



NJ Climate Adaptation Alliance

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

Prepared by Kaitlyn (Kate) Millsaps  
Master's Candidate, Edward J. Bloustein School of Planning and Public Policy  
Rutgers-The State University of New Jersey

Prepared for the New Jersey Climate Adaptation Alliance  
July 2016

This page intentionally left blank

# Basis and Background Document: Climate Change Adaptation in the Water Supply Sector

## Table of Contents

Introduction .....	1
Critical Recommendations from the Literature .....	1
Expectations for Vulnerability in New Jersey .....	1
Actionable Practices & Strategies .....	7
The Planning Process .....	7
Climate Modeling .....	7
Setting Priorities and Indicators .....	8
Integrated Water Resource Management (IWRM) .....	10
Risk & Vulnerability Assessment .....	11
Water Inventory .....	12
Evaluation & Timeframes .....	13
Correcting Information Gaps and Coordination .....	14
Broad Participation .....	15
Integrate Adaptation Planning with Other Planning Efforts .....	15
Development of Regional Water Supply Plans in Illinois .....	16
Protecting Infrastructure & Improving Resiliency .....	17
Flooding .....	18
Sea Level Rise & Storm Surges .....	20
Water Conservation, Efficiency and Reuse .....	20
Utility Water Conservation Plans .....	22
Pricing Schemes .....	23
Landscaping .....	23
Fix Infrastructure .....	25
Appliance Efficiency & Building Codes and Design .....	26
Monitoring Use .....	28
Beneficial Reuse .....	29
Source Water Quality .....	31
Runoff & Stormwater .....	32

Wetlands, Riparian Areas and Land Uses .....	35
Wastewater Discharges .....	39
Saltwater Intrusion.....	39
Utility Strategies.....	41
Ecological Impacts.....	42
Ecological Health.....	42
Stream flows .....	42
Ecological Limits on Hydrological Alteration (ELOHA) .....	42
Bibliography .....	45

# **Basis and Background Document: Climate Change Adaptation in the Water Supply Sector**

## **Introduction**

Last adopted in 1996, the New Jersey Statewide Water Supply Plan does not address the potential impacts that climate –warming trends will have on the management and distribution of the state’s water supply resources. The Northeast region of the United States is expected to experience a range of changes that will influence the quantity and quality of our water supply, including modified stream flows, increased sea level rise and storm surges, increased extreme precipitation events, and increased water temperatures. As a result, federal agencies and other state, county, and local governments around the country have begun integrating climate change adaptation policies into their water resource management and planning programs. This document is a literature review to provide a basis and background on policy guidelines being developed and techniques being used in other areas to better include climate change impacts in water management. The goal is to inform the policy discussion and provide examples of successful strategies to address one of the biggest challenges facing the state’s water supply as New Jersey moves forward with bringing its Water Supply Plan into the twenty-first century.

## **Critical Recommendations from the Literature**

- 1. Planning process needs to identify water system thresholds and challenges under different climate change models (Vulnerability)**
- 2. Evaluation criteria and dedicated funding sources are needed to ensure adaptation strategy is successfully implemented**
- 3. Water conservation is the most cost effective way to make New Jersey’s water system more resilient**
- 4. Flood control, land use and water quality measures can be implemented jointly to protect New Jersey’s surface water sources**
- 5. Source water protection can mitigate impacts of more frequent and potentially more severe storms and droughts**

## **Expectations for Vulnerability in New Jersey**

While the Northeast is often considered a water rich region, New Jersey is already facing regional shortages and ecological impacts from water overuse (New Jersey Department of Environmental Protection Office of Science 2012; hereafter NJDEP-OS). The most challenging areas of the state for water supply are the Northeast and lower Cape May County. NJDEP

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

predicts the state will have enough water through 2020 if efficiency measures, reduction in consumptive uses, and improved interconnections are implemented, but this date is five years from now and no significant climate change impacts are expected on such a short time frame. The state's Water Supply Master Plan has not been updated in two decades, and the 1996 plan did not assess the system's vulnerability to climate change impacts (NJDEP-OS 2012).

The U.S. Interagency Climate Change Adaptation Taskforce (2011; hereafter USICCAT) has identified the major challenges to water supply from climate change:

- Ensuring adequate supply (Quantity)
- Quality of Freshwater- surface and ground
- Protecting Human Life, Health, and Property
  - Water-borne disease
  - Increased difficulty in treating water (more nutrients from runoff and higher water temperatures)
  - Flooding
  - Service disruption in extreme weather events

Specifically, the Northeast region is expected to see the following impacts that will affect water supply:

- Increasing air temperatures: this will create warmer water temperatures, potentially leading to higher evaporation rates in reservoirs and reduced yields. Water quality issues are also created by warmer water temperatures: algal blooms and decreased dissolved oxygen levels and contaminant concentration (Climate Change Clearinghouse 2009).
- Runoff reduction: warmer air temperatures will increase evapotranspiration, impacting groundwater recharge and surface waters. Climate Change Clearinghouse (2009) cited a study that estimated a 3°C increase in mean annual temperature throughout New England will result in a decrease in runoff between 11% and 13%.
- Modified stream flows: while supplies are predicted to stay at current levels, flows will vary more throughout the year with peak river flows expected earlier in the year (Shaw et al 2011). Short term droughts are predicted up to once a summer in the Catskills, Adirondacks, and New England (EPA 2012, 28).
- Sea level rise and storm surges: increased sea levels paired with larger storm surges leaves coastal freshwater sources vulnerable to saltwater intrusion (Climate Change Clearinghouse 2009; EPA 2012).
- Extreme precipitation events: the number of days of very heavy precipitation in the Northeast region increased by 58% between 1958 to 2007 (USEPA 2012). During such events more erosion can lead to increased turbidity, nutrient loading, and pathogens in waterways (Climate Change Clearinghouse 2009).

The EPA Climate Ready Utility Guide (2012) identified the following priorities and challenges for preparing water supply in the Northeast for the impacts of climate change:

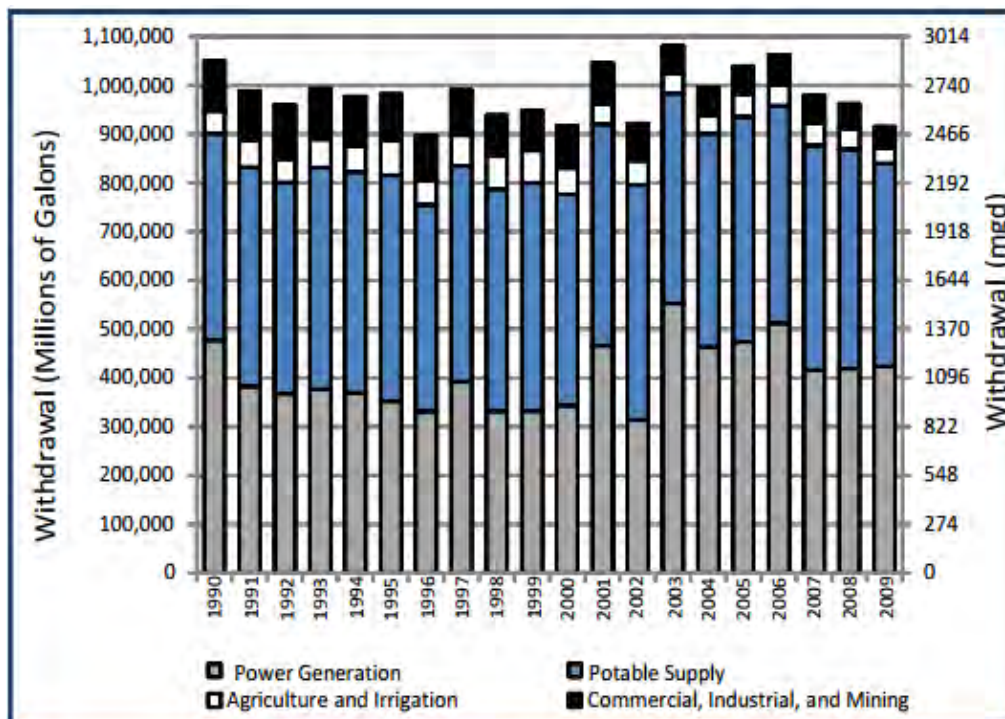
**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

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	💧💧	💧💧

*Water Use in New Jersey*

The State’s level of water use varies by year, but is typically between 900,000 million and 1 trillion gallons a year across all sectors from aquifers and surface waters (NJDEP-OS 2012). Potable water supply and power generation are the two largest water user sectors. Water use has been stable in the agricultural and commercial sectors.

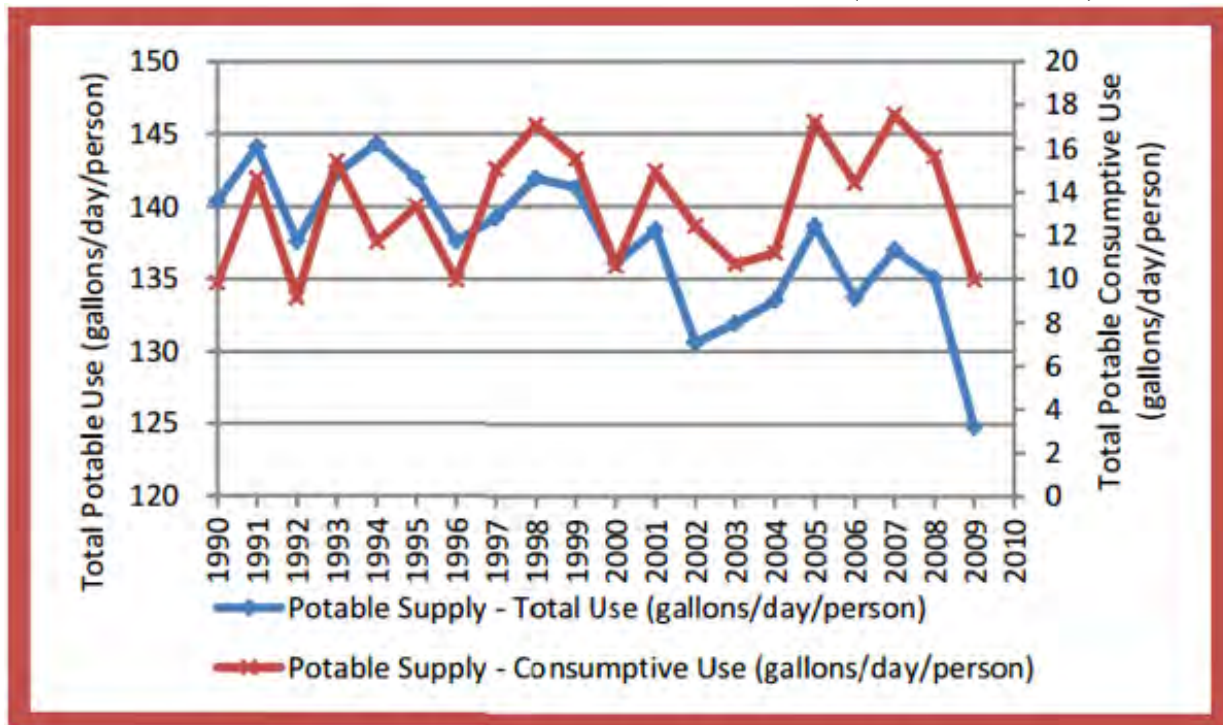
ANNUAL WITHDRAWALS PER YEAR FROM 1990-2009 (NJDEP-OS 2012)



**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

As one of the top water using sectors, potable use should be a priority in climate adaptation planning. The planning process must consider population growth and migration to accurately estimate future water withdrawals (Meyer et al. 2012; Massachusetts 2011; USICCAT 2011). New Jersey’s population is expected to grow 10% by 2030 (New Jersey Department of Labor and Workforce Development 2012). The most recent NJDEP data on potable use shows levels vary from year to year, but have remained relatively consistent in recent decades, despite the state’s growing population. It is uncertain if this is the result of reduced industrial use of potable water or increased efficiency in the residential and commercial sectors. Potable water use dropped in 2009 as it was a relatively wet year (NJDEP-OS 2012).

**PER CAPITA USE RATE OF POTABLE WATER SUPPLY (NJDEP-OS 2012)**



The second largest water use sector in New Jersey is power generation. There are currently 29 large power plants in New Jersey that use water cooling systems in their operations. Nearly all are on tidal waters, and most are in saline or estuarine environments. The federal government has prioritized reducing water use at such facilities as part of climate preparedness planning. USGS has completed work on estimating water use at such facilities and is currently developing guidelines and recommendations on how to achieve reductions, including use of recycled water (USICCAT 2011). However, this strategy may not be a top priority in New Jersey as the majority of withdrawals do not affect fresh waters used for drinking water supply.

In New Jersey there has been movement over the last two decades to reduce the volume of water used and seek alternative source water supplies. New natural gas combined-cycle plants are being built with cooling towers in accordance with the Federal CWA Section 316(b) provisions for new construction. Several of these plants also use treated effluent (gray water) as the source of their cooling tower makeup supply instead of potable water (city) or surface water



**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

withdrawals, including PSEG’s Bergen and Linden generating stations. In addition, with the increased use of the new natural gas plants to generate power, older once-through cooling coal plants are operating at lower capacities further reducing the water withdrawal levels needed to support this sector.

