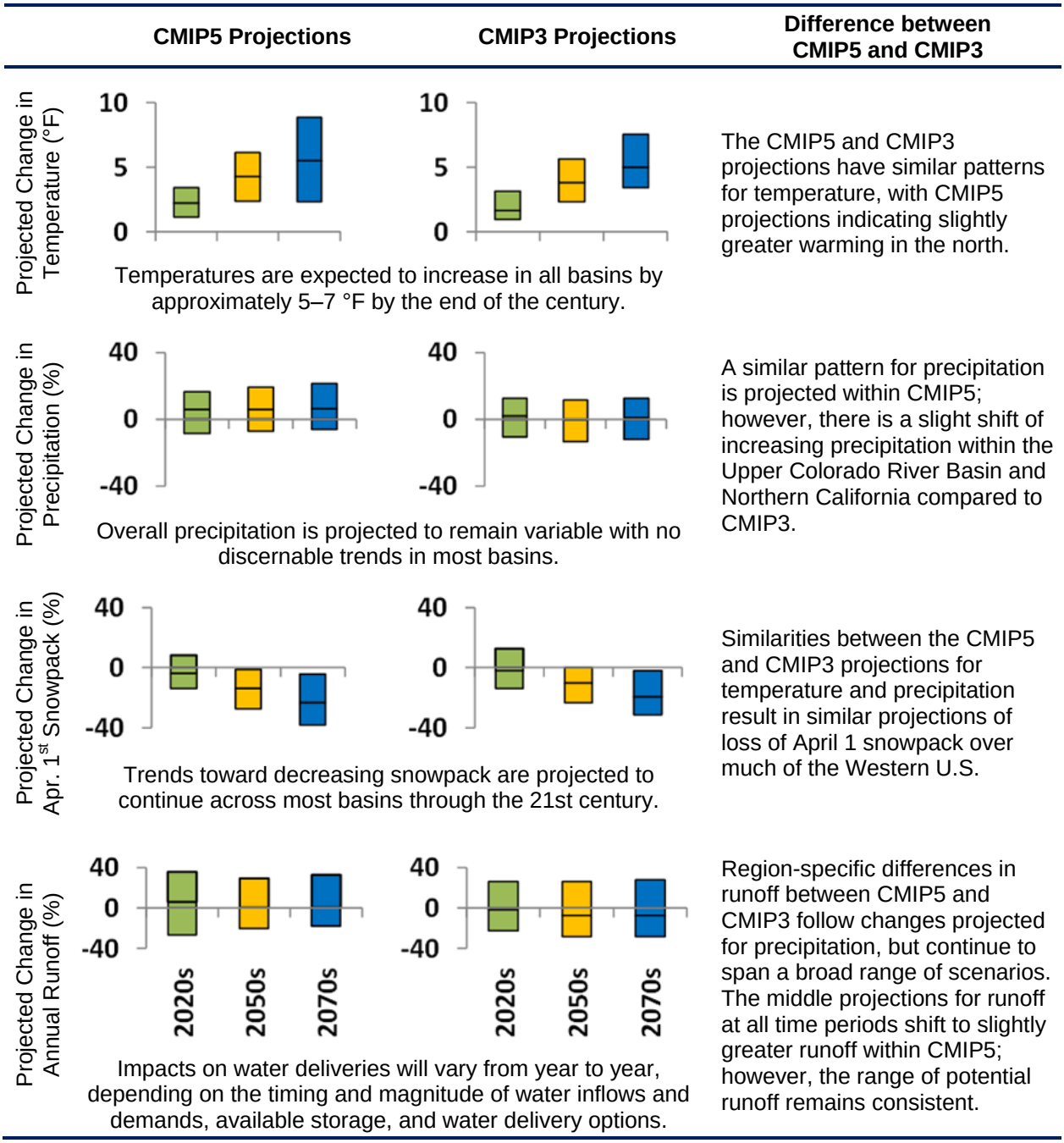


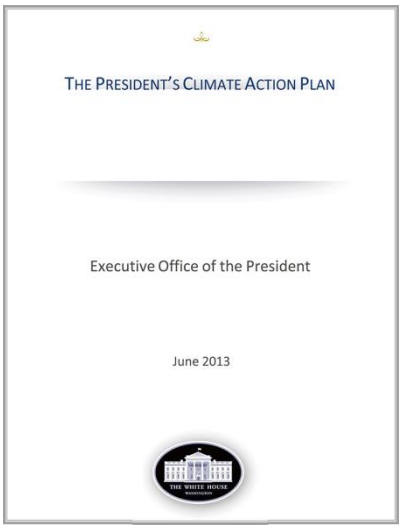
Figure 1–1. Comparison of CMIP3 and CMIP5 projections for temperature, precipitation, April 1st snowpack, and annual runoff relative to the 1990s for the 2020s, 2050s, and 2070s.

Bars represent the 10th (bottom of the box), 50th (middle black line), and 90th (top of the box) percentile projections for CMIP3 and CMIP5 for the Colorado River Basin at Imperial Dam.

This report takes advantage of the best available datasets and modeling tools, follows methodologies documented in peer-reviewed literature, and provides a consistent update to the assessment presented in the 2011 SECURE Water Act Report. The report also acknowledges the uncertainties in future hydroclimate possibilities. (See Section 2.2 of this chapter and additional discussions in chapter 2 of the report.)

1.4 Subsequent Federal Action on Climate Change

At the time of the 2011 SECURE Water Act Report, Reclamation was already working with stakeholders across the West to build a sustainable water strategy to meet the Nation's water needs. Since 2011, additional Federal actions have been taken to address risks associated with climate change. Listed are some of the key actions implemented by the President, by the Department of the Interior (DOI), and by Reclamation:

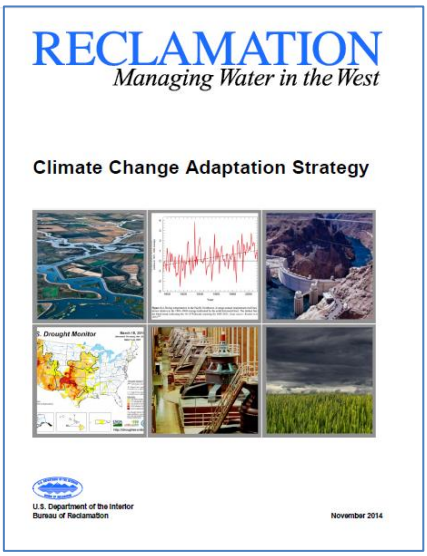


- **The President's Climate Action Plan**. In June 2013, President Obama released his *Climate Action Plan*, which provides a blueprint for steady national and international action to slow the effects of climate change. The plan includes efforts to identify vulnerabilities of the water supply sector to climate change, prepare for future flood risks, and manage drought through activities such as a National Drought Resilience Partnership. In March 2014, as follow-up to this plan, the Obama Administration kicked-off the *Climate Data Initiative* to more effectively disseminate the Federal Government's extensive, freely available, climate-relevant data resources.
- **DOI's Climate Change Adaptation Policy** (523 DM1). This policy, issued in December 2012, articulates and formalizes the Departmental approach to climate change adaptation and provides guidance to DOI bureaus and offices for addressing climate change impacts on the Department's mission, programs, operations, and personnel. It also establishes clear Departmental leadership responsibilities for climate change adaptation implementation, and directs Reclamation and other bureaus to participate in relevant Departmental workgroups.
- **DOI's Climate Change Action Plan**. Annually, DOI publishes a plan for addressing concerns related to climate change. DOI's 2013 Plan focused on assessing the Department's climate change-related vulnerabilities. Its 2014 Plan further assessed the Department's work to address climate change through implementation of Executive Order 13653 ("Preparing the United States for the Impacts of Climate Change," signed November 1, 2013) and DOI's *Climate Change Adaptation Policy*.
- **Reclamation's Climate Change Adaptation Policy** (CMP P16). In March 2015, Reclamation adopted an overarching policy establishing how

Reclamation addresses climate change impacts to its mission, facilities, operations, and personnel, in accordance with Departmental Policy 523 DM1. Among other things, this policy specifies that Reclamation will develop appropriate climate adaptation strategies to address impacts to land, water, natural, energy, cultural, and tribal resources; to Reclamation facilities and assets; and to personnel.

1.5 Reclamation's Climate Change Adaptation Strategy

In November 2014, Reclamation published its Climate Change Adaptation Strategy to build on existing actions and identify new activities that extend climate change adaptation efforts across Reclamation's mission responsibilities. Reclamation has made significant progress in assessing the impacts of climate change to water resources and implementing on-the-ground actions to mitigate impacts. The strategy highlights additional actions that are necessary to use information about future climate change to make decisions now about how best to operate Reclamation reservoirs, prioritize investments in new or improved facilities, and protect species and habitat in a changing climate. The strategy identifies four primary goals to improve Reclamation's ability to consider climate change information in agency decision making:

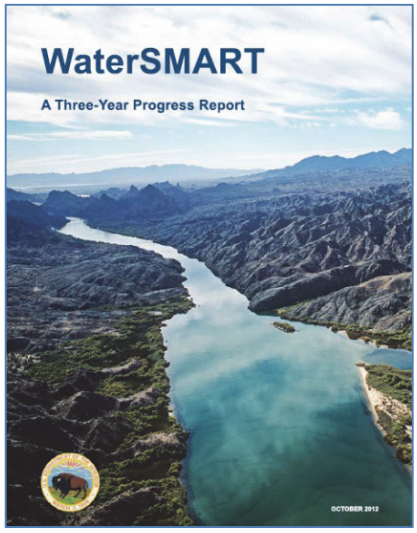


- **Goal 1 - Increase Water Management Flexibility:** Increase flexibility in reservoir operations, water conservation, efficiency, and reuse to maximize the efficient use of available water supplies and existing water infrastructure.
- **Goal 2 - Enhance Climate Adaptation Planning:** Develop capabilities, tools, and guidance to incorporate climate change information across Reclamation's planning processes. These enhanced planning efforts will help Reclamation understand and address climate change impacts to the delivery of water and power, to infrastructure, and to ecosystems and habitat affected by Reclamation projects.
- **Goal 3 - Improve Infrastructure Resiliency:** Improve infrastructure resilience, reliability, and safety to prepare for increased intensity and frequency of floods and droughts. Ultimately, Reclamation will include climate change considerations within evaluations of infrastructure safety as well as in setting priorities for operations and maintenance of existing facilities.
- **Goal 4 - Expand Information Sharing:** Collaborate with stakeholders to support mutual climate adaptation efforts through sharing data and tools.

The President's Climate Action Plan and Reclamation's Climate Change Adaptation Policy both identify the continued development of sound science, water management planning and conservation, and increasing the resiliency of infrastructure as critical actions to prepare the United States for the impacts of climate change. Highlights and accomplishments in implementing Reclamation's Climate Change Adaptation Strategy are provided in Section 4 of this chapter.

1.6 Reclamation's WaterSMART Program and Activities Addressing the SECURE Water Act

WaterSMART (Sustain and Manage America's Resources for Tomorrow) was established in February 2010 by DOI as a broad framework for Federal collaboration with States, tribes, local governments, and nongovernmental organizations to work toward secure and sustainable water resources. Reclamation has implemented the climate change adaptation activities authorized under Section 9503 of the SECURE Water Act through the **Basin Study Program**, which is part of WaterSMART. The Basin Study Program includes three complementary activities that represent a comprehensive approach to incorporate the best available science into planning activities for climate change adaptation:



- **Basin Studies:** Reclamation partners with basin stakeholders to conduct comprehensive studies to define options for addressing future water demands in river basins in the West where imbalances in supply and demand exist or are projected. These studies are comprehensive technical assessments that identify current or future imbalances between water supply and demand resulting from climate change and other stressors. In response to the identified imbalances, the studies assess options and strategies for addressing future water demands.

- **West-Wide Climate Risk Assessments (WWCRA):** WWCRAs complement the Basin Studies by developing key data on climate-induced risks and impacts to Reclamation's operations (including climate projections and baseline water supply, water demand, operational, and environmental response analyses) to provide a foundation for future Basin Studies as well as for project-specific applications. WWCRAs also generate important information, tools, and guidance that support the integration of climate information into planning activities, consistent with Reclamation's Climate Change Adaptation Strategy.

