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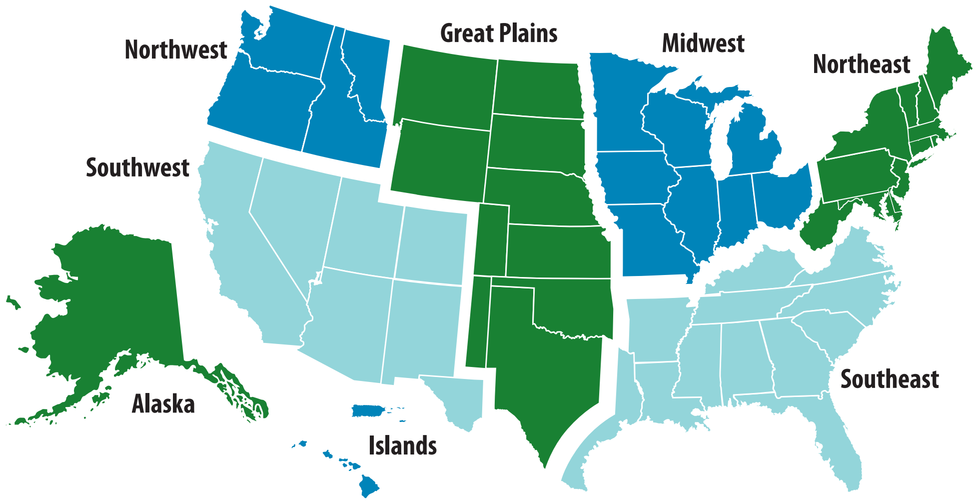
Adaptation Strategies Guide for Water Utilities



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Climate Ready Water Utilities Adaptation Strategies Guide for Water Utilities

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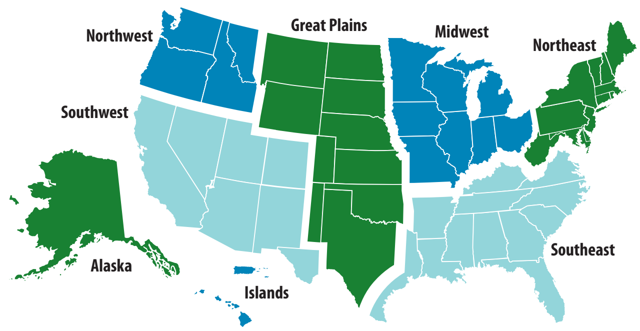

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Adaptation Strategies Guide for Water Utilities

ABOUT THIS GUIDE

Climate change presents several ***challenges*** to drinking water and wastewater utilities, including increased frequency and duration of droughts, floods associated with intense precipitation events and coastal storms, degraded water quality, wildfires and coastal erosion, and subsequent changes in demand for services. While these impacts have been documented in numerous publications, finding the right information for your ***type of utility*** or ***geographic region*** can be difficult and sometimes overwhelming. Therefore, the goals of the Adaptation Strategies Guide are (1) to provide drinking water and wastewater utilities with a basic understanding of how climate change can impact utility operations and missions, and (2) to provide examples of actions utilities can take (i.e., adaptation options) to prepare for these impacts.

The climate information included in this Guide (identified as ***projected changes*** statements throughout the document) was primarily drawn from the U.S. Global Change Research Program (USGCRP) 2009 Report. Global climate research, conducted by international research groups, has generated projections of future climate conditions based on historical climate data (i.e., temperature, precipitation, and sea level), as well as simulations based on scientific understanding of atmospheric processes. These groups and other research institutions have translated and downscaled projections from global models to produce projections at national, regional, and local scales. In many cases, these projected changes may generate specific impacts or challenges for drinking water and wastewater utilities that are described within this Guide. This process of translating global climate projections into the challenges that drinking water and wastewater utilities may face is outlined in **Figure 1.1** and is described in greater detail in the 2009 USGCRP report.

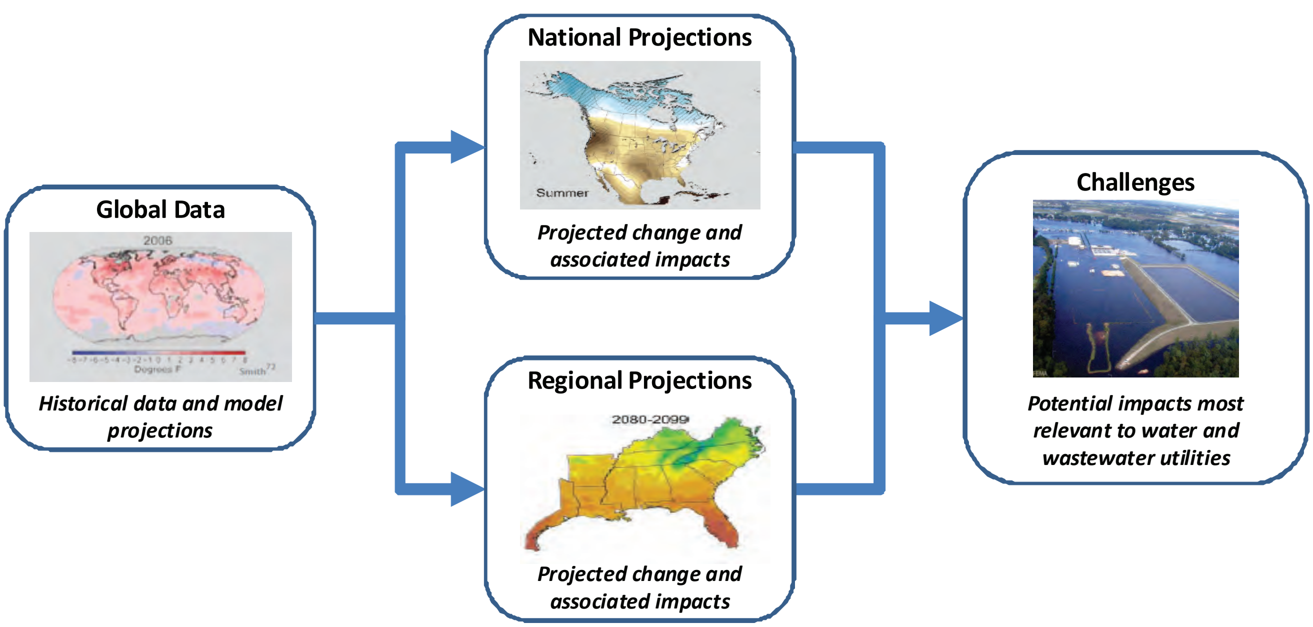

Figure 1.1. Translation scheme for climate data and model outputs into challenges for water utilities. Model run images from USGCRP (2009).

ABOUT THIS GUIDE

Adapting your system and operations to climate change challenges requires consideration and planning. However, adaptation planning is not necessarily a new effort, distinct from other utility practices. Because adaptation strategies can often provide multiple benefits, adaptation planning can be integrated into emergency response planning, capacity development, capital investment planning, water supply and demand planning, conservation practices, and infrastructure maintenance.

Using three different types of informational briefs, this Guide will walk you through an understanding of climate information at your location, what challenges you may expect to see, and what adaptation options you can use to address each climate challenge. It should be noted that there is no one-size-fits-all solution for utilities when it comes to adaptation planning. It is important to use the information provided within the Guide to develop an adaptation plan that fits with your utility's available resources, priorities, and relevant climate challenges. An adaptation planning worksheet is also included in the Guide to help identify and organize adaptation options that interest you. Either (1) print the worksheet and fill in the fields by hand while browsing through the Guide, or (2) type in the fields electronically, and make sure to print or save the worksheet before closing the Guide.

After reading the introductory material of the Guide, you will be able to choose one of nine different U.S. climate regions from a map. Selecting a region will bring you to the corresponding ***Climate Region Brief***, which lists projected changes to the climate that can be expected as an illustrative example of these changes. The Guide includes a Climate Region Brief for each of the nine regions, as well as a brief that outlines the major climate challenges that face the United States as a whole. The boundaries of the nine climate regions were taken from the USGCRP 2009 Report, and were determined based on historical and projected climate data and trends. It is expected that the locations within the same region can expect to experience similar climate impacts in the future (e.g., some regions will get wetter and warmer while some will get warmer and drier, etc.).

Each Climate Region Brief includes a table of climate challenges that are relevant to your utility (i.e., high flow events and flooding, volume and temperature changes, altered surface water quality). Clicking on one of those challenges for either drinking water or wastewater will bring you to a ***Challenge Brief***. These Challenge Briefs provide more information on a particular impact and list adaptation options that, when implemented at your utility, can help to address that challenge and ensure that your system is better prepared for a climate change-related impact. Relative cost information is included for each adaptation option as well.

Another set of briefs, the ***Challenge Group Briefs***, is included within this Guide to provide more general information on regional climate challenges. Individual challenges have been categorized into five different groups, with each group having its own brief: drought; flood; water quality degradation; ecosystem changes; and service demand & use. Each Challenge Group Brief summarizes the challenges within that group and also contains a compiled list of all adaptation measures applicable to the individual challenges within the group. **Figure 1.2** on the next page depicts the general process followed when using this Guide and the relationship between the Climate Region Briefs, Challenge Briefs, Challenge Group Briefs, and resulting adaptation options.

HOW TO USE THIS GUIDE

You can navigate this Guide as if it were a website. Instructions indicating clickable links can be found in the Table of Contents, the last section of the Introduction, and within all of the briefs. Many of the links are represented with an icon or picture, while others are hyperlinked and displayed with underlined text (e.g., ***Worksheet for Adaptation Planning***). Clicking on the **Return to Introduction** button at any location in the Guide will bring you back to the last section of the Introduction where you can select a Climate Region Brief, Challenge Brief, or Challenge Group Brief.

If you have any questions about or feedback on the Adaptation Strategies Guide for Water Utilities, or would like to suggest new material (e.g., examples) to include, please email CRWUhelp@epa.gov.

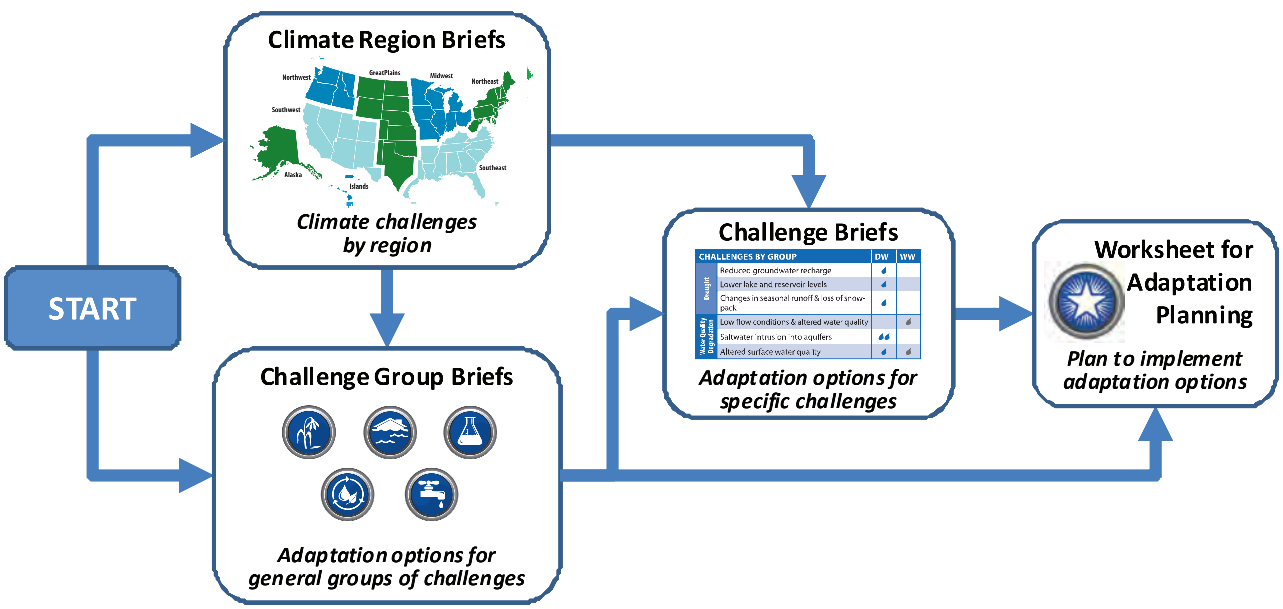

Figure 1.2. General process followed when using this Guide. Start with either Climate Region or Challenge Group Briefs to identify specific Challenge Briefs to review. Adaptation options from these briefs can be cataloged in the Worksheet for Adaptation Planning to support planning efforts.

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Adaptation Strategies Guide for Water Utilities
INTRODUCTION

The Adaptation Strategies Guide for Water Utilities provides adaptation options for drinking water, wastewater, and stormwater utilities based on region and projected climate impacts. The adaptation options are based on the projected climate impacts for different regions. While specific example adaptation options are described in the Guide, there is no one-size-fits-all solution for adaptation planning. Utilities will need to use the information included in this Guide to assist them in developing plans that contain adaptation options suited to their specific needs, taking into consideration their location, climate impacts of concern, and available resources. Water utilities should collaborate with state and federal authorities, interdependent sectors (i.e., energy and agriculture), and other nearby utilities early in the adaptation planning process to ensure comprehensive and consistent planning.

Readers should use this Guide as an informational resource to identify potential strategies for adapting to climate change impacts. The Introduction provides background information to promote a better understanding of the adaptation planning process. The document then allows a user to identify the relevant challenges by climate region and consider potential adaptation options to address these challenges. Finally, a Worksheet for Adaptation Planning is provided to allow users to organize the information in this Guide and to tailor it to their utility.

Why should a utility develop an adaptation plan?

Addressing climate change at a utility is a complex issue, but utilities are expected to face many challenges associated with the impacts of projected future climate change. It is therefore important to consider adaptation options that can provide greater resilience to these impacts, as well as provide additional benefits to the utility. Climate change adaptation strategies may provide benefits such as more sustainable and efficient operations, cost savings, maintenance of adequate water supply and quality, and the reduction of greenhouse gas emissions. Every utility has its own unique priorities and set of resources and will be impacted by climate change differently; therefore, it is important to consider many different options and the range of benefits offered in order to develop a comprehensive adaptation plan that satisfies utility needs without overstretching resources.

Adaptation planning is not necessarily a new, separate effort for managing utilities. Implementing adaptation strategies that provide multiple benefits can be integrated into current asset management, emergency response planning, capacity development, and other decision-making processes at utilities.

Example of Approach to Incorporate Climate Change into Long-Term Planning:

Following deadly flash floods in 1997, the City of Fort Collins Utilities (FCU), Colorado, refocused their planning efforts around extreme precipitation events. FCU has initiated a Climate Change Adaptation Study to examine possible future impacts of shifts in weather patterns. The purpose of this study is to understand the impacts of possible climate shifts and to design a framework to incorporate climate adaptation into FCU's ongoing asset management planning. As a mid-sized, combined drinking water, wastewater, stormwater and electric utility service provider, FCU has identified a need to adopt an integrated approach to adaptation and risk assessment. This approach would complement established integration of shifting weather patterns into utility design and management processes.

In summary, FCU has adopted the overarching goal of integrating adaptation planning into daily business practices by (1) embracing a dynamic, iterative process, (2) minimizing staff and resource burden by continually refining the process, and (3) leveraging ties to asset management. One

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Example of Approach to Incorporate Climate Change into Long-Term Planning: *(continued)*

important step towards this goal has been the use of the Joint Front Range Climate Vulnerability Study (CWCB 2011) as a source for climate scenarios that are based on model run results, including a range of possible futures: hot and dry; warm and wet; extreme drought; extreme precipitation; and an average or "median conditions" scenario. From these scenarios, FCU has drawn information on impacts to water resources and potential flood events. For example, warmer and wetter winters may lead to decreased winter snowpack, increased rainfall, and earlier spring melt and runoff for the area. With this information, FCU has (1) identified the risks related to these impacts, (2) considered consequences with respect to customers, operations, and the environment through these risk assessments, and (3) evaluated adaptation options to address these risks and build a more resilient operation.

What is adaptation planning?

An integral part of increasing utility climate change resilience is to conduct a risk assessment and adopt an associated decision-support framework (**Figure 2.1**). This framework should be an iterative process of identifying projected impacts and challenges associated with climate change, assessing risks from these impacts based on current thresholds for failure or damage, selecting and implementing adaptation options, and then revisiting assessments when new information is available or when additional capacity to implement options is in place. The framework should also include other stressors besides climate change (e.g., land-use, population, and regulatory changes).

Example of Adaptation Planning:

New York City's Department of Environmental Protection (DEP) provides drinking water, wastewater treatment, and stormwater management services to approximately 9.2 million people in its metropolitan region. DEP is involved in both local and national efforts to study and plan for climate change, including collaboration with other utilities as part of the Water Utility Climate Alliance, as well as with members of the research community (such as the Water Research Foundation and NOAA's Regional Integrated Sciences and Assessments), to establish sound decision making tools in light of climate uncertainty. Responding to current operational challenges and the threat of climate change, DEP collaborated with Columbia University and the City University of New York to better understand how climate change may affect its operations and infrastructure. Using downscaled projections from three General Circulation Models, DEP performed a vulnerability assessment which demonstrated that future challenges were likely to reflect an increased probability of some current challenges, such as high turbidity events caused by intense precipitation and highly erodible soils. Warming winters are projected to lead to less snow accumulation and increased winter streamflow. This may result in more nutrients and sediment entering the reservoirs during the winter as opposed to the spring. While not implemented specifically in response to climate change, existing DEP programs enhance resilience to challenges that may arise in the future. For instance, the acquisition of land in the Catskill Mountains and Delaware River watersheds and conservation efforts with landowners helps protect the areas surrounding reservoirs and controlled lakes. Other strategies being implemented to enhance the resilience of DEP's systems include more frequent sewer maintenance, enhancing green infrastructure to decrease stormwater runoff, promoting water conservation, and an Operations Support Tool that allows greater flexibility in response to conditions like high turbidity. DEP plans to adjust its adaptation strategies

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Example of Adaptation Planning: *(continued)*

as it develops tools and programs to manage existing demands and continues an iterative planning process to anticipate future challenges.

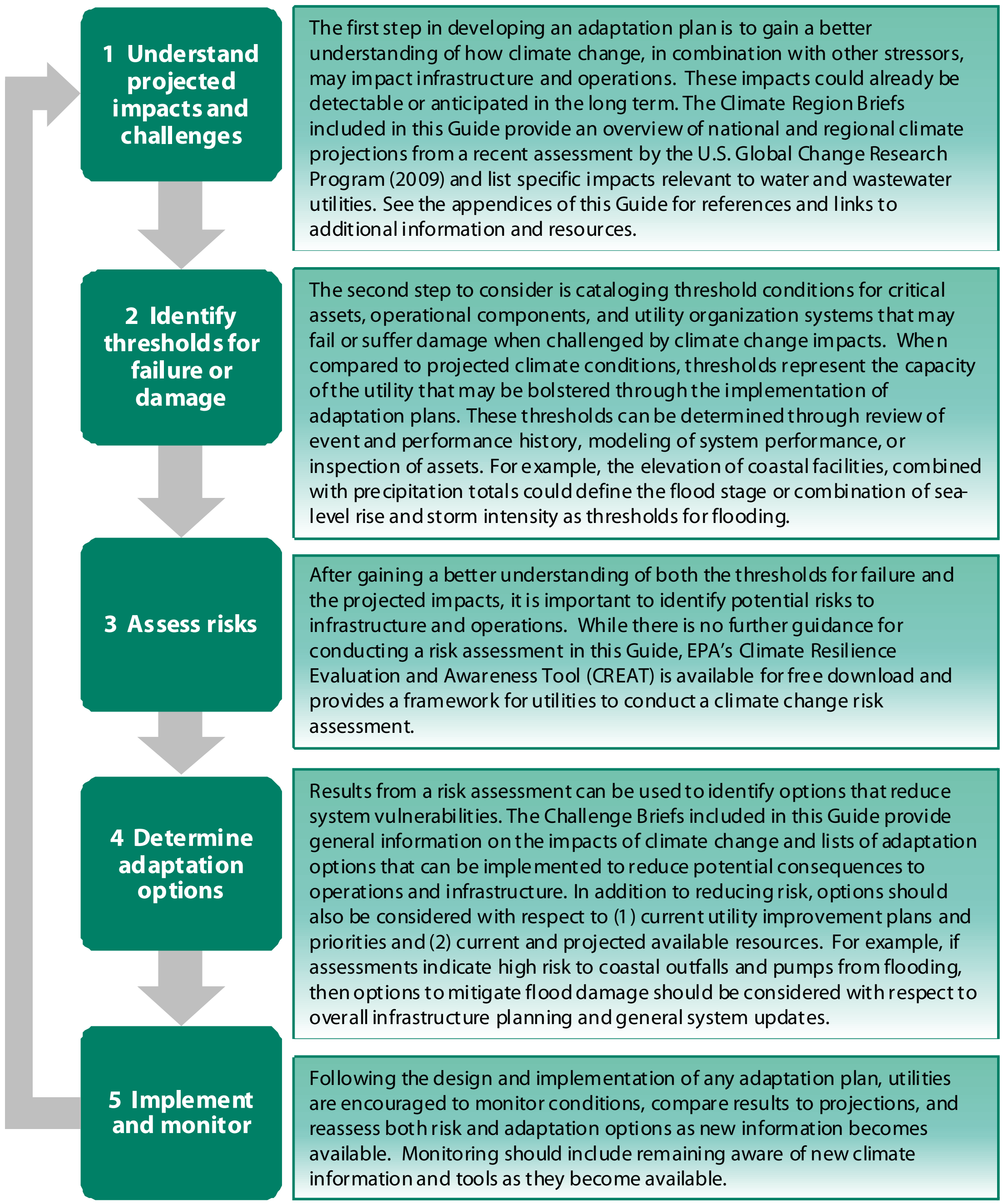

Figure 2.1. General process steps for adaptation planning. Steps are numbered based on the process described in this Guide. Other stressors (e.g., land-use changes and population growth) contribute to the overall assessment and may, in turn, be altered by the adaptation options implemented. Steps "1 Understand impacts & challenges" and "4 Determine adaptation options" are addressed within this Guide.

Adaptation planning involves more than just a review of options for facility owners and operators to consider. Several technical and informational resources are required to support planning. For example, inundation maps, precipitation projections, and flood models may all need to be employed in the determination of thresholds for flooding and the assessment of adaptation options to mitigate losses. Utilities can access this information through a number of resources (see Example Resources).

How does a utility identify adaptation strategies for consideration?

Historically, utilities have applied the assumption that, while observed conditions may exhibit large variations, the variability and average conditions will remain consistent into the future. This assumption, often referred to as stationarity, will be compromised as climate changes. Many climate models project that future climate conditions (e.g., intensity of precipitation events, sea-level rise, temperature increases) may increase variability outside of that seen in the past; historical data and trends may no longer be accurate indicators for future climate conditions. Utilities should therefore adopt a flexible and iterative approach when considering what adaptation options to implement, and ensure that strategies are complementary to capacity building, emergency response activities, and capital planning. An adaptive approach will result in robust decision-making that builds operations that are successful regardless of the climate impacts faced by a utility.

An Adaptive Response Framework (**Figure 2.2**) was developed by the National Drinking Water Advisory Council's (NDWAC) Climate Ready Water Utilities (CRWU) Workgroup in order to allow utilities to thoughtfully address climate impacts at their systems, and is included in their Report. The 10 steps included in the framework were designed specifically to be adaptable to local conditions, needs and capacity. The Adaptive Response Framework reinforces the idea that utilities need to continuously assess their "climate readiness" because climate science is evolving and uncertainty surrounds the timing, nature, direction and magnitude of related impacts.

The Adaptive Response Framework divides utility engagement into two stages, "Assess & Plan" and "Implement & Evaluate." The Assess and Plan stage enhances a utility's awareness and understanding of methods to address climate challenges, while the Implement and Evaluate stage encourages utilities to design and carry out short- and long-term adaptation initiatives and actions.

This Guide supports activities described in the "Climate Impacts & Uncertainties" and "Utility Adaptation & Mitigation Opportunities" steps. The text box on the next page provides suggested actions for utilities that fall into these two categories. Utilities are encouraged to review the CRWU NDWAC Report for more information on the remaining elements of the Adaptive Response Framework, such as coordinated planning with "Federal/State Policies & Programs," assessing and understanding "Climate-Related Community Conditions," and building relationships with "Interdependent Actors & Sectors."