<b>Thermoelectric Power Plants in New Jersey Using Water Cooling Systems in 2010 (Diehl et al 2013)</b>			
<b>County</b>	<b>EIA Plant Code</b>	<b>Plant Name</b>	<b>Nameplate Capacity (MW)</b>
Bergen	2398	Bergen Generating Station	545.2
Bergen	50852	Elmwood Energy Holdings LLC	24
Camden	10435	Camden Resource Recovery Facility	35
Camden	10751	Camden Plant Holding LLC	61.8
Cape May	2378	B L England	475.6
Cumberland	2434	Howard Down	25
Essex	10643	Covanta Essex Company	69.8
Essex	50385	Newark Bay Cogeneration Partnership LP	40
Gloucester	10043	Logan Generating Company LP	242.3
Gloucester	50561	Eagle Point Cogeneration	45
Gloucester	50885	Wheelabrator Gloucester LP	14
Hudson	2403	PSEG Hudson Generating Station	1,114.4
Hudson	50497	Bayonne Plant Holding LLC	61.4
Hunterdon	2393	Gilbert	135
Mercer	2408	PSEG Mercer Generating Station	652.8
Middlesex	2411	PSEG Sewaren Generating Station	431
Middlesex	10308	Sayreville Cogeneration Facility	143.4
Middlesex	50799	Parlin Power Plant	48
Middlesex	55239	AES Red Oak LLC	330
Middlesex	56119	Middlesex Generating Station	10.5
Ocean	2388	Oyster Creek	550
Salem	2384	Deepwater	73.5
Salem	2410	PSEG Salem Generating Station	2,340
Salem	6118	PSEG Hope Creek Generating Station	1,170
Salem	10099	Pedricktown Cogeneration Company LP	42.4
Salem	10566	Chambers Cogeneration LP	285
Union	2406	PSEG Linden Generating Station	542
Union	10805	Kenilworth Energy Facility	6.8
Warren	10012	Covanta Warren Energy	13.5

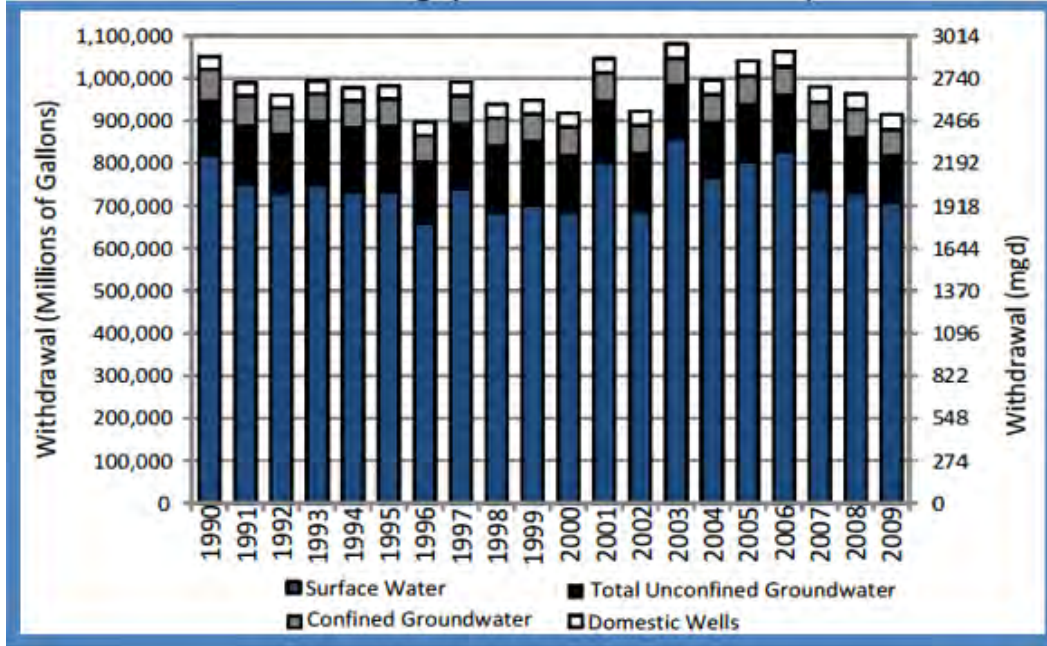
*Water Sources*

The majority of New Jersey’s water supply comes from surface water, a large portion of which is from tidal areas for power generation. Freshwater withdrawals are primarily for public water supply use. The second largest source is unconfined groundwater, and most domestic wells are

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

in this category. The NJDEP has called for the reduction of withdrawals from unconfined wells in the southern portion of the state to improve resiliency (NJDEP-OS 2012).

**SOURCE OF WATER WITHDRAWALS FOR THE PERIOD 1990-2009  
(NJDEP-OS 2012)**



## Actionable Practices & Strategies

### The Planning Process

The state of New Jersey and utility managers can begin the climate adaptation planning process now to ensure our water supply is resilient in the future. To be successful, adaptation planning must set clear priorities and indicators. A climate model and range of emission scenarios must be agreed upon and sensitivity analyses and water inventories must be conducted for each emission scenario to determine the scope of vulnerability. The outcomes of these analyses should be the basis for choosing priorities. Evaluation criteria and timeframes for implementation must also be included as part of the planning process to ensure adaptation strategies move forward. The limitations to implementation should be identified up front so they can be considered throughout the process. Bierbaum, R. et al. (2013, 395) found the most substantial are:

- Funding
- Identifying indicators to track; development of evaluation criteria for the adaptation strategy
- Policy and legal impediments
- Difficulties in adapting climate modeling to local scales; inability to know impacts at local level

Hansen et al. (2013, 8-9) also note that many entities are engaging in adaptation planning, but the plans are not implemented. The authors recommend greater focus on providing resource managers on the ground the information and tools they need to actually implement the adaptation plans. Aldrich, Dunkle, and Newcomb (2009) advocate for the creation of a state climate adaptation fund to ensure plans have the financial resources to be implemented.

### Climate Modeling

#### *Methods and Models Being Used*

Technical changes are needed in modeling water data as the historical record is no longer reliable in predicting the future conditions (USICCAT 2011, 19). Climate models should address different emission level scenarios (Rosenzweig et al. 2007, 1397).

Federal agencies are using US Global Change Research Program data for climate programs. Federal agencies are downscaling climate projections and hydrological analysis from the Coupled Model Intercomparison Project Phase 5 (CMIP5-based) (U.S. Water Resources and Climate Change Adaptation Workgroup 2015, 3; hereafter USWRCCA). Additionally, the EPA and USGS are updating low flow statistics calculation methods for evaluating impacts to water quality from climate change. (USWRCCA 2015, 6)

In New York City, the NYCDEP Climate Change Taskforce's initial scenario based planning was built upon global climate model (GCM) simulations for the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change. The City used different emission scenarios under the IPCC Special Report on Emissions Scenarios (SRES) (Rosenzweig et al.

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

2007, 1395). The NYC Climate Change Taskforce updates the models over time; by selecting the IPCC model, scenarios are updated with new GCM simulations, potentially every 3-5 years (Rosenzweig et al. 2007, 1396). Essentially, using the IPCC information creates a timeline for updating models and evaluation. The latest report from the New York City Panel on Climate Change 2 (NPCC2) notes that the modeling has been updated and is now based on the Coupled Model Intercomparison Project Phase 5, which is more advanced in modeling potential interactions between different impacts, or feedbacks, and has higher spatial resolution (Horton et al. 2015).

The Taskforce has principally looked at temperature and precipitation, and one model for sea level rise. Rosenzweig et al. (2007, 1398) underscore the importance of consistent inputs and assumptions to have accurate modeling and that the science being used should be coordinated across agencies. The NYC Taskforce downscales the models for application to New York City specifically using standard interpolation techniques (Rosenzweig et al. 2007, 1397). The downscaled models look at watersheds and the urban region, as well as specific humidity, solar radiation, and wind speed outputs. Local sea level rise projections are adjusted base on local data on subsidence, freshwater influx and thermal expansion. The scenario outputs are being used to assess potential impacts to water system operations (Rosenzweig et al. 2007, 1398). The NYC Taskforce is further studying methods of integrating the GCM inputs for reservoir system simulation models (Rosenzweig et al. 2007, 1402).

New York is still using some historical data, specifically existing regression models on low-flows. There is concern as the models cannot include changes induced by climate change in the frequency and size of summer storm events. Researchers in New York State have identified the lack of information on the timing of rainfall and precipitation events as a barrier in updating the low flow predictions (Shaw et al. 2011, 97).

In Chicago, six IPCC GCMS are used for monthly temperature and precipitation (GFDL, HadCM3 and PCM models for the A1fi higher and B1 lower scenarios) (Hayhoe and Wuebbles 2007, 2). The models are then statistically downscaled for the Midwest “with a resolution of 1/8° or about 8.5 by 6.5 miles, at the latitude of Chicago...Downscaled temperature and precipitation were then used as input to the Variable Infiltration Capacity (VIC) model version 4.1.0 r3” (Hayhoe and Wuebbles 2007, 2). The model looked at runoff, soil moisture profiles, freeze and thaw depths, evapotranspiration in fields, and snow water equivalent.

#### Setting Priorities and Indicators

The National Action Plan (USICCAT 2011, 14-15) recommends the planning process establish priorities and indicators as the first step and then evaluation criteria and outcome measures for each priority area. When developing an adaptation plan, consideration should be given to the risk of the future threat, cost, timing, and environmental impact and feasibility (Zimmerman and Farris 2010, 76).

Zimmerman and Farris (2010, 65) sum up the challenges to water supply from climate change and the areas that need to be addressed in the adaptation process:

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

Water supply <sup>d</sup>		
Quantity	Temperature	-Safe yield rate can decline for groundwater and surface water supplies due to increased evaporation -Reservoir levels decline
	Precipitation	-Uncertain changes in precipitation producing variable and unpredictable water supplies
Distribution of water supply	Sea level rise	-Impact on emergency supply from salt front movement
	Temperature	-Changes in characteristics of water flow through pipes
	Precipitation	-Pressure changes in water distribution system -Increased corrosion -Increased water loss
Quality	Sea level rise	-Increased flooding (infiltration and inflow) from flooded distribution lines
	Temperature	-Increased evaporation in surface water supplies contributes to deteriorating water quality due to concentration of contaminants
	Precipitation	-Impact on water quality from increased turbidity -Increased concentration of pollutants
	Sea level rise	-Impact on emergency supply from salt front movement -Potential increase in infiltration into distribution systems

New York City’s Nine Step Adaptation Assessment is based on standard water-resource planning procedures (Rosenzweig et al. 2007, 1400). The focus is infrastructure, but also includes management and policy categories:

**Table 1** Adaptation assessment steps

Adaptation assessment
Identify risk
Proposed project
Current infrastructure component
Ability to fulfill mandated responsibility
Identify main climate change impacts to that project
Apply future climate change scenarios
Characterize adaptation options:
Operations management
Investments in infrastructure, and/or
Policy
Conduct initial feasibility screening
Link to capital cycles
Evaluate options: e.g., benefit and cost analysis
Develop implementation plans, including timeframe for implementation
Monitor and reassess

Massachusetts (2011, 28) recommends the following be considered in prioritizing adaptation strategies:

- the probability and magnitude of potential impacts,
- the vulnerability of the groups or individuals affected,
- the range and feasibility of alternatives available,
- broad-based stakeholder input, and
- the opportunity to build upon current programs and successes

Massachusetts (2011) and EPA (2012) have identified some actions as “no regrets” adaptation strategies, such as water conservation, that are cost effective and will benefit states and utilities

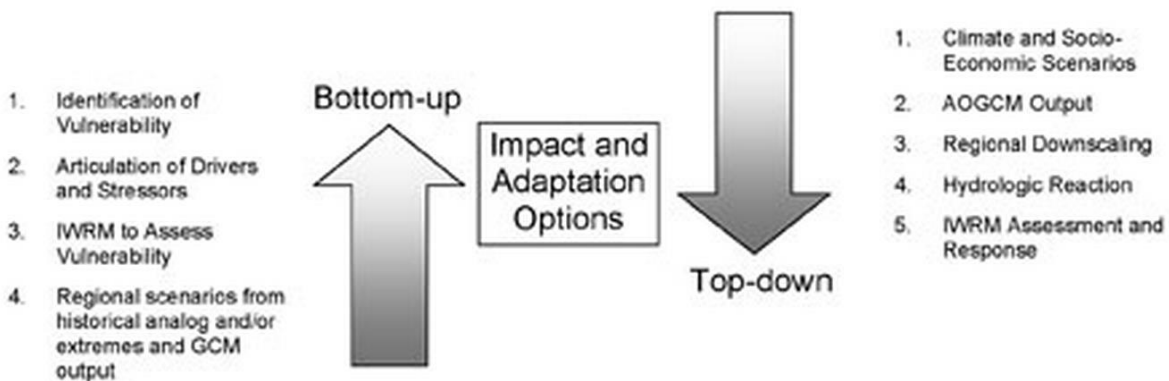
**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

no matter the future impacts of climate change. Massachusetts recommends the state incentivize such approaches and integrate them with existing programs.

**Integrated Water Resource Management (IWRM)**

Integrated water resources management (IWRM) places importance on social equity and ecological sustainability along with economic efficiency in managing water supply; essentially taking a “triple bottom line” approach. The IPCC has endorsed IWRM as the preferred planning process to explore and implement climate adaptation measures (USICCAT 2011, 27). The Global Water Partnership defines IWRM as promoting “the coordinated development and management of water, land, and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.” (USICCAT 2011, 27; Water Research Foundation 2009; hereafter WRF). IWRM uses a long-term planning process to look at supply and demand side management and modeling and relies on stakeholder input. The Water Research Foundation (2009) also recommends IWRM in climate adaptation planning because it provides structure to water resource managers and helps identify priorities and best management solutions. California’s Department of Water Resources has provided financial and technical assistance to encourage the adaptation of IWRM planning in the state, calling for the plans to include groundwater banking, climate adaptation and risk vulnerability assessments, conservation and efficiency efforts, infrastructure sharing strategies, and low-impact land use policies (California Department of Water Resources 2008, 12).

The Water Research Foundation (2009) outlines the steps to the two IWRM approaches that can be taken, bottom-up and top-down:



IWRM looks at a range of future conditions under different climate scenarios and other factors that can impact water supply, such as population changes and alteration of watersheds and other natural systems (USICCAT 2011, 29).

*Establish Commissions*

One of the key components in an IWRM strategy is the creation of watershed basin management authorities or commissions (USICCAT 2011, 28; Shaw et al. 2011, 98). Financial and technical



## **Basis and Background Document: Climate Change Adaptation in the Water Supply Sector**

support should be given to the commissions to bolster and improve water resource and climate adaptation planning (USICCAT 2011, 28). This approach helps distribute water allocations among competitive uses, such as the work currently done by the Delaware River Basin Commission. Shaw et al. (2011) call for the creation of additional commissions in areas with high population densities and high rates of growth, specifically in New York the Hudson and Mohawk basins. In addition to water allocation, commissions could consider water quality (Shaw et al. 2011, 98).

### **Risk & Vulnerability Assessment**

Risk assessment is important to determine vulnerabilities in the water system and develop targeted strategies. The amount of funding available will determine the extent and depth of vulnerability assessment and certain sectors may need to be prioritized for analysis based on limited funding (Massachusetts 2011). Vulnerability assessment can also help identify the most cost-effective adaptation strategies and the areas in the water system that need the most attention (Massachusetts 2011). Freas et al. (2008) recommend using a range when looking at climate impacts, given the uncertainty in the modeling.

Freas et al. (2008, 93) outline two analytical approaches to risk assessment, one looking at qualitative, threshold data and the other quantitative, scenario-based data. Each approach can be used separately or sequentially, with the qualitative analysis being done first. The authors recommend completing both as each provides a different level of detail and more flexibility identifying impacts in the planning process. In the threshold approach, the components of the water system are reviewed to determine vulnerabilities through a process of:

1. Establish thresholds or performance criteria (the normal function of the water system)
2. Establish concern climate variables (such as precipitation, temperature) and determine how the variables could impact the water system, what changes would violate the threshold criteria
3. Set up responses for especially vulnerable parts of the system
4. Develop adaptation strategies, i.e., actions, operations, or infrastructure changes

In the scenario approach, climate models are used to determine vulnerabilities and Freas et al. (2008, 94-95) recommend the following steps:

1. Select range using emission scenarios and climate models
2. Downscale
3. Establish climate variables of importance
4. Look at system response to downscaled historical hydrologic models and projected climate scenarios
5. Develop and refine adaptation strategies
6. Assess vulnerability of system based on robustness of climate projections
7. Evaluate system performance

As part of the risk and vulnerability analyses and adaptation planning, water supply managers should look at range of threats and potential challenges, including (USICCAT 2011, 14):

- population changes,
- aquifer depletion,
- saltwater intrusion,

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

- nutrient enrichment,
- aging infrastructure,
- flood protection,
- groundwater contamination,
- protecting and restoring aquatic ecosystems

The East Bay Municipal Utility District (EBMUD) of Oakland, California based its adaptation process on defining vulnerabilities and timeframes; researching and gathering information for short-, intermediate-, and long-term decision making (Wallis, Ambrose, and Chan 2008). EBMUD focused on infrastructure planning and budgeting, based on projected climate impacts. The utility formed a climate change committee to coordinate action and information sharing across various departments. The committee reviews the latest science, monitors and collects data from local watersheds to identify trends, determines water supply and infrastructure vulnerabilities, integrates adaptation into strategic planning and budgeting process and as part of the water supply management plan.