- **Landscape Conservation Cooperatives (LCC):** LCCs provide tools for analyzing and addressing climate change impacts for use in Basin Studies.

> The LCCs are partnerships of governmental (Federal, State, tribal, and local) and nongovernmental entities. The primary goal of the LCCs is to bring together science and resource management to inform strategies for adapting to climate change and other stressors within an ecological region or "landscape." Each LCC functions in a specific geographic area; the series of LCCs together form a national network. Reclamation and the Fish and Wildlife Service co-lead the Desert and Southern Rockies LCCs.[4]

Through WaterSMART, Reclamation also works with an array of partners to cost-effectively develop new water sources and make the most of existing supplies. In addition to the Basin Study Program, WaterSMART includes grants for water and energy improvement projects (**WaterSMART Grants**); water reclamation and reuse projects that provide flexibility during water shortages by diversifying the water supply (**Title XVI Program**); a comprehensive approach to drought planning and implementation actions that address water shortages (**Drought Response Program**); support for the water sustainability efforts of collaborative watershed groups (**Cooperative Watershed Management Program**); smaller-scale water conservation planning and improvements (the **Water Conservation Field Services Program**); and a program to identify resilient infrastructure investments that take into account potential effects of climate change while continuing to support healthy watersheds (**Resilient Infrastructure Program**).

Also under DOI's WaterSMART program, the U.S. Geological Survey (USGS) supports science activities that include developing estimates for components of the water budget; assessing groundwater resources; working with stakeholders to address water resource issues in basins that are experiencing water conflicts; enhancing the nation's streamflow and groundwater networks; and understanding drought impacts. In addition the USGS provides funding to States to participate in the National Groundwater Monitoring Network and to improve water use data through the Water Use Data and Research program.

Reclamation is also actively engaged with research partners to develop and share information for a common understanding of climate change impacts to water resources in the West. The **Science and Technology Program** is a Reclamation-wide competitive, merit-based applied research and development program focused on innovative solutions for water and power challenges in the Western U.S. Reclamation's Research and Development Office also manages the **Desalination and Water Purification Research Program**, which funds research projects to develop and pilot test new clean water treatment technologies that can make degraded water supplies available for consumptive use. Clean water

[4] Reclamation also participates in the other LCCs located in the 17 Western States, which include the Great Northern LCC, North Pacific LCC, Great Basin LCC, California LCC, Plains and Prairie Potholes LCC, Great Plains LCC, and Gulf Coast Prairie LCC. Currently, Reclamation is a steering committee member on the Great Northern LCC.

technologies developed in this program are implemented through complementary research projects under the WaterSMART Title XVI Program.

Reclamation partners with the U.S. Army Corps of Engineers (Corps), USGS, the National Oceanic and Atmospheric Survey (NOAA), and others through the Climate Change and Water Working Group (CCAWWG) to identify mutual science needs for short-term water management decisions and long-term planning. These programs are fundamental to developing new information for adapting to climate change by assessing the current state of knowledge, identifying where gaps exist, and finding opportunities to address those gaps.

Many of the activities carried out as part of WaterSMART are leveraged by partner participation to implement adaptation strategies identified in Basin Studies. Sections 4 and 5 of this chapter include further discussion of these activities, including how they fit within Reclamation's Climate Change Adaptation Strategy and accomplishments to date.

2 Climate and Hydrology

Climate change poses a fundamental challenge to Reclamation's mission and the national economy. The effects of climate change are already being felt across the West. As a result, Reclamation and its water management partners must be prepared to respond to shifts in the baseline of what is considered "normal" for drought, floods, water availability, and water demands over coming decades. Observed and projected changes to western climate and hydrology are summarized in Chapter 2 of this report. Key observations and projections relevant to western water management include the following:

- Temperature increases have resulted in decreased snowpack, differences in the timing and volume of spring runoff, and an increase in peak flows for some Western U.S. basins. Observed increases in mean annual temperature have been approximately 2 °F (1.1 degrees Celsius [°C]) since 1900. Continued warming of roughly 5 to 7 °F (3 to 4 °C), depending on location, is projected over the course of the 21st century. (See Figure 1–2).
- Precipitation changes are also expected to occur, interacting with warming to increase the duration and frequency of droughts and resulting in larger and more numerous floods, varying by basin. The increased intensity of droughts and floods raises concerns about infrastructure safety, the resiliency of species and ecosystems to these changes, and the ability to maintain adequate levels of hydropower production.

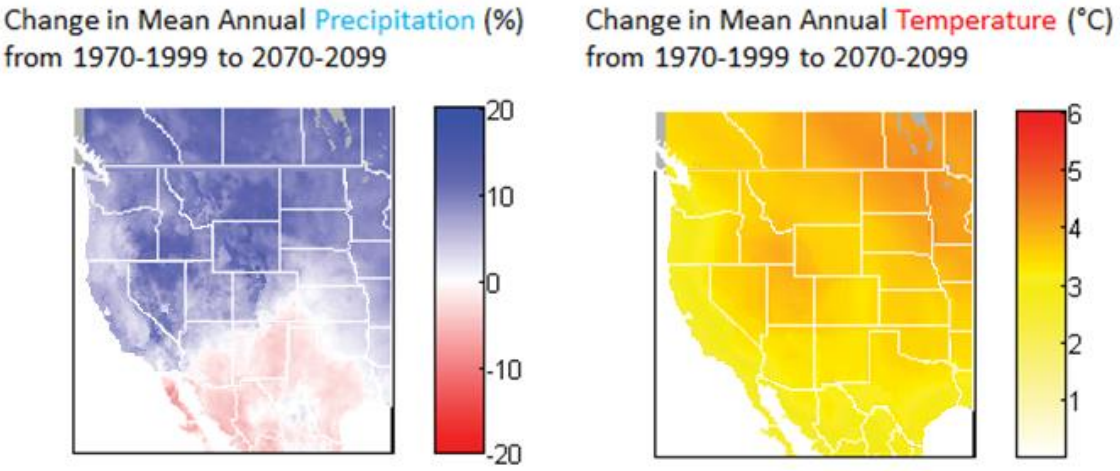


Figure 1–2. Projected changes to temperature and precipitation in the latter 21st century.

Figure represents the median change from a large collection of WCRP's Coupled Model Intercomparison Project phase 5 climate projections spatially downscaled over the U.S. Temperatures are shown to increase throughout the West by 2–5 °C. Mean annual precipitation is largely expected to increase for much of the Western U.S. with the exception of the Southwest, where precipitation is expected to decrease by between 5 and 20 percent.

The impacts to snowpack and runoff affect the timing and availability of water supplies. More variation in hydrology will make it more difficult for Reclamation to address competing demands for water. Key trends related to runoff include the following:

- Winter runoff is projected to increase over the West Coast basins from California to Washington and over the north-central U.S., but little change to slight decreases are projected over the area from the Southwestern U.S. to the Southern Rockies.
- Summer runoff is projected to decrease substantially over a region spanning southern Oregon, the Southwestern U.S., and the Southern Rockies. However, north of this region warm-season runoff is projected to change little or to increase slightly.
- Projected increases in annual precipitation in the northern tier of the Western U.S. could counteract decreases in warm-season runoff, whereas decreases in annual precipitation in the southern part of the Western U.S. could amplify the effect of decreases in warm-season runoff.

2.1 West-Wide Climate Risks to Water Supplies

It is expected that annual and seasonal natural runoff will continue to reflect the continuing changes to the climate. It is not possible to infer water management impacts from these natural runoff changes alone. Water management systems across the West have been designed to operate within envelopes of local hydrologic variability, handling annual and seasonal variations typical for their specific localities. As a result, their physical and operating characteristics vary in terms of storage capacity and conveyance flexibility. The ability to use water storage resources to control future hydrologic variability and changes in runoff seasonality is an important consideration in assessing potential water management impacts due to natural runoff changes.

The impacts of climate change on water resources give rise to difficult questions about how best to operate Reclamation facilities to address growing demands for water and hydropower now and how to upgrade and maintain infrastructure to optimize operations in the future. Figure 1–3 summarizes key risks to western water supplies identified in Reclamation's WaterSMART Basin Study Program. Additional information on impacts to water resources specific to each western river basin, including the strategies to address potential water shortages, is included in Chapters 3 through 10.

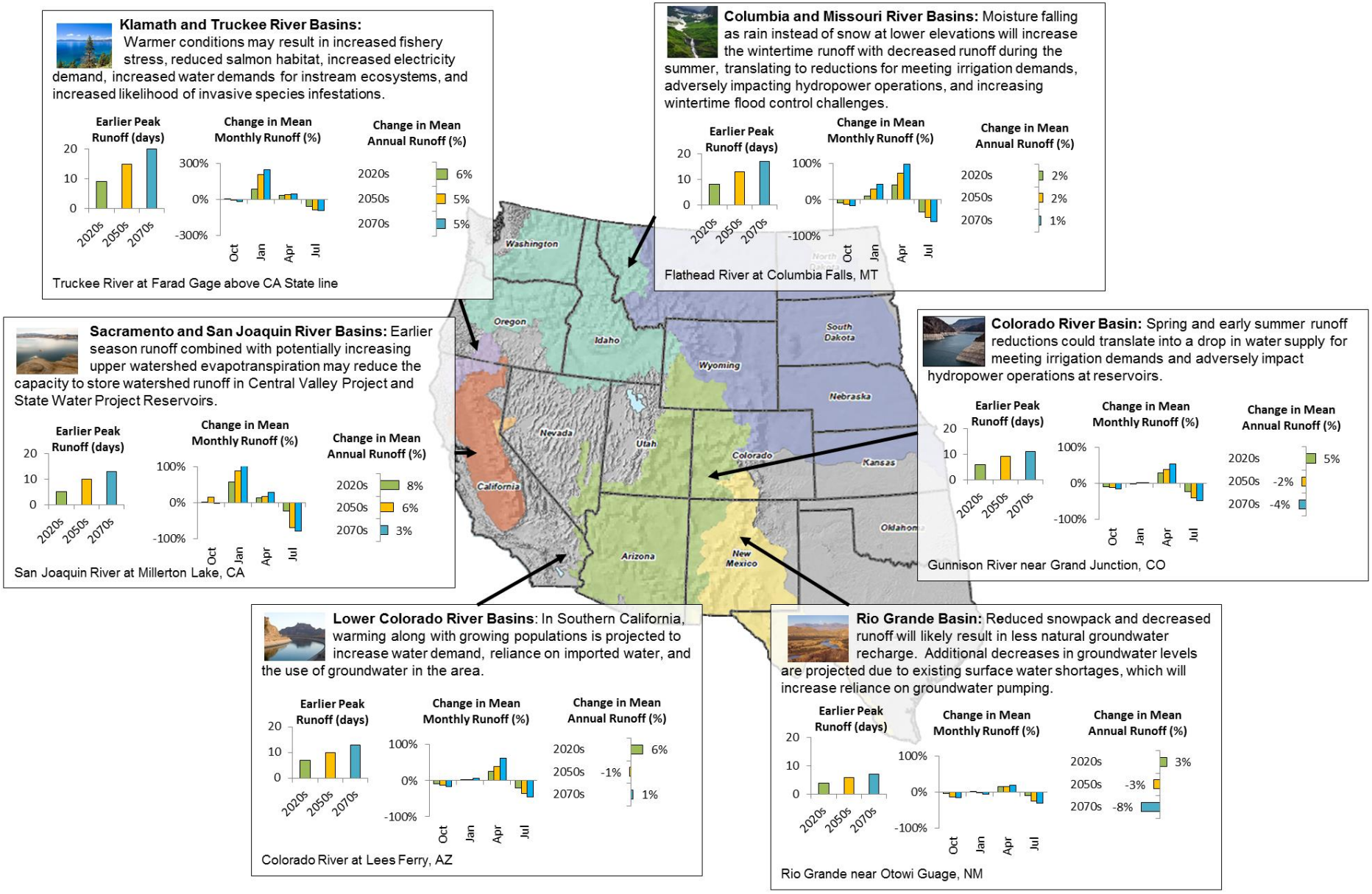


Figure 1–3. Projected climate impacts to water resources in western river basins.