Figure 2.2. CRWU Adaptive Response Framework

Suggested Activities from the Adaptive Response Framework:

Climate Impacts & Uncertainties:

- Maintain a basic awareness of climate science developments and implications for local operational conditions.
- Encourage utility personnel to examine operating conditions in light of the potential for climate change challenges.
- Conduct screening-level climate impact assessments to identify obvious threats and opportunities.
- Integrate climate impact considerations into normal planning and decision making, including emergency response, capacity, and capital planning.

Utility Adaptation & Mitigation Opportunities:

- Understand organizational, operational, and capital investment options undertaken by similar utilities to better understand opportunities for no- and low-cost, and no-regrets, operational actions and capital investments.
- Expand efforts to identify, understand, and evaluate utility climate adaptation and mitigation practices (e.g., enhanced long-range planning methods, hedging strategies, and supply and treatment diversification options).

What types of adaptation strategies are included in this Guide?

An effective adaptation plan should include a diverse set of actions that are integrated into other planning efforts, operating practices, and infrastructure improvements. Through integrated strategies, utilities can ensure that adaptation actions will address a broad range of challenges while remaining flexible enough to adapt to changing climate conditions and new information. For example, the need for infrastructure improvements can be informed by monitoring conditions, while current emergency response plans can provide resilience until improvements are in place. In this Guide, comparison and prioritization of adaptation options are not provided, although the options are broadly categorized based on the level of effort and relative costs required in their implementation. The three categories of adaptation options included are:

- **Planning strategies**, which include use of models, research, training, supply and demand planning, natural resource management, land use planning, and collaboration at watershed and community scales;
- **Operational strategies**, which include efficiency improvements, monitoring, inspections, conservation, demand management, flexible operations, and sustainable strategies; and
- **Capital / infrastructure strategies**, which include construction, water resource diversification, repairs and retrofits, upgrades, phased construction, new technology adoption, and green infrastructure.

These adaptation options are categorized in terms of the relative anticipated cost of implementation. Planning strategies tend to be relatively less costly than operational and capital strategies; however, there is some diversity in costs within each category. Three relative cost levels are used in the Guide:

$ Many utilities will try to cope with change by assessing their options to expand operational flexibility to meet the changed operating parameters driven by the climate threat. Costs associated with adaptation options may be minimal.

$$ Some systems can operate beyond design or current capacity without making large changes to the

system. Operations and maintenance costs may increase, but would remain less costly than making infrastructure changes.

$$$ After the existing system has reached the limit of its capacity to absorb climate impacts, it becomes necessary to augment or optimize capacity through adoption of new practices and resources. This typically involves a higher level of capital investment.

How do utilities assess adaptation strategies?

Many options exist to address climate change concerns at utilities. When evaluating a response to climate change and assessing potential adaptation strategies, there are several significant issues to be considered, including: deciding which climate information to use, deciding how to incorporate uncertainty, and obtaining a better understanding of system capabilities with regards to resources. Several common approaches used by utilities to assess risk and deal with uncertainty in decision-making are described below. In addition, tools have been developed to assess adaptation options in terms of cost and resilience gained (e.g., CREAT) as utilities pursue the integration of adaptation into overall capital investment and infrastructure planning.

Assessment approaches

There are many options available to assess how climate change will impact a utility. Three examples of these methods are:

- **Scenario-based** or top-down approaches, which use climate change projection data to inform decision-making. Projections from General Circulation Models (GCMs) are often downscaled to sub-regional spatial scales (tens of kilometers) for impact assessments. This climate information may be coupled with other models (e.g., hydrologic, flood) to predict a system response. Risk is based primarily on the consequences from a damaged or failing system under the scenario being considered (Freas et al. 2008, Brown 2010).
- **Decision-scaling** or threshold-based approaches, which consider how changes in climate will impact performance based on the current capacity of systems. These evaluations will produce thresholds for failure or damage. Risk is gauged based on the likelihood of exceeding thresholds using GCM projections and consequences from a failing or damaged system (Brown 2010).
- **Robust decision-making** approaches, which apply multiple scenarios derived from GCM projections to create ensembles of plausible futures. The performance of adaptation options are considered across these scenarios to identify those that reduce risk across all or most scenarios and avoid unacceptable outcomes or worst-case scenarios (Lembert and Groves 2010).

Example of Assessment Approaches:

Southern California's Inland Empire Utilities Agency used robust decision-making to evaluate the impacts of climate change on long-term urban water management. The goal was to reject any water strategy that cost above $3.75 billion. Scenario discovery using 21 climate models and a water management model concluded that the costs would exceed that figure if three things happened concurrently: large precipitation declines, large changes in the price of water imports, and reductions in the natural percolation into ground water aquifers. Based on this, a management plan was devised that included: water-use efficiency, capturing storm water for ground water replenishment, water recycling and importing water in wet years so ground water can be extracted in dry years. The Agency found that if all these actions were undertaken, the costs would almost never exceed the $3.75 billion limit (Lembert and Groves 2010).

Addressing uncertainty and varying capacity to respond at utilities

Because of the great deal of uncertainty surrounding the timing, nature, direction, and magnitude of localized climate impacts, it can be a challenge for utilities to balance climate change action with current obligations, maintain service affordability, and develop the financial, managerial, and technical capacity to meet future needs.

However, this uncertainty should not prevent utilities from taking action now with regards to potential climate change impacts. For some utilities, it is not an option to wait and see or take no action. In fact, the cost of inaction may be greatly underestimated and can be offset by taking preventative action today. Building climate considerations into everyday utility decision making is a current necessity because utility investments are often capital intensive, long-lived, and can require long lead times to ensure system reliability and maintenance of desired service levels. Flexible or adaptive management strategies provide a structure for implementing adaptation options for future operations despite these uncertainties and differing capacities.

When considering which climate-related actions to take now, it is important that utilities develop an understanding of all of the potential benefits of implementing adaptation options beyond increased overall resilience (Danilenko et al. 2010, UKCIP 2011). For example, many options may provide benefits under both current climate conditions and potential future climate conditions. These options are often described as ***No Regrets*** options. As used in this Guide, No Regrets describes those adaptation options that provide benefits regardless of future climate conditions. These options would increase resilience to the potential impacts of climate change while yielding other, more immediate economic, environmental, or social benefits (WUCA 2010; FAO 2011). However, No Regrets does not mean cost-free; No Regrets options still have real or opportunity costs or represent trade-offs that should be considered by utility owners and operators (Wilby 2008; Heltberg et al. 2009). Within the briefs, No Regrets adaptation options are identified with this icon.

Only implementing No Regrets options at a utility may not be enough to build resilience against climate impacts. Other types of actions include those that provide benefits particularly if climate projections become reality (***low-regrets*** or ***climate-justified***) as well as actions that reduce greenhouse gas emissions and provide co-benefits (i.e., energy efficiency, optimization, and reduced operating costs).

Example of an Adaption Strategy Utilizing No Regrets Options:

The Tualatin Valley Water District (TVWD) in Oregon provides an average of 23 million gallons of water per day to more than 200,000 customers. Many stressors, in addition to climate change, present potential risks and uncertainties as related to future water supply and water quality issues. Recognizing this and the uncertainty in climate change projections, TVWD has developed plans that employ no-regrets strategies focused on building a more resilient regional water supply. Actions being pursued include data collection, diversifying supply sources, investigating water system interties, and engaging customers in extensive conservation efforts.

As part of its overall strategy, TVWD collaborates with other utilities in the region through the area's Regional Water Providers Consortium (RWPC). The RWPC Strategic Plan identifies the need to encourage partnerships between providers and facilitate and support reliable back-up water supplies for all water providers should any source or transmission facilities become unavailable due to an emergency or natural disaster. Efforts thus far have produced an ArcGIS geodatabase of all existing water system facilities within the region, including existing water system interconnections and a pipe network overlay. As a result of this collaboration, TVWD has identified strategic regional interties and plans to diversify sources by identifying alternate surface water supplies and further evaluating aquifer storage and recovery.

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Example of Utilizing No Regrets Strategies: *(continued)*

TVWD first established an effective conservation program in 1993. The program has been very successful, and District customers recently reduced water usage from 2005 to 2011 by 13% (in gallons per capita per day), more than doubling its 0.8% per year goal. Admittedly, other factors likely contributed to the reduction, but conservation goals were met primarily through a combination of rebates, free water-efficient hardware, consultations, technical assistance to large water users, and outreach to customers. TVWD works to mitigate any negative operational environmental and societal effects through its Sustainability Program, which provides leadership, education, analysis, project management, and accountability for the District's sustainability efforts. Key objectives in pursuing sustainability include reducing TVWD's carbon footprint without compromising customer service, enhancing understanding of customer water usage and demand, generating on-site solar energy, and maintaining stewardship of assets.

TVWD uses a proactive adaptive management approach to continue meeting its sustainability and resiliency goals. TVWD collects and analyzes utility and regional data on a regular basis in order to ensure the District can meet future time demands and reliability concerns. As new information becomes available, water planning decisions are re-assessed and modified.

Where can utilities find more information on adaptation planning and other Climate Ready Water Utilities activities?

Adaptation options found in this Guide provide the building blocks for utility adaptation strategies. Further consideration of these options is required, as described above in the adaptation planning section. See the links below for supporting information on available products and resources available to support adaptation planning.

Supporting Information on Climate Ready Water Utilities Products

- Planning Worksheet
- EPA CRWU Information
- CREAT Fact Sheet
- NDWAC CRWU
- Adaptation Glossary

Example Technical and Informational Resources to Support Assessments

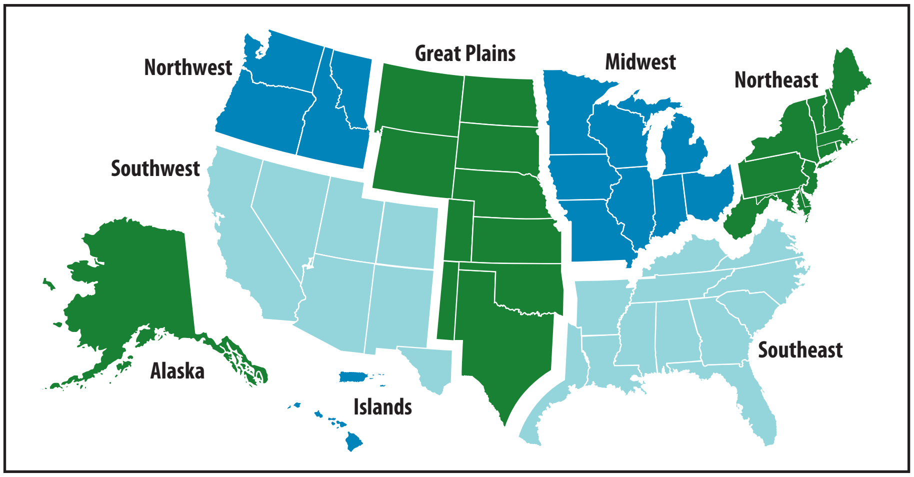
- NOAA Flood Watch Data
- FEMA Flood Model (HAZUS)
- FEMA Flood Maps
- US Global Change Research Program
- Bias Corrected & Downscaled WCRP CMIP3 Climate Projections

How does a utility get started?

This Guide includes a collection of briefs (see below) that provide summaries of climate change projections, descriptions of specific climate challenges that water utilities may face, and description of suggested adaptation options to address these challenges with their relative costs. The briefs provide the user with comprehensive information on climate change impacts and adaptation planning. Alternatively, each brief can also be considered a stand-alone resource.

Climate Region Briefs—National and regional descriptions of climate change projections are provided in the Climate Region Briefs. The material in these briefs is drawn from the most recent U.S. Global Change Research Program assessment (2009). These briefs provide an overview of climate change projections in each geographic region, along with associated impacts (i.e., challenges) drinking water and wastewater utilities will face. Clicking on a region will bring you to that particular Regional Brief.

LINKS TO CLIMATE REGION BRIEFS



Challenge Group and Challenge Briefs —Summaries of general impacts that drinking water and wastewater utilities may face are contained in the Challenge Group Briefs, which can be accessed by clicking on an impact group in the table below. These briefs contain a comprehensive list of adaptation options to address a group of similar potential impacts.

These briefs also include links to the more specific Challenge Briefs that provide more detailed information on potential climate change-related impacts for both water, stormwater, and wastewater utilities. Each Challenge Brief provides general climate information related to the challenge, options for adaptation strategies to address them, relative cost information, and an example describing how a specific utility has implemented at least one of the options listed. Clicking on a water drop in any challenge table will bring you to that Challenge Brief. Most briefs apply to either drinking water (DW) or wastewater and stormwater (WW) utilities. In the case of the ecosystem-related challenges and energy sector needs, briefs apply to DW and WW together.

LINKS TO CHALLENGE BRIEFS

CHALLENGES BY GROUP		DW	WW
Drought	Reduced groundwater recharge	💧	
	Lower lake and reservoir levels	💧	
	Changes in seasonal runoff & loss of snow-pack	💧	
Water Quality Degradation	Low flow conditions & altered water quality		💧
	Saltwater intrusion into aquifers	💧	
	Altered surface water quality	💧	💧
Floods	High flow events & flooding	💧	💧
	Flooding from coastal storm surges	💧	💧
Ecosystem Changes	Loss of coastal landforms / wetlands	💧	💧
	Increased fire risk & altered vegetation	💧	💧
Service Demand & Use	Volume & temperature challenges	💧	💧
	Changes in agricultural water demand	💧	
	Changes in energy sector needs	💧	
	Changes in energy needs of utilities	💧	💧

Click on a group name above to read more about these challenges or click on a water drop above to read more about a specific challenge.

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GLOSSARY

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This glossary provides additional explanation of the adaptation options listed in the climate challenge briefs provided in this Guide. Each option includes general descriptions of actions that may be taken or clarification of terminology. Pursuit of many of these options may require collaboration with other utilities, local or federal government agencies, other sectors (e.g., energy and agriculture), and the academic community. The options are grouped into categories of similar adaptation strategies, including:

Ecosystem & Land Use	Modeling	Monitoring	New Construction
Planning	Repair & Retrofit	System & Energy Efficiency	Water Demand & Use

Each option description includes a measure of relative cost, from $ to $$$ (see Page 5 in the Introduction for a description of this scale).

No Regrets options are marked with this icon. These adaptation options provide benefits regardless of future climate conditions and would increase resilience to the potential impacts of climate change while yielding other, more immediate, economic, environmental, or social benefits (WUCA 2010; FAO 2011).

ECOSYSTEM & LAND USE

Acquire and manage ecosystems ($$$)–Intact natural ecosystems have many benefits for utilities: reducing sediment and nutrient inputs into source water bodies, regulating runoff and streamflow, buffering against flooding, and reducing storm surge impacts and inundation on the coasts (e.g., mangroves, saltwater marshes, wetlands). Utilities can also work with regional floodplain managers and appropriate stakeholders to explore non-structural flood management techniques in the watershed. Protecting, acquiring, and managing ecosystems in buffer zones along rivers, lakes, reservoirs, and coasts can be cost-effective measures for flood control and water quality management.

Implement green infrastructure on site and in municipalities ($$$)–Green infrastructure can help reduce runoff and stormwater flows that may otherwise exceed system capacity. Examples of green infrastructure include: bio-retention areas (rain gardens), low impact development methods, pervious pavement, green roofs, swales (depressions to capture water), and the use of vegetation or pervious materials instead of impervious surfaces.

Implement watershed management ($$)–Watershed management includes a range of policy and technical measures. These generally focus on preserving or restoring vegetated land cover in a watershed and managing stormwater runoff. These changes help mimic natural watershed hydrology, increasing groundwater recharge, reducing runoff, and improving the quality of runoff.

Integrate flood management and modeling into land use planning ($)–It is critical that future water utility infrastructure be planned and built in consideration of future flood risks. Infrastructure can be built in areas that do not have a high risk of future flooding. Alternately, appropriate flood management plans can be implemented that involve 'soft' adaptation measures such as conserving natural ecosystems or 'hard' measures such as dikes and flood walls.

Study response of nearby wetlands to storm surge events ($)–Coastal wetlands act as buffers to storm surge. Protecting and understanding the ability of existing wetlands to provide protection for coastal infrastructure in the future is important considering projected sea-level rise and possible changes in storm severity.

Update fire models and practice fire management plans ($-$$)–Fire frequency and severity may change in the future, therefore it is important to develop, practice, and regularly update management plans to reduce fire risk. Controlled burns, thinning, and weed and invasive plant control help to reduce risk in wildfire-prone areas.

MODELING

Conduct extreme precipitation events analyses ($-$$)–An increase in the magnitude or frequency of extreme events can severely challenge water utility systems that were not designed to withstand intense events. Extreme event analyses and/or modeling can help develop a better understanding of the risks and consequences associated with these types of events.

Conduct sea-level rise and storm surge modeling ($)–Modeling sea-level rise and storm surge dynamics will better inform the placement and protection of critical infrastructure. Generic models have been developed to consider subsidence, global sea-level rise, and storm surge effects on inundation, including National Oceanic and Atmospheric Administration's (NOAA) SLOSH (Sea, Lake and Overland Surges from Hurricanes) Model and The Nature Conservancy's Coastal Resilience Tool, amongst others.

Develop models to understand potential water quality changes ($)–In many areas, increased water temperatures will cause eutrophication and excess algal growth, which will reduce drinking water quality. The quality of drinking water sources may also be compromised by increased sediment or nutrient inputs due to extreme storm events. These impacts may be addressed with targeted watershed management plans.

Model and monitor groundwater conditions ($)–Understanding and modeling groundwater conditions will inform aquifer management and projected water quantity and quality changes. Monitoring data for aquifer water level, changes in chemistry, and detection of saltwater intrusion can be incorporated into models to predict future supply. Climate change may lead to diminished groundwater recharge in some areas because of reduced precipitation and decreased runoff.

Model and reduce inflow/infiltration in the sewer system ($-$$$)–More extreme storm events will increase the amount of wet weather infiltration and inflow into sanitary and combined sewers. Sewer models can estimate the impact of those increased wet weather flows on wastewater collection system and treatment plant capacity and operations. Potential system modifications to reduce those impacts include infiltration reduction measures, additional collection system capacity, offline storage, or additional peak wet weather treatment capacity.

Use hydrologic models to project runoff and future water supply ($)–In order to understand how climate change may impact future water supply and water quality, hydrological models, coupled with projections from climate models, must be developed. It is important to work towards an understanding of how both the mean and temporal (seasonal) distribution of surface water may change. Groundwater recharge, snowpack and the timing of snowmelt are critical areas that may be severely impacted by climate change and should be incorporated into the analysis.

MONITORING

Conduct stress testing on wastewater treatment biological systems to assess tolerance to heat ($$)–Increased surface water temperature may require changes to wastewater treatment systems, as microbial species used may react differently in warmer environments. Stress testing involves subjecting biological systems or bench-top simulations of systems to elevated temperatures and monitoring the impacts on treatment processes.

Manage reservoir water quality ($$)–Increased precipitation, runoff, and higher temperatures due to climate change may lead to diminished reservoir water quality. Reservoir water quality can be maintained or improved by a combination of watershed management, to reduce pollutant runoff and promote groundwater recharge, and reservoir management methods, such as lake aeration.

Monitor and inspect the integrity of existing infrastructure ($-$$)–Monitoring is a critical component of establishing a measure of current conditions, detecting deterioration in physical assets, and evaluating when the necessary adjustments need to be made to prolong infrastructure lifespan.

Monitor current weather conditions ($)–A better understanding of weather conditions provides a utility with the ability to recognize possible changes in climate change and then identify the subsequent need to alter current operations to ensure resilient supply and services. Observations of precipitation, temperature, and storm events are particularly important for improving models of projected water quality and quantity.

Monitor flood events and drivers ($)–Understanding and modeling the conditions that result in flooding is an important part of projecting how climate change may drive change in future flood occurrence. Monitoring data for sea level, precipitation, temperature, and runoff can be incorporated into flood models to improve predictions. Current flood magnitude and frequency of storm events represents a baseline for considering potential future flood conditions.

Monitor surface water conditions ($)–Understanding surface water conditions and the factors that alter quantity and quality is an important part of projecting how climate change may impact water resources. Monitoring data for discharge, snowmelt, reservoir or stream level, upstream runoff, streamflow, in-stream temperature, and overall water quality can be incorporated into models of projected supply or receiving water quality.

Monitor vegetation changes in watersheds ($)–Changes in vegetation alter the runoff that enters surface water bodies and the risk of wildfire to facilities within the watershed. Monitoring vegetation changes can be conducted by ground cover surveys, aerial photography, or by relying on the research from local conservation groups and universities.

NEW CONSTRUCTION

Build flood barriers to protect infrastructure ($-$$)–Flood barriers to protect critical infrastructure include levees, dikes, and seawalls. A related strategy is flood proofing, which involves elevating critical equipment or placing it within waterproof containers or foundation systems.

Build infrastructure needed for aquifer storage and recovery ($$$)–Increasing the amount of groundwater storage available promotes recharge when surface water flows are in excess of demand, thus increasing climate resiliency for seasonal or extended periods of drought, and taking advantage of seasonal variations in surface water runoff. Depending on whether natural or artificial aquifer recharge is employed, the required infrastructure may include percolation basins and injection wells.

Diversify options for water supply and expand current sources ($$-$$$)–Diversifying sources helps to reduce the risk that water supplies will fall below water demand. Examples of diversified source water portfolios include using a varying mix of surface water and groundwater, employing desalination when the need arises, and establishing water trading with other utilities in times of water shortages or service disruption.

Increase water storage capacity ($$-$$$)–Increased drought can reduce the safe yield of reservoirs. To reduce this risk, increases in available storage can be made. Methods for accomplishing this may include raising a dam, practicing aquifer storage and recovery, removing accumulated sediment in reservoirs, or lowering water intake elevation.

Install low-head dam for saltwater wedge and freshwater pool separation ($$$)–Rising sea levels, combined with reductions in freshwater runoff due to drought, will cause the salt water-freshwater boundary to move further upstream in tidal estuaries. Upstream shifts of this boundary can reduce the water quality of surface water resources. Installation of low-head dams across tidal estuaries can prevent this upstream movement.

Plan and establish alternative or on-site power supply ($-$$)–Water utilities are one of the major consumers of electricity in the United States. With future electricity demand forecasted to grow, localized energy shortages may occur. The development of "off-grid" sources can be a good hedging strategy for electricity shortfalls. Moreover, redundant power supply can provide resiliency for situations in which natural disasters cause power outages. On-site sources can include solar, wind, inline microturbines, and biogas (i.e., methane from wastewater treatment). New and back-up electrical equipment should be located above potential flood levels.

Relocate facilities to higher elevations ($$$)–Relocating utility infrastructure, such as treatment plants and pump stations, to higher elevations would reduce risks from coastal flooding and exposure as a result of coastal erosion or wetland loss.

PLANNING

Adopt insurance mechanisms and other financial instruments ($)–Adequate insurance can insulate utilities from financial losses due to extreme weather events, helping to maintain financial sustainability of utility operations.

Conduct climate change impacts and adaptation training ($)–An important step in developing an adaptation program is educating staff on climate change. Staff should have a basic understanding of the projected range of changes in temperature and precipitation, the increase in the frequency and magnitude of extreme weather events for their region, and how these changes may affect the utility's assets and operations. Preparedness from this training can improve utility management under current climate conditions as well.

Develop coastal restoration plans ($-$$)–Coastal restoration plans may protect water utility infrastructure from damaging storm surge by increasing protective habitat of coastal ecosystems such as mangroves and wetlands. Restoration plans should consider the impacts of sea-level rise and development on future ecosystem distribution. Successful strategies may also consider rolling easements and other measures identified by EPA's Climate Ready Estuaries program.

Develop emergency response plans ($)–Emergency response plans (ERPs) outline activities and procedures for utilities to follow in case of an incident, from preparation to recovery. Some of the extreme events considered in ERPs may change in their frequency or magnitude due to changes in climate, which may require making changes to these plans to capture a wider range of possible events.

Develop energy management plans for key facilities ($)–Energy management plans identify the most critical systems in a facility, provide backup power sources for those systems, and evaluate options to reduce power consumption by upgrading to more efficient equipment. Utilities may develop plans to produce energy, reduce use, and work toward net-zero goals.

Establish mutual aid agreements with neighboring utilities ($)–Beyond the establishment of water trading in times of water shortages or service disruptions, these agreements involve the sharing of personnel and resources in times of emergency (e.g., natural disasters).

Identify and protect vulnerable facilities ($-$$)–Operational measures to isolate and protect the most vulnerable systems or assets at a utility should be considered. For example, critical pump stations would include those serving a large population and those located in a flood zone. Protection of these assets would then be prioritized based on the likelihood of flood damage and the consequence of service disruption.