To determine adaptation planning priorities, EBMUD ran sensitivity analyses on their system. The sensitivity analyses did not use historical data; downscaled climate models were used to predict a range of impacts and plan for those outcomes. For example, rather than looking at a downscaled climate model that predicts Oakland will have an X% decrease in precipitation by 2050, the utility used downscaled climate models to determine precipitation will drop overall in their region and looked at what impacts a 10%-20% decrease will have on their system (Wallis, Ambrose, and Chan 2008, 76). The resulting top impact areas were water supply quantity, flood management, demand for water, sea level rise, power generation demand, and water quality (Wallis, Ambrose, and Chan 2008).

The Metro North Georgia Water Planning District just completed a vulnerability study looking at the potential impacts on their water supply and infrastructure under a range of different climate change scenarios. The study was done to begin incorporating adaptation measures into the 2016 District Water Management Planning. The District developed six climate scenarios with different percentiles of precipitation and temperature, based on over 100 GCMs (CDM Smith 2015). The planning process included modeling future water demand and impacts to reservoirs under the different climate scenarios. The utility has also recommended completing an Extreme Precipitation Analysis to better identify vulnerable facilities and infrastructure for adaptation improvements.

### Water Inventory

To effectively plan, water managers and state officials need to know the status of existing supplies and water use across sectors. Completing a water inventory determines the status of existing supplies and where expansion to systems could potentially occur. The process should also identify how and where water is being used in the state to determine vulnerabilities and where conservation efforts should be focused. This inventory is critical for planning and resolving conflicts between sectors as water use intensifies with climate change (Shaw et al 2011, 99).



## **Basis and Background Document: Climate Change Adaptation in the Water Supply Sector**

Shaw et al. (2011) recommend that the statewide water plan determine existing excess supplies in the state and areas where additional sources can be developed. The authors encourage such a plan be used as a basis for land use decisions, stating “Specifically, a statewide water plan could provide guidance to commercial and industrial entities, as well as homebuilders and home buyers, on which communities are most likely and least likely to face water shortages, particularly with the additional stress of climate change.” (Shaw et al 2011, 100).

The adaptation process should include a better monitoring and data sharing process for water levels at reservoirs, lakes, and aquifers. Shaw et al. (2011, 98) recommend automated gauging systems and the creation of a central database and reporting network for public water supply systems to create an early warning system for utility managers and to gather more information on the impacts of climate change on the hydrology of specific watersheds.

In addition to a state wide inventory, analyses should also be done on each individual system to determine drought sensitivity. These studies should look at the system infrastructure, water demand, existing supply, and utility operating procedures (Shaw et al. 2011, 88). This can make water systems more resilient by helping to develop alternative sources and interconnections for the most vulnerable infrastructure, ensuring water can get where it is needed during times of drought. In New York state, Shaw et al. (2011, 88) found that most reservoirs with less than 200 days of water storage had alternative sources.

In New York, the water supply inventory categorized sensitivity by water source and how long of a drought each source could withstand, based on existing storage and current demand (Shaw et al. 2011, 92). The analyses found the most resilient systems had sizable storage and low demand, while the most vulnerable only had minimal storage; therefore, the larger the water body the water supply is drawn from, the less sensitive the supply is to climate change impacts. Shaw et al. (2011, 92) found the most vulnerable water supply systems to climate change were: run-of-the-river systems on small streams, shallow wells, wells in moderately productive aquifers, and systems with small reservoirs relative to demand. A revised Water Supply Master Plan for New Jersey should identify which water supply sources in the state fall into these vulnerable categories to be prioritized for vulnerability assessment.

In Southern Florida, the water inventory is done as “regional water demand projection scenarios” and assess changes in population, water consumption rates, and demand in the municipal, industrial, and agricultural sector that will result from increasing temperatures and drought. The analyses also look at the water demand from the energy sector and the impacts changing fuel sources will create (Institute for Sustainable Communities 2014; hereafter ISC).

### **Evaluation & Timeframes**

The federal government’s adaptation planning process occurs in four year cycles. Agencies produce an annual report and evaluation of the program is done in the third year by an independent entity such as the National Academy of the Sciences (USICCAT 2011, 15). The Southeast Florida Regional Climate Change Compact recommends vulnerability assessments and for water infrastructure be updated on a time cycle of “no later than every five years” (ISC 2014, 15).

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

To ensure evaluation occurs, adaptation planning could be required as part of the permitting process and the permit timeframe reduced. Currently in New Jersey, applicants must submit a water conservation plan and drought management plan to the NJDEP every ten years as part of their water supply allocation permit (Alliance for Water Efficiency 2012; hereafter AWE). New Jersey requires:

*The Water Conservation and Drought Management Plan shall include:*

- i. A description of water conservation components;*
- ii. Interim, voluntary water use restrictions for implementation during corresponding stages of drought warning, drought emergency, precipitation deficits or reservoir storage deficits;*
- iii. Voluntary transfers of water via interconnections between water supply systems for use when prescribed reservoir storage level thresholds are reached;*
- iv. Other measures designed to reduce demand, consumption or water usage or loss, or which otherwise have the effect of maximizing water supplies during periods in which precipitation is lower than average and/or water supply storage is less than normal; and*
- v. For purveyors with water supply reservoirs, rule curves for reservoirs that can be used to establish storage level thresholds.<sup>1</sup>*

Climate adaptation plan could be integrated into the two existing, required plans, or developed as a third requirement as part of the water supply allocation permitting process. Additionally, the permitting timeframe should be reduced or annual progress reports should be required to ensure the plans are being properly implemented and evaluated. For example, in Massachusetts, permit holders must provide a report yearly of the water conservation they have implemented and the water savings achieved by those efforts (AWE 2012, 22).

Adaptive management is critical in the implementation process, so that based on the outcome of evaluations, corrections and changes can be made to improve efficiency and success. The flexible decision-making is critical to adjust to new information as well (USICCAT 2011, 29).

#### Correcting Information Gaps and Coordination

The planning process needs to be based on current and accurate information and the best available science (Massachusetts 2011). The federal government and the states have been working to fill in information gaps and streamline information sharing beyond downscaling of climate models. Efforts include improving mapping of ecosystems and vulnerable areas, better monitoring of ecosystem health, and updating projections on rainfall intensity beyond the historical data provided by the National Weather Service (Massachusetts 2011).

At the federal level, action is being taken to ensure states have access to the same scientific data on climate change and to build relationships with states to encourage action. The federal government is working on some pilot programs, but most effort is focused on improving information collection and sharing (USICCAT 2011). Some states are also looking at setting up

---

<sup>1</sup> N.J. ADMIN. CODE § 7:19-6.5(a)(3)

## **Basis and Background Document: Climate Change Adaptation in the Water Supply Sector**

a “clearinghouse” where a single entity can share information and technical knowledge with local stakeholders (Massachusetts 2011, 27). Many local entities do not have the resources to plan for climate change and state level coordination can assist in sharing knowledge learned and successful outcomes.

The National Action Plan (USICCAT 2011) identified important areas for improvement in information sharing:

- Improve communication between research community and adaptation planners; better identify data and information needed in the adaptation process (15)
- Create a forum to connect climate modelers and water data systems managers (17)
- Implement a program to align “hydroclimatic” statistics with today’s climate and anticipate future changes (20)

New Jersey may also consider a “toolbox” approach for local water resource managers, where specific models and tools, such as EPA’s CREAT, are recommended and then resources, planning assistance, and financial aid are provided to further the adaptation process. The federal government launched a “[Federal Support Toolbox](#)” as part of their adaptation planning process (USWRCCA 2015, 22). This can also be done specifically for drought emergency preparedness as seen in New York. That state’s Department of Health maintains an equipment supply including mobile pumps, water tanks, and filters for municipalities to use when water supplies hit critically low levels (Shaw et al. 2011, 98). As part of the adaptation process, the state is considering updating and expanding this stockpile of equipment.

### **Broad Participation**

Community outreach and involvement is an important component in successfully developing and implementing an adaptation plan (Massachusetts 2011; Aldrich, Dunkle, and Newcomb 2009). Broad-based participation involving a number of different stakeholders from government, academia, the private and nonprofit sectors, and the public will increase support for the developed plan. Massachusetts (2011, 30) recommends “enhanced communication efforts, formal and informal public hearings, issue-based meetings with broad partners and interests, enhanced state agency presence in local communities, and advisory groups convened for deliberation on specific research topics and policy change proposals.” Once the adaptation plans are developed, they need to be effectively communicated to the local community (Massachusetts 2011; Aldrich, Dunkle, and Newcomb 2009).

### **Integrate Adaptation Planning with Other Planning Efforts**

Water supply adaptation planning strategies can be integrated with existing or new mitigation, emergency and hazard, drought, and flood risk planning to achieve additional benefits. In Massachusetts, water supply adaptation was integrated with mitigation and emergency preparedness strategies. One example of aligning mitigation and adaptation strategies is prioritizing the preservation of land that protects water supply and serves as a carbon sink (Massachusetts 2011).

The National Action Plan (USICCAT 2011, 14) calls for water resource management to be included in greenhouse gas emission reduction planning. The carbon footprint resulting from

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

each water supply adaptation strategy must be considered (Wallis, Ambrose, and Chan 2008). Energy use already accounts for a large portion of costs at water utilities, about 75% of municipal processing and transport and 40% of desalination costs, and expenses could increase under different climate change scenarios, if surface water requires more treatment and desalination use is increased (U.S. Global Change Research Program 2009; hereafter USGCRP). At the Cape May County desalination plant, electricity costs account for about 50% of the operating cost (Behrens 2007, 30). Water treatment and pumping constitutes 19% of California's overall electricity use (Klein 2005, 1). EPA (2012) warns without considering energy demand in water supply planning, utilities could see higher operating costs, increased incidence of power loss, and more frequent water shortages, especially in summer months. Because of these concerns, the EPA recommends future regional electricity demand projections be used in determining future water supply demand and adaptation planning. Increased use of recycled water in the energy sector, agriculture, and industry, can help reduce water and electricity demand (EPA 2012, USGCRP 2009).

[Development of Regional Water Supply Plans in Illinois](#)

In 2006, Illinois Governor Rod Blagojevich signed Executive Order 2006-01, requiring state agencies to draft and implement regional water supply plans through 2050 (Gregg and Hitt 2012). Three-year pilot studies were conducted in the East Central and Northeastern sections of the state, focusing on water availability and evaluating climate impacts on meeting future demand. Each project was led by a Regional Water Supply Planning Committee (RWSPC) that received technical support and assistance from the Illinois State Water Survey, Illinois State Geological Survey, and the Office of Water Resources of the Illinois Department of Natural Resources (Gregg and Hitt 2012). The Mahomet Aquifer Consortium headed the RWSPC in the East Central region, and the Chicago Metropolitan Agency for Planning directed the Northeast RWSPC.

The goals of the regional plans are (Gregg and Hitt 2012; Meyer et al. 2012):

- develop water supply planning and management guidelines
- 50-year planning horizon to provide information and support decision-making in changing socioeconomic and climatic conditions
- Plans are based on future temperature and precipitation conditions assessed by GCMs and estimated water withdrawals and uses through 2050. Those outputs were used in regional surface and ground water models to determine vulnerabilities and needed changes in water resource management and policies

Key recommendations from the Illinois Planning Process (Gregg and Hitt 2012):

- Assess vulnerability of existing facilities to predicted drought conditions
- Improve infrastructure resiliency by using historic and future climate projections in water supply planning scenarios
- Improve information sharing and coordination across agencies to assess cumulative impacts of water use and management
- use regional planning

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

Following the pilot studies, the RWSPCs continue to operate and a third region has been included in the southwestern portion of the state. These three areas have been designated Priority Water Quantity Planning Areas (Gregg and Hitt 2012).

**Protecting Infrastructure & Improving Resiliency**

The first step in protecting infrastructure is to conduct a risk vulnerability assessment, looking at infrastructure location and construction, climate change impacts, variability and extremes (USICCAT 2011, 21). Infrastructure is vulnerable because historical weather and storm impacts have been used in past assessments, but many jurisdictions are not anticipating future climate impacts- sea level rise and extreme storm events (Massachusetts 2011, 53). Flooding and storm surges can damage treatment plants, intake facilities, and conveyance and distribution systems (including pumping stations) and cause service disruptions (EPA 2012). Completing a vulnerability study allows state and local governments to assess the feasibility of an adaptation program and develop a timeline for implementation (Rosenzweig et al. 2007, 1401). The timeline should also assess the life expectancy of any existing infrastructure to help prioritize replacement and adaptive construction projects (Massachusetts 2011, 55). This is important in New Jersey as, by the end of the century, the region could experience almost twice as many days of extreme precipitation causing flood damage (Ntelekos et al. 2010).

As discussed above, the uncertainties and resolution issues of downscaling climate models can make it difficult to predict local impacts, but the federal government has developed a number of tools to help states and local water resource managers:

- EPA Climate Resilience Evaluation and Awareness Tool (CREAT) has been developed for utility owners and operators (USICCAT 2011, 4). This tool can also help develop parameters for which to prepare through:
  - 1) an interactive map assessing annual total precipitation, annual average temperature, precipitation intensity for the 100-year storm, and sea-level rise
  - 2) an interactive map of potential storm surge inundation on the Atlantic and Gulf coasts
- EPA Climate Ready Water Utilities Program<sup>2</sup> (USWRCCAW 2015, 21):
  - 1) Scenario Projection Mapping: interactive map for annual total precipitation, annual average temperature, precipitation intensity for the 100-year storm, and sea-level rise
  - 2) Storm Surge Mapping: assesses storm surge inundation potential on the Atlantic and Gulf coasts. Integrates NOAA Hurricane model for sea, lake, and overland surge (SLOSH model) and FEMA’s 100-year and 500-year flood zones (which do not incorporate future conditions but the 500-year flood zone can be used as an indicator). Future versions of the tool will also include historical hurricane location strike data.
  - 3) Stormwater Calculator: evaluates the effectiveness of green infrastructure to reduce runoff under alternative scenarios
  - 4) Water Utility Climate Resilience Support Projects: EPA selected over 20 drinking water and wastewater utilities for comprehensive climate-related risk assessments
- NOAA pilot projects under the National Integrated Drought Information System (NIDIS)

---

<sup>2</sup> <http://www.epa.gov/climatereadyutilities>

**Basis and Background Document:**  
**Climate Change Adaptation in the Water Supply Sector**

- NOAA Vulnerability Assessment Techniques and Applications (VATA) for coastal areas
- US Army Corps of Engineers' (USACE) Dam Safety Action Classification tool
- EPA Climate Ready Estuaries Program

NOAA and DOI had been working on a pilot climate change vulnerability index, but the program was cut due to budget constraints (USWRCCA 2015, 6).

Massachusetts has been using LiDAR mapping to identify vulnerable infrastructure (Massachusetts 2011, 54).

Similar to a vulnerability assessment, New York City has conducted a Water Dependability Study to determine how the system can continue to supply enough high quality water if parts of the system are taken off line in an emergency or for repairs and adaptation work (Rosenzweig et al. 2007, 1401). Based on the study's findings, the city is now considering a range of infrastructure alternatives including creating redundant tunnels, alternate supplies and storage capabilities (such as system interconnections), expanding the groundwater system and banking surface water, and desalination technology for both brackish groundwater and harbor water. Such redundancies in the system help prepare for climate change while easing system maintenance (Zimmerman and Farris 2010, 71). Conservation and demand reduction measures are being included with the infrastructure improvements.