2.2 Uncertainties in Climate and Water Projections

This report summarizes analyses on potential future climate and hydrologic conditions in the Western U.S. The information presented is gathered from Reclamation studies as well as other peer-reviewed literature and reflects the use of best available datasets and data development methodologies. While this report summarizes potential future climate and hydrologic conditions based on the best available datasets and data development methodologies, its characterization of future hydroclimate possibilities implicitly reflects several uncertainties.

- Uncertainties arise characterizing future global climate forcings such as greenhouse gas emissions, simulating global climate response to these forcings, correcting global climate model outputs for biases, spatially downscaling global climate model outputs to basin-relevant scales, and characterizing the hydrologic response to projected climatic changes within specific regions or basins.
- The impacts of climate change on water resources are evident; however, it is important to acknowledge the uncertainties inherent within climate change science and how they contribute to making climate adaptation a difficult challenge. Projections of future climate change contain uncertainties that vary geographically and depend on the weather variable of interest (e.g., temperature, precipitation, and wind).
- Trying to identify an exact climate change impact at a particular place and time remains difficult, despite advances in modeling efforts over the past half-century. As an example, it is not possible to say with certainty whether climatic change makes a particular flood or drought event exactly twice as likely to occur; however, current science may provide enough evidence to judge whether such an event is more or less likely to occur overall.

The concept of risk management in the face of uncertainty is one that is becoming well recognized for climate change adaptation. Notwithstanding these uncertainties, the Third National Climate Assessment identifies viable decision support tools currently available to support the incorporation of climate information into resource management decisions, including risk assessments, targeted projections for high-consequence events such as floods and droughts, and vulnerability assessments. In spite of the uncertainties, Reclamation and its stakeholders have identified a number of possible adaptation strategies, which are presented within this report.

3 Impacts to Water Management

In many regions of the West, projected climate-driven changes in water supply (quantities and timing), along with increased demands for water, are expected to strain the ability of existing infrastructure and operations to meet water needs – not only for consumptive uses such as agricultural, municipal, and industrial activities, but also for hydropower, flood control, fisheries, wildlife, recreation, and other largely nonconsumptive water-related benefits.

This section provides an overview of anticipated impacts to specific categories identified by the SECURE Water Act for analysis: water deliveries; hydropower; recreation; flood management; fish, wildlife, and ecological resources; and water quality. In addition, this section addresses anticipated impacts to groundwater management and watershed integrity, as these also impact the effectiveness of managing water supplies to provide multiple public benefits.

3.1 Water Deliveries

Both the timing and quantity of runoff are expected to continue to be impacted by the changing climate. Together with changes in the magnitude and timing of the demands for water and energy, this will impact the ability of existing water infrastructure to satisfy public interests in diverting, storing, and delivering water when and where it is needed. Shifts in water availability will impact water uses and increase reliance on deliveries of water from reservoir storage or groundwater. The likelihood of increased year-to-year variability in surface water supplies also presents challenges. Figure 1–4 summarizes key considerations and anticipated impacts to water deliveries.

Additional examples are provided below, as illustrations of the impacts described:[5]

- In the **Colorado River Basin**, future projected development of water supplies and increased consumptive use in the Upper Basin, combined with potential reductions in future supply, are expected to result in reduced volumes of water stored in system reservoirs and a vulnerability to water delivery shortages.
- In the **Missouri River Basin**, irrigation shortages are generally expected to increase, and earlier calls on reservoir releases for irrigation water are expected to lead to a stronger reliance on stored water during the late summer months.

[5] Only select examples are provided for each category, as illustrations of the impacts described. Typically, additional examples are identified and described in one or more of the river basin chapters 3–10.

Changes in Water Supply and Demand

Climate assessments project that the manageable water supply, in general, will decline in much of the West. A decrease of up to 8 percent in average annual stream flow is projected in several river basins, including the Colorado, the Rio Grande, and the San Joaquin river basins.

Changes in Timing of Runoff and Water Availability

West-wide, runoff is expected to shift to earlier times of the year (less in summer, more in winter and spring), making it more difficult to manage water deliveries as they have been managed in the past. Reservoirs are anticipated to fill earlier in the year, with a corresponding reduction in the water supply available through the summer season.

Change in Snowpack versus Rainfall

Across the West, snowpack generally is projected to decrease as more precipitation falls as rain and warming temperatures cause earlier snowmelt. Water deficits are expected to worsen throughout the Columbia River Basin due to more precipitation falling as rain, shifts in runoff timing, lengthening of the growing season, and greater reliance on stored water.

More Extreme Weather Events

A likelihood for more frequent extreme weather events is projected in many areas of the West. In the Rio Grande Basin, an increased potential for strengthening of the summer monsoons is projected, with corresponding increases in the portion of the basin's precipitation falling downstream of current water storage infrastructure.

Figure 1–4. Anticipated impacts to water deliveries.

- For the **Central Valley Project** in California, projected earlier seasonal runoff will cause reservoirs to fill earlier, thereby reducing overall storage capability, as current flood control constraints limit early season storage in these reservoirs. End-of-September reservoir storage is projected to decrease by 3 percent over the course of the 21st century.
- In the **Klamath Basin**, the seasonal shift in runoff, more precipitation falling as rain, and the expected increased reservoir evaporation are projected to result in more years with water shortages.
- In the **Rio Grande Basin**, decreases in winter snowpack are projected to result in a decreased water supply (e.g., by about one-fourth to one-third in the upper basin over the course of the 21st century), limiting storage available for use during the summer irrigation season.

3.2 Hydropower

Hydropower production at Reclamation facilities provides a large, renewable supply of power to the West with a relatively small carbon footprint, and helps keep consumer power costs low. Reclamation is the largest producer of hydroelectric power in the Western U.S. Reclamation's 53 powerplants provide more than 40 billion kilowatt-hours annually, generating nearly a billion dollars in power revenues and producing enough electricity to serve 3.5 million homes. Hydroelectric generation to satisfy power demands is sensitive to climate change impacts on basin precipitation, the amount and timing of river flows, and reservoir levels. Figure 1–5 summarizes the anticipated impacts to western hydropower.

Changes in Supply and Runoff Timing

West-wide, runoff is anticipated to shift to earlier periods of the year (less in summer, more in the winter and spring). Where peak demand for hydropower occurs during the hottest weeks of summer, shift in runoff timing is expected to impact summer hydropower revenues due to a reduction in peak-season hydropower generation.

Changes in Hydropower Demand

The warming projected across the West is generally expected to decrease energy demand during winter (for heating) and increase demand during summer (for cooling). These changes might necessitate adjustments in reservoir operations to better align with demand, although the reduced summer inflow may present its own challenges.

Figure 1–5. Anticipated impacts to hydropower.

Select examples are provided below, as illustrations of the impacts described:

- In some western river basins, including the **Colorado River and Upper Rio Grande basins**, reduced flows and lower reservoir levels together with increased consumptive water demands associated with climate change are anticipated to result in reduced hydropower production.
- In the Pacific Northwest, power customers currently use more electricity in the winter than in the summer, so projected increases in winter and spring flows in the **Columbia River Basin** should not negatively affect generation to meet power demands during those periods. Nevertheless, decreased summer flows could present challenges to meet increasing summer season power demands, partly associated with increasing summer temperatures.

3.3 Recreation

The recreation areas developed as a result of Reclamation water projects are among the Nation's most popular for water-based outdoor recreation. Reclamation projects include approximately 6.5 million acres of land and water that is, for the most part, available for public outdoor recreation. Reclamation and its partners manage 289 recreation sites that have 90 million visits annually. Recreational uses are diverse, and include seasonal activities such as swimming, fishing, and boating on reservoirs and rivers. Figure 1–6 summarizes anticipated impacts on recreation including impacts to flatwater and river recreation.

Flatwater Recreation

Increased summer and winter temperatures may increase visitation at reservoirs for camping, boating, swimming, fishing, and other activities. Lower reservoir levels will mean a decrease in the area available for those activities. In some cases, reduced reservoir storage could make it more difficult for water-dependent recreational opportunities.

River Recreation

Increased summer and winter temperatures may increase the popularity of recreational opportunities in and along Western rivers, while decreased snowpack resulting in reduced flows in key river tributaries has negative implications for flow-dependent recreation such as boating and fishing.

Figure 1–6. Anticipated impacts to recreation.

Select examples are provided below, as illustrations of the impacts described:

- The **Colorado River Basin Study** indicated that without future action, the projected development of water supplies and increased consumptive use in the Upper Basin could reduce the access to shoreline recreational facilities in both the Upper and Lower Basins.
- The **Upper Rio Grande Impact Assessment** concluded that river recreation, including fishing, kayaking, and rafting, will be negatively impacted by projected decreases in flows.

3.4 Flood Management

Flood control is an important function of many Reclamation reservoirs. From 1950 through 2014, for example, accumulated benefits from annual flood control in the Missouri River Basin are estimated to total over $2.9 billion. A trend toward earlier annual peak flows associated with warming temperatures and an increased frequency of rain-on-snow events is expected, especially in "transitional" basins – those that already straddle zones of rain- vs. snow-dominated hydrology – such as the Missouri River Basin. Figure 1–7 summarizes anticipated impacts to flood management.

At Reservoirs with Multiple Year Storage

Where reservoirs are designed to store several years of runoff, the additional flood risks associated with climate change are generally considered minimal, due to the considerable capacity of those facilities to deal with shorter-duration high flow events.

At Reservoirs Managed for Annual Refill

Where reservoirs require year-round balancing of flood control functions with other purposes, changes in the magnitude, intensity, and severity of extreme runoff events may prompt reconsideration of operating rules to better manage flood risks while maximizing storage opportunities.

Reservoir Sedimentation

At many reservoirs, the increased frequency of intense storms and flood events coupled with frequent, higher-intensity wildfires will lead to accelerated reservoir sedimentation due to increased sediment runoff during storm events.

Figure 1–7. Anticipated impacts to flood management.

Select examples are provided below, as illustrations of the impacts described:

- In the **Missouri River Basin**, warming is expected to lead to more rainfall runoff in higher-elevation watersheds such as Lake Sherburne and Fresno Reservoir, both in Montana, which provide flood-control benefits by storing water during the peak runoff period.
- In the **Rio Grande Basin**, runoff from forested areas subject to climate stress and impacted by an increased occurrence of catastrophic wildfires is projected to result in accelerated debris and sediment accumulation in reservoirs, which would lead to less reservoir storage and flood protection. In the **Upper Rio Grande Basin**, the frequency and intensity of floods is projected to increase at the main flood control reservoirs.
- Similarly, in the **Truckee River Basin**, an increase in the magnitude of peak flows is expected.
- Lake Powell and Lake Mead have the capacity to store several years of average Colorado River runoff. The **Colorado River Basin Study** indicated that flood control vulnerabilities were few over the next 50 years.

3.5 Fish, Wildlife, and Ecological Resources

The potential impacts of climate change on fish and wildlife habitats, federally listed species, and ecological systems in the West are complex and diverse. Current stresses on species habitats in many areas of the West are expected to be impacted by climate change. Changes in temperature and hydrology will shift the location and distribution of species and their preferred habitats, while improving conditions for certain species. Reclamation has many river restoration and enhancement efforts ongoing across the West that result in a broad array of benefits to fish and wildlife resources and their habitats. Climate change could adversely affect these programs, possibly impacting species populations and their resiliency to unpredictable shocks (e.g., disease, floods, fire, drought). The impacts could be positive, negative, or neutral, depending on the exact species, hydrology, and ecosystem affected. Figure 1–8 summarizes the anticipated impacts.

Water and Air Temperature Impacts

Fisheries sensitive to a warming aquatic habitat will be more frequently stressed, and suitable habitat for cold-water dependent species such as trout will be reduced. Shifts in the geographic range of various species are anticipated. The incidence of pathogens in warming waters also may increase.

Aquatic Migration

Changes in the timing of species migration will become more likely with increased water and air temperatures. In the Columbia River Basin, elevated temperatures would increase the number and severity of thermal barriers to migration for certain fish, including several federally listed species.

Invasive Species

Warmer water temperatures and other climate-related stresses on native species can confer competitive advantages to various non-native and invasive species. Studies indicate that quagga mussels could expand their range under projected climate scenarios, further complicating facility maintenance.