Integrate flood-related risks into capital improvement plans ($)–Plans to build or expand infrastructure should consider the vulnerability of the proposed locations to inland flooding, sea-level rise, storm surge, and other impacts associated with climate change.

Participate in community planning and regional collaborations ($-$$)–Effective adaptation planning requires the cooperation and involvement of the community. Water utilities will benefit by engaging in climate change planning efforts with local and regional governments, electric utilities and other local organizations.

Update drought contingency plans ($)–Drought leads to severe pressures on water supply. Drought contingency plans would include the use of alternate water supplies and the adoption of water use restrictions for households, businesses and other water users. These plans should be updated regularly to remain consistent with current operations and assets.

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REPAIR & RETROFIT

Implement policies and procedures for post-flood and/or post-fire repairs ($)–Post-disaster policies should minimize service disruption due to damaged infrastructure. These contingency plans should be incorporated into other planning efforts and updated regularly to remain consistent with any changes in utility services or assets.

Implement saltwater intrusion barriers and aquifer recharge ($$$)–As sea level rises, saltwater may intrude into coastal aquifers, resulting in substantially higher treatment costs. The injection of fresh water into aquifers can help to act as a barrier, thereby recharging groundwater resources.

Improve pumps for backflow prevention ($$)–Sea-level rise and coastal storm surge can cause wastewater outlets to backflow. To prevent this, stronger pumps may be necessary.

Increase capacity for wastewater and stormwater collection and treatment ($$$)–Precipitation variability will increase in many areas. Even in areas where precipitation and/or runoff may on average decrease, the distribution of rainfall patterns (i.e., intensity and duration) can change in ways that impact water infrastructure. In particular, more extreme storms may overwhelm combined wastewater and stormwater systems.

Increase treatment capabilities ($$$)–Existing water treatment systems may be inadequate to process water of significantly reduced quality. Significant improvement to existing treatment processes or implementation of additional treatment technologies may be necessary to ensure that quality of water supply (or effluent) continues to meet standards as climate change impacts influent or receiving water quality.

Install effluent cooling systems ($-$$)–Higher surface temperatures may make meeting water quality standards and temperature criteria more difficult. Therefore, to reduce the temperature of treated wastewater discharges, additional effluent cooling systems may be needed.

Retrofit intakes to accommodate lower flow or water levels ($$-$$$)–In areas where streamflow declines due to climate change, water levels may fall below intakes for water treatment plants.

SYSTEM & ENERGY EFFICIENCY

Finance and facilitate systems to recycle water ($$-$$$)–Recycling greywater frees up more finished water for other uses, expanding supply and decreasing the need to discharge into receiving waters. Receiving water quality limitations may increase due to more frequent droughts. Therefore, to limit wastewater discharges, reuse of reclaimed water in homes and businesses should be encouraged.

Improve energy efficiency and optimization of operations ($$-$$$)–Water utilities are one of the major consumers of electricity in the United States. With future electricity demand forecasted to grow, localized energy shortages may be experienced. Energy efficiency measures will save in energy costs and make utilities less vulnerable to electricity shortfalls due to high demand or service disruptions from natural disasters.

Practice conjunctive use ($$-$$$)–Conjunctive use involves the coordinated, optimal use of both surface water and groundwater, both intra- and inter-annually. Aquifer storage and recovery is a form of conjunctive use. For example, a utility may store some fraction of surface water flows in aquifers during wet years and withdraw this water during dry years when the river flow is low. Depending on whether natural or artificial aquifer recharge is employed, the required infrastructure may include percolation basins and injection wells.

WATER DEMAND & USE

Encourage and support practices to reduce water use at local power plants ($)–The electricity sector withdraws the greatest amount of water in the United States, compared with other sectors. Any efforts to reduce water usage by utilities (e.g., closed-loop water circulation systems or dry cooling for the turbines) will increase available water supply. For example, utilities may provide reclaimed water to electric utilities for electricity generation.

Model and reduce agricultural and irrigation water demand ($-$$$)–In order to forecast and plan for future water supply needs, agricultural (irrigation) demand must be projected, particularly in drought-prone areas. Agriculture represents the second largest user of water in the United States in terms of withdrawals. For example, to reduce agricultural water demand, utilities can work with farmers to adopt advanced micro-irrigation technology (e.g., drip irrigation).

Model future regional electricity demand ($)–The electricity sector represents the largest user of water in the United States in terms of withdrawals. In order to forecast future water supply needs, changes in electricity demand related to climate change must be projected.

Practice water conservation and demand management ($-$$)–An effective and low-cost method of meeting increased water supply needs is to implement water conservation programs that will cut down on waste and inefficiencies. Public outreach is an essential component of any water conservation program. Outreach communications typically include: basic information on household water usage, the best time of day to undertake water-intensive activities, and information on and access to water-efficient household appliances such as low-flow toilets, showerheads, and front-loading washers. Education and outreach can also be targeted to different sectors (i.e., commercial, institutional, industrial, public sectors). Effective conservation programs in the community include those that provide rebates or help install water meters, water-conserving appliances, toilets, and rainwater harvesting tanks.

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United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES EPA

Adaptation Strategies Guide for Water Utilities

WORKSHEET FOR ADAPTATION PLANNING

This adaptation planning worksheet is provided to help identify and organize adaptation options of interest. Either (1) print this worksheet and fill in the fields by hand while browsing through the Guide, or (2) type in the fields electronically, and make sure to print or save this worksheet before closing the Guide. There is a completed sample version for your reference following this worksheet.

Contact and Utility Information

Name

Phone

Email

Utility Name

Utility Type DW ☐ WW ☐ SW ☐

Climate Region

Coasts ☐

Climate-Related Challenges

Review the brief for your climate region and select those challenges that are of concern to your utility

Challenge Group: Drought

- ☐ Reduced groundwater recharge
- ☐ Lower lake and reservoir levels
- ☐ Changes in seasonal runoff & loss of snowpack

Challenge Group: Water Quality Degradation

- ☐ Low flow conditions & altered water quality
- ☐ Saltwater intrusion into aquifers
- ☐ Altered surface water quality

Challenge Group: Floods

- ☐ High flow events and flooding
- ☐ Flooding from coastal storm surges

Challenge Group: Ecosystem Changes

- ☐ Loss of coastal landforms / wetlands
- ☐ Increased fire risk & altered vegetation

Challenge Group: Service Demand & Use

- ☐ Volume & temperature challenges
- ☐ Changes in agricultural water demand
- ☐ Changes in energy sector needs
- ☐ Changes in energy needs of utilities

Note specific utility assets and water resources where any damage or loss would impair meeting your utility's mission

List the critical threshold conditions (e.g., specific flood heights, drought durations, and peak influent volumes that exceed your current operating capacity) that may result in damage or loss to your assets and water resources. For example, if your previous experience indicates that a daily rainfall total of 3 inches would flood critical pump stations, then document this type of event as a threshold to consider during adaptation planning.

Review the briefs for selected challenges and note the adaptation options that you would consider implementing to reduce the consequences of climate change at your utility

Communication with other utilities—what climate change-related actions have other drinking water and wastewater utilities in your area taken?

Adaptation Implementation Planning

Year for completion

Limitations

Priorities (select)

- ☐ Adaptation option type
- ☐ Cost of adaptation
- ☐ Timing of action
- ☐ Vulnerability assessment
- ☐ Assets impacted
- ☐ Other:

Potential collaborators

Use the information documented in this worksheet as a preliminary step in the adaptation planning process. As you continue to monitor conditions and begin implementing adaptation options, revisit the Guide and revise this worksheet accordingly to inform future planning efforts.

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

Adaptation Strategies Guide for Water Utilities

SAMPLE WORKSHEET FOR ADAPTATION PLANNING

This adaptation planning worksheet is provided to help identify and organize adaptation options of interest. Either (1) print this worksheet and fill in the fields by hand while browsing through the Guide, or (2) type in the fields electronically, and make sure to print or save this worksheet before closing the Guide.

Contact and Utility Information

Name Dan Frialini

Phone 708-555-1212

Email dfrialini@bcwu.org

Utility Name Big Creek Water Utility

Utility Type DW [X] WW [X] SW [X]

Climate Region Midwest (IL) **Coasts** [ ]

Climate-Related Challenges

Review the brief for your climate region and select those challenges that are of concern to your utility

Challenge Group: Drought

- [ ] Reduced groundwater recharge
- [ ] Lower lake and reservoir levels
- [ ] Changes in seasonal runoff & loss of snowpack

Challenge Group: Water Quality Degradation

- [ ] Low flow conditions & altered water quality
- [ ] Saltwater intrusion into aquifers
- [X] Altered surface water quality

Challenge Group: Floods

- [X] High flow events and flooding
- [ ] Flooding from coastal storm surges

Challenge Group: Ecosystem Changes

- [ ] Loss of coastal landforms / wetlands
- [X] Increased fire risk & altered vegetation

Challenge Group: Service Demand & Use

- [ ] Volume & temperature challenges
- [ ] Changes in agricultural water demand
- [ ] Changes in energy sector needs
- [ ] Changes in energy needs of utilities

Note specific utility assets and water resources where any damage or loss would impair meeting your utility's mission

Storage tanks to provide residual storage for maintaining inflow to treatment plant. Located in Big Creek Forest near creek shore. Past algal blooms in source water have contaminated tanks, resulting in loss of stored water for use as supply and an added expense of cleaning to re-use tanks.

Watershed for Big Creek, including Big Creek Forest, and paper mill. Watershed managers heard about the ongoing BCWU climate assessment and wanted to know if the utility was seeking input or collaboration opportunities. Collaboration could ensure that the implications of climate change impacts on the watershed was considered as part of adaptation planning at the utility.

WORKSHEET

List the critical threshold conditions (e.g., specific flood heights, drought durations, and peak influent volumes that exceed your current operating capacity) that may result in damage or loss to your assets and water resources. For example, if your previous experience indicates that a daily rainfall total of 3 inches would flood critical pump stations, then document this type of event as a threshold to consider during adaptation planning.

* 100-year flood would damage storage tanks
* Creek level drops below current intake would restrict supply
* 50% extent of forest loss would lead to increased erosion from forest into Big Creek

Review the briefs for selected challenges and note the adaptation options that you would consider implementing to reduce the consequences of climate change at your utility

BCWU has started climate change training for personnel and management.
For floods: BCWU currently employs flood models and a temporary flood barrier, and wants to evaluate a new levee, wetlands for flood protection, green infrastructure in the community, and recent investments in a collaborative land-use planning project as potential future flood protection measures.

For wildfire: BCWU currently employs land-use planning and monitoring weather, and wants to evaluate a wildfire surveillance and integrated land-use planning as potential future wildfire protection measures.

For drought: BCWU currently employs demand reduction and modeling efforts, and wants to evaluate improved supply-demand models, increased storage, and watershed management strategies.

Communication with other utilities—what climate change-related actions have other drinking water and wastewater utilities in your area taken?

Other Midwestern utilities have been successful in using wildfire surveillance in cooperation with U.S. Forest Service to limit losses.

Representatives planning to attend upcoming utility management conference and joining city-wide flood preparedness task force.

Adaptation Implementation Planning

Year for completion 2020

Limitations

Budget available for next decade / limited space for expansion of facilities / potential for relocation of facilities unknown

Priorities (select)

- [ ] Adaptation option type
- [x] Cost of adaptation
- [x] Timing of action
- [ ] Vulnerability assessment
- [x] Assets impacted
- [ ] Other:

Potential collaborators

Big Creek Watershed managers, regional assessment team, City of Cicero, City of Chicago, Big Creek Defenders (local advocacy group)

Use the information documented in this worksheet as a preliminary step in the adaptation planning process. As you continue to monitor conditions and begin implementing adaptation options, revisit the Guide and revise this worksheet accordingly to inform future planning efforts.

United States
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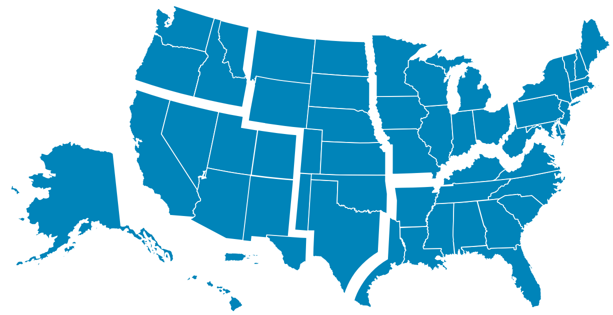
CLIMATE READY
WATER UTILITIES



Climate Region Brief > NATIONAL

Return to Introduction

Projected climate change in the United States will continue to follow trends that are already observable. Temperature rise, shifts in precipitation patterns and timing, and altered hydrologic cycles can be expected due to climate change. The following statements, drawn from a U.S. Global Change Research Program assessment (USGCRP 2009), are based on projections for climate conditions at the end of the 21st century under a higher emissions scenario (IPCC 2000).

PROJECTED CHANGES

ALL UTILITIES

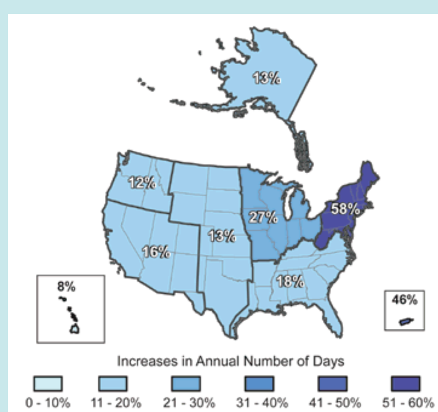
- U.S. average temperature has risen more than 2 °F over the past 50 years and is projected to rise more in the future.
- Sea level has risen along most of the coast over the last 50 years, and will rise more in the future.
- Many types of extreme weather events, such as heat waves and regional droughts, have become more frequent and intense during the past 40 to 50 years.
- Reduced snowpack, earlier breakup of ice on lakes and rivers, and earlier spring snowmelt have all resulted in earlier peak river flows.
- The amount of rain falling in the heaviest downpours has increased approximately 20% on average in the past century, and this trend is very likely to continue, with the largest increases in the wettest places.
- Cold-season storm tracks are shifting northward, and the strongest storms are likely to become stronger and more frequent.
- The intensity of Atlantic and eastern Pacific hurricanes has increased in recent decades, and the intensity of these storms is likely to increase in this century.
- Precipitation has increased an average of about 5% over the past 50 years, and projections of future precipitation generally indicate that northern areas will become wetter and southern areas, particularly in the West, will become drier.

CHALLENGES BY GROUP		DW	WW
Drought	Reduced groundwater recharge	💧	
	Lower lake and reservoir levels	💧	
	Changes in seasonal runoff & loss of snowpack	💧	
Water Quality Degradation	Low flow conditions & altered water quality		💧
	Saltwater intrusion into aquifers	💧	
	Altered surface water quality	💧	💧
Floods	High flow events & flooding	💧	💧
	Flooding from coastal storm surges	💧	💧
Ecosystem Changes	Loss of coastal landforms / wetlands	💧	💧
	Increased fire risk & altered vegetation	💧	💧
Service Demand & Use	Volume & temperature challenges	💧	💧
	Changes in agricultural water demand	💧	
	Changes in energy sector needs	💧	
	Changes in energy needs of utilities	💧	💧

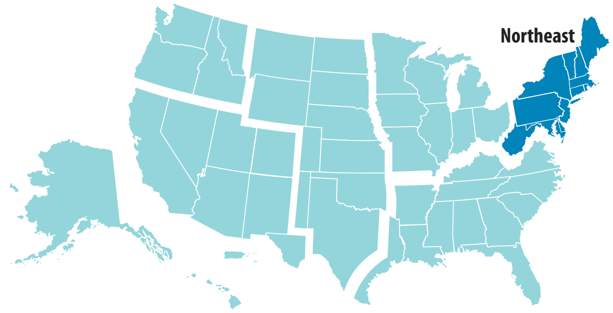
Click on a group name above to read more about these challenges or click on a water drop above to read more about a specific challenge.

EXAMPLE: Recent Increases in the Number of Days with Intense Precipitation

The map shows the percentage increases in the average number of days with very heavy precipitation (defined as the heaviest 1% of all events) from 1958 to 2007 for each region. There are clear trends toward more days with very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest.



SOURCES Groisman et al. 2005; USGCRP 2009.



Climate Region Brief > NORTHEAST

Return to Introduction

Projected climate change in the northeastern United States will continue to follow trends that are already observable. Temperature rise, shifts in precipitation patterns and timing, and altered hydrologic cycles can be expected due to climate change. The following statements, drawn from a U.S. Global Change Research Program assessment (USGCRP 2009), are based on projections for climate conditions at the end of the 21st century under a higher emissions scenario (IPCC 2000).

PROJECTED CHANGES

ALL UTILITIES

- More frequent days with temperatures above 90 °F and cities that today experience only a few days above 100 °F each summer would average 20 such days per summer.
- Severe flooding due to sea-level rise and heavy downpours are likely to occur more frequently.
- Sea level in this region is projected to rise more than the global average, possibly up to twice as fast in the mid-Atlantic.
- Increases in the extent and frequency of storm surge, coastal flooding, erosion, property damage, and loss of wetlands are anticipated.
- Winters in the Northeast are projected to be much shorter with fewer cold days and more precipitation.

DRINKING WATER UTILITIES

- There will be less winter precipitation falling as snow and more as rain.
- Reduced snowpack, earlier breakup of winter ice on lakes and rivers, and earlier spring snowmelt resulting in earlier peak river flows are anticipated to occur.
- Short-term droughts (e.g., those lasting from 1 to 3 months) are projected to occur as frequently as once each summer in the Catskill and Adirondack Mountains, and across the New England states.

	CHALLENGES BY GROUP	DW	WW
Drought	Reduced groundwater recharge	●	
	Lower lake and reservoir levels	●	
	Changes in seasonal runoff & loss of snow-pack	●●	
Water Quality Degradation	Low flow conditions & altered water quality		●●
	Saltwater intrusion into aquifers	●	
	Altered surface water quality	●	●
Floods	High flow events & flooding	●●	●●
	Flooding from coastal storm surges	●●	●●
Ecosystem Changes	Loss of coastal landforms / wetlands	●●	●●
	Increased fire risk & altered vegetation	●	●
Service Demand & Use	Volume & temperature challenges	●●	●●
	Changes in agricultural water demand	●	
	Changes in energy sector needs	●	
	Changes in energy needs of utilities	●●	●●

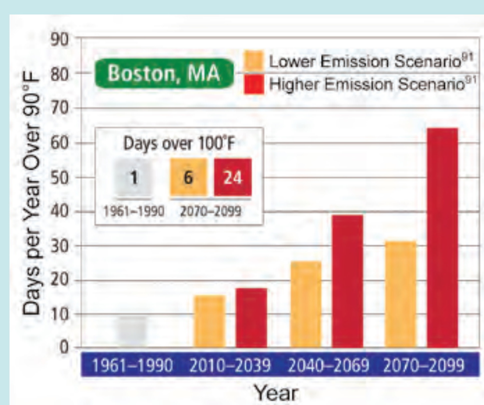
Click on a group name above to read more about these challenges or click on a water drop above to read more about a specific challenge.

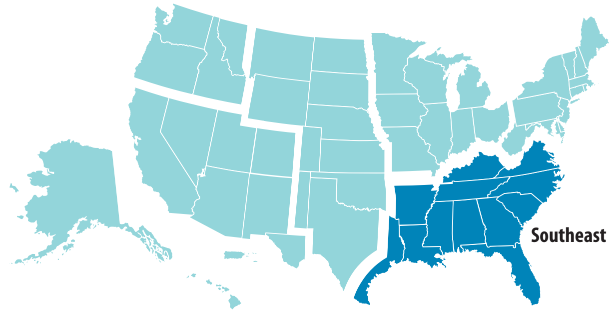
●● = Particularly relevant to Northeast ● = Somewhat relevant

EXAMPLE: More Frequent High Temperature Days

The graph shows model projections of the number of summer days with temperatures above 90 °F in Boston, Massachusetts, under lower and higher emissions scenarios (IPCC 2000). The inset shows projected days above 100 °F.

SOURCES Hayhoe et al. 2008; USGCRP 2009.





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CLIMATE READY WATER UTILITIES

Climate Region Brief > SOUTHEAST

Return to Introduction

Projected climate change in the southeastern United States will continue to follow trends that are already observable. Temperature rise, shifts in precipitation patterns and timing, and altered hydrologic cycles can be expected due to climate change. The following statements, drawn from a U.S. Global Change Research Program assessment (USGCRP 2009), are based on projections for climate conditions at the end of the 21st century under a higher emissions scenario (IPCC 2000).

PROJECTED CHANGES

ALL UTILITIES

- Sea level will gradually rise to a critical elevation and result in widespread inundation of natural and man-made resources and rapid saltwater intrusion into freshwater aquifers.
- More frequent storm surge flooding and permanent inundation of coastal ecosystems and communities is likely in some low-lying areas, particularly along the central Gulf Coast where the land surface is sinking.
- The sudden loss of coastal landforms that serve as a storm surge barrier for natural resources and coastal communities.
- Increasing intensity of Atlantic hurricanes is likely. Higher peak wind speeds, rainfall intensity, and storm surge height and strength would also increase inland and coastal flooding, coastal erosion rates, wind damage to coastal forests, and wetland loss.

DRINKING WATER UTILITIES

- Recharge of groundwater will decline as the temperature and spacing between rainfall events increase.
- The frequency, duration, and intensity of droughts are likely to continue to increase leading to the drying of lakes, ponds, and wetlands.
- Increasing evaporation and plant water use rates are likely to lead to saltwater intrusion into shallow aquifers.

WASTEWATER UTILITIES

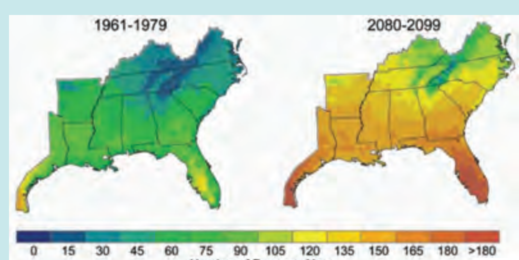
- The salinity of estuaries, coastal wetlands, and tidal rivers is likely to increase in the coastal zone.
- Dissolved oxygen in streams, lakes, and shallow aquatic habitats is likely to decline.

CHALLENGES BY GROUP		DW	WW
Drought	Reduced groundwater recharge	💧💧	
	Lower lake and reservoir levels	💧💧	
	Changes in seasonal runoff & loss of snowpack	💧	
Water Quality Degradation	Low flow conditions & altered water quality		💧
	Saltwater intrusion into aquifers	💧💧	
	Altered surface water quality	💧💧	💧💧
Floods	High flow events & flooding	💧	💧
	Flooding from coastal storm surges	💧💧	💧💧
Ecosystem Changes	Loss of coastal landforms / wetlands	💧💧	💧💧
	Increased fire risk & altered vegetation	💧💧	💧💧
Service Demand & Use	Volume & temperature challenges	💧	💧
	Changes in agricultural water demand	💧	
	Changes in energy sector needs	💧	
	Changes in energy needs of utilities	💧💧	💧💧

Click on a group name above to read more about these challenges or click on a water drop above to read more about a specific challenge.

💧💧 = Particularly relevant to Southeast 💧 = Somewhat relevant

EXAMPLE: Number of Extreme Heat Days per Year



The frequency of days with a peak temperature over 90 °F is expected to rise significantly, especially under a higher emissions scenario (IPCC 2000). By the end of the century, projections indicate that North Florida will have more than 165 days (or nearly six months) per year over 90 °F (right panel), up from roughly 60 days in the 1960s and 1970s (left panel). The increase in very hot days will have consequences for human health, drought, and wildfires.

SOURCES Hayhoe et al. 2004; Hayhoe et al. 2008; USGCRP 2009.

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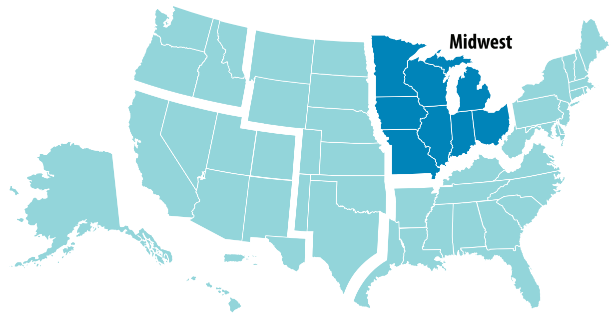
CLIMATE READY WATER UTILITIES



Climate Region Brief > MIDWEST

Return to Introduction

Projected climate change in the mid-western United States will continue to follow trends that are already observable. Temperature rise, shifts in precipitation patterns and timing, and altered hydrologic cycles can be expected due to climate change. The following statements, drawn from a U.S. Global Change Research Program assessment (USGCRP 2009), are based on projections for climate conditions at the end of the 21st century under a higher emissions scenario (IPCC 2000).