### Flooding

Flooding impacts to water supply can be addressed to a certain extent through a range of natural infrastructure improvements including increasing groundwater recharge, water reuses, wetlands protection and restoration efforts that retain water on site (CNRWG 2014, 34). However, existing water supply facilities in hazardous locations may also need to be physically protected through engineered systems.

The New York Rising Program was developed to help Hudson River communities implement natural infrastructure solutions to address the flooding impacts of climate change. The program looked at four different adaptation processes in the watershed, ranging from two scenarios with little climate adaptation action, hard infrastructure solutions, and finally natural infrastructure approaches. The program calls for increased incorporation of climate change in land use decision making, including low impact development in floodplains and conservation of natural systems that can mitigate climate change impacts. The authors of the report recommend (Aldrich, Dunkle, and Newcomb 2009, 13-14):

- Flood audits be conducted of wastewater treatment plants
- A reduction in the minimum size of wetlands regulated by the state
- Increase development setbacks from stream banks to 300 feet, providing flood protection and improving water quality
- Reduce stormwater runoff through urban greening programs, such as rain gardens and tree planting



**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

Massachusetts has also been taking steps to protect water infrastructure. In their adaptation process, the state outlined “no regrets” approaches, short term strategies, and long term strategies. The no regrets actions benefit the system overall, regardless of climate change impacts. These strategies include natural infrastructure for stormwater management, increasing groundwater recharge, and water conservation through updated Massachusetts Water Conservation Standards and water recycling and reuse (Massachusetts 2011, 60).

Short term strategies require less time to implement. For infrastructure, the state is looking at policy changes as well as hardening projects. To ensure better information standards and sharing, the state is adopting the latest FEMA mapping in its regulatory structure, creating a database of water infrastructure and waste treatment plants, and creating an educational program for utility managers on climate risks and adaptation (Massachusetts 2011, 61). Massachusetts is changing plumbing codes to promote the reuse of non-potable water and implementing grey water technologies (Massachusetts 2011, 60). State Revolving Fund for Infrastructure projects (similar to NJEIFP in NJ) is being revised to encourage local governments and utility managers to address climate change impacts and discourage investments in vulnerable areas (Massachusetts 2011, 61). Stormwater policies are being updated to promote increases in groundwater recharge and low impact development. Finally, the state is working to flood proof infrastructure through elevation, submersible pumps, relocation and increasing emergency backups and redundancy.

The state’s long term strategy is to create infrastructure sustainability plans, focusing on enhancing natural hydrology (Massachusetts 2011, 67). The state has identified watershed-based approaches as cost-effective and successful for adapting to extreme weather impacts, and is moving forward with integrating such policy in the MassDEP’s Comprehensive Resources Water Management Plans. Massachusetts is using green design and ecosystem services to support the existing built infrastructure, with a goal of diminishing or eliminating the non-climate stressors on the water system, increasing resiliency to climate impacts (Massachusetts 2011, 68). Investments in natural systems to restore natural hydraulic features increases resiliency and capacity redundancy (Massachusetts 2011, 55). The state points to the Charles River Natural Valley Storage project of an example in execution. Rather than constructing a \$100 million dam project to prevent flooding, in the 1970’s Massachusetts purchased 17 wetlands for \$8.3 million in the Charles River watershed to naturally store water during flooding events (Massachusetts 2011, 68). The project is estimated to have prevented \$3.2 million in flood damage (Massachusetts 2011, 68).

Additionally, Massachusetts is looking to update land use and zoning laws and regulations and building codes to reflect expected climate change impacts in the design and construction of new infrastructure and repairs and upgrades to existing infrastructure. The criteria will also be used to evaluate and select sites for future infrastructure development (Massachusetts 2011, 55).

Utility managers must also develop better tools for establishing rule curves and estimating demand from reservoirs to combat flooding impacts. Rule curves are specific guidelines dictating reservoir releases based on the amount of water stored at different times of the year and can be used to provide a consistent protocol for releases (Shaw et al. 2011, 98). New York City uses water-related thresholds in reservoirs to trigger their drought response plans (Shaw et al.

## **Basis and Background Document: Climate Change Adaptation in the Water Supply Sector**

2011, 98). The East Bay Municipal Utility District (EBMUD) is working to better estimate future water demand to ensure enough water is retained in reservoirs, while preventing downstream flooding during more frequently occurring extreme weather events (Wallis, Ambrose, and Chan 2008, 73).

### **Sea Level Rise & Storm Surges**

Sea level rise increases the risk of flooding in communities served by water infrastructure, leaving transmission infrastructure vulnerable (Wallis, Ambrose, and Chan 2008, 74). The New York City region is expected to see a 100-year coastal flood event (based on historical norms) every 15 to 35 years by 2100 as a result of sea level rise (Horton et al. 2010). At the federal level, NOAA and FEMA documented the impact of Sandy on area shorelines, both the surge forecast and high water levels, which can be used in New Jersey adaptation planning<sup>3</sup> (USWRCCA 2015, 16). Adaptation measures are being implemented to address these impacts and sea level rise and storm surge should be considered when selecting sites for water system infrastructure and facilities (Rosenzweig et al. 2007, 1401).

New York City is currently constructing flood walls to protect infrastructure and relocating intakes for their water system, such as the Hudson River intake for the Chelsea pump station (Rosenzweig et al. 2007, 1404).

In response to sea level rise, the City of London is implementing the Thames Estuary 2100 Plan. Under current projections, river levels could rise 20 to 90 cm and 45,000 properties are vulnerable to a 100-year flood event (EPA 2012). The plan, started in 2002, has three phases, 2010–2034, 2035–2069, and 2070–2100, focusing on land use and demographics. The focus of the plan is “maintaining and repairing existing defenses, tidal flood storage using marshes, developing a new tidal flood barrier, and installing that flood barrier with locks” (EPA 2012). Habitat restoration is a critical piece of the plan, with a goal of creating 1,200 hectares of new intertidal habitat over the next 100 years (EPA 2012).

### **Water Conservation, Efficiency and Reuse**

Increasing water conservation is widely recognized as a key way to increase water supply resiliency without costly infrastructure improvements. It is important to note that most consumptive residential water use is for nonessential uses such as landscaping, swimming pools, and car washing and that these water intensive practices, along with recreational fire hydrant openings and use of commercial air conditioning could potentially increase with higher temperatures in the future (Shaw et al. 2011, 99). Importantly, the City of New York (2011, 84) noted that although we are in a water rich region, water conservation helps “reduce wear and tear on the system, use less energy and fewer chemicals for treatment, and provide additional flexibility during droughts and extreme weather events.”

There are a number of strategies being implemented around the country, but water conservation efforts can be slow to gain traction.

---

<sup>3</sup> <https://water.usgs.gov/floods/events/2012/sandy/>



**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

The 2011 National Action Plan (USICCAT 2011, 25) identified key challenges to water conservation:

- End-users lack information on their usage
- Pricing and incentives: water is undervalued and underpriced so little incentive to conserve
- Conservation needs to be elevated in decision making on water supply management, land use, and energy development
- Increasing public awareness
- Providing incentives to increase development and adoption of efficiency technology

Strategies outlined below, such as smart metering and building codes, address some of these challenges, but it is beneficial to be cognizant of these limitations while thinking about practices that could be implemented in New Jersey.

New Jersey's estimated water use numbers vary, but are within a general range. The EPA Water Sense program (2010) estimates the average New Jersey resident uses 70 gallons of water per day, increasing to 155 gallons per day during peak season (April to October). The New Jersey Water Savers program (2015) found residents use 100 gallons of water per day on average, increasing up to 85 additional gallons per day in peak season.

This lack of clear water use numbers highlights the nationwide deficiency in good water use information. As such here are recommendations to undertake as the state considers conservation programs:

- Improve measurement techniques (USICCAT 2011, 26)
- Develop standardized methodology to collect data on water end use by sector: residential, commercial, institutional, and industrial. There is inconsistency in current billing and water use records at water utilities. (USWRCCA 2015, 29)

Both steps would improve forecasting to then set efficiency and conservation goals and measure compliance. Shaw et al. (2011) recommend a statewide inventory of water usage to plan around and anticipate competing water use demands between sectors, especially as demand increases as a result of climate change.

Federal agencies are focusing on efficiency, conservation, productivity (more output per unit of water), and substitution (alternatives sources) through these programs (USICCAT 2011, 25):

- DOI WaterSMART initiative,
- the U.S. Geological Survey (USGS) Water Census,
- EPA's WaterSense program,
- the USDA Natural Resources Conservation Service's (NRCS) Agricultural Water Enhancement Program,
- DOE research development and demonstration (RD&D) on water-efficient clean energy practices,
- National Academy of Sciences assessment of water reuse as an alternative water supply

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

Water conservation goals make our water systems more efficient and can also decrease energy use and associated greenhouse gas emissions. For example, “running a faucet for five minutes uses as much energy as leaving a 60-watt incandescent bulb on for 14 hours.” (City of Chicago 2010, 3) Lowering usage makes our water systems more resilient while cutting climate change pollution.

Water conservation helps avoid costly supply expansion projects in the future. In the 1980’s New York City had high consumption rates, causing low water levels during droughts. Instead of pursuing expensive projects to increase supply, New York used water conservation measures to reduce consumption levels by 200 mgd, achieving almost record lows, and has continued to see water use decreases despite the growing population (City of New York 2011, 85).

NJ is currently implementing water conservation measures through the Sustainable New Jersey and New Jersey Water Savers program but these tend to be focused on voluntary consumer actions to update appliances and water use reductions only during water emergencies. Below more proactive public policy approaches are outlined.

[Utility Water Conservation Plans](#)

As for municipalities and water suppliers, a water conservation plan and status reports are required as part of their Water Supply Allocation Permit from NJDEP.<sup>4</sup> Since it is part of the permitting process, there is public review, but public participation could be increased.

Christiansen et al. (2012, 28) call for the water conservation planning and approval process by state agencies to be independent of other permitting processes with their own notice and comment procedures, public hearings, and stakeholder involvement. Essentially the plans should be a separate requirement, not as part of another permit. Colorado, Connecticut, Kentucky, and Virginia all review and approve conservation plans independently.

However if maintained in the permitting process, the requirements can be strengthened. For example, California requires conservation as part of urban water management plans and Rhode Island uses a “Water Use Efficiency Rule” to set per capita per day water use targets and outline methods that users must include in their plan in achieve the reductions. Washington requires water conservation plans to look twenty years into the future and include a resource analysis and financial evaluation.

Additionally, review periods can be shortened. Right now in New Jersey the permit is good for ten years, so an updated plan is submitted each decade. In Massachusetts, where water conservation planning is done as part of the permit process, regulations require plans to be done every five years for compliance (if permit is for a term longer than five years) and the agency can update the permit terms and conditions based on the revised plan (Christiansen et al. 2012, 30).

---

<sup>4</sup> N.J. ADMIN. CODE § 7:19-2.14(a)

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

*Plan Implementation*

New Jersey conservation plans are currently enforced as a permit condition. California ties water management grants and loans to implementing the water conservation plans and has mandated a 20% reduction in per capita water use by water providers by December 31, 2020<sup>5</sup> (Christiansen et al. 2012, 33). In Oregon, municipal water suppliers must set 5 year targets in their water conservation plans and submit progress reports that are reviewed by the public (Christiansen et al. 2012, 33). In Texas, municipal water conservation plan must include proof on how they will be implemented and enforced, such as an ordinance, resolution, or tariff (Christiansen et al. 2012, 35).

Sydney Water in Australia is experiencing lower reservoir levels as a result of reduced inflows. As 80% of drinking water is supplied by the reservoir, the utility is using conservation methods to offset the lower inflow volumes (EPA 2012). The utility is offering rebates for rainwater tanks and more water efficient washing machines (1.97 billion/liters/year saved) and has started two programs to reduce residential and commercial water usage: (1) the Water Fix program has plumbers install water efficient appliances in homes (9.58 billion liters /year saved) and (2) the commercial office building and shopping center program incentives water efficient measures for businesses (13.406 billion liters/year saved) (EPA 2012).

*Pricing Schemes*

The pricing scheme strategy has had modest impact on reducing water consumption as many consumers do not track water use and the price of water is so low in our region (Shaw et al. 2011, 99). Shaw et. al (2011) did note that this approach is being revisited in the West, however initial findings indicate that residents are using more water overall, creating storage when the price is cheaper. This may be bad news for conservation efforts but could be good news for raising prices to cover needed infrastructure improvements to address leaks and aging.

*Landscaping*

Wallis, Ambrose, and Chan (2008, 74) note decreasing water consumption in landscaping is especially important as predicted climate change impacts will create conditions where lawns require more water, the “growing season is expected to lengthen, soil moisture content will decrease, evapotranspiration rates will increase, nights will be warmer, and more heat waves will occur”.

Water conservation through reductions in landscape watering is part of the Sustainable New Jersey program, but is unpopular. The program promotes the adoption of a Water Conservation Ordinance as one of the top actions a municipality can take for certification, yet of the 432 municipalities participating in the program, only 9 have passed the ordinance (Sustainable Jersey 2015):

- Stone Harbor Borough
- Avalon Borough
- Camden City
- Maple Shade Township

---

<sup>5</sup> First step was a 15% reduction by 2015 CAL. WAT. CODE § 10608.24

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

- Marlboro Township
- Flemington Borough
- City of Orange
- Bloomfield Township
- Nutley Township

The model ordinance crafted by NJDEP calls for year round reductions in water use including twice a week landscape watering with limited hours and more efficient irrigation systems (NJDEP 2011). However, enforcement costs are a limitation for some communities.

The Camden City ordinance was pushed by the Camden County MUA, which is currently working to reduce combined sewer overflows (CSOs). They saw the water conservation ordinance as a step to reduce sewage coming into the system, along with the construction of rain gardens and parks to reduce impervious cover (USEPA CRWU 2015). These programs were completed as part of the EPA Climate Ready Utilities project without raising rates for consumers.

New Jersey does have water efficient landscaping and appliance standards as part of the Neighborhood Preservation Balanced Housing Program, which helps finance affordable housing.<sup>6</sup>

New Jersey does require rain sensors on landscape irrigation systems (Christiansen et al. 2012, 57).

In other areas of the country, more innovative approaches are being taken to reduce the amount of water needed in landscaping through dry landscaping and turf removal programs. This approach also helps to reduce runoff and bolster water quality.

**Florida:**

The Florida Friendly Landscaping Program promotes dry landscaping through model ordinances promoting native plants. The model ordinance was developed by the state Department of Environmental Protection and University of Florida and achieves water use reductions by promoting low impact site design, incorporation of native plants appropriate for local conditions, efficient irrigation, composting, and turf reductions (Florida Department of Environmental Protection and University of Florida 2009). The model ordinances also address pesticide and fertilizer applications.

**California Turf Removal Program:**

Rebates are offered to residents and businesses in Southern California to replace turf with less water intensive landscaping. The Metropolitan Water District of Southern California (2015b; hereafter MWDSC) program removed 170 million square feet of turf and rebate requests have exceeded funding, resulting in a wait list.