Sea Level Rise

Sea level rise increases the salinity of vulnerable coastal waterways. Sea level rise is a significant concern in the Sacramento-San Joaquin Delta, affecting not only its suitability as a water source for agricultural, municipal, and environmental uses, but also the ability to move freshwater through the estuary to water users.

Riverine Habitat

In Western river basins, it is anticipated that changes to hydrology and climate may make it more difficult to achieve environmental flows to support endangered species. In the Columbia River Basin, projected increases in winter flooding and decreases in summer flows will affect Coho and Chinook salmon as well as steelhead. .

Figure 1–8. Anticipated impacts to fish, wildlife, and ecological resources.

3.6 Water Quality

The quality of water in western river basins is vital to human and environmental health. Whether water quality improves or deteriorates under a changing climate depends on multiple variables including water temperature; the rate, volume, and timing of runoff; and the physical characteristics of the watershed. Figure 1–9 summarizes anticipated impacts.

Water temperature

As water warms, less oxygen dissolves in the water column, affecting that water body's ability to support fisheries and other aquatic life. In addition, higher water temperatures can increase the incidence of toxic algal blooms occurring at reservoirs and other water bodies.

Pollutants

Where runoff decreases without a corresponding reduction in pollutants, maintenance of acceptable water quality will become more difficult, especially during periods of low flow. Increases in the frequency and intensity of high-precipitation events will also increase the runoff of pollutants into water bodies.

Turbidity and Sediment

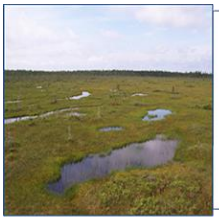
Where storm intensity and severity increases, there is a corresponding increase in land surface erosion, sediment transport, and occurrences of elevated surface water turbidity. Moreover, an increase in the frequency, extent, and intensity of forest fires associated with temperature- or drought-stressed forests will increase sediment production and surface water turbidity.

Figure 1–9. Anticipated impacts to water quality.

As one example of the anticipated impacts, in the **Rio Grande Basin** above the confluence of the Rio Grande with the Rio Puerco, concentrations of pollutants are expected to increase with increased surface water evaporation rates and more intense precipitation events.

3.7 Groundwater Management

Over the long term, groundwater supplies are sustainable only to the extent that aquifer recharge remains in approximate long-term balance with groundwater extraction. Climate change has the potential to affect this balance by altering the rate and/or the pathways of groundwater recharge associated with shifts in precipitation patterns, increased temperature, and other drivers of vegetative evapotranspiration and changes in streamflow. Figure 1–10 summarizes key groundwater considerations.



Changes in Groundwater Recharge

Studies project that warmer climate conditions could reduce groundwater recharge. In the Missouri River Basin (northern Great Plains) and in the Santa Ana watershed of southern California, groundwater recharge could be reduced as rising temperatures increase water demands and as decreased precipitation reduces recharge.

Changes in Groundwater Demands

With increased variability and uncertainty of precipitation and surface water supplies, many Western communities are expected to increase reliance on groundwater as a source for both agricultural and municipal purposes. In California's Central Valley, increased groundwater dependency may result in additional land subsidence and a reduction in aquifer storage capacity.

Coastal Saltwater Intrusion

In coastal communities, sea level rise and an increased reliance on aquifer withdrawals has the potential to increase the risk of saltwater intrusion into freshwater coastal aquifers.

Figure 1–10. Anticipated impacts to groundwater.

3.8 Watershed Integrity

To protect and sustain both surface-water and groundwater supplies, prudent management of contributing watersheds is essential. Forested lands, in particular, serve as crucial water supply zones in the West: high-elevation, forested landscapes are source areas for 65 percent of western water supplies. The health and integrity of these landscapes are fundamental to the maintenance of reliable quantities, timing, and quality of water supplies, including water to meet various Reclamation project purposes. Figure 1–11 summarizes the ways that climate change is expected to impact the landscape-scale factors that influence watershed hydrology.

Changes in Land Cover and Vegetation Mix and Density

Changes in precipitation, temperature, humidity, CO_2, and other climate conditions are expected to affect the composition, distribution, and productivity of vegetative communities, in turn affecting watershed hydrology. For example, in southern California, warmer temperatures are expected to cause forested landscapes to migrate over time northward and to higher elevations.

Forest Insects and Disease

Increased tree mortality from insects already has been observed throughout the West, raising concerns about the future distribution of forest vegetation. In the forests of some parts of New Mexico, moisture stress has led to bark beetle infestations, in turn leading to a potential transition of the affected forests to a new mix of species, forest structure, and ecological processes.

Forest Fires

In the Missouri River Basin, an increased risk of wildfires is projected due to the expectation that more intense droughts, higher temperatures, and disease will stress forest vegetation.

Figure 1–11. Anticipated impacts to watershed integrity.

4 Adaptation Strategies to Address Vulnerabilities

Reclamation, in consultation with customers and stakeholders, has already begun to identify and develop a variety of adaptation strategies to address vulnerabilities related to drought and climate change in western river basins. WaterSMART Basin Studies provide an important mechanism for identifying adaptation options appropriate for the area being studied. As collaborative studies that are cost-shared with non-Federal partners, Basin Studies evaluate the impacts of climate change and identify a broad range of potential options to address water supply and demand imbalances, both current and future. To date, Reclamation and its partners have initiated 24 Basin Studies in 15 of the 17 Western States, and 12 of those have now been released, meaning that a broad range of climate adaptation strategies have been developed.

Basin Studies evaluate *portfolios of multiple possible adaptation actions.* Rarely will one single action be sufficient to address all of the potential impacts of concern. While Basin Studies are not intended to be decision documents, they do provide a solid foundation for further exploring actions that will support sustainable water supplies and achieve other water management goals. The general categories of possible actions to adapt to climate change and other stresses on western water supplies are listed in Figure 1–12. Each type of adaptation strategy is discussed in the following section, with a brief description of Reclamation actions supporting implementation of these strategies.

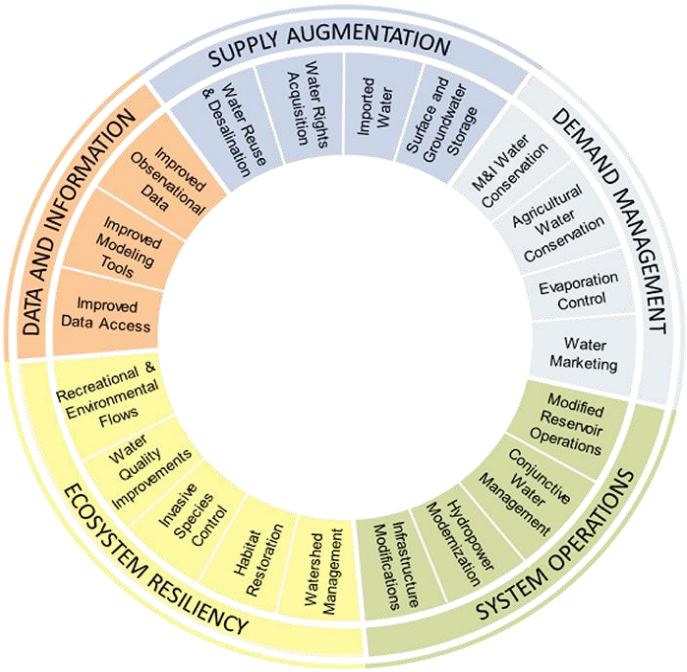


Figure 1–12. General categories of possible actions used in a water management portfolio to adapt to climate change.

Specifically, this section draws upon the extensive information and analysis provided by the WaterSMART Basin Study Program products (mapped in Figure 1–13). As Reclamation continues implementation of its Climate Change Adaptation Strategy, many adaptation strategies are already underway. In this section, examples of adaptation strategies are highlighted, along with the activities being undertaken by Reclamation and its partners to implement strategies and accomplishments to date.

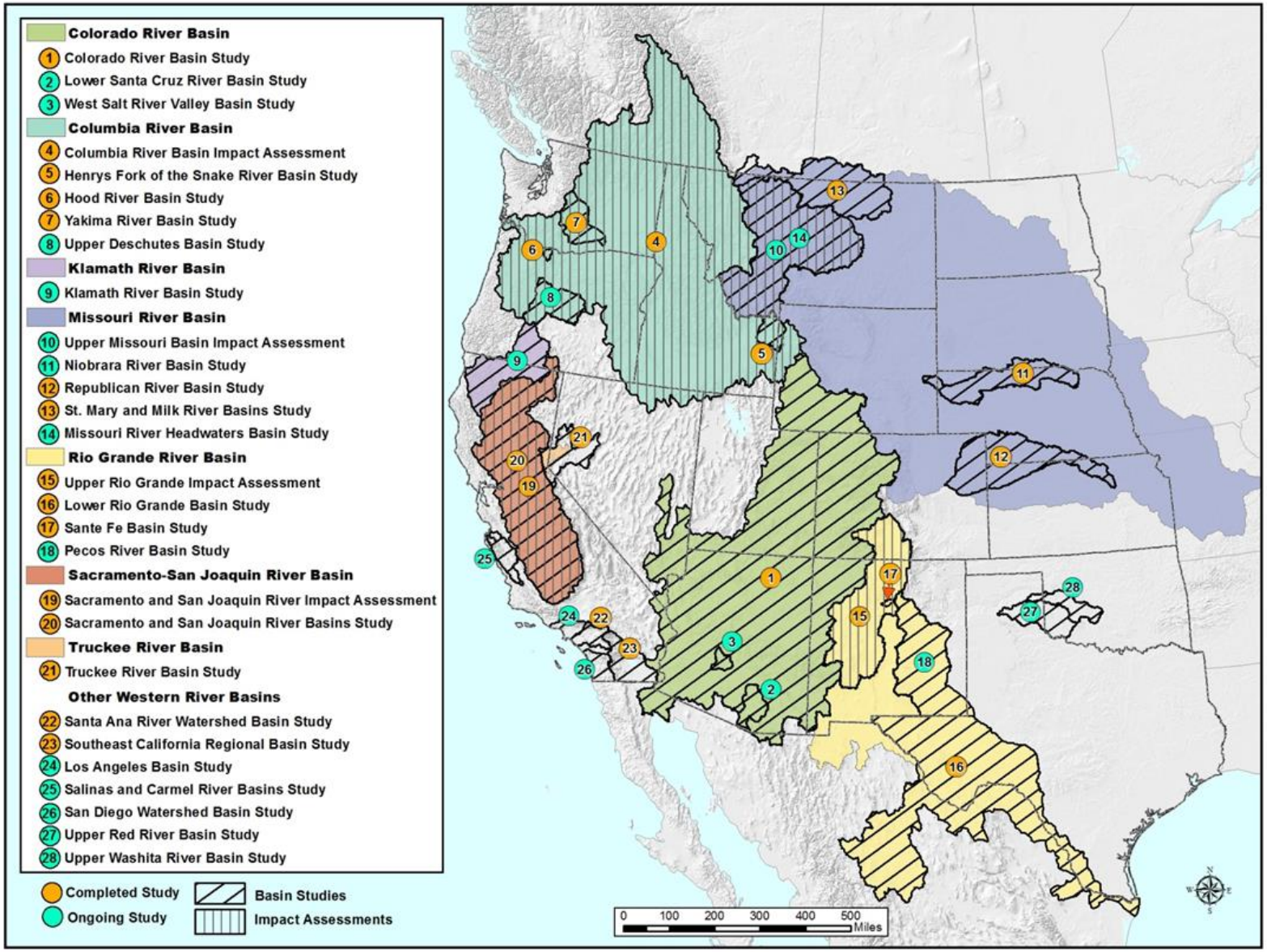


Figure 1–13. WaterSMART basin studies and climate impact assessments.

4.1 Supply Augmentation

The total supply of water available to meet user needs often can be augmented through one or more possible actions, including water reuse, desalination, stormwater capture, water rights acquisition, water importation, and new or expanded water storage. Augmented supplies can serve a variety of possible purposes, including municipal and industrial use, agricultural use, power generation, groundwater recharge, environmental restoration, fish and wildlife maintenance, and recreation. Select examples of potential adaptation strategies considered by Reclamation-sponsored Basin Studies and related efforts are identified in Figure 1–14.

Figure 1–14. Potential water supply augmentation strategies.[6]

[6] Select examples are provided in this figure, as illustrations of the options considered. Additional examples are described in Chapters 3–10 or in individual Basin Studies.