PROJECTED CHANGES

ALL UTILITIES

- Heat waves are anticipated to be more frequent, more severe, and longer lasting.
- As air temperatures increase, so will surface water temperatures and frequency of algal blooms.
- Precipitation is projected to increase in winter and spring, and to become more intense throughout the year, leading to more frequent flooding.
- Rainfall-induced flooding is projected to occur twice as often by the end of this century under the lower emissions scenario and three times as often under the higher emissions scenario.

DRINKING WATER UTILITIES

- In some lakes, mixing of the relatively warm surface lake water with the colder water below is reduced; this stratification can cut off oxygen from bottom layers, increasing the risk of oxygen-poor or oxygen-free "dead zones."
- In lakes with contaminated sediment, warmer water and low-oxygen conditions can more readily release mercury and other persistent pollutants into surface water.
- Reduced lake ice increases evaporation in winter, contributing to a decline in water levels.
- Reduced summer water levels are also likely to reduce the recharge of groundwater, dry up small streams, and reduce the area of wetlands in the Midwest.

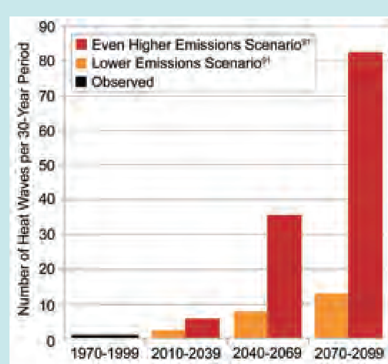
CHALLENGES BY GROUP		DW	WW
Drought	Reduced groundwater recharge	💧💧	
	Lower lake and reservoir levels	💧💧	
	Changes in seasonal runoff & loss of snowpack	💧	
Water Quality Degradation	Low flow conditions & altered water quality		💧
	Saltwater intrusion into aquifers	💧	
	Altered surface water quality	💧💧	💧💧
Floods	High flow events & flooding	💧💧	💧💧
	Flooding from coastal storm surges	💧	💧
Ecosystem Changes	Loss of coastal landforms / wetlands	💧	💧
	Increased fire risk & altered vegetation	💧	💧
Service Demand & Use	Volume & temperature challenges	💧💧	💧💧
	Changes in agricultural water demand	💧💧	
	Changes in energy sector needs	💧💧	
	Changes in energy needs of utilities	💧💧	💧💧

Click on a group name above to read more about these challenges or click on a water drop above to read more about a specific challenge.

💧💧 = Particularly relevant to the Midwest 💧 = Somewhat relevant

EXAMPLE: Number of 1995-like Chicago Heat Waves

Over the last 3 decades of this century, heat waves such as the one that occurred in Chicago in 1995 are projected to occur about once every 3 years under the lower emissions scenario. This 5-day heat wave peaked at 106 °F and resulted in more than 700 deaths. Under the even higher emissions scenario, such events are projected to occur on an average of nearly three times a year. In this analysis, heat waves were defined as at least 1 week of daily maximum temperatures greater than 90 °F, and nighttime minimum temperatures greater than 70 °F, with at least 2 consecutive days with daily temperatures greater than 100 °F and nighttime temperatures greater than 80 °F.



SOURCES USGCRP 2009; Hayhoe et al. 2010.

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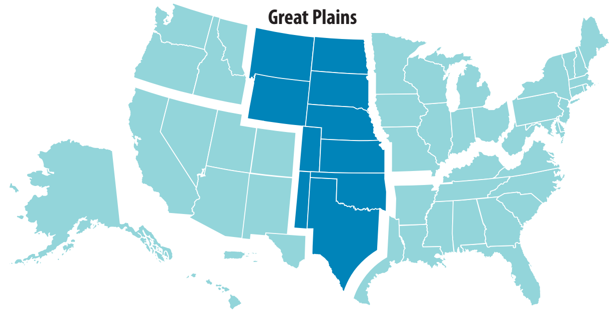
CLIMATE READY WATER UTILITIES



Climate Region Brief > GREAT PLAINS

Return to Introduction

Projected climate change in the Great Plains of the United States will continue to follow trends that are already observable. Temperature rise, shifts in precipitation patterns and timing, and altered hydrologic cycles can be expected due to climate change. The following statements, drawn from a U.S. Global Change Research Program assessment (USGCRP 2009), are based on projections for climate conditions at the end of the 21st century under a higher emissions scenario (IPCC 2000).

PROJECTED CHANGES

ALL UTILITIES

- Temperatures are projected to continue to increase over this century, with summer changes projected to be larger than those in winter in the southern and central Great Plains.
- More frequent extreme events such as heat waves, droughts, and heavy rainfall are projected to occur.
- Precipitation is also projected to change, particularly in winter and spring. Conditions are anticipated to become wetter in the north and drier in the south.

DRINKING WATER UTILITIES

- Projections of increasing temperatures, faster evaporation rates, and more sustained droughts brought on by climate change will only add more stress to overtaxed water sources.
- Projected increases in precipitation are unlikely to be sufficient to offset decreasing soil moisture and water availability in the Great Plains due to rising temperatures and aquifer depletion.
- Further stresses on agricultural water supply are likely as the region's cities continue to grow, increasing competition between urban and rural water users.

CHALLENGES BY GROUP		DW	WW
Drought	Reduced groundwater recharge	💧💧	
	Lower lake and reservoir levels	💧💧	
	Changes in seasonal runoff & loss of snowpack	💧	
Water Quality Degradation	Low flow conditions & altered water quality		💧
	Saltwater intrusion into aquifers	💧	
	Altered surface water quality	💧	💧
Floods	High flow events & flooding	💧💧	💧💧
	Flooding from coastal storm surges	💧	💧
Ecosystem Changes	Loss of coastal landforms / wetlands	💧	💧
	Increased fire risk & altered vegetation	💧💧	💧💧
Service Demand & Use	Volume & temperature challenges	💧💧	💧💧
	Changes in agricultural water demand	💧💧	
	Changes in energy sector needs	💧	
	Changes in energy needs of utilities	💧💧	💧💧

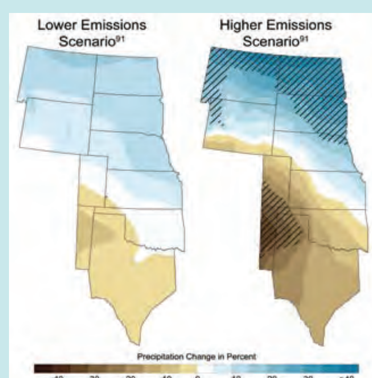
Click on a group name above to read more about these challenges or click on a water drop above to read more about a specific challenge.

💧💧 = Particularly relevant to the Great Plains 💧 = Somewhat relevant

EXAMPLE: Projected Spring Precipitation Change by 2080s–2090s

Northern areas of the Great Plains are projected to experience a wetter climate by the end of this century, while southern areas are projected to experience a drier climate (compared to 1960–1979 baseline). Confidence in the projected changes is highest in the hatched areas.

SOURCES Hayhoe et al. 2004; Hayhoe et al. 2008; USGCRP 2009.



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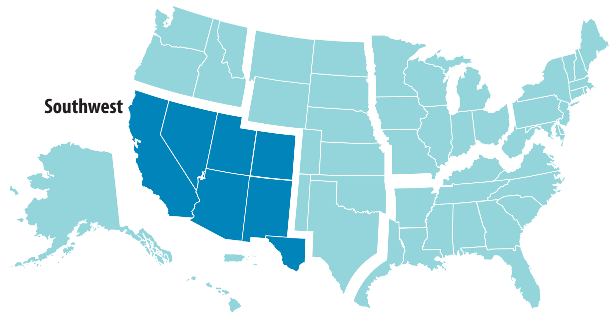
CLIMATE READY WATER UTILITIES



Climate Region Brief > SOUTHWEST

Return to Introduction

Projected climate change in the southwestern United States will continue to follow trends that are already observable. Temperature rise, shifts in precipitation patterns and timing, and altered hydrologic cycles can be expected due to climate change. The following statements, drawn from a U.S. Global Change Research Program assessment (USGCRP 2009), are based on projections for climate conditions at the end of the 21st century under a higher emissions scenario (IPCC 2000).

PROJECTED CHANGES

ALL UTILITIES

- Projected summertime temperature increases are greater than the annual average increases in parts of the region, and are likely to be exacerbated locally by expanding urban heat island effects.
- More intense, longer-lasting heat wave events are projected to occur over this century.
- Increased flood risk in the Southwest is likely to result from a combination of decreased snow cover on the lower slopes of high mountains, and an increased fraction of winter precipitation falling as rain and therefore running off more rapidly and altering timing of flooding.
- Increasing temperature, more drought sand, wildfires, and invasive species colonization will accelerate transformation of the landscape. In general, the total area burned by wildfire is projected to increase.

DRINKING WATER UTILITIES

- More frequent dry winters suggest an increased risk of these systems experiencing water shortages.
- Projections point to an increasing probability of more severe drought for the region; however, there is currently no consensus on how the region's summer monsoon, or rainy season, might change in the future.
- Projected temperature increases, combined with river-flow reductions, will increase the risk of water supply scarcity and water conflicts between sectors, states, and even nations.

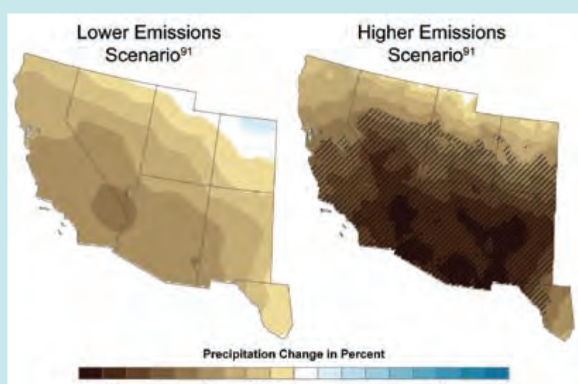
CHALLENGES BY GROUP		DW	WW
Drought	Reduced groundwater recharge	💧	
	Lower lake and reservoir levels	💧	
	Changes in seasonal runoff & loss of snow-pack	💧💧	
Water Quality Degradation	Low flow conditions & altered water quality		💧💧
	Saltwater intrusion into aquifers	💧	
	Altered surface water quality	💧	💧
Floods	High flow events & flooding	💧💧	💧💧
	Flooding from coastal storm surges	💧	💧
Ecosystem Changes	Loss of coastal landforms / wetlands	💧	💧
	Increased fire risk & altered vegetation	💧💧	💧💧
Service Demand & Use	Volume & temperature challenges	💧💧	💧💧
	Changes in agricultural water demand	💧💧	
	Changes in energy sector needs	💧💧	
	Changes in energy needs of utilities	💧💧	💧💧

Click on a group name above to read more about these challenges or click on a water drop above to read more about a specific challenge.

💧💧 = Particularly relevant to the Southwest 💧 = Somewhat relevant

EXAMPLE: Projected Change in Spring Precipitation 2080–2090

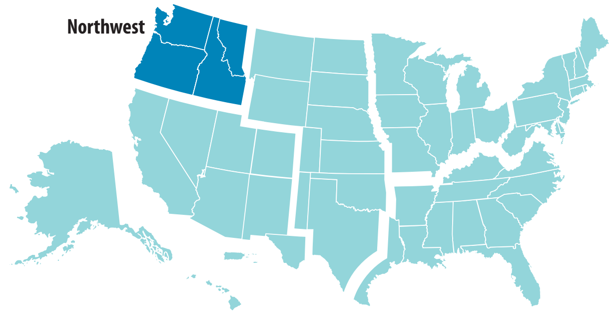
Percentage change in March-April-May precipitation for 2080 to 2099 compared to baseline from 1961 to 1979 for a lower emissions scenario (left) and a higher emissions scenario (right). Confidence in the projected changes is highest in the hatched areas.



SOURCES Hayhoe et al. 2004; Hayhoe et al. 2008; USGCRP 2009.

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES



Climate Region Brief > NORTHWEST

Return to Introduction

Projected climate change in the northwestern United States will continue to follow trends that are already observable. Temperature rise, shifts in precipitation patterns and timing, and altered hydrologic cycles can be expected due to climate change. The following statements, drawn from a U.S. Global Change Research Program assessment (USGCRP 2009), are based on projections for climate conditions at the end of the 21st century under a higher emissions scenario (IPCC 2000).

PROJECTED CHANGES

ALL UTILITIES

- Regionally averaged temperature is projected to increase another 3–10 °F during this century.
- Sea-level rise will increase erosion of the Northwest coast and cause the loss of beaches and other significant coastal land.
- Increasing winter rainfall (as opposed to snowfall) is expected to lead to more winter flooding and an increased number of landslides due to saturated soils.
- Sensitive watersheds are projected to experience both increased flood risk in winter and increased drought risk in summer due to warming.
- Low streamflow in late summer are projected to be even lower due to drought and reduced summer precipitation.

DRINKING WATER UTILITIES

- April 1 snowpack is projected to decline as much as 40% in the Cascades by the 2040s, leading to earlier peak streamflow, and a reduction in the amount of water available during the warm season.
- Areas dominated by rain, rather than snow, are not expected to see major shifts in the timing of runoff.

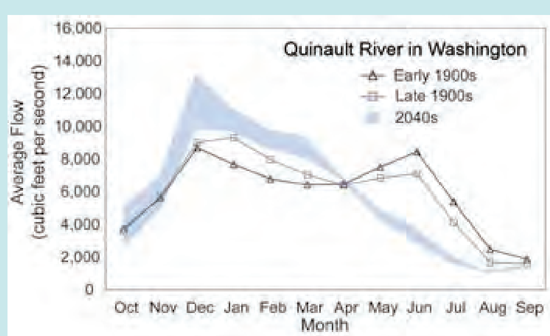
CHALLENGES BY GROUP		DW	WW
Drought	Reduced groundwater recharge	●	
	Lower lake and reservoir levels	●	
	Changes in seasonal runoff & loss of snowpack	●●	
Water Quality Degradation	Low flow conditions & altered water quality		●●
	Saltwater intrusion into aquifers	●	
	Altered surface water quality	●	●
Floods	High flow events & flooding	●●	●●
	Flooding from coastal storm surges	●	●
Ecosystem Changes	Loss of coastal landforms / wetlands	●●	●●
	Increased fire risk & altered vegetation	●●	●●
Service Demand & Use	Volume & temperature challenges	●●	●●
	Changes in agricultural water demand	●	
	Changes in energy sector needs	●	
	Changes in energy needs of utilities	●●	●●

Click on a group name above to read more about these challenges or click on a water drop above to read more about a specific challenge.

●● = Particularly relevant to the Northwest ● = Somewhat relevant

EXAMPLE: Shift to Earlier Peak Streamflow

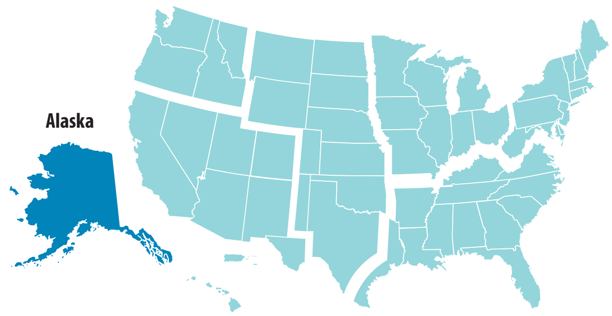
As precipitation continues to shift from snow to rain, by the 2040s, peak flow on the Quinault River is projected to occur in December, and flows in June are projected to be reduced to about half of what they were over the past century. On the graph, the blue swath represents the range of projected streamflow based on an increase in temperature of 3.6 to 5.4 °F. The other lines represent streamflow in the early and late 1900s. Figure provided by the Climate Impacts Group, University of Washington, Seattle. http://cses.washington.edu/cig/



SOURCE USGCRP 2009.

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES



Climate Region Brief > ALASKA

Return to Introduction

Projected climate change in Alaska will continue to follow trends that are already observable. Temperature rise, shifts in precipitation patterns and timing, and altered hydrologic cycles can be expected due to climate change. The following statements, drawn from a U.S. Global Change Research Program assessment (USGCRP 2009), are based on projections for climate conditions at the end of the 21st century under a higher emissions scenario (IPCC 2009).

PROJECTED CHANGES

ALL UTILITIES

- Average annual temperatures are projected to rise about 3.5 to 7 °F by the middle of this century.
- Higher temperatures are expected to continue to reduce Arctic sea ice coverage.
- Longer summers and higher temperatures are causing drier conditions, even in the absence of strong trends in precipitation.
- Alaska's coastlines, many of which are low in elevation, are increasingly threatened by a combination of the loss of their protective sea-ice buffer, increasing storm activity, and thawing coastal permafrost.
- Thawing permafrost damages roads, runways, water and sewer systems, and other infrastructure.
- The average area burned per year by wildfires in Alaska is projected to double by the middle of this century and triple under a moderate greenhouse gas emissions scenario by 2100.

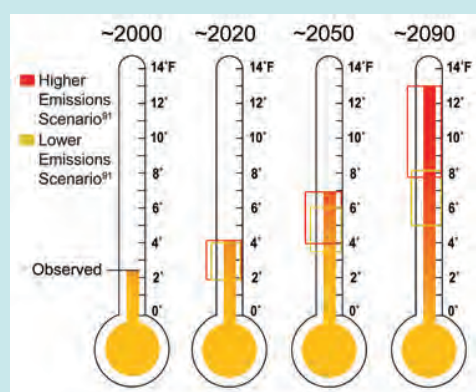
CHALLENGES BY GROUP		DW	WW
Drought	Reduced groundwater recharge	●	
	Lower lake and reservoir levels	●	
	Changes in seasonal runoff & loss of snow-pack	●	
Water Quality Degradation	Low flow conditions & altered water quality		●
	Saltwater intrusion into aquifers	●	
	Altered surface water quality	●	●
Floods	High flow events & flooding	●	●
	Flooding from coastal storm surges	●	●
Ecosystem Changes	Loss of coastal landforms / wetlands	●●	●●
	Increased fire risk & altered vegetation	●●	●●
Service Demand & Use	Volume & temperature challenges	●	●
	Changes in agricultural water demand	●	
	Changes in energy sector needs	●●	
	Changes in energy needs of utilities	●●	●●

Click on a group name above to read more about these challenges or click on a water drop above to read more about a specific challenge.

●● = Particularly relevant to Alaska ● = Somewhat relevant

EXAMPLE: Observed and Projected Temperature Rise

Alaska's average annual temperature has increased 3.4 °F over the past 50 years. The observed increase compares the average temperature from 1993 to 2007 with that from the 1960s / 1970s baseline. The brackets on the thermometers represent the likely range of model projections, although lower or higher outcomes are possible. By the end of this century, the average temperature is projected to rise by 5–13 °F above the baseline.



SOURCES Wehner 2005; Meehl et al. 2007; USGCRP 2009.

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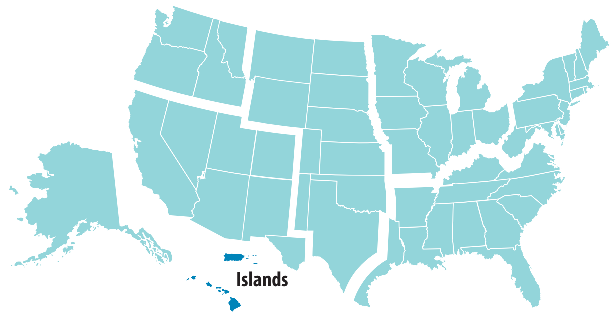
Agency

CLIMATE READY
WATER UTILITIES



Climate Region Brief > ISLANDS

Return to Introduction

Projected climate change for islands in both the Pacific Ocean and Caribbean Sea will continue to follow trends that are already observable. Temperature rise, shifts in precipitation patterns and timing, and altered hydrologic cycles can be expected due to climate change. The following statements, drawn from a U.S. Global Change Research Program assessment (USGCRP 2009), are based on projections for climate conditions at the end of the 21st century under a higher emissions scenario (IPCC 2000).

PROJECTED CHANGES

ALL UTILITIES

- Projections for the rest of this century suggest increases in air and ocean surface temperatures in both the Pacific Ocean and Caribbean Sea.
- Changes in weather patterns are projected to cause an increase in the frequency and intensity of extreme storm events, sea-level rise, coastal erosion, coral reef bleaching, ocean acidification, and contamination of freshwater resources by saltwater.
- Islands and other low-lying coastal areas will be at increased risk from coastal inundation due to sea-level rise and storm surge.
- Hurricane (typhoon) wind speeds and rainfall rates are likely to increase, which, combined with sea-level rise, is expected to cause higher storm surge levels.
- Projections suggest an overall decrease in rainfall in the Caribbean and an increased frequency of heavy downpours. Rainfall during summer months, the traditionally drier part of the year, is also expected to increase in the Pacific and may result in unusual summer flooding.

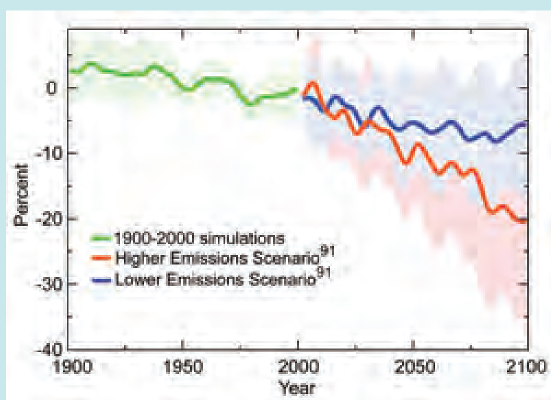
CHALLENGES BY GROUP		DW	WW
Drought	Reduced groundwater recharge	💧	
	Lower lake and reservoir levels	💧	
	Changes in seasonal runoff & loss of snowpack	💧	
Water Quality Degradation	Low flow conditions & altered water quality		💧
	Saltwater intrusion into aquifers	💧💧	
	Altered surface water quality	💧	💧
Floods	High flow events & flooding	💧💧	💧💧
	Flooding from coastal storm surges	💧💧	💧💧
Ecosystem Changes	Loss of coastal landforms / wetlands	💧💧	💧💧
	Increased fire risk & altered vegetation	💧	💧
Service Demand & Use	Volume & temperature challenges	💧	💧
	Changes in agricultural water demand	💧	
	Changes in energy sector needs	💧	
	Changes in energy needs of utilities	💧💧	💧💧

Click on a group name above to read more about these challenges or click on a water drop above to read more about a specific challenge.

💧💧 = Particularly relevant to islands 💧 = Somewhat relevant

EXAMPLE: Caribbean Precipitation Change 1900 to 2100

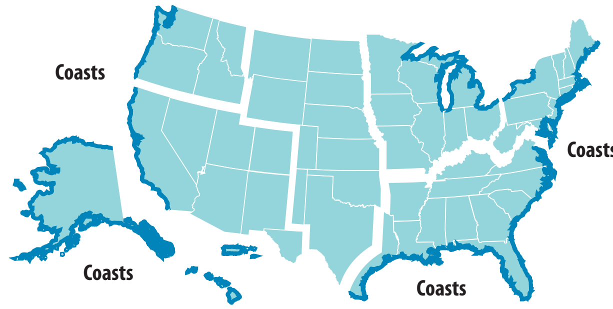
Total annual precipitation has declined in the Caribbean, and climate models project stronger declines in the future, particularly under higher emission scenarios. Such decreases threaten island communities that rely on rainfall for replenishing their freshwater supplies. The shaded areas show the likely ranges, while the lines show the central projections from a set of climate models.



SOURCES Wehner 2005; Meehl et al. 2007; USGCRP 2009.

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES



Climate Region Brief > COASTS

Return to Introduction

Projected climate change for U.S. coastal areas will continue to follow trends that are already observable. Temperature rise, shifts in precipitation patterns and timing, and altered hydrologic cycles can be expected due to climate change. The following statements, drawn from a U.S. Global Change Research Program assessment (USGCRP 2009), are based on projections for climate conditions at the end of the 21st century under a higher emissions scenario (IPCC 2000).