Additional jurisdictions offering rebates include:  
City of Beverly Hills

---

<sup>6</sup><http://www.state.nj.us/dca/divisions/dhcr/publications/docs/bhp/bhrulesfinal121107.pdf>

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

City of Anaheim  
Los Angeles Department of Water and Power  
City of Long Beach – commercial customers

The rebate is offered to remove grass and install permeable surfaces, preferably plants. Commercial rebates are restricted to \$25,000 per property annually but an application can be submitted the following year for additional areas (MWDSC 2015a).

**Fix Infrastructure**

Water conservation is promoted as a way to avoid infrastructure improvement costs, but in New Jersey, aging infrastructure is a serious contributor to water inefficiency. The Water Infrastructure Protection Act, signed by Gov. Christie in February 2015, was passed to help finance infrastructure improvements but has raised concerns by potentially facilitating water privatization. The EPA estimates it will cost \$7.9 billion to maintain the state’s existing drinking water infrastructure over the next 20 years, excluding potential projects to increase resiliency to climate impacts (Associated Press 2015).

*Addressing Water Loss in the Distribution System*

New Jersey has strong regulations on utility distribution water loss, although the accounting methodology should be updated to industry best practices (the American Water Works Association’s (AWWA) most current M36 Manual) instead of using percentages (Christiansen et al. 2012, 20). The Delaware River Basin Commission currently requires the AWWA M36 Manual accounting methodology for New Jersey water purveyors extracting from the Delaware River Basin. New Jersey requires all municipal purveyors to apply leak detection and to “proceed expeditiously to correct leakage”.<sup>7</sup> “New Jersey requires the purveyors with the highest proportion of lost water for each purveyor size class to reduce losses to the median percentage for that class within one year, or else be subject to a specified compliance schedule” (Christiansen et al. 2012, 20). Texas, Tennessee and Georgia are using the most current AWWA water loss accounting methodologies (Christiansen et al. 2012, 22).

**Chicago**

Chicago has implemented a water rate increase to pay for improvements to its aging infrastructure system, treatment plants, and pumping stations. In 2012, residents saw a 25% rate increases and then an additional 15% annually for 3 years (City of Chicago 2013). More than 25% of the system is over 100 years old, therefore the repairs to water mains result in better water conservation (Chicago Climate Action Plan Natural Environment Adaptation Working Group 2011, 7; hereafter CCAPNEAWG).

The city is on track to replace 900 miles of water mains over ten years. 218 total miles of mains were replaced by 2014 (City of Chicago 2014, 14). Mains are selected for replacement based on break history records and may have reduced water losses and water pumpage. Up to 2012, the goal was to replace 1% of the system each year; but that has increased to 2% for 2012 onwards (about 70 miles of pipe per year) (City of Chicago 2013).

---

<sup>7</sup> N.J. ADMIN. CODE tit. 7, § 19-6.5(a).

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

Another infrastructure improvement Chicago is making to reduce water loss is cutting and sealing unused services (City of Chicago 2013).

The city has also updated its own leak detection software to TriCorr TM 2001 correlator and Digicorr correlators from FCS, but also contracts leak detection to a third party (City of Chicago 2013). Below are the leak detection numbers for Chicago from 2001-2012:

The following table demonstrates the Department's efforts toward leak detection.

Year	01	02	03	04	05	06	07	08	09	10	11	12
Miles of Pipe Surveyed	2364	2390	2310	2200	700	734	1220	1700	1460	1220	1600	1900
Number of Underground Leaks Located	994	809	1050	938	400	320	356	590	477	402	300	660

Chicago also saves water at pumping stations using the SCADA system and variable speed electric drives at some pumping stations to prevent over pressuring (City of Chicago 2013).

**Appliance Efficiency & Building Codes and Design**

To promote conservation, many communities look at measures to promote water efficient appliances and indoor plumbing, including low-flow showerheads, toilets, and washing machines (Shaw et al. 2011, 99). Some states give out rebates and free products, but in New Jersey there is no such program directly to promote water efficiency. The New Jersey Clean Energy Program through the Board of Public Utilities offers rebates for energy efficient clothes washers, hot-water heaters and air conditioning units, which could potentially reduce water use.<sup>8</sup>

As of 2012, New Jersey required but did not exceed federal water efficiency standards for toilets, showerheads, urinals, clothes washers, or pre-rinse spray valves and there was no mandatory building or plumbing codes requiring water efficient products beyond federal guidelines (Alliance for Water Efficiency 2012).<sup>9</sup> These standards apply to new construction and to major reconstruction of any bathroom or kitchen. However, as of 2012, no states had policies that exceeded federal standards for showerheads, clothes washers, or pre-rinse spray valves, only stricter toilet and urinal standards were required in California, Texas, and Georgia (Christiansen et al. 2012, 18).

In October 2015, the International Code Council (ICC) and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) published the *2015 WEP: Water Efficiency Provisions of the International Green Construction Code (IgCC)* (Johnson and Scott 2015). The resource contains the most modern codes in a variety of areas to help promote water efficient buildings, including plumbing, appliances, landscape irrigation, and reclaimed water.

The EPA WaterSense Program certifies appliances and plumbing products that use less water. There are residential and commercial standards. Additionally, ENERGY STAR also includes

<sup>8</sup> <http://www.njcleanenergy.com/rebates>

<sup>9</sup> <http://www.state.nj.us/dca/divisions/codes/codreg/>

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

water use as a recognition category for its National Building Competition (USWRCCA 2015, 30).

The US Green Building Council (USGBC) calls for a number of water efficiency measures as part of its Leadership in Energy & Environmental Design (LEED) new construction certification process. The program's required measures focus on potable water use and additional credits can be earned for use of recycled or alternative source water. The Water Efficiency program requires (1) no irrigation on site or a 30% reduction from baseline peak watering month projections based on plants and efficient irrigation systems, (2) EPA WaterSense appliances and 20% reduction in water use for indoor appliances such as faucets, showerheads, urinals, and toilets, (3) ENERGY STAR or CEE Tier 3A clothes washers, dishwashers and ice machines, (4) reduced water use in heating and cooling and standards for cooling towers and evaporative condensers, and (5) potable water metering for the building and grounds (USGBC 2015). USGBC requires the building owner to share building water use data for five years after LEED certification or "typical occupancy". Additional credits can be earned for (1) cutting irrigation water use by 50%, (2) exceeding the 20% water use reduction for appliances, (3) performing a "potable water analysis" on cooling towers and evaporative condensers and limiting cooling tower cycles, and (4) installing additional water meters on building subsystems such as indoor plumbing, irrigation system, and reclaimed water (USGS 2015).

**New York City**

In 1994, New York ran a toilet, showerhead and fixture replacement program, resulting in the installation of 1.3 million more efficient toilets between 1994 and 1997; Average water consumption was reduced by 70 mgd and participating apartments decreased water use by 37% (City of New York 2011, 85). In June 2014, NYC Department of Environmental Protection announced a new toilet replacement program for multifamily units that will run until June 2016 (or vouchers run out). Qualifying units receive a \$125 voucher for a "new WaterSense®-labeled high-efficiency 1.28 gpf toilets with a Maximum Performance ("MaP") score of at least 600 grams" (NYCDEP 2014).

**Chicago**

The city has been a leader on incorporating building code updates into sustainability planning. All Chicago public buildings must qualify for LEED Silver Rating. Updated building codes for private buildings requiring more efficiency and **a process to expedite permits for developers who are building sustainable properties** (City of Chicago 2010, 3) In 2010, Chicago had 134 LEED certified buildings compared with 95 in San Francisco and 82 in New York City (City of Chicago 2010, 4). One example is the Richard J. Daley Center, which dropped water use by 62% from 1994 levels, after receiving funding from the Clinton Climate Initiative to replace water fixtures and install updated chilled water conversion systems (City of Chicago 2010, 3).

Chicago (2010) has implemented the following measures to reduce water usage:

- reusing chiller and condenser water within City Hall;
- installing low-flow aerators in City facilities;
- installing low-flow shower heads in police stations; and
- installing low flow urinals and dual flush-toilets



**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

Additionally, the city is looking at developing codes on grey water reuse (City of Chicago 2015, 14).

Chicago (2010, 12) has also developed a Green Office Challenge for office tenants and property owners to reduce greenhouse gas emissions, and water and energy use. In 2009, over 40 building managers and 150 companies participated in the Challenge, achieving \$5.1 million in total energy savings. The average amount saved per building per year is \$135,000.

**Georgia**

All new construction in the state requires high-efficiency plumbing fixtures, including “new buildings, the alteration of existing buildings, and even replacement of malfunctioning, unserviceable, or obsolete fixtures, regardless of the owner or location” (Christiansen et al. 2012 19). This includes toilets, urinals, bathroom faucets and aerators, and kitchen faucets. Additionally, new construction of multiunit residential, commercial, and light industrial building must allow for water use to be measured by unit (Christiansen et al. 2012, 19).

**Monitoring Use**

New Jersey is a leader in volumetric billing, with a rate structure that encourages conservation (Christiansen et al. 2012, 36). Water meters are required at all service connections in systems unless there are less than 500 connections and the utility demonstrates to NJDEP water use is under 75 gallons per person per day.

However, it is unclear how much that rate structure influences behavior as water is relatively cheap in New Jersey and residents have little ability to monitor usage numbers as the faucet is running. Some jurisdictions are putting in place updated meters with radio transmitters to better track usage such as American Water in Toms River.

Chicago ran a six-month pilot program to encourage water conservation through updated metering. Participants volunteered for the Meter Save program and received a new automatic meter reading (AMR) installed by the Department of Water Management. The Department also guaranteed that water charges would not increase for seven years if the new meters did show a significant increase from previous readings. The program encouraged residents to track their water use and resulted in an average 72% reduction in water use; the maximum was a 90% reduction (City of Chicago 2010, 3). The Meter Save program also provides volunteers with a choice from two incentive packages, or both if the entire block participates:

*“outdoor water conservation kit”*: a hose timer, rain gauge, water restricting hose nozzle, moisture censor;

*“indoor water conservation kit”*: low flow shower head, shower timer, toilet flapper, leak detection tablets, toilet tank bank (water displacement pouch), 4-quart fill cycle diverter for toilet, Swivel low-flow kitchen aerator, Two bathroom sink aerators, Teflon tape, and Water Conservation wheel<sup>10</sup>

---

<sup>10</sup> <https://www.metersave.org/>



**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

In 2012, 41% of residents had signed up for the program and 50,000 water meters were installed by July 2014 (Byrne 2012; City of Chicago 2015, 14). Through its various programs, Chicago has decreased water use by 38%, 300 mgd, between 1991 and 2012 (City of Chicago 2013).

New York is also heavily investing in installing AMR technology; by 2011 650,000 of their 835,000 water customers had the new meters (City of New York 2011, 84). In addition to installing the meters, New York is implementing two ways residents can track their water usage: a voluntary notification program and a smart phone application. The city is hoping this will reduce water consumption and lead to faster reporting of leaks.

Jurisdictions are also beginning to use smart water meters that charge different rates based on system demand. Dubuque is implementing such a program now (Shaw et al. 2011). A pilot study in Colorado found metering increased consumption, more water was used during less expensive periods. “This suggests that water consumers’ behavior is malleable and that with the right pricing structure, overall water use could be reduced.” (Shaw et al. 2011, 99)

### Beneficial Reuse

Reclaimed Water for Beneficial Reuse (RWBR) is an important method to reduce consumptive uses. Highly treated wastewater can decrease withdrawals in areas such as landscaping and agriculture, industrial uses, aesthetics such as fountains, construction, fire protection, and sewer flushing. Currently, New Jersey discharges 700 million gallons of treated wastewater daily (NJDEP-OS 2012). The 1996 New Jersey Water Supply Plan found that 80% of discharges go to coastal waters, providing a major target for reuse. The NJDEP Office of Science (2012) also found “preliminary estimates indicate that the water demand for potable water by golf courses and other major consumptive users in the coastal areas is over 5.5 billion gallons per year. The use of reclaimed water for these activities in place of potable sources can protect a portion of the coastal water supply”. Beneficial reuse is best suited for those communities that discharge to coastal waters or can reclaim stormwater for non-potable uses.

Water Reuse is a prominent trade organization promoting the reuse of water and has created a number of tools and manuals to help agencies develop this resource at the local level. This includes the “[Manual of Practice: How to Develop a Water Reuse Program](#)” and training materials on how to operate the various systems.

Florida is a leader in the field, reusing 727 MGD of reclaimed in 2014, believed to have obviated the need for the use of 139 billion gallons of potable water.<sup>11</sup> About 55% of the total reused water (sourced from public access reuse systems) goes toward irrigation of residences, schools, golf courses and parkland.<sup>12</sup> Southern Florida especially is targeting beneficial reuse to irrigation practices, specifically looking at systems where water used for irrigation comes from potable shallow groundwater sources (ISC 2014, 6). There is discussion of mandating compulsory reuse zones for irrigation if a treated water source is available (ISC 2014, 15).

California has developed statewide goals for water reuse and many utilities have been recycling water for decades. The state Department of Health Services has developed Water Recycling

---

<sup>11</sup> <http://www.dep.state.fl.us/water/reuse/activity.htm>

<sup>12</sup> *Ibid.*

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

Criteria standards utilities must meet. The Irvine Ranch Water District in Orange County, California, has begun installing distribution lines for recycled water in new residential and commercial developments, with 3,400 recycled water connections currently (Crook 2015, 6). Customers are served by the Michelson Water Reclamation Plant (WRP), which came online in 1967, and the Los Alisos WRP, recycling water that would otherwise be sent to a regional wastewater utility that discharges to the ocean (Crook 2015, 6). The system contains 656 million gallons of storage capacity and is primarily used for irrigation at businesses and public properties.

**Reuse Flow Per Capita for the Nine States that Reported Having Reuse in 2006<sup>13</sup>**

State	Population (2006 est)	Reported Reuse <sup>1</sup> in Millions of Gallons per Day	Reuse per Capita in Gallons per Day per Person	Rank
Florida	18,019,093	663.0	36.79	1
California	36,121,296	580.0 <sup>2</sup>	16.06	2
Virginia	7,628,347	11.2	1.46	3
Texas	23,367,534	31.4	1.34	4
Arizona	6,178,251	8.2	1.33	5
Colorado	4,751,474	5.2	1.09	6
Nevada	2,484,196	2.6	1.03	7
Idaho	1,461,183	0.7	0.50	8
Washington <sup>3</sup>	6,360,529	0	0	9

<sup>1</sup>From the Water Reuse Foundation National Database of Water Reuse Facilities Summary Report, 2006

<sup>2</sup>The reuse data for California was updated in the National Database using data from California's 2002 reuse survey, which was previously missing. So while the 2006 Summary Report reported 87 MGD of reuse for California, the actual reuse flow was more like 580 MGD.

<sup>3</sup>The state of Washington reported reuse systems and reuse pipe, but no reuse flow as of 2006.

Multiple governments noted that beneficial reuse and graywater system implementation was delayed due to regulatory restrictions or guidance documents in development (City of New York 2011, Combs 2014). In most recycled water projects, water is treated to a tertiary level, but some public health concerns do remain and standards are needed that address those concerns but allow permitting to move forward to get systems installed. In 2013, the City of Austin, Texas, worked to revise its graywater requirements as only one household qualified for a permit in three years. With the changes, additional households did qualify (Combs 2014, 13). California offers subsidies to residents for graywater permit applications (Combs 2014).