Taking Action to Augment Supply

Reclamation has made significant progress in assessing the impacts of climate change to water resources and implementing on-the-ground actions to mitigate impacts of climate change. Reclamation's Climate Change Adaptation Strategy identifies increasing water management flexibility and enhanced adaptation planning as key goals to implementation the strategy.

To augment traditional surface and groundwater supplies, the **Title XVI Water Reclamation and Reuse Program** provides cost-shared funding for research, planning, design, and construction of water reuse projects. Water reuse and recycling can turn currently unusable water sources into a new source of supply that is less vulnerable to drought and climate change, increasing flexibility and reducing the pressure to transfer water from agricultural to urban uses. The State of California estimates that 900,000 to 1.4 million acre-feet of "new water" could be added to its supply by reusing municipal wastewater that currently flows to the ocean.

Purple pipe prior to installation by the Napa Sanitation District in California. The pipeline was constructed as part of Reclamation's Title XVI Program.

Since 1992, approximately $639 million in Federal cost-share funds have been leveraged with more than $2.4 billion in non-Federal funding to design and construct water recycling projects. In 2015, Reclamation announced grants totaling $25 million for continued construction of seven water reclamation and reuse projects in California and seven water reclamation and reuse feasibility studies in California and Texas.

As a next step to the Santa Fe Basin Study, the City of Santa Fe and Santa Fe County, New Mexico, are collaborating to develop greater resiliency and diversity in their water portfolios by exploring alternatives for reclaimed wastewater. In 2014, the City of Santa Fe received Title XVI funding for a feasibility study to evaluate alternatives for both potable and non-potable applications of reclaimed water to augment water supplies. The current water supply is vulnerable to uncontrolled factors, which include drought, fire, environmental regulations, and water quality limits.

Reclamation's **Desalination and Water Purification Research (DWPR) Program** funds research projects to develop and test new advanced water treatment technologies that can make degraded water supplies available for consumptive use. In 2015, Reclamation announced grants totaling $1.4 million to nine laboratory and pilot-scale research studies in the field of water desalination and purification. The DWPR Program also supports operation and maintenance of Reclamation's Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo, New Mexico, which provides a field environment to test and develop advanced water treatment technologies. The facility brings together researchers from Federal government agencies, universities, the private sector, research organizations, and State and local agencies to work collaboratively and in partnership. BGNDRF hosted the final round of the 2015 Desal Prize,[7] in partnership with U.S. Agency for International Development, focused on innovative brackish groundwater treatment technologies powered by renewable energy.

Reclamation's Brackish Groundwater National Desalination Research Facility in Alamogordo, NM.

Reclamation's Water Quality Improvement Center at the Yuma Area Office, AZ.

Reclamation also has a state-of-the-art advanced water treatment research center, the Water Quality Improvement Center[8], located at the Yuma, Arizona, Area Office. These centers represent two of six National Centers for Water Treatment Technologies.

[7] See http://www.securingwaterforfood.org/the-desal-prize/

[8] See http://www.usbr.gov/lc/yuma/facilities/wqic/yao_facilities_wqic.html

4.2 Demand Management

Activities that reduce the demand for water, particularly during periods of water scarcity, provide valuable flexibilities for helping to bring those demands into better balance with supply. With water deliveries in the West facing increasing vulnerabilities from population growth and climate change, various strategies to ease demands are being implemented by communities across the West. These strategies include improved water conservation and efficiencies in water and energy use. Examples of the relevant adaptation options and actions considered by Reclamation-sponsored basin studies are identified in Figure 1–15.

Figure 1–15. Potential demand management strategies.[9]

[9] Select examples are provided in this figure, as illustrations of the options considered. Additional examples are described in Chapters 3–10 or in individual Basin Studies.

Taking Action to Implement Demand Management Strategies

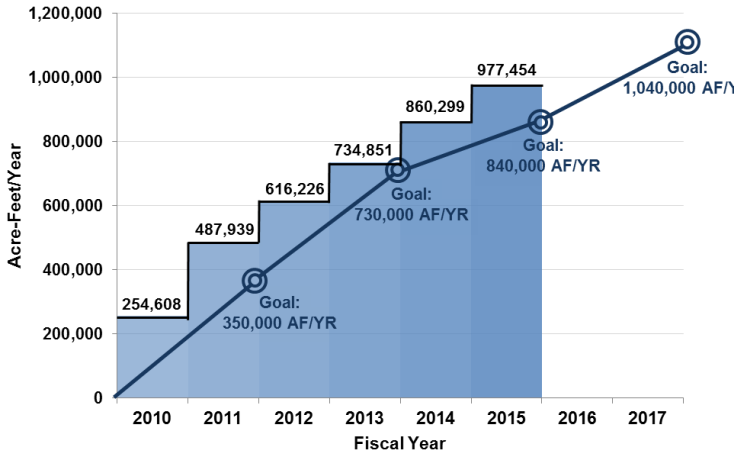
Reclamation continues to work with its partners to complete agricultural and municipal and industrial water conservation improvements that implement demand-management strategies identified through Basin Studies. Consistent with Reclamation's Climate Change Adaptation Strategy, which recognized a role for Reclamation in helping to increase water management flexibility, **WaterSMART Grants** make cost-shared funding available to non-Federal partners to carry out water conservation and efficiency projects collaboratively, and they prioritize projects that implement adaptation strategies identified through Basin Studies.

Hidalgo County Irrigation District #2 Water and Energy Efficiency Grant

Since 2009, about $149 million in Federal funding has been leveraged with non-Federal funding to implement 257 WaterSMART Grant projects that together represent more than $560 million in water management improvements across the West.

As Basin Studies are completed, water managers look to WaterSMART Grants to help them implement adaptation strategies. In southern Texas, for example, the Hidalgo County Irrigation District #2 is using $1 million in WaterSMART Grant funding, along with more than $4 million in non-Federal funding, to implement one of the demand management adaptation strategies identified in the Lower Rio Grande Basin Study, which the District participated in as a cost-share partner. The District's work to line 5.3 miles of an unlined canal and install advanced check gate structures is expected to result in annual water savings of more than 2,000 acre-feet currently lost to spills and seepage.

In 2010, DOI and other Federal agencies established a series of outcome-based performance goals, including a **Priority Goal for Water Conservation**. Activities funded through WaterSMART Grants, the Title XVI Program, and other water conservation programs through 2015 are expected to result in more than 970,000 acre-feet of water savings once completed — roughly the

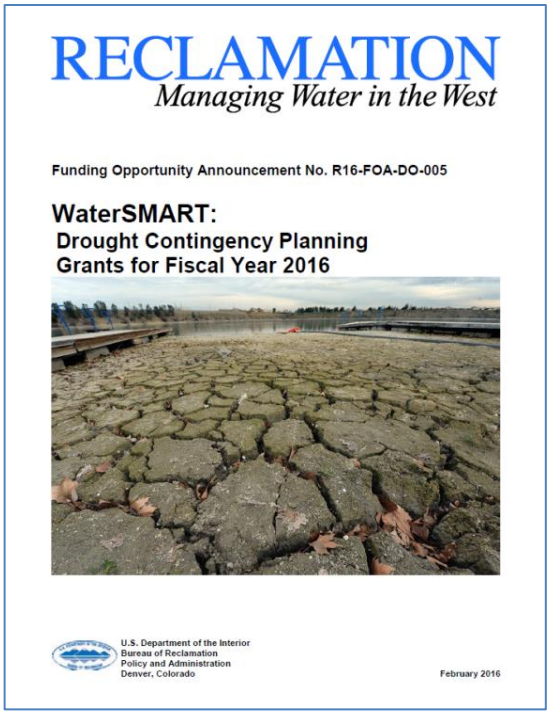


Priority Goal for Water Conservation

amount of water needed for household use in Phoenix and the surrounding area each year – and the Department of Interior is on track to meet its goal of 1,040,000 acre-feet of water savings by the end of 2017.

Climate change is expected to increase the frequency, intensity, and duration of drought conditions in the West. Drought contingency planning provides an important tool to proactively manage drought risks. In 2015, Reclamation reformulated its drought program to incorporate climate information and build resiliency against future droughts.

The new **Drought Response Program**[10] helps Reclamation and its partners avoid drought-related crises in the short term while laying a foundation for climate resiliency in the long term. In 2015, under this program, Reclamation announced grants for western communities totaling $5.1 million to implement 23 proactive projects to build long-term drought resiliency in nine western States. The program helps to implement Reclamation's Climate Change Adaptation Strategy and also directly supports the National Drought Resilience Partnership, identified in the President's Climate Action Plan, helping communities develop long-term resilience strategies by providing key climate change and drought information.



In northern Nevada, for example, the Truckee Meadows Water Authority is using Drought Response Program funding and its own cost-share contribution to update its current Drought Contingency Plan. The updated plan will incorporate climate projections developed through the Truckee River Basin Study and will specify mitigation actions that will help adapt to short-term changes in hydrologic conditions caused by drought. The Truckee Meadows Water Authority will update its plan by engaging stakeholders through established and successful stakeholder groups representing Federal, State, and local governmental organizations, tribes, agricultural producers, industries, and environmental and recreational interests.

[10] See http://www.usbr.gov/drought.

4.3 System Operations

With or without a change in future water supplies and demands, building additional flexibility and reliability into the systems used to manage those supplies helps to ensure that adequate water is available. The potential for increased frequency and intensity of floods and droughts brings additional challenges to operations and infrastructure conditions. Climate change, coupled with the fact that much of the water resources infrastructure in the Western U.S. is beyond its originally envisioned service life, highlights the importance of enhancing infrastructure resiliency to meet Reclamation's mission requirements in the future. Examples of the adaptation options and actions to improve system operations and resiliency are identified in Figure 1–16.

Figure 1–16. Potential system operations adaptation strategies.[11]

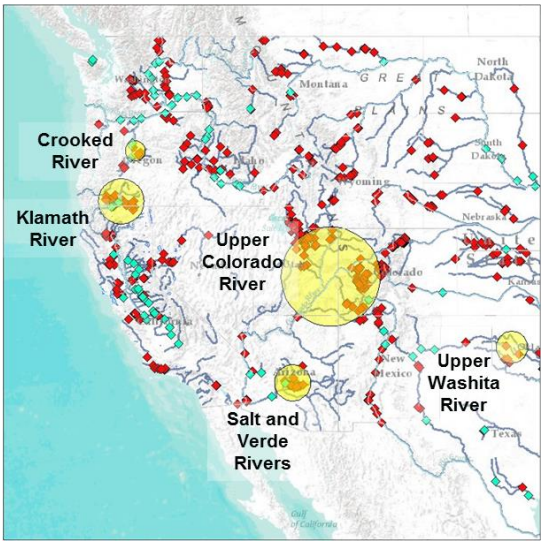
[11] Select examples are provided in this figure, as illustrations of the options considered. Additional examples are described in Chapters 3–10 or in individual Basin Studies.

Taking Action to Improve System Operations

To prepare for new extremes, Reclamation's Climate Change Adaptation Strategy identifies opportunities to incorporate climate change information into decisions regarding reservoir operations, infrastructure investments, and safety upgrades. The President's Plan provides support for this goal, prioritizing the need to build safer communities and infrastructure, manage drought, and prepare for future floods.

In 2014, Reclamation launched the **Reservoir Operations Pilot Initiative**[12] to determine how reservoir operations are impacted by climate change and how reservoir operations can be made more flexible to adapt to impacts. Reclamation's reservoirs are operated using criteria to meet a number of different water management priorities, including reliable water deliveries, power generation, environmental requirements, and needs for flood control management. Historically, uncertainties in weather prediction and assumptions of an unchanging climate have resulted in general rules for reservoir management, often seasonal to annual that will shift with future climate conditions.

In 2015, Reclamation initiated five pilot studies to evaluate how weather, hydrology, and climate-change information could better inform reservoir operations. Reservoir operation pilots are critical to understanding where flexibilities in reservoir operations may be increased through identifying trends in historic and current climate and hydrology, and through improved use of weather forecasting. Reclamation will use these pilot studies to develop guidance on considering climate change within reservoir operations.