PROJECTED CHANGES

ALL UTILITIES

- Coastal waters are very likely to continue to warm by as much 4 to 8 °F in this century, both in summer and winter.
- Significant sea-level rise and storm surge will erode shorelines and adversely affect coastal cities and ecosystems.
- Recent estimates of global sea-level rise substantially exceed the Intergovernmental Panel on Climate Change (IPCC) estimates, suggesting sea-level rise between 3 and 4 feet in this century.
- Sea-level rise is expected to increase saltwater intrusion into coastal freshwater aquifers, making some unusable without desalination.
- More spring runoff and warmer coastal waters will increase the seasonal reduction in oxygen and increase the area and intensity of coastal dead zones in places such as the northern Gulf of Mexico and the Chesapeake Bay.

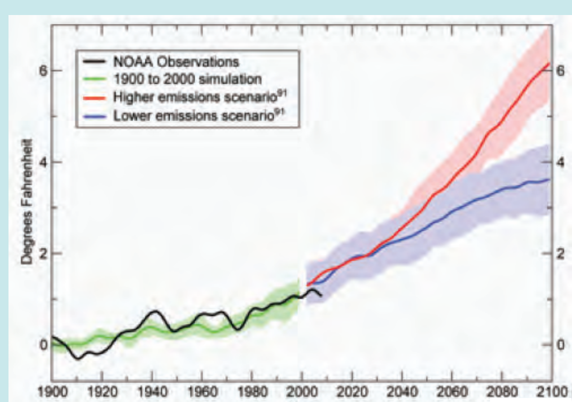
CHALLENGES BY GROUP		DW	WW
Drought	Reduced groundwater recharge	💧	
	Lower lake and reservoir levels	💧	
	Changes in seasonal runoff & loss of snow-pack	💧💧	
Water Quality Degradation	Low flow conditions & altered water quality		💧💧
	Saltwater intrusion into aquifers	💧	
	Altered surface water quality	💧	💧
Floods	High flow events & flooding	💧💧	💧💧
	Flooding from coastal storm surges	💧💧	💧💧
Ecosystem Changes	Loss of coastal landforms / wetlands	💧💧	💧💧
	Increased fire risk & altered vegetation	💧	💧
Service Demand & Use	Volume & temperature challenges	💧💧	💧
	Changes in agricultural water demand	💧	
	Changes in energy sector needs	💧	
	Changes in energy needs of utilities	💧💧	💧💧

Click on a group name above to read more about these challenges or click on a water drop above to read more about a specific challenge.

💧💧 = Particularly relevant to the coasts 💧 = Somewhat relevant

EXAMPLE: Projected Increase in Sea Surface Temperature in the Atlantic Hurricane Formation Region

Increased intensity of hurricanes is linked to rising sea surface temperatures in the region of the ocean where hurricanes form. Projected changes, relative to observed temperatures for the 20th century, differ based on the emission scenario considered (shaded lines for lower and higher emissions scenarios; IPCC 2000). The shaded areas show the likely ranges while the lines show the central projections from a set of climate models.



SOURCES Wehner 2005; Meehl et al. 2007; USGCRP 2009.

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CLIMATE READY WATER UTILITIES

Climate Challenge Group: DROUGHT (DW)

Return to Introduction

The challenges to water utilities from drought associated with climate change may be driven or forced by changing water levels in aquifers and reservoirs, loss of snowpack, and reductions in surface water flows. Clicking on the drinking water icon next to each challenge will bring you to that particular Challenge Brief.

Reduced Groundwater Recharge DW

Reduced precipitation and higher loss of water from plants and evaporation due to higher temperatures will decrease surface water supplies and groundwater recharge, impacting utilities that rely on groundwater supplies.

Lower Lake and Reservoir Levels DW

Decreases in mean annual precipitation and higher loss of water from plants and evaporation due to higher temperatures will lead to lower levels in the lakes and reservoirs that water utilities rely on for surface water supplies. These lower levels will cause difficulty in meeting water demands, especially in the summer months, and may drop water levels below intake infrastructure.

Changes in Runoff and Loss of Snowpack DW

Increased temperatures and shifting precipitation patterns will alter seasonal runoff and storage of water in snowpack. These changes in water supply could strain the capacity of reservoirs to hold larger and earlier peak runoff flows, cause shortages in the summer due to longer duration of warmer and drier season, and compromise biodiversity goals (e.g., managing cold-water fish, such as salmon and trout). Lower annual precipitation will lead to lower streamflow in many locations, which may lead to diminished water quality. Diminished water quality in receiving waters may lead to more stringent requirements for wastewater discharges, leading to higher treatment costs and the need for capital improvements.

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs

Click name of any option to review more information in the Glossary

No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
	Incorporate monitoring of groundwater conditions and climate change projections into groundwater models.	$
	Use hydrologic models to project runoff and incorporate model results during water supply planning.	$
	Conduct climate change impacts and adaptation training for personnel.	$
	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$

✓	OPERATIONAL STRATEGIES	COST
	Monitor current weather conditions, including precipitation and temperature.	$
	Monitor surface water conditions, including river discharge and snowmelt.	$

Continued on page 2

✓	OPERATIONAL STRATEGIES (continued)	COST
	Finance and facilitate systems to recycle water, including use of greywater in homes and businesses.	$$-$$$
	Practice conjunctive use (i.e., optimal use of surface water and groundwater).	$$-$$$
	Reduce agricultural and irrigation water demand by working with irrigators to install advanced equipment (e.g., drip or other micro-irrigation systems with weather-linked controls).	$$-$$$
	Practice demand management through communication to public on water conservation actions.	$
	Practice water conservation and demand management through water metering, rebates for water conserving appliances/toilets and/or rainwater harvesting tanks.	$-$$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	★ Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to regulate runoff.	$$$
	Build infrastructure needed for aquifer storage and recovery, (either for seasonal storage or longer-term water banking), (e.g., recharge canals, recovery wells).	$$$
	★ Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
	★ Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
	★ Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
	★ Increase or modify treatment capabilities to address treatment needs of marginal water quality in new sources.	$$$
	Retrofit intakes to accommodate lower water levels in reservoirs and decreased late season flows.	$$-$$$
	Build or expand infrastructure to support conjunctive use.	$$$
	Build systems to recycle wastewater for energy, industrial, agricultural, or household use.	$$$

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CLIMATE READY WATER UTILITIES

REDUCED GROUNDWATER RECHARGE (DW)

Return to Introduction

Reduced precipitation and higher loss of water from plants and evaporation due to higher temperatures will not only mean decreases in surface water supplies; it will also lead to decreased groundwater recharge, impacting utilities that rely on groundwater supplies.

CLIMATE INFORMATION

- Mean annual precipitation has increased by about 5% over the last 50 years in the United States, but there have been important regional and seasonal differences. Decreases occurred in much of the Southeast in all but the fall season and in the Northwest in all seasons except spring.
- Some parts of the Southwest are projected to have decreases in spring and winter precipitation of greater than 20% and 40%, respectively. The Pacific Northwest may experience declines in summer precipitation of greater than 30% (USGCRP 2009). Declines in precipitation may translate into decreased groundwater recharge in many areas.

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs

Click name of any option to review more information in the Glossary

No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
☐	★ Incorporate monitoring of groundwater conditions and climate change projections into groundwater models.	$
☐	★ Conduct climate change impacts and adaptation training for personnel.	$
☐	★ Participate in community planning and regional collaborations related to climate change adaptation.	$-$$

✓	OPERATIONAL STRATEGIES	COST
☐	★ Monitor current weather conditions, including precipitation and temperature.	$
☐	Finance and facilitate systems to recycle water, including use of greywater in homes and businesses.	$$-$$$
☐	Practice conjunctive use (i.e., optimal use of surface water and groundwater).	$$-$$$
☐	Reduce agricultural and irrigation water demand by working with irrigators to install advanced equipment (e.g., drip or other micro-irrigation systems with weather-linked controls).	$$-$$$
☐	Practice demand management through communication to public on water conservation actions.	$
☐	Practice water conservation and demand management through water metering, rebates for water conserving appliances/toilets and/or rainwater harvesting tanks.	$-$$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
☐	Build infrastructure needed for aquifer storage and recovery, (either for seasonal storage or longer-term water banking), (e.g., recharge canals, recovery wells).	$$$
☐	★ Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$

Continued on page 2

✔	CAPITAL/ INFRASTRUCTURE STRATEGIES (continued)	COST
	Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
	Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
	Build or expand infrastructure to support conjunctive use.	$$$
	Build systems to recycle wastewater for energy, industrial, agricultural, or household use.	$$$

EXAMPLE

The Inland Empire Utilities Agency (IEUA) is a wholesale water and wastewater provider in Southern California's Riverside County. Currently, the IEUA region receives more than half of its average water needs from groundwater sources (primarily the underlying Chino Basin Aquifer), about a quarter from Northern California via a large intrastate water distribution system (the California State Water Project), and the rest from surface water and a rapidly expanding recycled water system. An analysis, based on projections from an ensemble of 21 climate models, showed that winter precipitation between 2000 and 2030 could change from -27% to +19%. Moreover, owing to the potentially hotter and drier conditions, outdoor water demand could increase by 11% by 2040 assuming constant land use patterns, demand factors, and water supply variability. There may be decreasing sustainable groundwater yields of up to -15% by 2040 (Groves et al. 2008). IEUA conducted a robust decision-making analysis with the goal of adopting adaptation measures that would not exceed $3.75 billion. In response to the results of this analysis, the utility decided to accelerate expansion of its dry-year-yield program (i.e., groundwater recharge using stormwater) as well as implementation of its water recycling efforts. These efforts involve the reuse of tertiary treated wastewater for groundwater recharge and other functions. In total, the water recycling plan calls for an increase in recycled water from 9.9 million m^3/year in 2005 to 85 million m^3/year in 2025 (Groves et al. 2008, Lembert and Groves 2010). Implementing these measures will help counteract the effects of reduced groundwater recharge due to climate change.

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

LOWER LAKE AND RESERVOIR LEVELS (DW)

Return to Introduction

Decreases in mean annual precipitation and higher loss of water from plants and evaporation due to higher temperatures will lead to lower levels in the lakes and reservoirs that water utilities rely on for surface water supplies. These lower levels will cause difficulty in meeting water demands, especially in the summer months, and may drop water levels below intake infrastructure.

CLIMATE INFORMATION

- Mean annual precipitation has increased by about 5% over the last 50 years in the United States, but there have been important regional and seasonal differences. Decreases occurred in much of the Southeast in all but the fall season and in the Northwest in all seasons except spring.
- Some parts of the Southwest are projected to have decreases in spring and winter precipitation of greater than 20% and 40%, respectively. The Pacific Northwest may experience declines in summer precipitation of greater than 30% (USGCRP 2009). Declines in precipitation may translate into decreased volumes in source lakes and reservoirs.

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs

Click name of any option to review more information in the Glossary

No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Conduct training for personnel in climate change impacts and adaptation.	$
	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$

✓	OPERATIONAL STRATEGIES	COST
	Monitor current weather conditions, including precipitation and temperature.	$
	Finance and facilitate systems to recycle water, including use of greywater in homes and businesses.	$$-$$$
	Practice conjunctive use (i.e., optimal use of surface water and groundwater).	$$-$$$
	Reduce agricultural and irrigation water demand by working with irrigators to install advanced equipment (e.g., drip or other micro-irrigation systems with weather-linked controls).	$$-$$$
	Practice demand management through communication to public on water conservation actions.	$
	Practice water conservation and demand management through water metering, rebates for water conserving appliances/toilets and/or rainwater harvesting tanks.	$-$$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to regulate runoff.	$$$
	Build infrastructure needed for aquifer storage and recovery, (either for seasonal storage or longer-term water banking), (e.g., recharge canals, recovery wells).	$$$
	Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$

Continued on page 2

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES (continued)	COST
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	\$\$-\$\$\$
	Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	\$\$-\$\$\$
	Increase or modify treatment capabilities to address treatment needs of marginal water quality in new sources.	\$\$\$
	Retrofit intakes to accommodate lower water levels in reservoirs.	\$\$-\$\$\$
	Build or expand infrastructure to support conjunctive use.	\$\$\$
	Build systems to recycle wastewater for energy, industrial, agricultural, or household use.	\$\$\$

EXAMPLE

Sydney Water (Australia) receives about 80% of its supplies from one reservoir: the Warragamba Dam over the Hawkesbury Nepean River. Inflows into the river have declined recently. From 1991 to 2002, inflow volumes were 697 billion liters per year on average, compared to 2,135 billion liters per year during the period 1949–1990 (Boerema 2008). There are concerns about further reductions in streamflow with climate change. Sydney Water has instituted a number of demand management actions. Water conservation measures have included rainwater tank rebates, a program that involves plumbers installing water-saving devices in homes (Water Fix) (9.58 billion liters/year saved), washing machine rebates (1.97 billion liters / year saved), and a water conservation program in commercial office buildings and shopping centers (13.406 billion liters/year saved) (Danilenko 2010).

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CLIMATE READY
WATER UTILITIES
EPA

CHANGES IN SEASONAL RUNOFF & LOSS OF SNOWPACK (DW)

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Increased temperatures and shifting precipitation patterns will alter seasonal runoff and storage of water in snowpacks. These disruptions in water supply could strain the capacity of reservoirs to hold larger and earlier peak runoff flows, cause shortages in the summer due to longer duration of warmer and drier season, and compromise biodiversity goals (e.g., managing cold-water fish, such as salmon and trout).

CLIMATE INFORMATION

- Over the last 50 years, there have been widespread temperature-related reductions in snowpack in the West, particularly in the low-elevations of the western United States. In both the West and the Northeast, there has been a transition to more rain and less snow. Runoff in snowmelt-dominated areas is occurring up to 14 and 20 days earlier in the Northeast and West, respectively (USGCRP 2009).
- In California's Sierra Nevada Mountains, snowpack reductions are projected to range from 25% to 40% by 2050, leading to a loss of snowpack storage from an average of 15 million acre-feet to perhaps 10.5 to 9 million acre-feet per year. By 2090, assuming an increase in mean temperatures of 3.8 °F, the watershed upstream of the San Francisco estuary could lose 50% of its April snowpack (Standish-Lee and Lecina 2008).
- By the end of the century, spring runoff in the West in some cases may be up to 60 days earlier, while in the Northeast, it could advance 14 days (USGCRP 2009).

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs
Click name of any option to review more information in the Glossary
No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
	Use hydrologic models to project runoff and incorporate model results during water supply planning.	$
	Conduct training for personnel in climate change impacts and adaptation strategies.	$
	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$

✓	OPERATIONAL STRATEGIES	COST
	Monitor current weather conditions, including precipitation and temperature.	$
	Monitor surface water conditions, including river discharge and snowmelt.	$
	Finance and facilitate systems to recycle water, including use of greywater in homes and businesses.	$$-$$$
	Practice conjunctive use (i.e., optimal use of surface water and groundwater).	$$-$$$
	Reduce agricultural and irrigation water demand by working with irrigators to install advanced equipment (e.g., drip or other micro-irrigation systems with weather-linked controls).	$$-$$$
	Practice water conservation and demand management through water metering, rebates for water conserving appliances/toilets and/or rainwater harvesting tanks.	$-$$

Continued on page 2

✔	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to regulate runoff.	$$$
	Build infrastructure needed for aquifer storage and recovery, (either for seasonal storage or longer-term water banking), (e.g., recharge canals, recovery wells).	$$$
	Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
	Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
	Retrofit intakes to accommodate decreased flow in source waters.	$$-$$$
	Build or expand infrastructure to support conjunctive use.	$$$

EXAMPLE

The Portland Water Bureau supplies water to approximately 800,000 people in the Portland, Oregon metropolitan area, delivering 40 billion gallons per year. The primary water source is the Bull Run Watershed, and there are two reservoirs with total storage capacity of 10 billion gallons. Precipitation over the watershed ranges from 59 to more than 80 inches per year – most falling during the winter months. The greatest challenge for the utility is supplying water during the summer months, when demand (220 million gallons per day) is double average daily use. The utility's secondary source is groundwater located along the south shore of the Columbia River.

The utility generated future scenarios of water supply and demand using four different climate model projections and regional population growth projections. Results such as increased winter precipitation, earlier snowmelt, and drier summers were consistent across the models. The main concern is not a reduction in annual precipitation but seasonal changes in runoff: spring runoff may increase by 15%, followed by late spring reductions in runoff of 30%. The analysis suggests that reduced summer precipitation combined with increased seasonal demand may lead to decreased reliability of supply without additional infrastructure. The impact would result in a 2.8–5.4 billon gallon decrease in reservoir storage. To ameliorate this, the utility is considering expanding groundwater supply or surface water storage. The latter would allow for the sustainability of the emergency groundwater supply. Besides storage augmentation, other measures that are being considered include conjunctive use strategies that coordinate the optimal use of existing surface and groundwater supplies, including use of aquifer storage and recovery (ASR) (Miller and Yates 2005).

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

Climate Challenge Group: WATER QUALITY DEGRADATION (DW/WW)

Return to Introduction

Changes in water quality associated with climate change may be driven or forced by saline intrusion into aquifers and altered surface water quality. Clicking on either the drinking water or wastewater icon next to each challenge will bring you to that particular Challenge Brief.

Low Flow Conditions and Altered Water Quality (WW)

Many areas are projected to receive less annual total precipitation concentrated in fewer, more extreme rainfall events. Lower annual precipitation will lead to lower streamflows in many locations, which may lead to diminished water quality. Turbidity from sediment washing downstream following storm events also impacts water quality, particularly in areas where fires have diminished the ability of landscapes to hold soil. Diminished water quality in receiving waters may lead to more stringent requirements for wastewater discharges and impacts to ecosystems that are sensitive to temperature.

Saltwater Intrusion into Aquifers (DW)

Projected sea-level rise, combined with higher water demand from coastal communities, can lead to saltwater intrusion in both coastal groundwater aquifers and estuaries. This combination may reduce water quality and increase treatment costs for water treatment facilities drawing from coastal aquifers or surface intakes in tidal estuaries near the saltwater line. Desalination plants may have to treat water with higher salt content, which would also increase costs.

Altered Surface Water Quality (DW) (WW)

Climate models project that the average temperature in the United States is going to increase, as will the number of extreme hot days. Higher temperatures can lead to algal blooms, which compromise source water quality and may require more advanced treatment. These water quality impacts will drive additional treatment processes for drinking water utilities, potentially leading to higher energy demand and capital and operating costs. For wastewater utilities, the change in receiving water quality may lead to more stringent discharge requirements and the need for more advanced effluent treatment.

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs

Click name of any option to review more information in the Glossary

No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
☐	Update fire models and fire management plans for any water supply sources in fire-prone watersheds to incorporate any changes in fire frequency, magnitude and extent due to projected future climatic conditions.	$-$$
☐	Conduct sea-level rise and storm surge modeling. Incorporate resulting inundation mapping and estimates of saltwater intrusion into groundwater or estuaries into land use, water supply, and facility planning.	$
☐	(No Regrets) Develop models to understand potential water quality changes (e.g., increased turbidity or salinity) and costs of resultant changes in treatment.	$
☐	(No Regrets) Model groundwater conditions, including saltwater intrusion into aquifers associated with sea-level rise, and evaluate feasibility of implementing intrusion barriers.	$
☐	(No Regrets) Conduct climate change impacts and adaptation training.	$
☐	(No Regrets) Develop emergency response plans to deal with the relevant natural disasters and include stakeholder engagement and communication.	$
☐	(No Regrets) Participate in community planning and regional collaborations related to climate change adaptation.	$-$$

Continued on page 2

✓	OPERATIONAL STRATEGIES	COST
	Practice fire management plans in the watershed, such as mechanical thinning, weed control, selective harvesting, controlled burns and creation of fire breaks.	$-$$
	Manage reservoir water quality by investing in practices such as lake aeration to minimize algal blooms due to higher temperatures.	$$
	Monitor current weather conditions, including precipitation and temperature.	$
	Monitor flood events and drivers that may impact flood and water quality models (e.g., precipitation, catchment runoff).	$
	Monitor surface water conditions, including water quality in receiving bodies.	$
	Monitor vegetation changes in watersheds.	$
	Finance and facilitate systems to recycle water, including use of greywater in homes and businesses.	$$-$$$
	Reduce agricultural and irrigation water demand by working with irrigators to install advanced equipment (e.g., drip or other micro-irrigation systems with weather-linked controls).	$$-$$$
	Practice water conservation and demand management through water metering, rebates for water conserving appliances/toilets and/or rainwater harvesting tanks.	$-$$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to buffer against sediment and nutrient inflows into waterways.	$$$
	Implement green infrastructure on site and in municipalities (e.g., green roofs, filter strips, and more permeable building materials) to reduce runoff and associated pollutant loads into waterways.	$$$
	Implement watershed management practices to limit pollutant runoff to reservoirs.	$$
	Implement or retrofit source control measures at treatment plants to deal with altered influent flow and quality.	$$-$$$
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
	Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
	Increase water storage capacity to accommodate increased, earlier runoff. This would include silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
	Install low-head dams to separate saltwater wedge from intakes upstream in the freshwater pool.	$$$
	Implement barriers and aquifer recharge to limit effects of saltwater intrusion. Consider use of reclaimed water to create saltwater intrusion barriers.	$$$
	Increase capacity for wastewater and stormwater collection, treatment and discharge, including redundancies to hedge against infrastructure losses and disruptions.	$$$
	Increase treatment capabilities to address water quality changes (e.g., increased turbidity).	$$$
	Install effluent cooling systems (e.g., chillers, wetlands or trees for shading).	$-$$

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

LOW FLOW CONDITIONS & ALTERED WATER QUALITY (WW)

Return to Introduction

Climate models project that in the future, many areas are likely to receive less annual precipitation, but that when precipitation falls, it will be in fewer, more extreme rainfall events. Lower annual precipitation will lead to lower streamflows in many locations, which may lead to diminished water quality. Projected increases in algal growth resulting from the higher temperatures may further impact water quality. Turbidity from sediment washing downstream following storm events also impacts water quality, particularly in areas where fires have diminished the ability of landscapes to hold soil.

Diminished water quality in receiving waters may lead to more stringent requirements for wastewater discharges, leading to higher treatment costs and the need for capital improvements. In some locations, lower flows and higher temperatures may impact ecosystems that are sensitive to temperature, requiring utilities to cool effluent prior to discharge.

CLIMATE INFORMATION

- Precipitation intensity (e.g., precipitation per rainy day) is projected to increase by mid-century for most of the United States (Meehl et al. 2007). Intense precipitation events can impair water quality through nonpoint source pollution and soil erosion.
- Increased pollutant concentrations and frequency of algal blooms in surface waters due to decreased water volumes and increased temperatures are projected.
- Model projections of future precipitation indicate that southern areas, particularly the Southwest, will become drier. Some parts of the Southwest are projected to have decreases in spring and winter precipitation of greater than 20% and 40%, respectively.
- The Pacific Northwest may experience declines in summer precipitation of greater than 30% (USGCRP 2009).
- By the end of the century, the average U.S. temperature is projected to increase by approximately 7–11 °F under the higher emissions scenario and by approximately 4–6.5 °F under the lower emissions scenario (USGCRP 2009).
- Water availability may decrease on the order of 15% to 30% in the Southwest by mid-century (Milly et al. 2005, 2008). Lower volumes in surface water bodies may lead to higher pollutant concentrations.
- Increased turbidity and pollution inputs can be expected due to extreme storms, high flow events, and altered or reduced vegetation cover in watersheds.
- By 2070, the length of the fire season could increase by 2 to 3 weeks in the southwestern United States (Barnet et al. 2004). Burned areas result in sediment-laden runoff and siltation of water bodies.

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs

Click name of any option to review more information in the Glossary

No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
	Conduct climate change impacts and adaptation training for personnel.	$
	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$

Continued on page 2

✓	OPERATIONAL STRATEGIES	COST
	Monitor current weather conditions, including precipitation and temperature.	$
	Monitor surface water conditions, including water quality in receiving bodies.	$
	Finance and facilitate systems to recycle water to decrease discharges to receiving waters.	$$-$$$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to buffer against floods and sediment and nutrient inflows into source waterways.	$$$
	Implement green infrastructure on site and in municipalities (e.g., green roofs, filter strips, and more permeable building materials) to reduce runoff and associated pollutant loads into waterways.	$$$
	Increase capacity for wastewater and stormwater collection, treatment and discharge, including redundancies to hedge against infrastructure losses and disruptions.	$$$
	Increase treatment capabilities and capacities to address more stringent treament requirements (e.g., tertiary treatment).	$$$
	Install effluent cooling systems (e.g., chillers, wetlands or trees for shading).	$-$$

EXAMPLE

Spartanburg Water is a public water and wastewater utility in South Carolina that is composed of two distinct legal entities: Spartanburg Water System (SWS) and Spartanburg Sanitary Sewer District (SSSD). Future droughts of increased frequency and severity may affect wastewater system operations due to changed water quality in outflow streams. Several of Spartanburg Water's wastewater treatment plants discharge into small streams, where wastewater discharges may constitute up to 80% of streamflow. With prolonged drought, future permit limits for these facilities may be affected if the 7Q10 (i.e., lowest streamflow for 7 consecutive days that occurs once every 10 years) changes for the receiving streams. In an adjacent county, similar conditions resulted in the wastewater utility upgrading to tertiary treatment. Besides evaluating the feasibility of modifying future treatment at 3 of its 10 wastewater treatment plants, Spartanburg Water is taking an integrated approach and considering water supply in conjunction with wastewater treatment. For example, the largest of its 10 wastewater treatment plants is located just downstream of the Blalock Reservoir, its second largest water supply reservoir. Coordinating releases from the reservoir with the wastewater system can help ameliorate water quality issues associated with wastewater discharge (EPA 2010).