Power generation is the second largest use of water in the state and beneficial reuse can be employed at such facilities to decrease annual withdrawals (NJDEP-OS 2012; EPA 2012). The key benefit in New Jersey will come from focusing on power generation facilities that are using freshwater for operations and supplying them with effluent that would otherwise be discharged

<sup>13</sup> <http://www.dep.state.fl.us/water/reuse/inventory.htm>

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

to coastal waters. Melbourne Water in Australia is completing tertiary level upgrades on its wastewater treatment plants and will use the reclaimed water to supply power utilities that are currently pulling surface water to cool their systems (EPA 2012).

**Additional Steps to Consider:**

- Include water use efficiency in agency review of major water infrastructure and resource projects and projects relying on water (ex. energy facilities) (USICCAT 2011, 26)
- NYC Water Dependability Study looking at demand reduction and programs to increase efficiency in restaurants and small businesses. NYC successfully reduced water use in the 1990's by 300 mgd (twice the daily yield of their Croton Reservoir system) implementing universal water metering and an incentive program for upgrading toilets (Shaw et al. 2011).
- Targeting the energy sector to improve water efficiency. Documenting the industry's water use and looking at programs has been a focus for USGS and DOE through their **Water-Energy Nexus: Challenge and Opportunities**<sup>14</sup> (USWRCCA 2015, 15 and 27).
- California legislation requiring a 20% per capita reduction in water use by 2020<sup>15</sup>
- Funding water efficiency: Colorado's Water Efficiency Grant Program<sup>16</sup> and Oregon's Water Conservation, Re-use and Storage Grant Program<sup>17</sup>
- North Carolina requires achievement of water efficiency targets to qualify for Drinking Water State Revolving Fund or the Drinking Water Reserve funding for treatment capacity and delivery expansion. Requirements include<sup>18</sup>:
  - Rate structure to pay for maintenance
  - Leak detection and repair
  - Meters all uses
  - Do not reduce residential per unit water rate and use increases
  - Study reclaimed water use
  - Consumer education program
- Investments should be made in public outreach and education campaigns on the importance of water conservation (EPA 2012).

**Source Water Quality**

The changing climate in the Northeast is expected to have major impacts on water quality and actions need to be undertaken now to prevent degradation. The Climate Change Clearinghouse (2009), part of the Water Research Foundation, has identified three areas of concern:

- Increased temperatures. Surface water temperatures are expected to increase with warmer air temperatures, contributing to algal blooms and decreased levels of dissolved oxygen and concentration of contaminants.

<sup>14</sup> <http://www.energy.gov/downloads/water-energy-nexus-challenges-and-opportunities>  
<http://pubs.usgs.gov/sir/2014/5184/>

<sup>15</sup> <http://www.water.ca.gov/wateruseefficiency/sb7/docs/SB7-7-TheLaw.pdf>

<sup>16</sup> <http://cwcb.state.co.us/LoansGrants/water-efficiency-grants/Pages/main.aspx>

<sup>17</sup> [http://www.oregon.gov/owrd/Pages/LAW/conservation\\_reuse\\_storage\\_grant.aspx](http://www.oregon.gov/owrd/Pages/LAW/conservation_reuse_storage_grant.aspx)

<sup>18</sup> NC General Statute §143-355.4. Water system efficiency

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

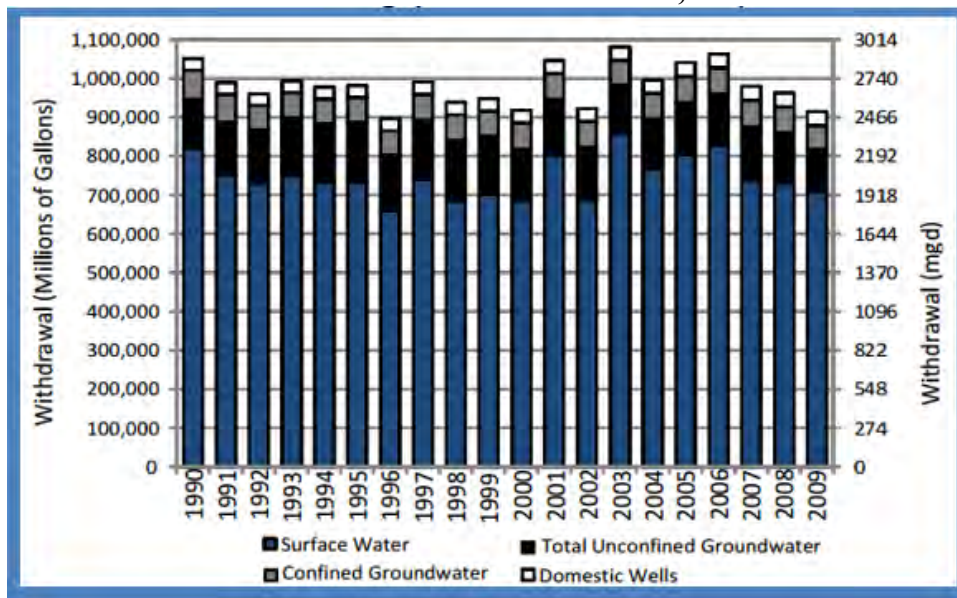
- Sea level rise and storm surges. Larger storm surges increase the vulnerability of freshwater supplies to saltwater intrusion.
- Precipitation. Extreme precipitation events will result in more erosion and therefore increased turbidity in surface waters. There is also concern about nutrient loading and an increase in bacteria and pathogens entering water supplies.

Wallis, Ambrose, and Chan (2008, 75) also express concerns about high water temperatures and turbidity, noting that following extreme storms the East Bay Municipal Utility District’s (EBMUD) treatment operations were slowed significantly while treatment costs increased. Poor water quality increases vulnerability in treatment time and costs.

The Northeast is especially vulnerable to more extreme precipitation events. EPA (2012) found the region experienced a 58% increase in the average number of days with very heavy precipitation between 1958 and 2007.

Protecting surface water quality is especially important as roughly 75% of New Jersey water withdrawals are from surface water and action now can prevent the construction of costly treatment facilities (NJDEP-OS 2012).

**NJDEP-OS Source of Water Withdrawals, 1990-2009**



**Runoff & Stormwater**

*Pathogens*

Increased extreme precipitation events and rising temperatures leave New Jersey’s water supply more susceptible to the risk of pathogens. Pathogen viability is influenced by a number of environmental conditions and more monitoring needs to be done to determine which water quality impacts are the result of climate change rather than changed land uses (Shaw et al. 2011, 101). However, there is growing evidence of a link and federal and state agencies are beginning to take action.

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

Shaw et al. (2011, 96) note that other environmental conditions have a significant impact, but that elevated levels of E. Coli on 23 Chicago beaches were linked to increased water temperatures and in the Chesapeake Bay, *Vibrio cholera*, the pathogen causing cholera, was discovered 10 times more frequently in waters with temperatures exceeding 66 degrees Fahrenheit versus waters with temperatures below that threshold. Higher concentrations of disinfection byproducts (DBP) can also occur with more algal blooms and decreased dissolved oxygen levels, but increases have not been definitively linked with climate change (Shaw et al, 2011).

Various entities are developing improved tracking systems in response, as recommended by the 2011 National Action Plan (USICCAT 2011, 20). The Centers for Disease Control (CDC) has increased surveillance of waterborne diseases in the Great Lakes and is updating the National Outbreak Reporting System to help states report harmful algal bloom outbreaks (USWRCCA 2015, 3). Additionally, the CDC is currently providing funding to 15 states for waterborne disease prevention surveillance activities, including Maryland, Virginia, and New Hampshire (USWRCCA 2015, 15). Massachusetts is also developing a database for monitoring and reporting water borne diseases following major precipitation events (Massachusetts 2011). Shaw et al. (2011, 101) recommends, “as a starting point, frequent monitoring of primary nutrients, turbidity, and pathogen indicators on major rivers would enable a clearer picture to emerge of the associations among climate factors, land use, and water quality.”

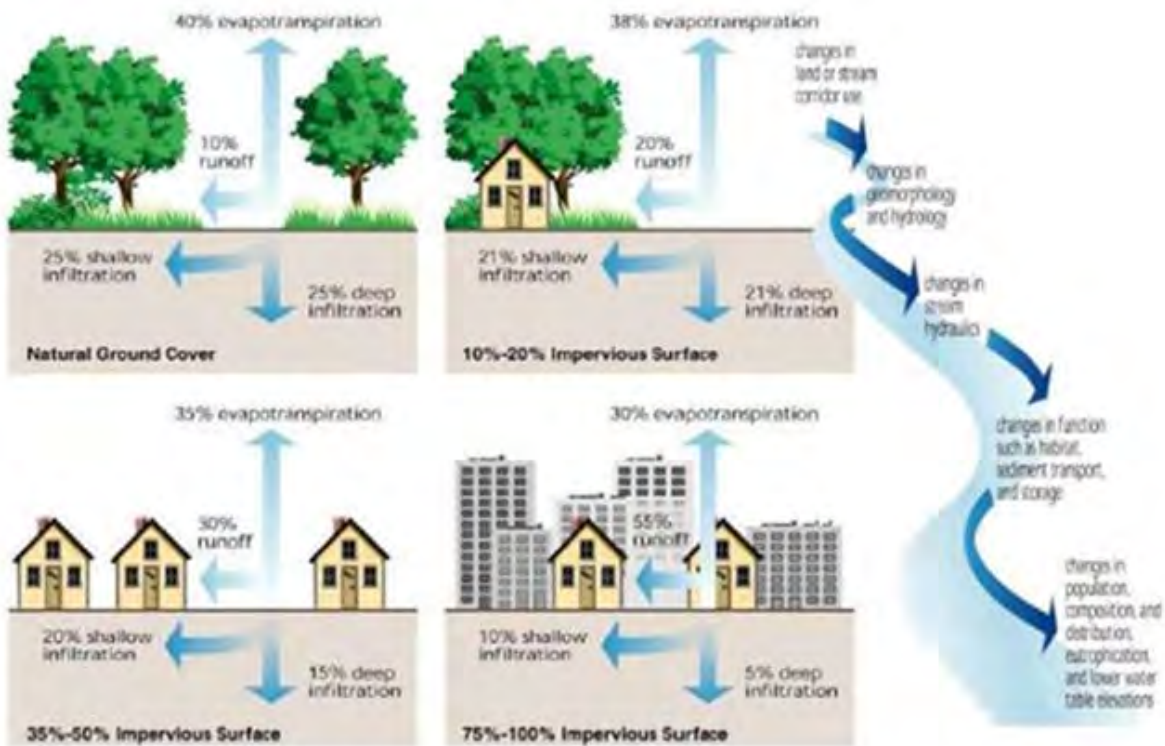
*Stormwater Management in Urban Areas*

More extreme precipitation events will result in more precipitation coming in shorter periods of time. However, more intense events may not result in increased in pollutant loading. Shaw et al. (2011, 95) notes, “pollutant loads mainly depend on total runoff volume and only weakly on the intensity of runoff or precipitation”; the same amount of rainfall in less, more intense events could result in fewer acute pollution events.

Many are investing in green infrastructure and stormwater management in response. Green infrastructure can retain and infiltrate water on site, while projects like rooftop gardens and urban forests can also reduce urban heat island effect and use of air conditioning (U.S. Climate and Natural Resources Working Group 2014; hereafter CNRWG). This reduces runoff while promoting groundwater recharge.



**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**



Source: U.S. Environmental Protection Agency. 2010. Stormwater rulemaking consultation with state and local governments. Available at <http://www.naco.org/legislation/policies/Documents/Energy,Environment,Land%20Use/EPA%20SW%20Rulemaking%20Briefing.pdf>.

**Effect of Urbanization on Stormwater Discharges**

Chicago has been a leader in the field of stormwater management as Lake Michigan is the city’s primary source of drinking water and the largest drinking water source in Illinois, serving nearly 6.6 million people<sup>19</sup>. Lake Michigan is vulnerable to untreated runoff and combined sewer overflows (CSOs) during storms (CCAPNEAWG 2011; EPA 2012). The City has implemented a number of strategies to capture and clean stormwater:

- **2008 Stormwater Management Ordinance:** The ordinance requires the first ½ inch of rainfall be retained on site or a 15% reduction in impervious cover for all developments 15,000 square feet and larger and all parking areas 7,500 square feet and larger (EPA 2012). Implementation of the ordinance has increased permeable area per site by 20% and created 55 acres of permeable surface area (City of Chicago 2010, 10)
- **Green Roof Grant Program and Green Roof Improvement Fund:** Started in 2007, the program offers \$500,000 for grants of up to \$100,000 to construct green roofs in the Central Loop District; 300 buildings have installed over 4 million square feet of green roofs (EPA 2012).
- **Chicago Sustainable Backyard Program:** offers rebates on rain barrels, native plants, compost bins, and other technologies to reduce basement flooding and improve Lake Michigan water quality.<sup>20</sup> (CCAPNEAWG 2011, 8)

<sup>19</sup> <http://www.epa.illinois.gov/topics/water-quality/monitoring/lake-michigan/index>

<sup>20</sup> <http://stormwater.wef.org/2013/05/chicago-launches-new-website-for-sustainable-backyards-program/>

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

- **Green Alley Program:** pilot projects are built in alleys to increase permeable paving. 120 green alleys have been constructed, covering 32,000 square feet (EPA 2012; City of Chicago 2010).
- **Urban forestry:** Chicago has planted over 6,000 trees between 2005-2008 to reduce urban heat island effect and increase stormwater capture (CCAPNEAWG 2011, 8).
- **“Space to Grow” program:** Invests \$50 million over five years to transform asphalt schoolyards into green playgrounds, including rain gardens and water storage (City of Chicago 2014, 14).

Philadelphia has implemented new stormwater regulations for new development and redevelopment and a Stormwater Management Service charge (Philadelphia Water Department 2016). Applied to residential and non-residential properties, the charge is a utility user fee that covers the service Philadelphia provides to residents of handling stormwater, which costs \$110 million each year (City of Philadelphia 2015a). The charge is based on the total lot size (excluding public right of way) and amount of impervious cover on the lot for nonresidential customers. Residential households pay a standard fee based on the city average lot size and impervious coverage (City of Philadelphia 2015b). The revenue goes to infrastructure improvements and stream restoration to combat pollutant loading and combined sewer overflows. Additionally, Philadelphia has invested heavily in green infrastructure programs to address stormwater discharges (Philadelphia Water Department 2016). The Green Streets program has built improvements such as tree trenches and planters and installed additional pervious cover around the city. The city is also focusing on implementing programs through schools, including green roofs. The Green Parking program is transforming lots with swales, infiltration beds, and pervious cover.

Portland, Oregon, charges residential and non-residential utility customers to provide stormwater management services. Starting in 2013, the fee was instituted in 25% increments over four years directly on the water/sewer utility bills and in July, 2016, customers will pay the full 100% charge for off-site management of stormwater. The city has been divided into different drainage districts with customers within and outside districts paying different rates. The charge is a monthly fee for each 1,000 square feet of impervious surface on their lot, and the “days of service” i.e. when the infrastructure is actually in use. The rates for July 2014-2015 were (City of Portland Environmental Services, 2016):

<b>Portland, Oregon, Stormwater Management Fee Rates (2014-2015)</b>	
<b>Outside Drainage District</b>	<b>Within the 3 Drainage Districts:</b>
Residential: \$6.97 per 1,000 square feet	Residential: \$3.48 per 1,000 square feet
Commercial: \$7.27 per 1,000 square feet	Commercial: \$3.64 per 1,000 square feet

**Wetlands, Riparian Areas and Land Uses**

Investments and improvements can be made in land use regulation and headwaters and wetland protection to improve water quality and supply in the face of climate impacts. A first step is including climate change impacts in the local government review process for any new developments (Rosenzweig et al. 2007, 1404). Massachusetts (2011, 29) is working on

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

developing land use guidelines and model bylaws that can be used by local governments and providing them technical support.