Reservoir Operations Pilot Studies Initiated in 2015

WaterSMART also includes the **Resilient Infrastructure Program**, through which Reclamation proactively maintains and improves existing infrastructure for system reliability, safety, and efficiency to prepare for extremes and to support healthy and resilient watersheds. Prioritization of infrastructure investments is influenced by climatic conditions as well as by watershed management opportunities. In 2016, Reclamation is developing an enhanced decision-making framework to select a project to serve as a model for refining design considerations and decision-making criteria.

[12] The Reservoir Operations Pilot Initiative is funded through Reclamation's WaterSMART Basin Study Program: www.usbr.gov/watersmart/wcra/index.html

Hydropower production is vulnerable to altered water availability resulting from climate change; consequently, **optimizing hydropower production** is a key part of Reclamation's overall strategy to respond to the impacts of climate change. Reclamation is building on successful efforts already underway to continue generating clean energy, and it is providing Federal leadership in renewable energy development, both of which are priorities in the President's Climate Action Plan to slow the pace of climate change.

Reclamation has a long, successful history of working with customers to upgrade turbines and rewind generators at powerplants to achieve water and energy conservation benefits. Such investments improve hydropower generation resilience as climate change impacts occur and increase the generation of clean renewable energy. Initial assessments have also identified an opportunity to improve efficiency and flexibility at some Reclamation-owned pumping plants, reducing the amount of Reclamation hydropower energy required for water deliveries.

Aerial View of Hoover Dam and Lake Mead

Reclamation has identified equipment upgrades at hydropower and pumping plants to increase hydropower efficiency. For example, in cooperation with the Hoover power contractors, Reclamation has begun replacing 5 of the 17 existing generating turbines with wide-head turbines at Hoover Dam. These wide-head turbines can operate at a much wider range of reservoir levels that will allow the Hoover Powerplant to generate electricity more efficiently at lower Lake Mead levels. Since 1947, an average of about 4.4 billion kilowatt-hours of energy has been generated at the dam annually, or enough to supply about 400,000 U.S. households with all of their electricity needs for one full year.

The use of climate-change information to inform decisions about infrastructure investments is complex and on the cutting edge of climate science development. Warming is contributing to trends of heavier downpours over much of the U.S., which may lead to increases in local flood potential for some areas. However, at the local scale, substantial uncertainty remains about how global climate change will impact wet weather extremes.

Reclamation has a pilot initiative underway to incorporate climate change information into the Dam Safety risk assessment process. Reclamation's **Dam Safety Program** is developing a methodology for incorporating climate change information into hydrologic hazard analyses. An initial pilot completed at Friant Dam in California indicated that climate change is an important factor to consider in the hydrologic hazard analysis. A follow-on study is currently underway at Taylor Park Dam, Colorado. Additional work is also ongoing to integrate projections of future hydrology into existing methodologies for Reclamation dam safety comprehensive review studies, which are performed at all Reclamation dams on an 8-year cycle to identify and address risks to life and property.

4.4 Ecosystem Resiliency

Ecological resiliency refers the capacity of an ecological system to absorb change without major disruption to the system's structures and processes. Maintaining ecosystems and habitat affected by Reclamation projects is more challenging in changing climate and hydrology conditions. Anticipated changes in climate, the quantity and timing of river flows, and associated habitat conditions threaten ecological resiliency in many areas of the West. Examples of potential adaptation options and actions to enhance ecosystem resiliency are identified in Figure 1–17.

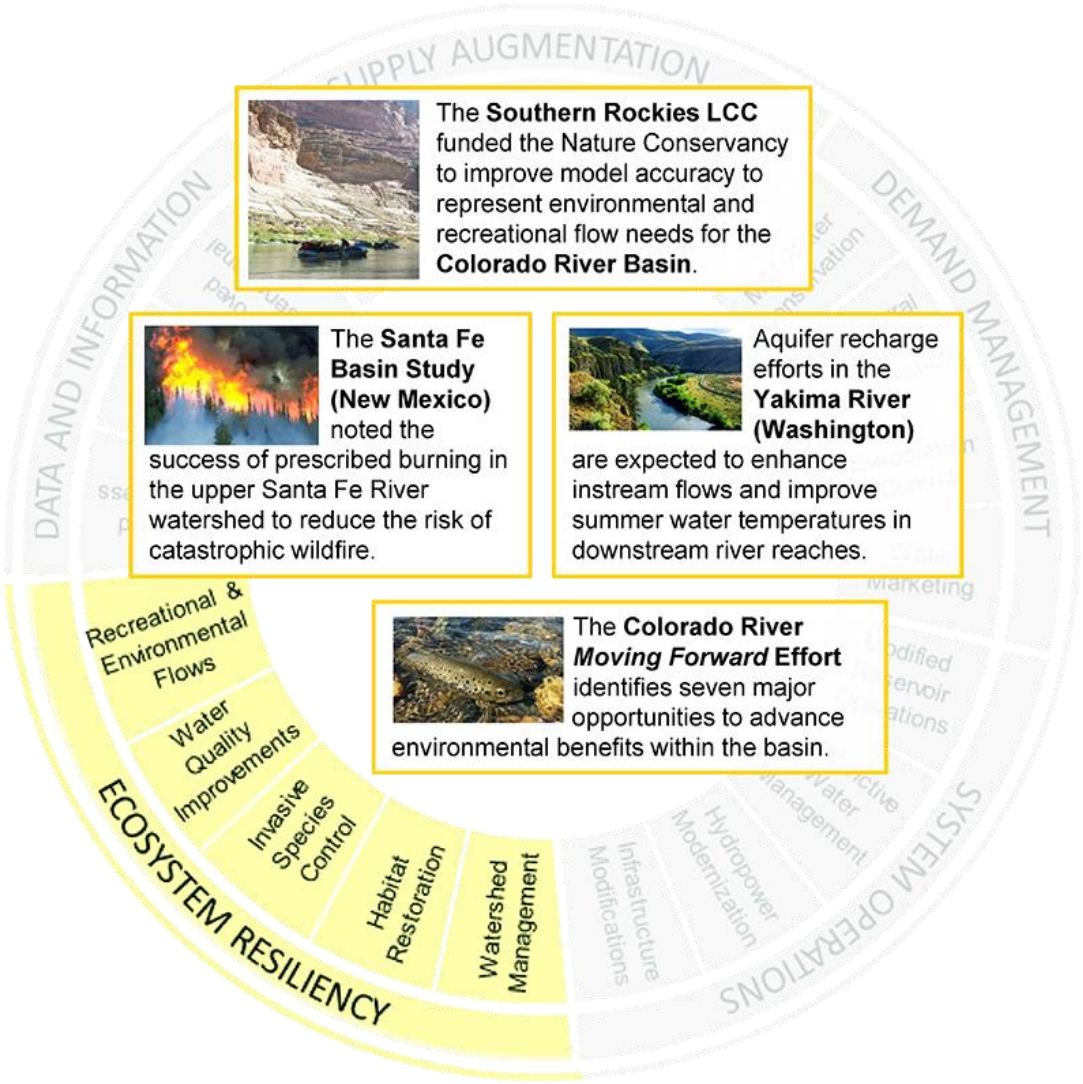


Figure 1–17. Potential ecosystem resiliency adaptation strategies.[13]

[13] Select examples are provided in this figure, as illustrations of the options considered. Additional examples are described in Chapters 3–10 or in individual Basin Studies.

Taking Action to Build Ecosystem Resiliency

Though meaningful and significant steps have been taken to protect or improve ecological and recreational resources, opportunities exist to expand environmental and recreational flow activities. Reclamation's Climate Change Adaptation Strategy identifies existing programs, including the WaterSMART Program, to address climate change impacts to ecosystems.

Under WaterSMART, the **Cooperative Watershed Management Program** provides financial assistance grants to improve water quality and ecological resilience and to reduce conflicts over water through collaborative conservation efforts in the management of local watersheds. To date, Phase 1 of the program has been initiated funding the formation or expansion of 19 watershed groups. Phase 2 of the program is under development and is expected to begin in 2017, to carry out projects in accordance with the goals of watershed groups to improve water quality and ecological resilience.

With the signing of Secretarial Order No. 3289, DOI launched the **Landscape Conservation Cooperatives (LCC)** to better integrate science and management to address climate change and other landscape-scale issues. By building a network that is holistic, collaborative, adaptive, and grounded in science, LCCs are working to ensure the sustainability of our economy, land, water, wildlife, and cultural resources. Reclamation and the U.S. Fish and Wildlife Service co-lead the Desert and Southern Rockies LCCs. Key highlights of ecological resource studies funded through the LCCs include:

1) *Building Decadal Prediction of Extreme Climate for Managing Water in the Intermountain West:* By reconstructing the history of streamflow and precipitation for watersheds in the Uinta Mountains and the Wasatch Range using tree-growth rings, a team of researchers at Utah State University improved water managers' understanding of streamflow variability and impact from climate extremes. Data from this research are being used directly by the Weber Basin Water Conservancy District to compare recent droughts and historic reconstructed records, in order to plan changes in operations management.
2) *Managing Water and Riparian Habitats on the Bill Williams River with Scientific Benefit for Other Desert River Systems:* The Corps Hydrologic Engineering Center, U.S. Fish and Wildlife Service, and USGS developed new operational rules for water managers to guide reservoir releases in the Bill Williams River that promote the establishment of native cottonwood and willow stands downstream of reservoirs while balancing other water management needs. By codifying water flow-ecology relationships for riparian species as operational rules for water managers and testing those rules under different climate scenarios, project benefits can be transferable to other managed river systems in the arid southwest.

3) *Predicting Snow Water Equivalence and Soil Moisture Response to Restoration Treatments in Headwater Ponderosa Pine Forests of the Desert LCC:* Northern Arizona University built upon the U.S. Forest Service's Four Forest Restoration Initiative to investigate how restoration efforts affect the water volume available in the snowpack and soil moisture. Models of snow water equivalence and soil moisture response to ponderosa pine forest restoration treatments are helping identify optimal treatments for sustaining water availability for plants as well as downstream water users in Verde Valley and the Phoenix metropolitan area.

4) *A Study of Climate Change Impacts on Water Quality and Internal Nutrient Recycling in Lake Mead, Arizona-Nevada:* Southern Nevada Water Authority modeled impacts of climate change on water quality and sediment transport in Lake Mead. This information enables organizations with water supply responsibilities to evaluate the likely quality of raw water in the future and plan for infrastructure or treatment changes. Additionally, organizations that discharge into Lake Mead or the Lower Colorado River can use the results to assess whether target nutrient loads for the point-source discharges may have to be reduced to offset the increased internal nutrient loading driven by climate change.

High-elevation forested zones are crucial for maintaining the quantities, timing, and quality of water supplies that serve Reclamation projects and western water users. Through the **Western Watershed Enhancement Partnership,** the U.S Forest Service and Reclamation seek to proactively improve the health and resiliency of National Forest System watersheds to reduce the potential for severe wildfire. Improving watershed functions and reducing the risk of uncharacteristically severe wildfire benefits Reclamation's water supply, irrigation, and hydroelectric customers.

Horsetooth Reservoir. The 2012 High Park Fire was the impetus for the Colorado-Big Thompson Headwaters Watershed Enhancement Partnership.

In 2015, projects in several areas of the West were competitively awarded a total of $770,000 in cost-shared funding to advance on-the-ground activities. This program supports site-specific treatments to mitigate risks by protecting upland ecosystem and watershed functions on Reclamation or U.S. Forest Service lands with a direct connection to facilities in order to avoid adverse impacts to water supplies.

4.5 Data and Information

Access to quality data on past and projected future hydrology, water use, land cover, and climate is essential if meaningful adaptation strategies are to be effectively evaluated and implemented. In many cases, quality data already exist, and considerable value can be added by merely making the data more accessible, understandable, and useful. In other cases, the development of tools that can analyze available data and use the data to model alternative scenarios can be useful. Where quality observational data are scarce or nonexistent, the collection of additional data to address key informational gaps may be invaluable. Examples of the relevant actions and data strategies identified within Reclamation-sponsored basin studies are provided in Figure 1–18.