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

SALTWATER INTRUSION INTO AQUIFERS (DW)

Return to Introduction

Projected sea-level rise, combined with higher water demand from coastal communities, can lead to saltwater intrusion, both in coastal groundwater aquifers and in estuaries. This combination may reduce water quality and increase treatment costs for water treatment facilities drawing from coastal aquifers or from surface intakes in tidal estuaries near the saltwater line. Desalination plants may have to treat water with higher salt content, which would also increase costs.

CLIMATE INFORMATION

- Climate change induced sea-level rise is due to two components: thermal expansion of the oceans as they warm and inputs from the melting of glaciers and ice sheets (Antarctica, Greenland) on land. The IPCC Fourth Assessment Report estimates that sea level will rise 0.18–0.59 m (7.1–23.2 inches) over the course of the 21st century (Meehl et al. 2007). This estimate is partly based on observed 1993–2003 rates of ice flow for Greenland and Antarctica. If ice flow increases linearly with global mean temperature, then sea-level rise may be more in the range of 0.28–0.79 m (11.0–31.1 inches) (Meehl et al. 2007). Other scientists estimate that sea-level rise could reach 1.4 m (4.6 feet) by the end of the century (Rahmstorf 2007).
- For the United States, a recent study projects sea-level rise to be greatest on the Texas Gulf Coast and the Florida Panhandle (13–30 inches), where land subsidence is the largest (NACWA 2009). The projections for other regions include: Northeast Atlantic (10–11 inches), West Coast (7–9 inches), and South Florida and Southeast Atlantic (approximately 9 inches) (NACWA 2009).
- Along with sea-level rise, the brackish water line in tidal estuaries can move upstream, potentially impacting intakes. This is a concern for example for the intakes on the Delaware River for utilities in the Camden, New Jersey area.

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs
Click name of any option to review more information in the Glossary
No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
☐	Conduct sea-level rise and storm surge modeling. Incorporate resulting inundation mapping and estimates of saltwater intrusion into groundwater or estuaries into land use, water supply, and facility planning.	$
☐	(No Regrets) Develop models to understand potential water quality changes (e.g., increased turbidity or salinity) and costs of resultant changes in treatment.	$
☐	(No Regrets) Model groundwater conditions, including saltwater intrusion into aquifers associated with sea-level rise, and evaluate feasibility of implementing intrusion barriers.	$
☐	(No Regrets) Conduct training for personnel in climate change impacts and adaptation.	$
☐	(No Regrets) Participate in community planning and regional collaborations related to climate change adaptation.	$-$$

✓	OPERATIONAL STRATEGIES	COST
☐	Finance and facilitate systems to recycle water, including use of greywater in homes and businesses.	$$-$$$
☐	Reduce agricultural and irrigation water demand by working with irrigators to install advanced equipment (e.g., drip or other micro-irrigation systems with weather-linked controls).	$$-$$$
☐	Practice water conservation and demand management through water metering, rebates for water conserving appliances/toilets and/or rainwater harvesting tanks.	$-$$

Continued on page 2

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
	Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
	Install low-head dams to separate saltwater wedge from intakes upstream in the freshwater pool.	$$$
	Implement barriers and aquifer recharge to limit effects of saltwater intrusion. Consider use of reclaimed water to create saltwater intrusion barriers.	$$$
	Increase treatment capabilities and capacities to address decreased water quality due to saltwater intrusion.	$$$

EXAMPLE

In the first half of the 20th century, groundwater extractions in the Central and West Coast Basins in the Los Angeles area were double natural replenishment, causing severe overdraft and resulting in the lowering of groundwater levels to 100 feet below sea level. To address this problem, in 1951 the Los Angeles County Flood Control District (LACFCD) used an abandoned water well in Manhattan Beach to inject potable water to test whether pressure could be built up in a confined aquifer to block the intrusion of seawater (i.e., groundwater injection barrier). The test worked – the LACFCD eventually constructed three barrier projects: the West Coast Basin Barrier Project, the Dominguez Gap Barrier Project, and the Alamitos Gap Barrier Project. Currently, both potable water and recycled municipal wastewater (treated by microfiltration, reverse osmosis, and advanced oxidation in some cases, which involves ultraviolet light and hydrogen peroxide) are used in the barriers. The water is injected into the aquifers to depths up to 700 feet. These barrier projects have been successfully protecting freshwater aquifers in the Los Angeles Basin for more than 50 years from saltwater intrusion (Johnson 2007).

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

ALTERED SURFACE WATER QUALITY (DW)

Return to Introduction

Climate models project that the average temperature in the United States is going to increase, as will the number of extreme hot days. Higher temperatures can lead to algal blooms, which compromise source water quality and may require more advanced treatment. Compounding the degradation of water quality, turbidity and pollution inputs may increase due to extreme storm and high flow events and altered or reduced vegetation cover in watersheds. These water quality impacts will drive the need for additional drinking water treatment processes, potentially leading to higher energy demand and capital and operating costs.

CLIMATE INFORMATION

- Precipitation intensity (e.g., precipitation per rainy day) is projected to increase by mid-century for most of the United States (Meehl et al. 2007). This can be expected to lead to more high flow events and flooding. Moreover, by 2070, the length of the fire season could increase by 2–3 weeks in the southwestern United States (Barnet et al. 2004). Altered or reduced vegetation cover in watersheds, coupled with extreme storm and high flow events, will lead to increased runoff, turbidity, and pollution inputs into surface waters.
- Some parts of the Southwest are projected to have decreases in spring and winter precipitation of greater than 20% and 40%, respectively. The Pacific Northwest may experience declines in summer precipitation of greater than 30% (USGCRP 2009). Lower volumes in surface water bodies, coupled with rising temperatures, may lead to higher pollutant concentrations and algal blooms in surface water.

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs

Click name of any option to review more information in the Glossary

No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Update fire models and fire management plans for any water supply sources in fire-prone watersheds to incorporate any changes in fire frequency, magnitude and extent due to projected future climatic conditions.	$-$$
	Conduct sea-level rise and storm surge modeling. Incorporate resulting inundation mapping and estimates of saltwater intrusion into groundwater or estuaries into land use, water supply, and facility planning.	$
	Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
	Conduct climate change impacts and adaptation training for personnel.	$
	Develop emergency response plans to deal with the relevant natural disasters and include stakeholder engagement and communication.	$
	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$

Continued on page 2

✔	OPERATIONAL STRATEGIES	COST
☐	Practice fire management plans in the watershed, such as mechanical thinning, weed control, selective harvesting, controlled burns and creation of fire breaks.	$-$$
☐	Manage reservoir water quality by investing in practices such as lake aeration to minimize algal blooms due to higher temperatures.	$$
☐	Monitor flood events and drivers that may impact flood and water quality models (e.g., precipitation, catchment runoff).	$
☐	Monitor vegetation changes in watersheds.	$

✔	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
☐	Implement watershed management practices to limit pollutant runoff to reservoirs.	$$
☐	Implement or retrofit source control measures that address altered influent flow and quality at treatment plants.	$$-$$$
☐	Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
☐	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
☐	Increase treatment capabilities to address water quality changes (e.g., increased turbidity).	$$$

EXAMPLE

The East Bay Municipal Utility District (EMBUD) in California has found that severe storms can both slow its ability to treat water and increase the costs of production. While its treatment plants were designed to treat water with low turbidity, increased severe storms due to climate change may result in higher turbidity in source waters. There is also a concern that increasing temperatures will affect water quality by promoting algal growth in surface water bodies, which may result in algal byproducts such as taste and odor compounds. The main water source for EBMUD is the Mokelumne River Watershed (577 square miles), which is located in the Sierra Nevada Mountains and provides approximately 90% of the water supply. Two primary water supply reservoirs on the Mokelumne – Pardee and Comanche – provide water supply, flood protection, hydropower, resource management, and recreation. EBMUD uses a combination of watershed management and lake aeration to control water quality in these water sources.

One strategy EBMUD is pursuing to address water quality issues is to diversify water sources. Groundwater, for example, can in many cases be less costly than surface water to treat. The utility is adding two additional water sources: (1) 100 million gallons per day of raw surface water from the Sacramento River via the Freeport Regional Water Project and (2) the first phase of the Bayside Groundwater Project. The former will supply approximately 22% of water needs during dry years. In the Bayside Project, treated drinking water will be injected into the South East Bay Plain Basin during wet years and extracted during dry years. The utility is exploring other water portfolio management strategies, such as recycling, interbasin transfers, more surface water storage, desalination, and groundwater banking (Wallis et al. 2008, US EPA 2010).

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

ALTERED SURFACE WATER QUALITY (WW)

Return to Introduction

Average temperature in the United States is projected to increase, as will the number of extreme hot days. Higher temperatures can lead to algal blooms, which compromise receiving water quality, leading to more stringent discharge requirements and the need for more advanced treatment. In some locations, higher temperatures may impact ecosystems that are sensitive to temperature, leading to the need to cool effluent prior to discharge. Finally, biological wastewater treatment processes may be impaired due to changes in the efficacy of microbial populations due to higher plant and influent temperatures on hot days.

CLIMATE INFORMATION

- Precipitation intensity (e.g., precipitation per rainy day) is projected to increase by mid-century for most of the United States (Meehl et al. 2007). This can be expected to lead to more high flow events and flooding. Moreover, by 2070, the length of the fire season could increase by 2–3 weeks in the southwestern United States (Barnet et al. 2004). Altered or reduced vegetation cover in watersheds, coupled with extreme storm and high flow events, will lead to increased runoff, turbidity, and pollution inputs into surface waters.
- Some parts of the Southwest are projected to have decreases in spring and winter precipitation of greater than 20% and 40%, respectively. The Pacific Northwest may experience declines in summer precipitation of greater than 30% (USGCRP 2009). Lower volumes in surface water bodies, coupled with rising temperatures, may lead to higher pollutant concentrations and algal blooms in surface water.

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs
Click name of any option to review more information in the Glossary
No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Conduct training for personnel in climate change impacts and adaptation.	$
	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$

✓	OPERATIONAL STRATEGIES	COST
	Monitor current weather conditions, including precipitation and temperature.	$
	Monitor surface water conditions, including water quality in receiving bodies.	$
	Finance and facilitate systems to recycle water to decrease discharges to receiving waters.	$$-$$$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to buffer against floods and sediment and nutrient inflows into source waterways.	$$$
	Implement green infrastructure on site and in municipalities (e.g., green roofs, filter strips, and more permeable building materials) to reduce runoff and associated pollutant loads into waterways.	$$$
	Increase capacity for wastewater and stormwater collection, treatment and discharge, including redundancies to hedge against infrastructure losses and disruptions.	$$$
	Increase treatment capabilities and capacities to address more stringent treatment requirements (e.g., tertiary treatment).	$$$

Continued on page 2

EXAMPLE

Spartanburg Water is a public water and wastewater utility in South Carolina that is composed of two distinct legal entities: Spartanburg Water System (SWS) and Spartanburg Sanitary Sewer District (SSSD). Future droughts of increased frequency and severity may affect wastewater system operations due to changed water quality in outflow streams. Several of Spartanburg Water's wastewater treatment plants discharge into small streams, where wastewater discharges may constitute up to 80% of streamflow. With prolonged drought, future permit limits for these facilities may be affected if the 7Q10 (i.e., lowest streamflow for 7 consecutive days that occurs once every 10 years) changes for the receiving streams. In an adjacent county, similar conditions resulted in the wastewater utility upgrading to tertiary treatment. Besides evaluating the feasibility of modifying future treatment at 3 of its 10 wastewater treatment plants, Spartanburg Water is taking an integrated approach and considering water supply in conjunction with wastewater treatment. For example, the largest of its 10 wastewater treatment plants is located just downstream of the Blalock Reservoir, its second largest water supply reservoir. Coordinating releases from the reservoir with the wastewater system can help ameliorate water quality issues associated with wastewater discharge (EPA 2010).

United States
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CLIMATE READY
WATER UTILITIES

Climate Challenge Group: FLOODS (DW/WW)

Return to Introduction

The challenges to water utilities from flooding associated with climate change may be driven or forced by either high flows from intense precipitation events or from storm surges associated with coastal storms in combination with sea-level rise. Clicking on either the drinking water or wastewater icon next to each challenge will bring you to that particular Challenge Brief.

High Flow Events and Flooding DW WW

While in some locations average annual precipitation is expected to decrease, climate models consistently show that across the United States, precipitation will occur in more concentrated extreme events. These intense precipitation events may challenge current infrastructure for water management and flood control. When these protections fail, inundation may damage infrastructure such as treatment plants, intake facilities and water conveyance and distribution systems, and cause disruption of service. Episodic peak flows into reservoirs will strain the capacity of these systems, and inflow will be of lesser quality due to erosion and contaminants from overland flows. Wastewater infrastructure is particularly at risk to flooding when these extreme events occur due to the typically low elevation of facilities in the watershed. In addition, more extreme events can lead to more overflows in combined systems and reduce the capacity of sewer systems already impacted by inflow and infiltration.

Flooding from Coastal Storm Surges DW WW

Coastal storm surges may increase in frequency and extent where sea-level rise is combined with projected increases in storm frequency or intensity. This combination results in inundation of coastal areas, disruption of service, and damage to infrastructure such as treatment plants, intake facilities and water conveyance and distribution systems, pump stations, and sewer infrastructure. Water treatment plants are typically not as vulnerable as wastewater plants to coastal flooding, as they are often located at higher elevations. However, desalination plants would be very vulnerable to sea-level rise and storm surges, and intrusion of saltwater into wastewater outfall systems may cause backflows or necessitate higher pumping costs. Moreover, cities built on coastal estuaries may not have very much high ground and could be strongly affected by changes in sea level or storm surge magnitude.

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs

Click name of any option to review more information in the Glossary

No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Integrate flood management and modeling into land use planning.	$
	Conduct extreme precipitation events analyses with climate change to understand the risk of impacts to the wastewater collection system.	$-$$
	Conduct sea-level rise and storm surge modeling. Incorporate resulting inundation mapping and estimates of saltwater intrusion into groundwater or estuaries into land use, water supply, and facility planning.	$
	Develop models to understand potential water quality changes (e.g., increased turbidity or salinity) and costs of resultant changes in treatment.	$
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
	Plan for alternative power supplies to support operations in case of loss of power.	$
	Adopt insurance mechanisms and other financial instruments, such as catastrophe bonds, to protect against financial losses associated with infrastructure losses.	$
	Conduct climate change impacts and adaptation training for personnel.	$

Continued on page 2

✓	PLANNING (continued)	COST
	Ensure that emergency response plans deal with flooding and include stakeholder engagement and communication.	$
	Establish mutual aid agreements with neighboring utilities.	$
	Identify and protect vulnerable facilities, including developing operational strategies that isolate these facilities and re-route flows.	$-$$
	Integrate climate-related risks, including flooding and storm surge, into capital improvement plans to build facility resilience against current and potential future risks.	$
	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
	Implement policies and procedures for post-flood repairs.	$

✓	OPERATIONAL STRATEGIES	COST
	Monitor and inspect the integrity of existing infrastructure.	$-$$
	Monitor current weather conditions, including precipitation and temperature.	$
	Monitor flood events and drivers that may impact flood and water quality models (e.g., precipitation, catchment runoff, storm intensity, sea level).	$
	Monitor surface water quality to set a baseline and to gauge whether there is a relationship between water quality and recent weather events and/or trends in climate.	$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	Acquire and manage coastal ecosystems, such as coastal wetlands, to attenuate storm surge and reduce coastal flooding ("soft protection").	$$$
	Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to buffer against floods and sediment and nutrient inflows into source waterways.	$$$
	Set aside land to support future flood-proofing needs (e.g., berms, dikes, and retractable gates).	$$$
	Implement green infrastructure on site and in municipalities (e.g., green roofs, filter strips, and more permeable building materials) to reduce runoff and associated pollutant loads into waterways.	$$$
	Implement or retrofit source control measures that address altered influent flow and quality at treatment plants.	$$-$$$
	Build flood barriers, flood control dams, levees, and related structures to protect infrastructure.	$$-$$$
	Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
	Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
	Establish alternative power supplies, potentially through on-site generation, to support operations in case of loss of power.	$-$$
	Relocate facilities (e.g., treatment plants) to higher ground.	$$$
	Improve pumps for backflow prevention.	$$
	Increase capacity for wastewater and stormwater collection, treatment and discharge, including redundancies to hedge against infrastructure losses and disruptions.	$$$
	Increase treatment capabilities to address water quality changes (e.g., increased turbidity or salinity).	$$$

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

HIGH FLOW EVENTS AND FLOODING (DW)

Return to Introduction

Intense precipitation events may increase in frequency, concentrating the annual total rainfall into episodes that challenge current infrastructure for water management and flood control. When these protections fail, inundation may disrupt service and damage infrastructure such as treatment plants, intake facilities, and water conveyance and distribution systems. Episodic peak flows into reservoirs will strain the capacity of these systems. Furthermore, inflow will be of lesser quality due to erosion and contaminants from overland flows, leading to treatment challenges and degraded conditions in reservoirs.

CLIMATE INFORMATION

- From 1951 to 1999, observations showed an intensification of heavy precipitation events found over approximately two-thirds of Northern Hemisphere land areas having available data, including the vast majority of the United States (Min et al. 2011).
- Precipitation intensity (e.g., precipitation per rainy day) is projected to increase by mid-century for most of the United States. This change is expected even for regions that are projected to experience decreases in mean annual precipitation, such as the Southwest (Meehl et al. 2007, USGCRP 2009). This increasing intensity can be expected to lead to more flooding and high flow events in rivers. For example, by the end of the century, New York City is projected to experience almost twice as many days of extreme precipitation that cause flood damage (Ntelekos et al. 2010).
- Atlantic hurricane intensity in the United States has risen in the last 25 years. While future trends in hurricane frequency and intensity remain uncertain, it is likely that there will be more intense hurricanes over this century with accompanying increases in wind, rain, and storm surges (USGCRP 2009). This can be expected to lead to increased flooding in coastal and near-coast areas.

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs
Click name of any option to review more information in the Glossary
No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Integrate flood management and modeling into land use planning.	$
	Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
	Plan for alternative power supplies to support operations in case of loss of power.	$
	Adopt insurance mechanisms and other financial instruments, such as catastrophe bonds, to protect against financial losses associated with infrastructure losses.	$
	Conduct training for personnel in climate change impacts and adaptation.	$
	Ensure that emergency response plans deal with flooding contingencies and include stakeholder engagement and communication.	$
	Establish mutual aid agreements with neighboring utilities.	$
	Identify and protect vulnerable facilities, including developing operational strategies that isolate these facilities and re-route flows.	$-$$
	Integrate climate-related risks into capital improvement plans, including flood-proofing options to build facility resilience against current and potential future risks.	$
	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
	Implement policies and procedures for post-flood repairs.	$

Continued on page 2

✓	OPERATIONAL STRATEGIES	COST
	Monitor and inspect the integrity of existing infrastructure.	$-$$
	Monitor flood events and drivers that may impact flood and water quality models (e.g., precipitation, catchment runoff).	$
	Monitor surface water conditions, including streamflow and water quality.	$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to buffer against floods and sediment and nutrient inflows into source waterways.	$$$
	Set aside land to support future flood-proofing needs (e.g., berms, dikes, and retractable gates).	$$$
	Implement green infrastructure on site and in municipalities (e.g., green roofs, filter strips, and more permeable building materials) to reduce runoff and associated pollutant loads into waterways.	$$$
	Implement or retrofit source control measures that address altered influent flow and quality at treatment plants.	$$-$$$
	Build flood barriers, flood control dams, levees, and related structures to protect infrastructure.	$$-$$$
	Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
	Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
	Establish alternative power supplies, potentially through on-site generation, to support operations in case of loss of power.	$-$$
	Increase treatment capabilities to address water quality changes (e.g., increased turbidity).	$$$

EXAMPLE

New York City is one of five U.S. cities without a filtration plant processing its drinking water. The 1986 Safe Drinking Water Act mandates that such cities must receive a special waiver, known as a Filtration Avoidance Determination (FAD), to continue to do so. In order to maintain water quality and protect land along reservoirs without the filtration plant, the city has developed the $462 million Watershed Protection Program. The city currently owns nearly 114,000 acres within the watersheds that supply the city's drinking water, but over the next decade, the Department of Environmental Protection will seek to purchase an additional 60,000 – 75,000 acres in key locations to protect even more of the land along the reservoirs. Moreover, as privately owned forests and farms cover two-thirds of the watershed land area, the city is working with foresters to establish sustainable forest management plans and with farmers to minimize fertilizers and manure washing into waterways. This acquisition of new protected areas and land management is an important adaptation to potentially increasing future precipitation intensity and runoff into waterways that supply the city's drinking water (NYC 2011).

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

HIGH FLOW EVENTS AND FLOODING (WW)

Return to Introduction

While in some locations, average annual precipitation is expected to decrease, climate models consistently show that across the United States, precipitation will occur in more concentrated extreme events. Because wastewater facilities are often located at low points in the watershed, wastewater infrastructure is particularly at risk to flooding when these extreme events occur. In addition, more extreme events can lead to more overflows in combined systems, and can tax the capacity of separate sewer systems already impacted by inflow and infiltration.

CLIMATE INFORMATION

- Climate change is already manifesting itself in the form of more extreme precipitation events. From 1951 to 1999, increases in greenhouse gases have contributed to the observed intensification of heavy precipitation events found over approximately two-thirds of Northern Hemisphere land areas having available data, including the vast majority of the United States (Min et al. 2011).
- Precipitation intensity (e.g., precipitation per rainy day) is projected to increase by mid-century for most of the United States. This change is expected even for regions that are projected to experience decreases in mean annual precipitation, such as the Southwest (Meehl et al. 2007, USGCRP 2009). This increasing intensity can be expected to lead to more flooding and high flow events in rivers. New York City, for example, is projected to experience almost twice as many days of extreme precipitation that cause flood damage by the end of the century as today (Ntelekos et al. 2010).
- Hurricane intensity in the United States has risen in the last 25 years. While future trends in hurricane frequency and intensity remain uncertain, it is likely that there will be more intense hurricanes over this century with accompanying increases in wind, rain, and storm surges (USGCRP 2009). This can be expected to lead to increased flooding in coastal and near-coast areas.