The federal government recommends local entities map the location and function of both existing and potential future wetlands (USICCAT 2011, 21). U.S. Fish and Wildlife Service (FWS) has made wetlands data available to help the process through the National Wetlands Inventory<sup>21</sup> (USWRCCA 2015, 16).

Massachusetts (2011, 48-49) has prioritized wetland protections in their climate adaptation strategy and is implementing the following measures:

- Land and Buffer zone protection
- Flood plain restoration
- Encourage geotextiles and bioengineering techniques for erosion control and stream stability over the use of traditional engineering solutions
- Monitoring, research on adaptive strategies, and pilot projects

Many governments are investing in riparian area restoration programs focused on repairing hydrologic processes (restoring flood plain connectivity and water storage) and reestablishing vegetative buffers to protect water supply. Such restoration projects better prepare our riparian and aquatic ecological systems and the water supplies they support to withstand climate impacts, improve the rate systems can recover from impacts such as drought and flooding, and equip the systems for gradual changes (Seavy et al 2009). One of the most successful programs to improve water quality in agricultural areas has been Virginia's Conservation Reserve Enhancement Program (CREP), which provides financial incentives, cost-sharing, and rental fees to land owners who implement practices to reduce nonpoint source pollution through buffer creation and wetland restoration. CREP targets agricultural lands in two regions: within the Chesapeake Bay the goal is to plant 27,000 acres of riparian buffers and 3,000 acres of wetland vegetation and outside the Chesapeake basin, the Southern Rivers region, the target is 13,500 acres of riparian buffers and 1,500 acres of wetland vegetation; this goal reduces yearly nitrogen loading in waterways by over "710,000 pounds, phosphorus by more than 114,000 pounds and sediment by more than 62,000 tons" (Virginia Department of Conservation and Recreation 2015; hereafter VDCR). The local Soil and Water Conservation District offices administer the program's cost-share incentive program. The state offers up to 50% reimbursement for restoration activities and a 25% state income tax credit for out-of-pocket costs. The federal Farm Service Agency also offers an up to 50% reimbursement for some restoration activities. Beyond the reimbursements, there are four payment programs farmers can also participate in. The first offers rental and maintenance payments for CREP contracted acres, up to \$100 per acre in the Chesapeake region, \$90 per acre in the Southern Rivers region (VDCR 2015). The lease is for 10 or 15 years, decided by the landowner. Federal payments come in two forms: a signing incentive payment (SIP) at \$10 per acre annually and a federal practice incentive payment (PIP), essentially a 40% reimbursement for riparian projects and 25% for wetland projects. The site restoration plans are developed by the land owner working in conjunction with representatives

---

<sup>21</sup> <http://www.fws.gov/wetlands/Data/Mapper.html>



**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

from the USDA Natural Resources Conservation Service and Farm Service Agency. Plans and contracts must be approved before payments are made, and the Farm Service Agency monitors the project over the life of the contract (VDCR 2015).

The EPA (2012) Climate Ready Utilities program offers a number of strategies for improving wetlands and land uses to protect water quality and quantity, across three categories. Strategies that are listed as “No Regrets” are measures that can be taken preemptively in the face of climate change as they benefit our water systems and water supply regardless of future climate impacts:

**Ecosystem and Land Use Recommendations (EPA 2012, 15)**

- Acquire and manage ecosystems (\$\$\$) No Regrets
- Green Infrastructure (\$\$\$) No Regrets
- Implement watershed management (\$\$): restore vegetated cover and manage stormwater; helps increase groundwater recharge
- Integrate flood management and modeling into land use planning (\$): especially for utility infrastructure
- Study response of nearby wetlands to storm surge events (\$), especially in coastal areas

**Monitoring (EPA 2012, 17)**

- Manage reservoir water quality (\$\$): more runoff and high temperatures decrease quality, but can be improved with watershed management, increasing groundwater recharge, and reservoir management techniques such as lake aeration
- Monitor flood events and drivers (\$) No Regrets
- Monitor surface water conditions (\$) No Regrets
- Monitor vegetation changes in watersheds (\$)

**Repair and retrofit (EPA 2012, 20)**

- Increase capacity for wastewater and stormwater collection and treatment (\$\$\$)– No Regrets
- Increase treatment capabilities (\$\$\$)- No Regrets because expecting significantly reduced water quality for supply
- 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” (EPA 2012, 20).

*Open Space Preservation*

Changing land uses, such as preserving lands now, can help reduce future flooding impacts and protect and improve water quality. The New Jersey Water Supply Authority has established a Source Water Protection (SWP) program funding preservation in high priority areas of the Raritan River, Manasquan River, and Delaware and Raritan Canal watersheds. The SWP program is funded through a charge on water utility customers, beginning in 2002 (NJWSA 2016). Additionally, the Authority secures low interest loans through the state Environmental Infrastructure Trust to pay for acquisition. The Authority has a Land and Resource Preservation Program focusing on acquiring and managing land with a goal of water quality protection. The Authority’s Watershed Protection Unit began working on the Spruce Run Initiative in 2001, and

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

has since expanded the efforts to other watersheds. As part of the Spruce Initiative, the Authority developed GIS mapping techniques to identify critical acquisition areas and has created maps for other watershed. The Authority is working with local non-profit and government partners to preserve adjacent areas of open space and share costs. Through the program, the Authority has acquired 3,100 acres and holds conservation easements on an additional 316 acres (NJWSA 2016).

The Wisconsin Fox Basin Flood Plan focuses on open space acquisition and Transfer of Development Rights (TDR) programs. The Plan found the Baird Creek subwatershed was a major contributor of sediment load during precipitation events, 60 to 70 percent of the total sediment load (Kousky et al. 2011, 47). To improve water quality, a flood damage mitigation policy was developed that prioritized open space creation. Kousky et al. (2011) recommend that in developing such a policy, the cost-benefit analysis monetize water quality improvements as co-benefits and water quality degradation as a cost. Under this paradigm, water quality improvement investments would also create recreational economic benefits, which is especially important in New Jersey, as tourism is one of the state's largest industries, and such programs could result in positive benefits like less beach closings and healthier fisheries as a result of less pathogens in stormwater discharges.

New Jersey currently operates the Blue Acres program<sup>22</sup> to acquire land from voluntary sellers of developed lands within targeted flood prone areas. TDR programs currently operate in the Highlands and Pinelands regions, to varying degrees of success, to protect water sources. Kousky et al. (2011, 57) cite Montgomery County, Maryland which has protected 49,000 acres through TDR. The region was downzoned from 5 acres to 25 acres at the beginning of the programs and receiving zones were established in the DC suburbs. However, developers can elect to pay a fee to the local government rather than purchase TDRs and that revenue is used for open space acquisition. Development impact fees cannot be used for broader environmental purposes; they can only cover the "marginal infrastructure costs associated with new development" (Kousky et al. 2011, 57).

*New York Watershed Protection Program*

New York City invests \$462 million a year in the upstate Watershed Protection Program to obviate the need for treatment for 90% of its water supply (City of New York 2011, 81). In the Delaware and Catskill watersheds, the program funds land acquisition, the replacement of failing septic systems, and improvements at wastewater treatment plants near the City reservoirs. New York City currently owns 115,000 acres of watershed land and is working to expand its holdings by continuing to contact local landowners (reaches out to the owners of a total of 50,000 acres a year) (City of New York 2011, 81).

The program has replaced 3500 septic systems in the two watersheds and has set a goal of 300 residential septic rehabilitations a year moving forward (City of New York 2011, 81). The City also works with the Watershed Agricultural Council to promote sustainable farming techniques to limit fertilizer and waste into reservoirs. While all New Jersey utilities drawing surface water

---

<sup>22</sup> [http://www.nj.gov/dep/greenacres/blue\\_flood\\_ac.html](http://www.nj.gov/dep/greenacres/blue_flood_ac.html)

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

use filtration currently, similar investments can be made in New Jersey to avoid increased treatment costs from decreased water quality under different climate change scenarios.

New York City operates a third reservoir system, Croton in Westchester County, providing 10% of the city's water supply (up to 30% during drought (City of New York 2011, 81). However, overdevelopment in the watershed has required a treatment plant be built to meet the standards of the Safe Drinking Water Act. The City's first treatment plant opened in 2013 in Van Cortlandt Park, and costed \$3 billion to construct (City of New York 2011, 82).

*Land Use Approvals*

Miami- Dade county has integrated water supply planning with land use planning in flagged critical areas to support infrastructure improvements. For all new construction, expansions, and renovations, developers must secure an increased water allocation, which is tracked, and agree to infrastructure improvements to serve the expanded water use (ISC 2014, 10). The water allocation can be voided if the developer does not agree with the terms and conditions.

Wastewater Discharges

Wastewater discharges above water supply intakes can also harm water quality as climate change may increase the occurrence of low flow conditions or change the time period in which they occur, affecting contaminant dilution (Massachusetts 2011). Shaw et al (2011) advises that state governments should review all discharge permits based on water quality and determine if all facilities should continue to receive general discharge approvals into surface waters. Water supplies will be especially vulnerable during the summer months.

Saltwater Intrusion

Saltwater intrusion exists in New Jersey, with NJDEP recognizing lower Cape May as one of the biggest challenge areas in the state for providing drinking water (NJDEP-OS 2012). Additionally, aquifer withdrawal limits have been established in Water Supply Critical Areas in the Monmouth and Ocean Counties area (#1) and the Camden metro area (#2) due to saltwater intrusion concerns. Saltwater intrusion into coastal freshwater aquifers is expected to increase with sea level rise, and the Northeast Atlantic could see a 10-12 inch rise by 2100 (EPA 2012). In addition to aquifer impacts, the saltwater line can move upstream in tidal estuaries, and the Delaware River is especially vulnerable, including intakes in the Camden area (EPA 2012). Saltwater intrusion can also damage water supply infrastructure through corrosion (Massachusetts 2011).

Monitoring saltwater intrusion is the first step in addressing the challenge and USGS has been working with impacted communities to develop the needed tools. The Broward County (Florida) Natural Resources Planning and Management Division and local municipalities have partnered with USGS to develop a downscaled saltwater intrusion model for surface and groundwater based on Global Circulation Models for the county (IGS 2014).<sup>23</sup> The County also uses the USGS SEAWAT software, to track saltwater intrusion in groundwater. Miami-Dade County is working with USGS to model sea level rise impacts on saltwater levels in ground and surface water. USGS operates a network of salinity monitoring wells in Palm Beach and Broward

---

<sup>23</sup> <http://water.usgs.gov/ogw/seawat/>

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

Counties, Florida. The information gained from the wells is tracked by the South Florida Water Management District to flag areas of concern and produce updated mapping of the saltwater interface every three to five years (IGS 2014, 8).

Localities tend to face the challenge by implementing one or both of two preferred solutions: construction of desalination plants and fortifying aquifers with intrusion barriers and increasing their recharge capacity. Other options include drilling additional wells and tapping different aquifers and building new interconnections (Behrens 2007, 14).

Cape May City constructed a desalination plant to address saltwater intrusion in 1998. The plant treats 2 MGD, drawn from the Atlantic City 800-Foot Sand Aquifer (Behrens 2007, 28). The \$5.1 million project was funded through a \$250,000 grant from the Governor's office, a \$1.75 million loan from the New Jersey Environmental Infrastructure Trust, and \$100,000 from the City of Cape May. The project also received funding from the United States Department of Agriculture: a \$1 million grant and a \$2 million low interest 40-year loan (Behrens 2007, 21).

In 2012, the Borough of Keansburg constructed an 800,000 gallon per day desalination plant to serve residents after coastal wells were harmed by saltwater intrusion into the aquifer (Taylor 2012). The plant cost \$3 million to construct; about half the money came from federal stimulus funding and the rest was financed by the New Jersey Environmental Infrastructure Trust (Biese 2012).

Desalination plants can be built to treat full saline or brackish groundwater and saltwater. New desalination plants must not be built in areas that are vulnerable to coastal flooding and storm surges (EPA 2012). Additionally, there are potentially significant environmental impacts associated with the operation of desalination plants: "impact on marine life, the disposal of concentrated brines that may contain chemical waste, and the large energy use (and associated carbon footprint) of the process" (USGCRP 2009, 147).

Saltwater intrusion barriers are created by injecting fresh or recycled water into aquifers to keep saltwater out, but is fairly expensive to implement (EPA 2012). The Los Angeles County Flood Control District (LACFCD) has been using the technique successfully since the 1950's on three separate sites: the West Coast Basin Barrier Project, the Dominguez Gap Barrier Project, and the Alamitos Gap Barrier Project. Both potable and recycled municipal waste are injected into the aquifers to prevent saltwater from entering.

Recycled water and stormwater runoff is used to recharge aquifers in the Central Basin of California at the Montebello Forebay Groundwater Recharge Project. The Central Basin underlies Los Angeles, has a storage capacity of 780,000 acre feet and contains over 400 active wells (Crook 2015, 10). As of 1991, the program allows for 60,000<sup>24</sup> acre-feet a year to be recharged from recycled water, 35% of the aquifer's recharge (Crook 2015, 11). The project site has two spreading areas, 570 acres and 128 acres large, adjacent to the WRPs that serve the project.

---

<sup>24</sup> Must average 50,000 acre feet over 3 years but can recharge up to 60,000 acre feet in one year.

## **Basis and Background Document: Climate Change Adaptation in the Water Supply Sector**

### **Utility Strategies**

Water utilities will face the problem of peak flows entering reservoirs being of lower quality. As climate change presents increased temperatures and associated algal blooms, and more turbidity in water supply, enhancement of water treatment infrastructure is often proposed as a solution. However, approach creates significant capital and operating costs and higher levels of energy use in the water sector (EPA 2012).

Expansion and diversification of sources is also very costly but can decrease dependence on treatment and overall vulnerability to climate change impacts. Miller and Yates (2005) found that diversification of sources can offset temperature related treatment costs because “groundwater often requires less treatment than surface water, and water recycling reduces the total amount of water that needs to be treated.” EBMUD’s treatment plants are for low turbidity waters, and the utility is investing in the diversification approach rather than treatment capacity expansion. EBMUD is constructing the Freeport Regional Water Project to tap into a new surface water source, the Sacramento River, which will provide 22% of water needed during drought (EPA 2012). They are also creating the Bayside Groundwater Project, where water will be injected during wet years and extracted during drought. EBMUD is also investing in recycling, surface water storage, and desalination.

The Metropolitan Water District of Southern California is focusing on conservation, but also water recycling, increasing use of groundwater, and expanding water storage. The utility is working with local agencies on recycling and groundwater recovery, establishing 75 programs (EPA 2012). Los Angeles’ wastewater is treated to a tertiary level by the West Basin Municipal Water District and is then used for landscape and industrial purposes and to create an exclusion barrier for salt water intrusion in the South Bay area. Recycling creates 20,000 acre feet of water each year, increasing to 70,000 acre-feet by 2025 (EPA 2012). Metropolitan is also building new storage capacity in Diamond Valley Lake and groundwater sources.