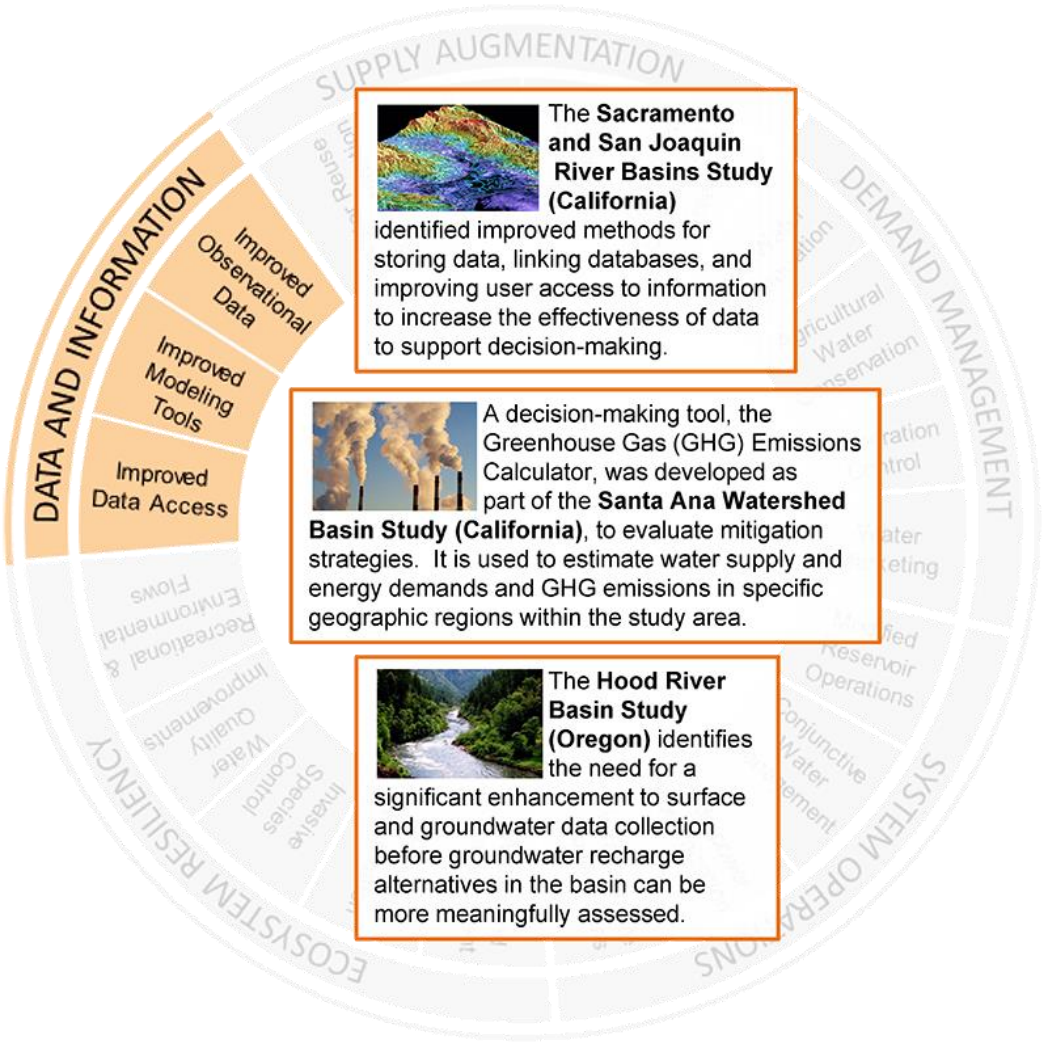


Figure 1–18. Potential data and information development strategies.[14]

[14] Select examples are provided in this figure, as illustrations of the options considered. Additional examples are described in Chapters 3–10 or in individual Basin Studies.

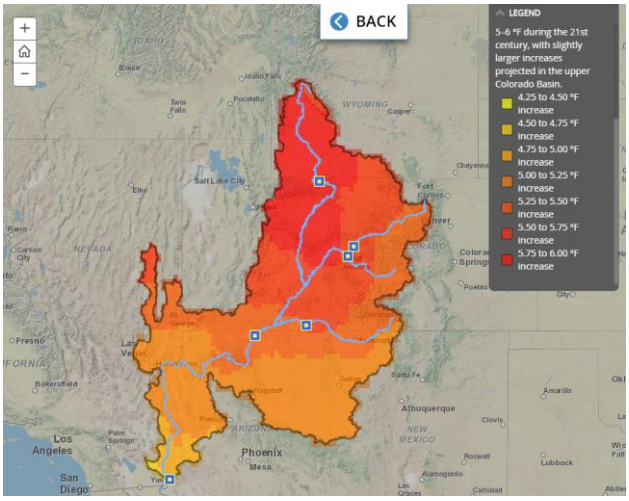
Taking Action to Access Data and Information

Reclamation's Climate Change Adaptation Strategy acknowledges that Reclamation and its stakeholders will benefit from increased access to climate change and water resources data. In order to successfully implement any supply augmentation strategy or demand management program, one must have a way to gauge needs and success, which requires an assessment of conditions before, during, and after exploration. Fundamental to developing new information for adapting to climate change is assessing the current state of knowledge, identifying where gaps exist, and finding opportunities to address those gaps.

Reclamation's Science and Technology Program is taking a leading role to develop the data and tools necessary to support climate change adaptation within Reclamation and by customers and stakeholders. During the course of these efforts, the research team has remained engaged with Reclamation-wide programs to enhance the relevance and utility of the climate adaptation strategies.

Downscaled Climate and Hydrology Projections Web Service:[15] Since 2007, Reclamation has led a partnership of nine Federal, academic, and nongovernmental organizations to provide future projections of temperature, precipitation, hydrology, and streamflow throughout the continental U.S. to support locally relevant decision making. These information resources are served though a website that provides users access to the monthly gridded precipitation, temperature, and hydrologic projection data, as well as additional climate projection information that covers the contiguous U.S.

Through the WaterSMART Basin Study Program, a data visualization site has been produced to accompany the release of this 2016 SECURE Water Act Report to Congress.[16] This tool allows users to view changes in temperature, precipitation, and snowpack in major river basins and to download supporting projection data sets as they walk through the SECURE Water Act Report.



SECURE Water Act Data Visualization Tool — Projected temperature change in the 2070s for the Colorado River Basin

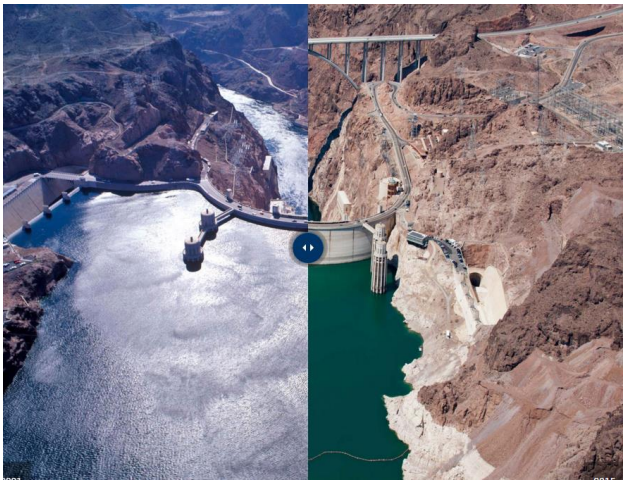
[15] Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections Web Service site : http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html

[16] SECURE Water Act Report website: http://www.usbr.gov/climate/SECURE

Climate Training: Since 2012, Reclamation and USACE have been collaborating with CCAWWG and the University Center for Atmospheric Research COMET® program to develop and pilot climate change training tools for Federal and non-Federal water agency staff and to explore sustained delivery approaches.

- *Technical Series:* Initial efforts focused on developing a new COMET® Professional Development Series, "Assessing Natural Systems Impacts under Climate Change." The series is designed to provide technical training to water resources professionals on how to incorporate climate change science and uncertainties into a variety of natural resource impacts assessments, including those related to surface water hydrology, crop irrigation requirements, water temperature, river and reservoir sedimentation, water quality, and land cover.
- *General Audience Series:* While the initial effort to develop technical training series has successfully engaged technical practitioners, there is also a need to provide training for senior leaders, program managers, project managers, resource specialists, public affairs specialists, and others who play critical roles in mainstreaming climate change into mission activities. In response, training partners have recently begun to scope and develop a parallel professional development series aimed at these communities.

Open Water Data Initiative: Reclamation is addressing the requirements of the President's Open Data Policy and DOI's Open Water Data Initiative by making Reclamation's water and related data more comparable across locations, easier to find, more shareable with other agencies, stakeholders, and the public, leading to an overall outcome of better managed data.



Colorado Drought Visualization Web Tool — Lake Mead in 2001 and 2015.

One example of an open data product is the specialized web tool developed by the USGS and Reclamation: "Drought in the Colorado River Basin – Insights Using Open Data."[17] This visualization is an effort to showcase the usefulness of open data by exploring the current 16-year drought and its effects on the Colorado River Basin. The dramatic data interactions show the interconnected results of a reduced water supply as reservoir levels have declined from nearly full to about 50 percent of capacity.

[17] See https://www.doi.gov/water/owdi.cr.drought/en/index.html

5 Collaboration

Given the important partner equities in water resource management, Reclamation has a responsibility to demonstrate leadership and to leverage resources by sharing information and capabilities with partners interested in climate adaptation. Reclamation recognizes that for Federal investments in climate resiliency to be successful, strong partnerships with State, tribal, and local governments and with water users, stakeholders, the public, and other Federal agencies are crucial. The President's Climate Action Plan emphasizes the importance of providing open government data that "can fuel entrepreneurship, innovation, scientific discovery, and public benefits."

5.1 Collaboration and Coordination with Federal Agencies

Reclamation is actively engaged in multiple collaborative efforts with Federal and non-Federal partners to monitor, develop, and share information for a common understanding of climate change impacts to water resources in the West. This section highlights activities that implement Section 9503(b)(1) of the SECURE Water Act, which directs the Secretary of the Interior, through Reclamation, to "coordinate with the USGS, National Oceanic and Atmospheric Survey (NOAA), the program, and each appropriate State water resource agency, to ensure that the Secretary has access to the best available scientific information with respect to presently observed and projected future impacts of global climate change on water resources."

Reclamation coordinates with the USGS, NOAA, and the Natural Resources Conservation Service on climate monitoring activities through the **WWCRA Implementation Team**. Climate monitoring objectives for the Implementation Team include:

- Sustain active communication between agencies on monitoring activities, climate and water resources data, and science tools for water management decisions,
- Understand data availability, accessibility, and applicability for direct use and implementation in Reclamation's climate change impact and planning studies, and
- Identify opportunities to improve climate monitoring data available for water management decisions.

Reclamation is using climate monitoring data networks in a broad set of studies to determine impacts and risks to water resources due to climate change. Inter-agency coordination to acquire and maintain water resources data aids in strengthening the understanding of water supply trends and assists in the assessments and analyses conducted by Reclamation. Information generated through WWCRA provides a foundation of climate change data, information, and tools that partners can build from to develop adaptation strategies.

Reclamation is coordinating with other Federal and non-Federal agencies to implement Section 9503 of the SECURE Water Act through multiple collaborative approaches. Together, these activities will allow Reclamation to better assess the risks and impacts of climate change on the hydrological cycle and to implement collaborative adaptation strategies. In addition to the climate-monitoring activities listed under Section 9503(b)(1), Reclamation also coordinates closely with the following other Federal agencies authorized under the SECURE Water Act.

As directed by Congress in **Section 9505 of the SECURE Water Act**, the U.S. Department of Energy (DOE), in consultation with the Federal Power Marketing Administrations and other Federal agencies, examines the potential effects of climate change on water available for hydropower generation at Federal facilities and on the marketing of that power. Through the WWCRAs, Reclamation coordinates with DOE to compare climate modeling analyses that project climate conditions and impacts to hydropower into the future and compare basin-specific climate impacts to hydropower.

The **SECURE Water Act Sections 9507 and 9508** authorized the "Water Data Enhancement by the United States Geological Survey" and the "National Water Availability and Use Assessment Program," respectfully. As previously mentioned, through WaterSMART, the USGS has implemented a National Water Census. The SECURE Water Act authorized $20 million for each of fiscal years 2009 through 2023 for the USGS through the National Water Census; appropriations for this effort as of 2015 totaled $28 million. With this funding, the USGS continues to engage stakeholders in a discussion of priorities.