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs
Click name of any option to review more information in the Glossary
No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Integrate flood management and modeling into land use planning.	$
	Conduct extreme precipitation events analyses with climate change to understand the risk of impacts to the wastewater collection system.	$-$$
	(No Regrets) Plan for alternative power supplies to support operations in case of loss of power.	$
	(No Regrets) Conduct climate change impacts and adaptation training for personnel.	$
	(No Regrets) Ensure that emergency response plans deal with flooding and include stakeholder engagement and communication.	$
	Integrate climate-related risks into capital improvement plans, including flood-proofing options to build facility resilience against current and potential future risks.	$
	(No Regrets) Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
	Implement policies and procedures for post-flood repairs.	$

Continued on page 2

✓	OPERATIONAL STRATEGIES	COST
	Monitor and inspect the integrity of existing infrastructure.	$-$$
	Monitor current weather conditions, including precipitation and temperature.	$
	Monitor flood events and drivers that may impact flood and water quality models (e.g., precipitation, catchment runoff).	$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to buffer against floods and sediment and nutrient inflows into source waterways.	$$$
	Set aside land to support future flood-proofing needs (e.g., berms, dikes, and retractable gates).	$$$
	Implement green infrastructure on site and in municipalities (e.g., green roofs, filter strips, and more permeable building materials) to reduce runoff and associated pollutant loads into waterways.	$$$
	Build flood barriers, flood control dams, levees, and related structures to protect infrastructure.	$$-$$$
	Establish alternative power supplies, potentially through on-site generation, to support operations in case of loss of power.	$-$$
	Relocate facilities (e.g., treatment plants) to higher ground.	$$$
	Increase capacity for wastewater and stormwater collection, treatment and discharge, including redundancies to hedge against infrastructure losses and disruptions.	$$$

EXAMPLE

Like many cities that installed sewage collection systems prior to the 1930s, Chicago has a system that conveys both sewage and stormwater runoff. Large precipitation events can overwhelm the system, leading to combined sewer overflows (CSOs) that result in sewage flowing into the Chicago River, which degrades water quality in Lake Michigan. Chicago is building a deep tunnel system to expand capacity during flood events. This system will not be completed until 2019, and there are also concerns that extreme storm events will overwhelm even this expanded infrastructure. The city has therefore begun plans to implement a program to encourage the implementation of green infrastructure throughout the city, including:

- A Stormwater Management Ordinance mandates that as of 2008, any development that involves an area of 15,000 sq ft or creates a parking lot of 7,500 square feet must retain the first half inch of rainfall on site or reduce the prior imperviousness by 15%.
- The Green Streets Program that has increased the proportion of the city shaded by tree canopy by 15%.
- The Green Roof Grant Program and Green Roof Improvement Fund that offers incentives for building green roofs. In 2007, the Chicago City Council allocated $500,000 to the Fund, and authorized the Department of Planning and Development to award grants of up to $100,000 to green roof projects within the City's Central Loop District.
- The Green Alley Program that began in 2006 and has started a series of pilot projects to test a variety of permeable paving materials to reduce flooding in alleys and increase infiltration of runoff. The City estimates that as of 2006, 1,900 miles of public alleys are paved with 3,500 acres of impervious cover.

These green infrastructure programs have been very successful. As of 2010, nearly 600,000 trees have been added to the cityscape and more than 4 million sq ft of green roofs have been installed on 300 buildings (U.S. EPA 2010). Green infrastructure can help both attenuate stormwater runoff and moderate the temperature of the water entering surface waters, and is thus an important climate change adaptation strategy.

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

FLOODING FROM COASTAL STORM SURGES (DW)

Return to Introduction

Coastal storm surges may increase in frequency and extent where sea-level rise is combined with projected increases in storm frequency or intensity. This combination results in inundation of coastal areas and damage to infrastructure such as treatment plants, intake facilities, water conveyance and distribution systems, and may result in disruption of service. Drinking water treatment plants are typically not as vulnerable as wastewater plants to coastal flooding, as they are often located at higher elevations. However, desalination plants would be vulnerable to sea-level rise and storm surges. Moreover, cities built on coastal estuaries may not have much high ground and could be strongly affected by changes in sea level and/or storm surge magnitude.

CLIMATE INFORMATION

- For the United States, a recent study projects sea-level rise to be greatest on the Texas Gulf Coast and the Florida Panhandle (13–30 inches), where land subsidence is the largest (NACWA 2009). The projections for other regions include: Northeast Atlantic (10–11 inches), West Coast (7–9 inches), and South Florida and Southeast Atlantic (approximately 9 inches).
- Sea-level rise is a gradual coastal flooding threat, but it will exacerbate more sudden coastal storm surges during severe storms, including but not limited to hurricanes. In the future, there are likely to be more frequent strong low-pressure systems (storms) outside the Tropics, including the continental United States, during the cold season with stronger winds and more extreme wave heights (USGCRP 2008). For example, the 1-in-100 year coastal flood event in New York City is expected to occur once in every 15 to 35 years by the end of the century (Horton 2010).
- While future trends in hurricane frequency and intensity remain uncertain, it is likely that there will be more intense hurricanes over this century with accompanying increases in wind, rain, and storm surges (USGCRP 2009). More intense hurricanes can be expected to lead to increased flooding in coastal and near-coast areas.

ADAPTATION OPTIONS

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No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Conduct sea-level rise and storm surge modeling. Incorporate resulting inundation mapping and estimates of saltwater intrusion into groundwater or estuaries into land use, water supply, and facility planning.	$
	Develop models to understand potential water quality changes (e.g., increased turbidity or salinity) and costs of resultant changes in treatment.	$
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
	Plan for alternative power supplies to support operations in case of loss of power.	$
	Adopt insurance mechanisms and other financial instruments, such as catastrophe bonds, to protect against financial losses associated with infrastructure losses.	$
	Conduct climate change impacts and adaptation training for personnel.	$
	Ensure that emergency response plans deal with flooding contingencies and include stakeholder engagement and communication.	$
	Establish mutual aid agreements with neighboring utilities.	$

Continued on page 2

✓	PLANNING (continued)	COST
	Identify and protect vulnerable facilities, including developing operational strategies that isolate these facilities and re-route flows.	\$-\$\$
	Integrate climate-related risks into capital improvement plans, including options that provide resilience against current and potential future sea-level and storm surge risks.	\$
	Participate in community planning and regional collaborations related to climate change adaptation.	\$-\$\$
	Implement policies and procedures for post-flood repairs.	\$

✓	OPERATIONAL STRATEGIES	COST
	Monitor and inspect the integrity of existing infrastructure.	\$-\$\$
	Monitor flood events and drivers that may impact flood and water quality models (e.g. storm intensity, sea level).	\$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	Acquire and manage coastal ecosystems, such as coastal wetlands, to attenuate storm surge and reduce coastal flooding ("soft protection").	\$\$\$
	Set aside land to support future flood-proofing needs (e.g., berms, dikes, and retractable gates).	\$\$\$
	Build flood barriers, sea walls, levees, and related structures to protect infrastructure.	\$\$-\$\$\$
	Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	\$\$\$
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	\$\$-\$\$\$
	Establish alternative power supplies, potentially through on-site generation, to support operations in case of loss of power.	\$-\$\$
	Relocate facilities (e.g., treatment plants) to higher ground.	\$\$\$
	Increase treatment capabilities to address water quality changes (e.g., increased turbidity or salinity).	\$\$\$

EXAMPLE

As part of New York City's "plaNYC", an action plan to make the city greener and more climate resilient by 2030, an effort is being made to create redundancy in the aqueduct system. New York City is essentially built on a marine estuary and is vulnerable to sea-level rise and storm surge. By the 2080s, the 100 year flood event may occur approximately four times as often due to sea-level rise (Horton et al. 2010).

Responding to the threat of sea-level rise and other climate change impacts, the city has created an inter-departmental task force to evaluate critical infrastructure vulnerabilities (NYC 2010b). Adaptation actions such as sea walls (concrete barriers that would surround the city's coast line) or a series of more targeted storm surge barriers – that would deploy only during storm surge events and would otherwise allow tidal exchange and ship movement – are being considered (NYC 2011b).

EPA United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES EPA

FLOODING FROM COASTAL STORM SURGES (WW)

Return to Introduction

Coastal storm surges may increase in frequency and extent where sea-level rise is combined with projected increases in storm frequency or intensity. This combination results in inundation of coastal areas and damage to infrastructure such as treatment plants, pump stations, and sewer infrastructure. Wastewater facilities are uniquely vulnerable in that they are often located in coastal zones likely to be inundated as a result of sea-level rise, and where flooding impacts may be exacerbated by storm surge. Intrusion of saltwater into wastewater outfall systems may cause backflows or necessitate higher pumping costs. Moreover, cities built on coastal estuaries may not have much high ground and could be strongly affected by changes in sea level and/or storm surge magnitude.

CLIMATE INFORMATION

- For the United States, a recent study projects sea-level rise to be greatest on the Texas Gulf Coast and the Florida Panhandle (13–30 inches), where land subsidence is the largest (NACWA 2009). The projections for other regions include: Northeast Atlantic (10–11 inches), West Coast (7–9 inches), and South Florida and Southeast Atlantic (approximately 9 inches).
- Sea-level rise is a gradual coastal flooding threat, but it will exacerbate more sudden coastal storm surges during severe storms, including but not limited to hurricanes. In the future, there are likely to be more frequent strong low-pressure systems (storms) outside the Tropics, including the continental United States, during the cold season with stronger winds and more extreme wave heights (USGCRP 2008). For example, the 1-in-100 year coastal flood event in New York City is expected to occur once in every 15 to 35 years by the end of the century (Horton 2010).
- While future trends in hurricane frequency and intensity remain uncertain, it is likely that there will be more intense hurricanes over this century with accompanying increases in wind, rain, and storm surges (USGCRP 2009). More intense hurricanes can be expected to lead to increased flooding in coastal and near-coast areas.

ADAPTATION OPTIONS

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Click name of any option to review more information in the Glossary

No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Conduct sea-level rise and storm surge modeling. Incorporate resulting inundation mapping and frequency estimates into land use and facility planning.	$
	Develop models to understand potential water quality changes (e.g., increased turbidity or salinity) and costs of resultant changes in treatment.	$
	Plan for alternative power supplies to support operations in case of loss of power.	$
	Adopt insurance mechanisms and other financial instruments, such as catastrophe bonds, to protect against financial losses associated with infrastructure losses.	$
	Conduct climate change impacts and adaptation training for personnel.	$
	Ensure that emergency response plans deal with flooding contingencies and include stakeholder engagement and communication.	$
	Establish mutual aid agreements with neighboring utilities.	$
	Identify and protect vulnerable facilities, including developing operational strategies that isolate these facilities and re-route flows.	$-$$

Continued on page 2

✓	PLANNING (continued)	COST
	Integrate climate-related risks into capital improvement plans, including options that provide resilience against current and potential future sea-level and storm surge risks.	$
	★ Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
	Implement policies and procedures for post-flood repairs.	$

✓	OPERATIONAL STRATEGIES	COST
	★ Monitor and inspect the integrity of existing infrastructure.	$-$$
	★ Monitor flood events and drivers that may impact flood and water quality models (e.g., storm intensity, sea level).	$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	★ Acquire and manage coastal ecosystems, such as coastal wetlands, to attenuate storm surge and reduce coastal flooding ("soft protection").	$$$
	★ Set aside land to support future flood-proofing needs (e.g., berms, dikes, and retractable gates).	$$$
	Build flood barriers, sea walls, levees, and related structures to protect infrastructure.	$$-$$$
	★ Establish alternative power supplies, potentially through on-site generation, to support operations in case of loss of power.	$-$$
	Relocate facilities (e.g., treatment plants) to higher ground.	$$$
	Improve pumps for backflow prevention.	$$
	★ Increase capacity for wastewater and stormwater collection, treatment and discharge, including redundancies to hedge against infrastructure losses and disruptions.	$$$
	★ Increase treatment capabilities to address water quality changes (e.g., increased turbidity or salinity).	$$$

EXAMPLE

The Massachusetts Water Resources Authority (MWRA) incorporated sea-level rise into plans for building a wastewater treatment plant on Deer Island in Boston Harbor. Raw sewage collected from on-shore communities is pumped under Boston Harbor and up to the treatment plant. After treatment, the effluent is discharged into the harbor through a gravity outflow. The MWRA originally planned to lower the level of Deer Island about 1.6 feet to be closer to sea level, reducing pumping costs. However, design engineers were concerned that sea-level rise would necessitate construction of a seawall around the treatment plant, which would require pumping the effluent over the seawall. To avoid this outcome, the plant was built 1.9 feet higher than it would otherwise have been built. This height was chosen because it accommodated the predicted amounts of sea-level rise through 2050 as well as the planned life of the facility. Construction on Deer Island Wastewater Treatment Plant was completed in 1998 (Easterling et al. 2004, CAP 2007, CAKE 2011).

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

Climate Challenge Group: ECOSYSTEM CHANGES (DW/WW)

Return to Introduction

The challenges to water utilities from ecosystem changes associated with climate change may be driven or forced by loss of coastal systems, increases in wildfires, and altered vegetation. Clicking on either the drinking water or wastewater icon next to each challenge will bring you to that particular Challenge Brief.

Loss of Coastal Landforms and Wetlands DW WW

Sea-level rise and increasing frequency of damaging tropical storms can lead to losses of coastal and stream ecosystems. Loss of coastal wetlands can reduce the buffer against coastal storms, which may damage coastal treatment plants and infrastructure and lead to service disruptions.

Increased Fire Risk and Altered Vegetation DW WW

Changes in climate are likely to disturb the ecosystem and alter the diversity of vegetation. These changes, coupled with potential droughts or changes in evaporation and soil-water retention, may lead to increased risks of wildfire. In addition to potential degradation of water supply, fires present a direct risk to property and infrastructure. Runoff and flash floods from burned areas can increase sedimentation in reservoirs, reducing their capacity and effective service lifespan. In reservoirs, increased pollutant loads, such as heavy metals and nutrients, could result in higher turbidity, algal blooms, and treatment costs.

ADAPTATION OPTIONS

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No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Study response of nearby wetlands to storm surge events.	$
	Update fire models and fire management plans to incorporate any changes in fire frequency, magnitude and extent due to projected future climate conditions.	$-$$
	Conduct sea-level rise and storm surge modeling. Incorporate resulting inundation mapping and frequency estimates into land use and facility planning.	$
	(No Regrets) Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
	(No Regrets) Plan for alternative power supplies to support operations in case of loss of power.	$
	Adopt insurance mechanisms and other financial instruments, such as catastrophe bonds, to protect against financial losses associated with infrastructure losses.	$
	(No Regrets) Conduct climate change impacts and adaptation training for personnel.	$
	Develop coastal restoration plans, including consideration of barrier islands, coastal wetlands, and dune ecosystems.	$-$$
	(No Regrets) Ensure that emergency response plans deal with flooding and wildfire and include stakeholder engagement and communication.	$
	Integrate climate-related risks into capital improvement plans, including options that provide resilience against current and potential future sea-level and storm surge risks.	$
	(No Regrets) Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
	Implement policies and procedures for post-flood and/or post-fire repairs.	$

Continued on page 2

✓	OPERATIONAL STRATEGIES	COST
☐	Practice fire management plans in the watershed, such as mechanical thinning, weed control, selective harvesting, controlled burns and creation of fire breaks.	$-$$
☐	★ Monitor and inspect the integrity of existing infrastructure.	$-$$
☐	★ Monitor current weather conditions, including precipitation and temperature.	$
☐	★ Monitor flood events and drivers that may impact flood and water quality models (e.g., precipitation, catchment runoff, storm intensity, sea level).	$
☐	★ Monitor surface water conditions, including streamflow and water quality.	$
☐	Monitor vegetation changes in watersheds.	$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
☐	★ Acquire and manage coastal ecosystems, such as coastal wetlands, to attenuate storm surge and reduce coastal flooding ("soft protection").	$$$
☐	★ Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to buffer against floods and sediment and nutrient inflows into source waterways.	$$$
☐	★ Set aside land to support future flood-proofing needs (e.g., berms, dikes, and retractable gates).	$$$
☐	Implement or retrofit source control measures that address altered influent flow and quality at treatment plants.	$$-$$$
☐	Build flood barriers, sea walls, levees, and related structures to protect infrastructure.	$$-$$$
☐	★ Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
☐	★ Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
☐	★ Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
☐	★ Establish alternative power supplies, potentially through on-site generation, to support operations in case of loss of power.	$-$$
☐	Relocate facilities (e.g., treatment plants) to higher ground.	$$$
☐	Implement barriers and aquifer recharge to limit effects of saltwater intrusion. Consider use of reclaimed water to create saltwater intrusion barriers.	$$$
☐	★ Increase treatment capabilities to address water quality changes (e.g., increased turbidity or salinity).	$$$

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

LOSS OF COASTAL LANDFORMS / WETLANDS (DW/WW)

Return to Introduction

Sea-level rise and increasing frequency of damaging tropical storms can lead to losses of coastal and stream ecosystems. Loss of coastal wetlands can reduce the buffer against coastal storms, leading to damage to coastal treatment plants and infrastructure, such as intake facilities and water conveyance and distribution systems, and may cause disruption of service.

CLIMATE INFORMATION

- Climate change-induced sea-level rise is due to two processes: thermal expansion of the oceans as they warm and melting of glaciers and ice sheets (Antarctica, Greenland) on land. The IPCC Fourth Assessment Report estimates that sea level will rise 0.18–0.59 m (7.1–23.2 inches) over the course of the 21st century (Meehl et al. 2007). This estimate is partly based on observed 1993–2003 rates of ice flow for Greenland and Antarctica. If ice flow increases linearly with global mean temperature, then sea-level rise may be more in the range of 0.28–0.79 m (11.0–31.1 inches) (Meehl et al. 2007). Other scientists estimate that sea-level rise could reach 1 m (3 feet) by the end of the century (Rahmstorf 2007).
- For the United States, a recent study projects sea-level rise to be greatest on the Texas Gulf Coast and the Florida Panhandle (13–30 inches), where land subsidence is the largest (NACWA 2009). The projections for other regions include: Northeast Atlantic (10–11 inches), West Coast (7–9 inches), and South Florida and Southeast Atlantic (approximately 9 inches).
- Sea-level rise is a gradual coastal flooding threat, but it will exacerbate more sudden coastal storm surges during severe storms, including but not limited to hurricanes. In the future, there are likely to be more frequent deep low pressure systems (strong storms) outside the Tropics, including the continental United States, during the cold season with stronger winds and more extreme wave heights (USGCRP 2008). For example, the 1-in-100 year coastal flood event in New York City is expected to occur once in every 15 to 35 years by the end of the 21st century (Horton 2010).
- While future trends in hurricane frequency and intensity remain uncertain, it is likely that there will be more intense hurricanes over this century with accompanying increases in wind, rain, and storm surges (USGCRP 2009). More intense hurricanes can be expected to lead to increased flooding in coastal and near-coast areas.

ADAPTATION OPTIONS

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No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Study response of nearby wetlands to storm surge events.	$
	Conduct sea-level rise and storm surge modeling. Incorporate resulting inundation mapping and frequency estimates into land use and facility planning.	$
	Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
	Plan for alternative power supplies to support operations in case of loss of power.	$
	Adopt insurance mechanisms and other financial instruments, such as catastrophe bonds, to protect against financial losses associated with infrastructure losses.	$
	Conduct climate change impacts and adaptation training for personnel.	$
	Develop coastal restoration plans, including consideration of barrier islands, coastal wetlands, and dune ecosystems.	$-$$
	Develop emergency response plans to deal with flooding contingencies and include stakeholder engagement and communication.	$

Continued on page 2

✓	PLANNING (continued)	COST
	Integrate climate-related risks into capital improvement plans, including options that provide resilience against current and potential future sea-level and storm surge risks.	$
	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
	Implement policies and procedures for post-flood repairs.	$

✓	OPERATIONAL STRATEGIES	COST
	Monitor and inspect the integrity of existing infrastructure.	$-$$
	Monitor current weather conditions, including precipitation and temperature.	$
	Monitor flood events and drivers that may impact flood and water quality models (e.g., storm intensity, sea level).	$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	Acquire and manage coastal ecosystems, such as coastal wetlands, to attenuate storm surge and reduce coastal flooding ("soft protection").	$$$
	Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to buffer against floods and sediment and nutrient inflows into source waterways.	$$$
	Set aside land to support future flood-proofing needs (e.g., berms, dikes, and retractable gates).	$$$
	Build flood barriers, sea walls, levees, and related structures to protect infrastructure.	$$-$$$
	Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
	Establish alternative power supplies, potentially through on-site generation, to support operations in case of loss of power.	$-$$
	Relocate facilities (e.g., treatment plants) to higher ground.	$$$
	Implement barriers and aquifer recharge to limit effects of saltwater intrusion. Consider use of reclaimed water to create saltwater intrusion barriers.	$$$
	Increase treatment capabilities to address water quality changes (e.g., increased turbidity or salinity).	$$$

EXAMPLE

The Thames River in England is a 300 km tidal river, with 500 km of tributaries. About 80% of the floodplain is developed, and currently, 45,000 properties are vulnerable to the 1 in 100 year flood event. Climate change will likely increase the flood risk in the Thames River system – from extreme storms inland and from the effects of tidal surge and sea-level rise. Sea-level rise on the Thames may be on the order of 20 to 90 cm. Future peak freshwater flows for the Thames at some locations could increase by around 40% by 2080.

The Thames Estuary 2100 Plan was established by the UK Environment Agency in 2002 to develop a strategic flood risk management plan for London and the Thames estuary through the end of the century. The key charge of the project was to consider how tidal flood risk was likely to change in response to future changes in climate, land use, and demographics. The Plan is organized around three phases: 2010–2034, 2035–2069, and 2070–2100. Both "hard" and "soft" adaptation measures are being considered (i.e., maintaining and repairing existing defenses, tidal flood storage using marshes, developing a new tidal flood barrier, and installing that flood barrier with locks). Habitat restoration is also a component of the plan; more than 1,200 ha of new intertidal habitat will be created over 100 years. Furthermore, freshwater habitat will be created to compensate for any loss in the above intertidal expansion (UK Department of Environment 2011).

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

INCREASED FIRE RISK & ALTERED VEGETATION (DW/WW)

Return to Introduction

Changes in climate are likely to disturb the ecosystem and alter the diversity of vegetation. These changes, coupled with potential droughts or changes in evaporation and soil-water retention, may lead to increased risks of wildfire. Fires present a direct risk to property and infrastructure, in addition to potential degradation of water supply. Runoff and flash floods from burned areas can increase sedimentation in reservoirs, reducing their capacity and effective service lifespan. In reservoirs, increased pollutant loads, such as heavy metals and nutrients, could result in higher turbidity, algal blooms, and subsequent higher treatment costs.

CLIMATE INFORMATION

- The frequency of large wildfires and length of fire season have increased substantially since 1985, a trend which is most closely linked with earlier spring snowmelt. Much of this increased fire activity occurred in the mid-elevation forests in the northern Rocky Mountains and Sierra Nevada Mountains. (Westerling et al. 2006; CCSP 2008). Earlier snowmelt contributes to fire frequency by increasing the ignition period and decreasing water availability later in the summer, increasing fuel loads.
- By 2070, the length of the fire season could increase by 2–3 weeks in the southwestern United States (Barnet et al. 2004). Climate models project that there will be more low humidity days in the western United States in the future, allowing for more fire activity. Future snowpacks are also expected to be reduced. In California's Sierra Nevada Mountains, for example, snowpack reductions are projected to range from 25% to 40% by 2050 (Standish-Lee and Lecina 2008). Insect pests, such as bark beetles, are expected to expand their range and exacerbate fire conditions. This increased wildfire activity is not confined to the West; the forest fire seasonal severity rating (related to fire intensity and difficulty of fire control) is projected to increase from 10% to 30% and 10% to 20% in the Southeast and Northeast, respectively, by 2060 (Flannigan et al. 2000).
- There will be ecosystem shifts, such as possible shifts from closed forest to savannah and grassland in the Southeast during this century. Many tree species will have distributions that are shifted northward and to higher elevations. In general, invasive plants will benefit from increased warming (CCSP 2008, GCRP 2009). These phenomena will have complex and difficult-to-predict impacts on water availability and runoff in watersheds.

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs

Click name of any option to review more information in the Glossary

No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Update fire models and fire management plans (or development plans and models) to understand and protect against the risks associated with changes in fire frequency, magnitude and extent under future projected climate conditions.	$-$$
	Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
	Plan for alternative power supplies to support operations in case of loss of power.	$
	Adopt insurance mechanisms and other financial instruments, such as catastrophe bonds, to protect against financial losses associated with infrastructure losses.	$
	Conduct climate change impacts and adaptation training for personnel.	$
	Ensure that emergency response plans deal with flooding and wildfire and include stakeholder engagement and communication.	$

Continued on page 2

✓	PLANNING (continued)	COST
☐	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
☐	Implement policies and procedures for post-flood and/or post-fire repairs.	$

✓	OPERATIONAL STRATEGIES	COST
☐	Practice fire management plans in the watershed, such as mechanical thinning, weed control, selective harvesting, controlled burns and creation of fire breaks.	$-$$
☐	Monitor flood events and drivers that may impact flood and water quality models (e.g., precipitation, catchment runoff).	$
☐	Monitor surface water conditions, including streamflow and water quality.	$
☐	Monitor vegetation changes in watersheds.	$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
☐	Implement or retrofit source control measures that address altered influent flow and quality at treatment plants.	$$-$$$
☐	Build flood barriers, flood control dams, levees, and related structures to protect infrastructure.	$$-$$$
☐	Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
☐	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
☐	Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
☐	Establish alternative power supplies, potentially through on-site generation, to support operations in case of loss of power.	$-$$
☐	Increase treatment capabilities to address water quality changes (e.g., increased turbidity).	$$$

EXAMPLE

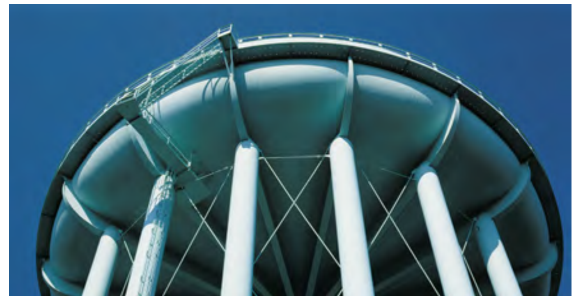
On May 18, 1996, the 11,900 acre Buffalo Creek fire occurred on a seemingly insignificant tributary to the upper South Platte River, the main source of Denver, Colorado's water supply. While Buffalo Creek itself contributes a very small share of Denver's water supply, it is strategically located directly upstream of the critically important Strontia Springs Reservoir, which is the intake point for the Foothills Treatment Plant – a facility that handles approximately 80% of Denver's water.

Two months after the Buffalo Creek fire, heavy thunderstorms occurred directly over the burned area, causing a flash flood that washed more sediment into the reservoir than had accumulated over the past 13 years, resulting in an estimated loss of 30 years of the reservoir's planned 50 year life. The emergency cleanup costs totaled nearly $1 million, chronic cleanup costs due to increased turbidity totaled $250,000 in water treatment costs per year, and dredging was estimated to cost $15 to $20 million over 10 years (Miller and Yates 2005).

To mitigate future damage, the utility installed sensors upstream of the Strontia Springs reservoir to monitor the pulse of debris and sediment coming down the river, allowing the utility to shut down its treatment plant before flash floods could cause damage (Miller and Yates 2005). Recently, Denver Water and the U.S. Forest Service Rocky Mountain Region announced their plans in August 2010 to equally share an investment of $33 million over a 5-year period for restoration projects on more than 38,000 acres of National Forest lands (Denver Water 2011). The work will include mechanical thinning, fuel reduction, creating fire breaks, erosion control, decommissioning roads, and reforestation.

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES



Climate Challenge Group: SERVICE DEMAND & USE (DW/WW)

Return to Introduction

Changes in service demand associated with climate change may be driven or forced by altered volume and temperature of influent, as well as future challenges to meet the changing needs of agricultural and energy sectors. Clicking on either the drinking water or wastewater icon next to each challenge will bring you to that particular Challenge Brief.

Volume and Temperature Challenges DW WW

Climate change may lead to a growing imbalance in the demand for service and the ability of drinking water and wastewater utilities to meet it. Adaptation measures to identify additional water sources, improve efficiency of operations, and promote conservation will provide benefits where changes in the supply and the scarcity of resources are of concern.

Changes in Agricultural Water Demand DW

Changes in agricultural practices in response to climate change could significantly impact the ability of drinking water utilities to provide sufficient supply for their ratepayers. Rather than competing for limited resources during times of scarcity, these two sectors may have opportunities to collaborate on mutually beneficial solutions that meet their water needs.

Changes in Energy Sector Needs and Energy Needs of Water Utilities DW WW

Changes in climate will impact both the energy sector directly and the energy needs of water utilities. The need for water used in energy generation is significant: thermoelectric power generation accounted for 49% of total water withdrawals in 2005 (USGS 2009). The energy required by the water sector for providing services is significant as well. Electricity accounts for about 75% of the cost of municipal water processing and transport and consumes about 4% of the nation's electricity (USGCRP 2009). Without cross-sectoral consideration of increased water and energy demands, future impacts from climate change may include higher operating costs, frequent loss of power, and water shortages.

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs

Click name of any option to review more information in the Glossary

No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
	Model sewer systems to understand the impact of higher groundwater infiltration on plant capacity and operating costs.	$
	Use hydrologic models to project runoff and incorporate model results during water supply planning.	$
	Plan for alternative power supplies to support operations in case of loss of power.	$
	Conduct climate change impacts and adaptation training for personnel.	$
	Develop energy management plans for key facilities.	$
	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
	Update drought contingency plans.	$
	Establish a relationship with the local power utility and work jointly on strategies to reduce seasonal or peak water and energy demands (e.g., water reclamation for use in power generation).	$
	Work with power companies to evaluate feasibility of using recycled water or alternative cooling methods to meet power plant needs.	$

Continued on page 2

✓	PLANNING (continued)	COST
☐	Model agricultural water demand under future scenarios of climate change and projections of cropping types. Consider evaluating the use of recycled water for irrigation.	$-$$
☐	Model or understand existing models of regional electricity demand under future scenarios of climate change and regional growth.	$

✓	OPERATIONAL STRATEGIES	COST
☐	Conduct stress testing on wastewater treatment biological systems to assess tolerance to heat.	$$
☐	★ Monitor current weather conditions, including precipitation and temperature.	$
☐	★ Monitor surface water conditions, including water quality in receiving bodies.	$
☐	★ Monitor surface water conditions, including streamflow and water quality.	$
☐	Finance and facilitate systems to recycle water, including use of greywater in homes and businesses.	$$-$$$
☐	★ Improve energy efficiency of operations (e.g., installing more energy efficient pumps).	$$-$$$
☐	★ Optimize operations by restricting some energy-intensive activities during the summer to times of reduced electricity demand (i.e., nighttime) and work with energy utility on off-peak pricing.	$$-$$$
☐	Practice conjunctive use (i.e., optimal use of surface and groundwater).	$$-$$$
☐	Reduce agricultural and irrigation water demand by working with irrigators to install advanced equipment (e.g., drip or other micro-irrigation systems with weather-linked controls).	$$-$$$
☐	Practice demand management through communication to public on water conservation actions.	$
☐	Practice water conservation and demand management through water metering, rebates for water conserving appliances/toilets and/or rainwater harvesting tanks.	$-$$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
☐	★ Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to regulate runoff.	$$$
☐	★ Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to buffer against floods and sediment and nutrient inflows into source waterways.	$$$
☐	★ Implement green infrastructure on site and in municipalities (e.g., green roofs, filter strips, and more permeable building materials) to reduce runoff and associated pollutant loads into waterways.	$$$
☐	Reduce inflow and infiltration into the sewer system by increasing control measures to decrease the volume of water to be pumped and treated.	$$-$$$
☐	Build infrastructure needed for aquifer storage and recovery, (either for seasonal storage or longer-term water banking), (e.g., recharge canals, recovery wells).	$$$
☐	★ Diversify options to complement current water supply to include those that require less energy for treatment, conveyance, and distribution.	$$$
☐	★ Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
☐	★ Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
☐	★ Establish alternative power supply via on-site power sources.	$-$$
☐	★ Increase capacity for wastewater and stormwater collection, treatment and discharge, including redundancies to hedge against infrastructure losses and disruptions.	$$$
☐	★ Increase treatment capabilities to address water quality changes (e.g., increased turbidity).	$$$
☐	Install effluent cooling systems (e.g., chillers, wetlands, or trees for shading).	$-$$
☐	Retrofit intakes to accommodate decreased source water flows or reservior levels.	$$-$$$
☐	Build or expand infrastructure to support conjunctive use.	$$$
☐	Build systems to reclaim wastewater for energy, industrial, agricultural, or household use.	$$$

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

VOLUME & TEMPERATURE CHALLENGES (DW)

Return to Introduction

Drought may increase in frequency and severity in some areas due to projected declining precipitation and increased loss of water from plants and evaporation. In areas dependent on snowpack, higher temperatures will reduce snowpack and can decrease water storage. This combination results in decreased streamflow, reservoir safe yield, and groundwater recharge. These impacts will reduce the available supplies for water systems dependent on surface water as well as groundwater, and potentially lead to service disruption. Diversifying water sources addresses some challenges associated with increased temperature, such as increased treatment costs associated with declining surface water quality. Groundwater often requires less treatment than surface water, and water recycling reduces the total amount of water that needs to be treated (Miller and Yates 2005).

CLIMATE INFORMATION

- Model projections of future precipitation indicate that southern areas, particularly the Southwest, will become drier. Some parts of the Southwest are projected to have decreases in spring and winter precipitation of greater than 20% and 40%, respectively. The Pacific Northwest may experience declines in summer precipitation of greater than 30% (USGCRP 2009).
- By the end of the century, the average U.S. temperature is projected to increase by approximately 7–11 °F under the higher emissions scenario and by approximately 4–6.5 °F under the lower emissions scenario (USGCRP 2009). The hottest day that occurs once every 20 years today is expected to occur once every 3 years.

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs

Click name of any option to review more information in the Glossary

No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✔	PLANNING	COST
	Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
	Use hydrologic models to project runoff and incorporate model results during water supply planning.	$
	Conduct climate change impacts and adaptation training for personnel.	$
	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
	Update drought contingency plans.	$

✔	OPERATIONAL STRATEGIES	COST
	Monitor current weather conditions, including precipitation and temperature.	$
	Monitor surface water conditions, including streamflow and water quality.	$
	Finance and facilitate systems to recycle water, including use of greywater in homes and businesses.	$$-$$$
	Practice conjunctive use (i.e., optimal use of surface water and groundwater).	$$-$$$
	Reduce agricultural and irrigation water demand by working with irrigators to install advanced equipment (e.g., drip or other micro-irrigation systems with weather-linked controls).	$$-$$$
	Practice water conservation and demand management through water metering, rebates for water conserving appliances/toilets and/or rainwater harvesting tanks.	$-$$

Continued on page 2

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
☐	Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to regulate runoff.	$$$
☐	Build infrastructure needed for aquifer storage and recovery (either for seasonal storage or longer-term water banking), e.g., recharge canals, recovery wells.	$$$
☐	Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
☐	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
☐	Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
☐	Increase treatment capabilities to address water quality changes (e.g., increased turbidity).	$$$
☐	Retrofit intakes to accommodate decreased source water flows or reservoir levels.	$$-$$$
☐	Build or expand infrastructure to support conjunctive use.	$$$
☐	Build systems to recycle wastewater for energy, industrial, agricultural, or household use.	$$$

EXAMPLE

The Metropolitan Water District of Southern California (Metropolitan) is a wholesale water supplier for southern California. Metropolitan improved its Integrated Resource Plan in 1996 to enhance and diversify water supply reliability. Over the past decade, imported water supplies have been complemented by aggressive conservation programs, local water recycling, groundwater supplies, enhanced water storage, and conveyance and water transfers. Metropolitan has helped develop more than 75 water recycling and groundwater recovery programs with local agencies through funding incentives. For example, the West Basin Municipal Water District receives secondary, treated wastewater from the City of Los Angeles, treats it to a tertiary level, and delivers it primarily for landscape irrigation and various industrial purposes. A portion of this water is injected to create an exclusion barrier against seawater intrusion into drinking water wells in the South Bay area. This project currently produces more than 20,000 acre-feet of water each year and is expected to expand to around 70,000 acre-feet of water each year by 2025. Moreover, Metropolitan has increased its storage capacity tenfold through the completion of both the Diamond Valley Lake in Hemet, new groundwater storage, and by acquiring contractual storage in state reservoirs. It has also been a leader in voluntary water transfers with agricultural districts. In August 2004, Metropolitan and the Palo Verde Irrigation District (PVID) executed a 35-year agreement under which individual landowners agree not to irrigate up to 29% of the valley's farm land, saving up to 111,000 acre-feet for other uses (Metropolitan 2010).

United States
Environmental Protection
Agency

CLIMATE READY
WATER UTILITIES

VOLUME & TEMPERATURE CHALLENGES (WW)

Return to Introduction

Climate models project that in the future, many areas are likely to receive less annual precipitation, but that when precipitation falls, it will be in fewer, more extreme rainfall events. These storm events wash sediment downstream and degrade water quality. Coupled with increases in algal growth resulting from the higher temperatures, generally diminished water quality in receiving waters may lead to more stringent requirements for wastewater discharges, higher treatment costs, and the need for capital improvements. In some locations, lower flows and higher temperatures may impact ecosystems that are sensitive to temperature, requiring the utility to cool effluent prior to discharge.

CLIMATE INFORMATION

- Model projections of future precipitation indicate that southern areas, particularly the Southwest, will become drier. Some parts of the Southwest are projected to have decreases in spring and winter precipitation of greater than 20% and 40%, respectively. The Pacific Northwest may experience declines in summer precipitation of greater than 30% (USGCRP 2009). Lower volumes in surface water bodies may lead to higher pollutant concentrations.
- By the end of the century, the average U.S. temperature is projected to increase by approximately 7–11 °F under the higher emissions scenario and by approximately 4–6.5 °F under the lower emissions scenario (USGCRP 2009). The hottest day that occurs once every 20 years today is expected to occur once every 3 years.

ADAPTATION OPTIONS

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Click name of any option to review more information in the Glossary
No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
	Model sewer systems to understand the impact of higher groundwater infiltration on plant capacity and operating costs.	$
	Conduct climate change impacts and adaptation training for personnel.	$
	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$

✓	OPERATIONAL STRATEGIES	COST
	Conduct stress testing on wastewater treatment biological systems to assess tolerance to heat.	$$
	Monitor current weather conditions, including precipitation and temperature.	$
	Monitor surface water conditions, including water quality in receiving bodies.	$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to buffer against floods and sediment and nutrient inflows into source waterways.	$$$
	Implement green infrastructure on site and in municipalities (e.g., green roofs, filter strips, and more permeable building materials) to reduce runoff and associated pollutant loads into waterways.	$$$

Continued on page 2

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES (continued)	COST
	Reduce inflow and infiltration into the sewer system by increasing control measures to decrease the volume of water to be pumped and treated.	$$-$$$
	★ Increase capacity for wastewater and stormwater collection, treatment and discharge, including redundancies to hedge against infrastructure losses and disruptions.	$$$
	★ Increase treatment capabilities and capacities to address more stringent treatment requirements (e.g., tertiary treatment).	$$$
	Install effluent cooling systems (e.g., chillers, wetlands, or trees for shading).	$-$$

EXAMPLE

Like many cities that installed sewage collection systems prior to the 1930s, Chicago has a system that conveys both sewage and stormwater runoff. Large precipitation events can overwhelm the system, leading to combined sewer overflows (CSOs) that result in sewage flowing into the Chicago River, which degrades water quality in Lake Michigan. Chicago is building a deep tunnel system to expand capacity during flood events. This system will not be completed until 2019, and there are also concerns that extreme storm events will overwhelm even this expanded infrastructure. The city has therefore begun plans to implement a program to encourage the implementation of green infrastructure throughout the city, including:

- A Stormwater Management Ordinance mandates that as of 2008, any development that involves an area of 15,000 sq ft or creates a parking lot of 7,500 sq ft must retain the first half inch of rainfall on site or reduce the prior imperviousness by 15%.
- The Green Streets Program that has increased the proportion of the city shaded by tree canopy by 15%.
- The Green Roof Grant Program and Green Roof Improvement Fund that offers incentives for building green roofs. In 2007, the Chicago City Council allocated $500,000 to the Fund, and authorized the Department of Planning and Development to award grants of up to $100,000 to green roof projects within the City's Central Loop District.
- The Green Alley Program that began in 2006 and has started a series of pilot projects to test a variety of permeable paving materials to reduce flooding in alleys and increase infiltration of runoff. The City estimates that as of 2006, 1,900 miles of public alleys are paved with 3,500 acres of impervious cover.

These green infrastructure programs have been very successful. As of 2010, nearly 600,000 trees have been added to the cityscape and more than 4 million sq ft of green roofs have been installed on 300 buildings (U.S. EPA 2010). Green infrastructure can help both attenuate stormwater runoff and moderate the temperature of the water entering surface waters, and is thus an important climate change adaptation strategy.

United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

CHANGES IN AGRICULTURAL WATER DEMAND (DW)

Return to Introduction

Changing water needs of agricultural practices due to climate change could significantly impact the ability of drinking water utilities to provide sufficient supply. Competition could lead to shortfalls in water supply in the summer growing period, in particular. However, collaboration between the water and agricultural sectors can assist in meeting the water needs of both of these sectors. The following information describes strategies that water utilities can pursue while partnering with agricultural interests in their region.

CLIMATE INFORMATION

- By the end of the century, the average U.S. temperature is projected to increase by approximately 7–11 °F under the higher emissions scenario and by approximately 4–6.5 °F under the lower emissions scenario (USGCRP 2009).
- Increased temperatures mean increased evapotranspiration and crop water demands.
- Irrigation water requirements are projected to increase 23% in North America by 2080 (Fischer et al. 2007).
- Warming will increase the cultivation period of some crops (and irrigation water requirements); while others will have shorter periods due to heat stress (Backlund et al. 2008, USGCRP 2009).

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $’s (**$-$$$**) indicate relative costs

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No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Use hydrologic models to project runoff and incorporate model results during water supply planning.	$
	Conduct climate change impacts and adaptation training for personnel.	$
	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
	Model agricultural water demand under future scenarios of climate change and projections of cropping types. Consider evaluating the use of recycled water for irrigation.	$-$$

✓	OPERATIONAL STRATEGIES	COST
	Monitor current weather conditions, including precipitation and temperature.	$
	Finance and facilitate systems to recycle water, including use of greywater in homes and businesses.	$$-$$$
	Practice conjunctive use (i.e., optimal use of surface water and groundwater).	$$-$$$
	Reduce agricultural and irrigation water demand by working with irrigators to install advanced equipment (e.g., drip or other micro-irrigation systems with weather-linked controls).	$$-$$$
	Practice demand management through communication to public on water conservation actions.	$
	Practice water conservation and demand management through water metering, rebates for water conserving appliances/toilets and/or rainwater harvesting tanks.	$-$$

Continued on page 2

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to regulate runoff.	$$$
	Build infrastructure needed for aquifer storage and recovery (either for seasonal storage or longer-term water banking), e.g., recharge canals, recovery wells.	$$$
	Diversify options to complement current water supply, including recycled water, desalination, conjunctive use, and stormwater capture.	$$$
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
	Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
	Build or expand infrastructure to support conjunctive use.	$$$

EXAMPLE

Water banking, a water leasing and trading tool used by the water sector to meet changing water demand, has been effectively applied in Kern County, California. Located at the southern end of the San Joaquin Valley, Kern County is one of the most productive agricultural counties in the nation, with more than 800,000 acres of irrigated farmland. The county is favorably situated for water banking in terms of geology, surface water supply, and delivery systems. Most of the water banks are highly permeable and well-suited for recharging underground aquifers. The earliest water banking programs began in the late 1970s and early 1980s with development of recharge ponds by the city of Bakersfield and the Kern County Water Agency. Today, the three major water banks have a combined storage capacity of about 3 million acre-feet – more than five times the amount of water in Millerton Lake, one of the larger reservoirs feeding the Central Valley surface-water system (Pacific Institute 2010).

CHANGES IN ENERGY SECTOR NEEDS AND ENERGY NEEDS OF UTILITIES (DW/WW)

Return to Introduction

Changes in climate will impact the energy sector directly and the energy needs of water utilities. Water usage in energy generation depends on many factors and is significant in scale. Thermoelectric power plants in Arizona, Colorado, New Mexico, Nevada, and Utah consumed an estimated 292 million gallons of water a day (MGD) in 2005, approximately equal to the water consumed by Denver, Phoenix, and Albuquerque, combined. The same year, thermoelectric power generation accounted for 49% of total water withdrawals in the U.S. – considerably more than the 31% withdrawn for agriculture (USGS 2009).

The energy required by the water sector to provide services is also significant. Electricity accounts for about 75% of the cost of municipal water processing and transport and consumes about 4% of the nation's electricity (USGCRP 2009). Surface water often requires more treatment than groundwater, and desalination is very energy intensive – energy accounts for 40% of the total desalination costs. Treated wastewater and recycled water (used primarily for agriculture and industry) require energy for treatment, but little for supply and conveyance (Cohen 2007, USGCRP 2009).

The following information describes strategies that water utilities can pursue while partnering with the energy sector in their region to reduce the amount of energy used in an effort to meet future water and energy needs. Without cross-sector consideration of increased water and energy demands, future impacts from climate change may include higher operating costs, frequent loss of power, and water shortages. These impacts will be most significant and likely during the summer when water and electricity demand peak.

CLIMATE INFORMATION

- Summer electricity generation will likely be constrained by rising temperatures and water shortages. The efficiency of thermal power plants is sensitive to ambient air and water temperatures – higher temperatures reduce power outputs by decreasing the efficiency of cooling. Moreover, future water constraints on thermoelectric power plants are projected for Arizona, Utah, Texas, Louisiana, Georgia, Alabama, Florida, California, Oregon, and Washington state by 2025 (USGCRP 2009).
- By 2030, water use for power production in the Rocky Mountain/Desert Southwest region is projected to grow by 200 MGD – the amount of water that would otherwise be used to meet the needs of 2.5 million people (WRA 2010).
- The total electricity demand for the United States is projected to increase 30% by 2035 compared to 2008 levels (US EIA 2010). Resultant increases in water demand will be a function of the fuel types used, cooling systems at thermoelectric plants, and the rate at which existing plants are retired (DOE 2006).
- There will be disproportionately more electricity demand in the summer – every 1.8 °F increase in mean temperature leads to a 5–20% increase in demand for cooling energy (USGCRP 2009).

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s (**$-$$$**) indicate relative costs

Click name of any option to review more information in the Glossary

No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 7 in the Introduction.

✓	PLANNING	COST
	Use hydrologic models to project runoff and incorporate model results during water supply planning.	$
	Plan for alternative power supplies to support operations in case of loss of power.	$

Continued on page 2

✓	PLANNING (continued)	COST
	Conduct climate change impacts and adaptation training for personnel.	$
	Develop energy management plans for key facilities.	$
	Participate in community planning and regional collaborations related to climate change adaptation.	$-$$
	Establish a relationship with the local power utility and work jointly on strategies to reduce seasonal or peak water and energy demands (e.g., water reclamation for use in power generation).	$
	Work with power companies to evaluate feasibility of using recycled water or alternative cooling methods to meet power plant needs.	$
	Model or understand existing models of regional electricity demand under future scenarios of climate change and regional growth.	$

✓	OPERATIONAL STRATEGIES	COST
	Improve energy efficiency of operations (e.g., installing more energy efficient pumps).	$$-$$$
	Optimize operations by restricting some energy-intensive activities during the summer to times of reduced electricity demand (i.e., nighttime) and work with energy utility on off-peak pricing.	$$-$$$
	Practice conjunctive use (i.e., optimal use of surface and groundwater).	$$-$$$
	Practice demand management through communication to public on water conservation actions.	$
	Practice water conservation and demand management through water metering, rebates for water conserving appliances/toilets and/or rainwater harvesting tanks.	$-$$
	Practice water conservation and demand management to reduce energy demand and associated costs.	$-$$

✓	CAPITAL/ INFRASTRUCTURE STRATEGIES	COST
	Acquire and manage ecosystems, such as forested watersheds, vegetation strips, and wetlands, to regulate runoff.	$$$
	Build less energy-intensive treatment systems, such as using engineered wetlands.	$$$
	Reduce inflow and infiltration into the sewer system by increasing control measures to decrease the volume of water to be pumped and treated.	$$-$$$
	Build infrastructure needed for aquifer storage and recovery (either for seasonal storage or longer-term water banking), e.g., recharge canals, recovery wells.	$$$
	Diversify options to complement current water supply to include those that require less energy for treatment, conveyance, and distribution.	$$$
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
	Increase water storage capacity, including silt removal to expand capacity at existing reservoirs and construction of new reservoirs and/or dams.	$$-$$$
	Establish alternative power supplies, potentially through on-site generation, to support operations in case of loss of power.	$-$$
	Build or expand infrastructure to support conjunctive use.	$$$
	Build systems to reclaim wastewater for energy, industrial, agricultural, or household use.	$$$

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EXAMPLE

Drinking Water

Melbourne Water (Victoria, Australia) is employing several strategies to expand water supply in response to climate change, given that precipitation and streamflow in its source areas may decline by 13% and 35%, respectively, by 2050. First, a major desalination plant is being constructed (due to be completed by the end of 2011), which will supply 150 billion liters of water – or about 1/3 of needed annual water supply – and will inherently be independent of hydrological variability. Second, the utility is upgrading its wastewater treatment plants to tertiary level, which will allow it to divert reclaimed water to power utilities that are currently using Latrobe Valley river water in power system cooling (Danilenko et al. 2010).

Wastewater

The Albuquerque Bernalillo County Water Utility Authority (ABCWUA) has installed methane digesters in its wastewater treatment plant, capturing methane and using it to generate both electricity and heat. In 2008, the treatment plant generated 26% of its power from utilizing waste methane instead of flaring it off as is commonly done (WRA 2010).

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