Reclamation coordinates closely with the USGS to leverage information produced by a number of activities, including groundwater assessments and surface water focus area studies in Reclamation's Basin Studies. In 2016, the USGS began three additional Geographic Focus Area Studies of water availability and use in the Coastal Basins of the Carolinas and two which overlap with ongoing or completed assessments in the Basin Study Program: the Red River Basin and the Upper Rio Grande Basin. In addition, five topical areas are producing information on water budget components that are national in scope. The topical studies include:

- Estimating streamflow at ungaged locations and characterization of long-term trends in streamflow;
- Assessing regional groundwater availability of principal aquifers;
- Using remote sensing to quantify evapotranspiration;
- Improving information on human water withdrawals, consumptive uses, and return flows; and
- Developing tools and web-available resources to understand the effects of streamflow alteration on aquatic ecosystems.

Additionally, in 2015, the USGS received $1.5 million for grants to States to improve water use collection, estimation, and delivery. The USGS also received $2.4 million for grants to States to implement the National Groundwater Monitoring Network. These two efforts greatly enhance the ability of the Water Availability and Use Science Program to produce the information and tools necessary to improve water budget component information for water management decisions and are critical to Reclamation's climate resilience and adaptation planning efforts.

Reclamation's Research and Development Office focuses on researching innovative, workable solutions to our challenging issues with managing water and power in the Western U.S. CCAWWG is a partnership with the USACE, the USGS, NOAA, and others to identify mutual science needs for long-term planning and short-term operations. The development of these groups has included strong stakeholder interaction and involvement through the Western States Water Council, the American Water Works Association, Family Farm Alliance, Western Area Power Administration, and Seattle City and Light Department. Reclamation's Science and Technology Program has invested in a range of solutions to meet needs identified collaboratively by CCAWWG, including climate change training programs for Reclamation staff.

Reclamation is also collaborating with Federal entities on the National Fish, Wildlife and Plants Climate Adaptation Strategy. This strategy provides a framework for actions needed now to help safeguard our valuable natural resources and the communities and economies that depend on them in a changing climate. Implementing the strategy will also fill critical gaps in the science, monitoring, modeling and training to sustain fish, wildlife, and plants in a changing climate. Its implementation is being overseen by a Joint Implementation Working Group made up of representatives from the same Federal, State, and Tribal agencies that led the successful completion of the strategy, including Reclamation. The group's purpose is to help facilitate and promote implementation across multiple agencies, as well as to share information among participants.

5.2 Collaboration and Coordination with States and Stakeholders

Western water management and operations at Reclamation facilities are closely intertwined with the activities and interests of various western stakeholders. This includes other Federal agencies, States, Indian tribes, local water and irrigation districts, and other nongovernmental organizations. Although Reclamation builds, owns, and continues to operate much of its infrastructure, local partners also play a huge role in system operations and maintenance. The SECURE Water Act has catalyzed collaboration between Reclamation and multiple stakeholders, and has promoted the exchange of valuable technical assistance that otherwise may be difficult to acquire.

As Reclamation has taken steps to implement the SECURE Water Act, it also has engaged with State interests via participation in the **Western Federal Agency Support Team (WestFAST)** meetings and discussions. WestFAST is a collaboration of 12 Federal agencies with water management responsibilities in the West, established to support the Western States Water Council and the Western Governors' Association in coordinating Federal water resources efforts. WestFAST is engaged in a variety of activities related to water resources and climate change.

The **Western States Water Council (WSWC)** is a collaborative body created by western governors in 1965 and comprised of member States – from Texas to North Dakota and westward – which allows the governors to effectively address and work toward solutions that are larger than single states and across a regional scale. Over the past decade, a barrier to regional cooperation was identified: a lack of or difficulty accessing available water data that would assist with regional water resource management issues. To address this, the WSWC initiated the Water Data Exchange (WaDE) Program. Begun in 2012, the WaDE program is a cooperative effort between the WSWC, the Western Governors' Association, DOE, WestFAST, and the National Environmental Information Exchange Network.

The WaDE Program seeks to (1) better enable the States to share important water planning and administrative datasets with each other and the public, and (2) encourage Federal agencies to begin to share their datasets using "open data" formats and publication methods. WSWC support of Federal data-sharing stems from the difficulty of assembling and preparing myriad data produced by Federal agencies for incorporation into models and tools. It would greatly improve and ease the development of hydrologic and groundwater models, etc., for State agency water planners if they could access these datasets in a more interoperable and possibly centralized location. WSWC has engaged with Federal agencies that have water management responsibilities in the West through WestFAST, and asked that they consider what standards and formats exist for the types of data they wish to share and whether they could publish them using "open data" formats. WSWC has also offered to help agencies to develop standardized formats for specific data types if needed, and to provide feedback on any pilots or preliminary work done to make datasets publically accessible in interoperable and machine-readable formats. Specific examples include:

- **Reclamation's Lower Colorado River Data Sharing Pilot:** In 2014, Reclamation's Lower Colorado Region Office staff members asked WSWC for assistance with the development and review of a possible data-sharing portal for Colorado River data maintained by their offices. WSWC and the regional office team discussed and refined the potential products and interfaces that might be used in the future for publishing Reclamation datasets.

- **Open Water Data Initiative Coordination:** In late 2014, DOI began to pursue an Open Water Data Initiative — an effort to improve the availability of water datasets generated not only by Federal agencies, but by a wide range of authoritative public and private water data providers. The goals of Open Water Data Initiative are to integrate fragmented water information into a connected national framework and leverage existing shared resources, while encouraging more partners to share their information using interoperable and machine-readable formats.

WSWC and Reclamation are collaborating on the Open Water Data Initiative framework and on finding ways that Reclamation and State-managed data can be leveraged and integrated into useful tools for decision-making. The intent of these efforts is to demonstrate the value of "open data" when used to support key visualizations and policy tools in an automated and timely fashion.

The **Basin Study Program** is a key avenue of collaboration and coordination between Reclamation and various local, State, and tribal interests. With 24 Basin Studies now initiated (and 18 completed as of the release of this document), Reclamation has forged collaborative relationships in 15 of the 17 Western States with a diverse assortment of non-Federal partners, including State water resource agencies, regional water authorities, local planning agencies, water districts, agricultural associations, environmental interests, cities and counties, and tribal governments (see Table 1–1).

A number of these non-Federal partners point to the usefulness of efforts through Basin Studies to incorporate the best available science into planning activities. As part of the Los Angeles Basin Study, for example, Reclamation worked with partners to down-scale future precipitation projections to time intervals that could be used as part of existing planning efforts. Lee Alexanderson of the Los Angeles County Department of Public Works notes that those efforts allowed the county to incorporate more robust climate science into future water demand and supply analysis so that planning efforts can be adjusted accordingly: "In the end, that effort reaffirmed our confidence that the Los Angeles Basin is well-positioned to cope with anticipated climate changes and water demands for the remainder of this century, provided that we continue to implement appropriate planning and policies."

Similarly, Larry Dolan, Hydrologist at the Montana Department of Natural Resources, points to the usefulness of work carried out through the Upper Missouri River Impact Assessment and Missouri River Headwaters Basin Study: "Basin modeling enabled us to understand how water supplies in the future, although they might be similar to what we have today, will not be sufficient to meet future needs in the region for irrigation and other uses. Warming trends will mean higher shortages in the future due to a longer growing season and higher crops irrigations demands for the water that we have available to us."

Table 1–1. Basin Studies Initiated, Study Locations and Cost Share Partners

	Basin Study	Study Location	Cost Share Partners
Chapter 3	Colorado River Basin Study	Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming	Arizona Department of Water Resources, (California) Six Agency Committee, Colorado Water Conservation Board, New Mexico Interstate Stream Commission, Southern Nevada Water Authority, Utah Division of Water Resources, Wyoming State Engineer's Office
	Lower Santa Cruz River Basin Study	Arizona	Southern Arizona Water Users Association
	West Salt River Valley Basin Study	Central Arizona	West Valley Central Arizona Project Subcontractors
Chapter 4	Henrys Fork of the Snake River Basin Study	Central Idaho	Idaho Water Resource Board
	Hood River Basin Study	North-central Oregon	Hood River County Water Planning Group
	Upper Deschutes Basin Study	Oregon	Deschutes Basin Board of Control
	Yakima River Basin Study	South-central Washington	State of Washington Department of Ecology
Chapter 5	Klamath River Basin Study	California and Oregon	Oregon Water Resources Department, California Department of Water Resources
Chapter 6	Missouri River Headwaters Basin Study	Montana	Montana Department of Natural Resources and Conservation
	Niobrara River Basin Study	Northern Nebraska	Nebraska Department of Natural Resources
	Republican River Basin Study	Colorado, Kansas and Nebraska	Colorado Division of Water Resources, Kansas Department of Agriculture, Kansas Division of Water Resources, Kansas Water Office, Nebraska Department of Natural Resources
	St. Mary and Milk River Basins Study	Montana, southern Alberta and Saskatchewan Canada, Blackfeet and Ft. Belknap Indian Reservations	Montana Department of Natural Resources and Conservation

	Basin Study	Study Location	Cost Share Partners
Chapter 7	Santa Fe Basin Study	Northern New Mexico and southern Colorado	City of Santa Fe and County of Santa Fe
	Lower Rio Grande Basin Study	United States/Mexico border from Fort Quitman, Texas to the Gulf of Mexico	Rio Grande Regional Water Authority
	Pecos River Basin Study	New Mexico	New Mexico Interstate Stream Commission
Chapter 8	Sacramento and San Joaquin Rivers Basin Study	California	California Dept. of Water Resources, Stockton East Water District, California Partnership for the San Joaquin Valley, El Dorado County Water Agency, Madera County Flood Control and Water Conservation Agency
	Salinas and Carmel River Basins	California	Monterey Peninsula Water Management District, Monterey County Water Resources Agency, Monterey Regional Water pollution Control Agency, San Luis Obispo County
Chapter 9	Truckee River Basin Study	California and Nevada	Truckee River Flood Management Project, Placer County Water Agency, Truckee Meadows Water Authority and the Tahoe Regional Planning Agency
Chapter 10	Santa Ana River Watershed Basin Study	California	Santa Ana Watershed Project Authority
	Southeast California Regional Basin Study	California	Borrego Water District
	San Diego Watershed Basin Study	California	City of San Diego Public Utilities Department
	Los Angeles Basin Study	California	Los Angeles County Flood Control District
	Upper Washita River Basin Study	Oklahoma	Oklahoma Water Resources Board, Fort Cobb Reservoir Master Conservancy District, Foss Reservoir Master Conservancy District
	Upper Red River Basin Study	Oklahoma	Oklahoma Water Resources Board

Other non-Federal partners highlight the ways that collaborative efforts through Basin Studies are continuing, even after work on a particular study has been completed. For example, Hood River County Commissioner Les Perkins notes that the hydrological model developed as part of the Hood River Basin Study helped the community focus on strategies for long-term sustainability of water supplies, and that those efforts are continuing: "The study launched follow-up efforts to evaluate new storage options in Hood River County, and it spurred us to enhance groundwater monitoring in order to better understand local surface and groundwater interactions."

Others note that sharing of data developed through the Basin Study Program is helping with local planning efforts. Aaron Sussman, formerly with the Mid-Region Council of Governments in Albuquerque, New Mexico, points out that information on the projected effects of climate, developed as part of the Upper Rio Grande Climate Impact Assessment, is being used outside of water resources planning: "Together with our water demand analyses, that information jump-started community discussions on how we want to see our area grow—in particular, looking at our transportation needs in the broader and more comprehensive context of future land use and water resource needs."

Relationships established through the Basin Studies lead to additional collaborative efforts, such as the Colorado River Basin *Moving Forward* Effort, a collaborative partnership among Reclamation, the seven Colorado River Basin States, the Ten Tribes Partnership, and conservation organizations designed to pursue several areas of the "next steps" identified in the *Colorado River Basin Water Supply and Demand Study*. Collaboration with stakeholders is critical to the successful implementation of climate adaptation strategies through WaterSMART Grants, the Title XVI Program, Drought Response Program, Cooperative Watershed Management Program, and the Water Conservation Field Services Program. Additional information on coordination activities specific to each western river basin, including the strategies developed to address potential water shortages, is included in Chapters 3 through 10.