The Srontia Spring Reservoir and Foothills Treatment plant in Denver, Colorado, has installed sensors above the reservoir to monitor debris and sediment and shuts down treatment operations when levels are too high (Miller and Yates 2005).

Aquifer storage and recovery (ASR) is a technique where potable water is injected into an existing aquifer for storage until it will be used at a later date. This process can help combat expected variability in extreme precipitation events and peak flows resulting from climate change, as well as quality concerns to which surface waters are vulnerable. ASR may be a more cost effective way to expand storage capacity to improve resiliency than new reservoirs: the initial capital costs to create the ASR systems are significantly less than reservoirs, but additional treatment requirements (before injection and before delivery) may eventually make the system operating and maintenance costs similar (Coates 2012). Three major Texas cities are currently using ASR to store drinking water, investing in the technology because of its low cost: El Paso, Kerrville, and San Antonio. San Antonio operates the Carrizo ASR facility, with a maximum capacity of 120,000 acre-feet, built at a capital cost of 87 cents per gallon per day (Combs 2014, 14). However, concerns do still remain, primarily poor water quality in recovered water and that stored water can be accessed by other users (Combs 2014).

## **Basis and Background Document: Climate Change Adaptation in the Water Supply Sector**

### **Ecological Impacts**

#### **Ecological Health**

Climate change will have impacts on the ecological health of waterways. Warmer water temperatures will decrease water quality and dissolved oxygen levels and harm cold water fisheries, such as trout (Shaw et al. 2011, 94). Wallis, Ambrose, and Chan (2008) predict it will be harder to achieve cold water fisheries standards.

Nutrient loading by nitrates in watersheds may decrease in the northeast as a result of warmer temperatures. Schaefer and Alber (2007, 333) found that only 9% of anthropogenic nitrogen inputs in southeastern watersheds reached coastal waters compared to 25% in the northeast, and hypothesize that the higher temperatures in the southeast lead to higher rates of gaseous loss of nitrogen to the air. However, other studies have shown a link between long term wetter conditions and increased loss of nitrogen from watersheds to waterbodies (Shaw et al. 2011, 96). Therefore, future nutrient loading will be difficult to predict and dependent on land uses, temperature, and soil moisture changes. Phosphorus levels are likely to increase as increased stream flows degrade bank and bottom soils, releasing more phosphorus into the water column (Miller et al. 2014).

New Jersey's waterways may also be harmed by increased fire risks and altered by changing upland vegetation as a result of climate change. By 2060, the Northeast is expected to see a 10% to 20% increase in forest fire severity, endangering water supply infrastructure and producing dirtier runoff in burned areas (EPA 2012). Climate change will cause changes in vegetation in forests and invasive species are expected to increase. This will result in "complex and difficult to predict impacts" on both water availability and runoff (EPA 2012).

#### **Stream flows**

New Jersey must determine what impacts climate change will have on average annual water supplies (quantity) and what the variability will be in stream flows and seasonal runoff throughout the year. By 2100, spring runoff could advance 14 days in the Northeast (USGCRP 2009). The EPA (2012) notes that intakes may be vulnerable and need to be retrofitted for lower stream flows. Changes in the timing and frequency of low flow conditions and higher temperatures will potentially reduce the ability of waterways to dilute pollution discharges. Shaw et al. (2011, 100) recommend more research be done on pollutant assimilative capacity at such low flow, high temperature conditions, and new methodologies are being developed to estimate low-flows.

#### **Ecological Limits on Hydrological Alteration (ELOHA)**

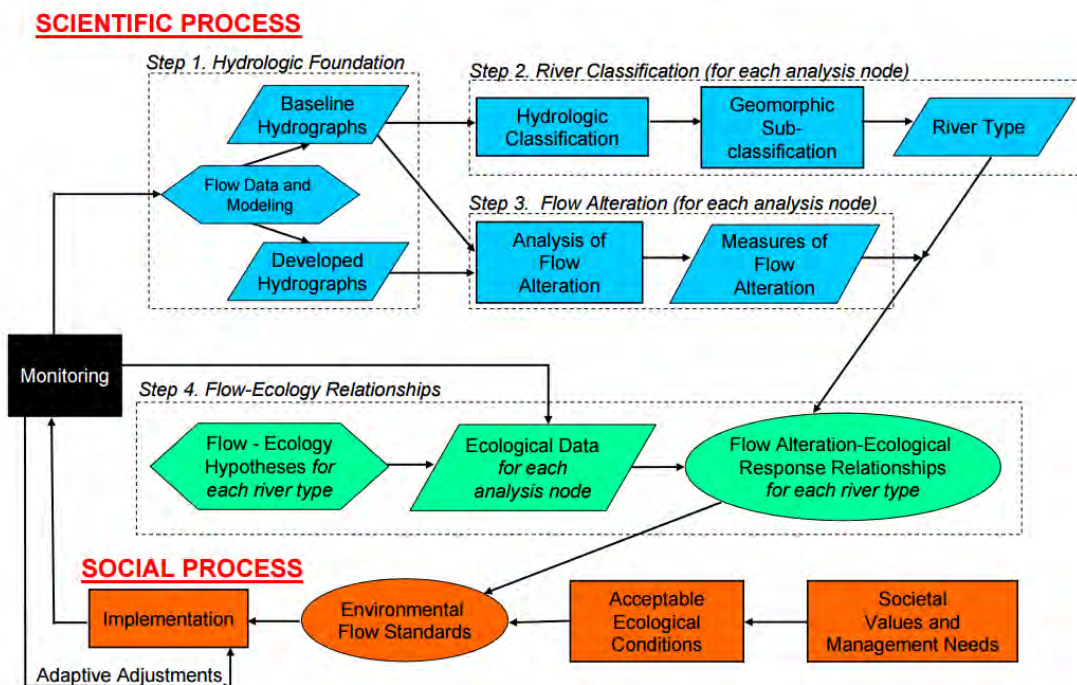
The ecological health of drinking water sources depends on maintaining adequate freshwater environmental flows: the water quantity, water quality, and seasonal timing needed to promote and sustain ecosystem functioning and biodiversity (Poff et al. 2011). Water supply allocations can alter the natural flow of water sources. Environmental flow assessments determine potential impacts to ecosystems from those management decisions and informs the quantity available and timing of diverting flows for water supply use that will have the least impact to ecosystems (Kendy 2009).



**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

Traditionally, environmental flows have been assessed on individual rivers, sometimes taking years to complete. The Ecological Limits on Hydrological Alteration (ELOHA) framework obviates the need to study each source individually; instead data already collected on the impacts of human-induced streamflow alterations is translated and applied to sites within the watershed, region, or state that have not been subject to specific study, ensuring scientific accuracy but saving time and resources. Using the scientifically-based ELOHA framework, environmental flows can be assessed and implemented at the regional level based on existing information on hydrology and biological indicators (Poff et al. 2011). This approach allows for faster integration of environmental flows into regional water resource planning and management, with a goal of minimizing ecological impacts and accelerating flow restoration projects. Using the hydrologic and ecological data collected from the study of other waterways, flow alteration-ecological response relationships are identified for waterways not studied in the past. These relationships are a correlation of ecological health with streamflow conditions, as streamflow conditions can be improved through policy implementation and management to increase the health of ecosystems (Poff et al. 2011). The ELOHA framework can be used in climate adaptation planning because the framework looks at how changes in the natural flow of a waterway, potentially induced by climate change, can affect that waterway’s ecology and how management decisions to combat climate change impacts to water supply could impact ecological health (Poff et al. 2010).

**ELOHA Framework: Scientific and Social Processes (Poff et al. 2010):**



Currently the NJDEP water use permits require a “minimum passing-flow” requirement, typically a low-flow statistic like the 7-day, 10-year low flow, which does not fully address ecological health (Kennen, Henriksen, and Nieswand 2007). NJDEP partnered with US



**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

Geological Survey (USGS) in 2007 to establish a methodology, the Hydroecological Integrity Assessment Process (HIP), to assess river segments and determine environmental flows that support ecological health. During the study, researchers developed two new software programs: the New Jersey Stream Classification Tool (NJSCT) to identify stream segments types and the New Jersey Hydrologic Assessment Tool (NJHAT) outlining the baseline hydrologic information to compare flow alterations and help determine appropriate environmental flows (Kennen, Henriksen, and Nieswand 2007). USGS and NJDEP were developing the tools and environmental flows to be incorporated into various regulatory programs, but the standards have not been adopted at the state level since their creation. The Water Supply Management Act has not been updated since 2008<sup>25</sup> and the hydroecological models were not incorporated at that time. Additionally, the NJDEP Water Supply Allocation Permit rules have not been amended since 2005<sup>26</sup>, before the USGS study was done. Work is also being done by the USGS and NJDEP to incorporate ELOHA standards into Total Maximum Daily Load (TMDL), using hydrological alteration as a surrogate for ecological impairment (Kennen et al 2013). The Highlands Regional Master Plan requires a “Low Flow Margin of Safety” to protect and in some areas restore ecological health, and the revised state Water Supply Master Plan uses this approach as well (Van Abs 2013).

The most expensive and time-intensive step in developing an ELOHA framework is the creation of a hydrologic foundation or baseline for the model (Kendy 2009). Much of this work has already been done in New Jersey through the tools developed by USGS and NJDEP. Examples of states currently using environmental flows and hydrologic foundations include the Michigan Water Withdrawal Assessment Tool, the Colorado DSS Watershed Flow Evaluation Tool and California’s CALSIM Sacramento Ecological Flows Tool (Kendy 2009).

---

<sup>25</sup> [http://www.nj.gov/dep/watersupply/pdf/njsa\\_58\\_1a\\_1.pdf](http://www.nj.gov/dep/watersupply/pdf/njsa_58_1a_1.pdf)

<sup>26</sup> [http://www.nj.gov/dep/rules/rules/njac7\\_19.pdf](http://www.nj.gov/dep/rules/rules/njac7_19.pdf)

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

## Bibliography

- Aldrich, S., Dunkle, M., & Newcomb, J. (2009). Rising Waters: Helping Hudson River Communities Adapt to Climate Change, Scenario Planning 2010-2030. Retrieved from [http://www.nature.org/media/newyork/rw\\_070509\\_exec.pdf](http://www.nature.org/media/newyork/rw_070509_exec.pdf)
- Alliance for Water Efficiency. (2012). New Jersey- 2012 State Policy Information. Retrieved from <http://www.allianceforwaterefficiency.org/New-Jersey-Policy-Info-2012.aspx>
- Associated Press. (2015, Sept 27). New Jersey working to cut into water infrastructure backlog. *The Trentonian*. Retrieved from <http://www.trentonian.com/general-news/20150927/new-jersey-working-to-cut-into-water-infrastructure-backlog>
- Behrens, C. (2007). Desalination in New Jersey; the Cape May Experience. Retrieved from <http://www.njawwa.org/njpdf/nj955d.pdf>
- Bierbaum, R. et al. (2013, March). A comprehensive review of climate adaptation in the United States: more than before, but less than needed. *Mitigation and Adaptation Strategies for Global Change (18)* 3, 361-406. Retrieved from <http://link.springer.com/article/10.1007/s11027-012-9423-1#page-1>
- Biese, A. (2012, April 9). Keansburg water gets tastier as desalination plant starts operating. *Asbury Park Press*. Retrieved from <http://archive.app.com/article/20120409/NJNEWS/304090048/Keansburg-water-gets-tastier-desalination-plant-starts-operating>
- Byrne, J. (2012, Sept 25). Emanuel: City will stick with voluntary water meters. *The Chicago Tribune*. Retrieved from [http://articles.chicagotribune.com/2012-09-25/news/chi-emanuel-city-will-stick-with-voluntary-water-meters-20120925\\_1\\_water-meters-meter-installation-free-meters](http://articles.chicagotribune.com/2012-09-25/news/chi-emanuel-city-will-stick-with-voluntary-water-meters-20120925_1_water-meters-meter-installation-free-meters)
- California Department of Water Resources. (2008). Managing an Uncertain Future: Climate Adaptation Strategies for California's Water. Retrieved from <http://www.amwa.net/galleries/climate-change/CaliforniaWhitePaper-Oct08.pdf>
- CDM Smith. (2015). Utility Climate Resiliency Study. Metropolitan North Georgia Water Planning District. Retrieved from [http://northgeorgiawater.org/wp-content/uploads/2015/05/MNGWPD\\_Utility-Climate-Resiliency-Study.pdf](http://northgeorgiawater.org/wp-content/uploads/2015/05/MNGWPD_Utility-Climate-Resiliency-Study.pdf)
- Chicago Climate Action Plan Natural Environment Adaptation Working Group. (2011). Guiding Document: Overview, Priorities, Accomplishments. Retrieved from <http://www.chicagoclimateaction.org/filebin/pdf/CCAPNaturalEnvironmentAdaptationGuidingDocumentMay2011.pdf>

**Basis and Background Document:**  
**Climate Change Adaptation in the Water Supply Sector**

- Christiansen, W. et al. (2012). The Water Efficiency and Conservation State Scorecard: An Assessment of Laws and Policies. *Alliance for Water Efficiency (AWE)*. Retrieved from <http://www.allianceforwaterefficiency.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=8306>
- City of Chicago (2010). Climate Action Plan Progress Report 2008-2009: The First Two Years. Retrieved from <http://www.chicagoclimateaction.org/filebin/pdf/CCAPProgressReportv3.pdf>
- City of Chicago (2013, Mar 11). 2012 Annual Water Use Audit Form (LMO-2) to the Illinois Department of Natural Resources. Retrieved from [http://www.cityofchicago.org/content/dam/city/depts/water/general/Engineering/LMO-2\\_2012.pdf](http://www.cityofchicago.org/content/dam/city/depts/water/general/Engineering/LMO-2_2012.pdf)
- City of Chicago. (2014). 2015 Sustainable Chicago Action Agenda Year Two Progress Report Fall 2014. Retrieved from <http://www.cityofchicago.org/content/dam/city/progs/env/SCYear2Report.pdf>
- City of New York. (2011). PlaNYC Update: A greener, greater New York. Retrieved from [http://www.nyc.gov/html/planyc/downloads/pdf/publications/planyc\\_2011\\_planyc\\_full\\_report.pdf](http://www.nyc.gov/html/planyc/downloads/pdf/publications/planyc_2011_planyc_full_report.pdf)
- City of Philadelphia. (2015a). Non-Residential Stormwater Billing. Retrieved from <http://www.phila.gov/water/wu/stormwater/Pages/NonResidentialStormwaterBilling.aspx>
- City of Philadelphia. (2015b). Residential Stormwater Billing. Retrieved from <http://www.phila.gov/water/wu/stormwater/Pages/ResidentialSWBilling.aspx>
- City of Portland Environmental Services. (2016). Stormwater Charges in Drainage Districts. Retrieved from <https://www.portlandoregon.gov/bes/59147>
- The Climate Change Clearinghouse. (2009). Northeast. *Water Research Foundation*. Retrieved from <http://www.theclimatechangeclearinghouse.org/Resources/RegionalResources/Pages/Northeast.aspx>
- Coates, M. (2012). Comparison of Costs and Operational Requirements for an Off-Stream Raw Water Storage Reservoir and an Aquifer Storage and Recovery System at the Peace River Water Treatment Facility. *Florida Water Resources Journal*, 46-50. Retrieved from <https://www.fwrj.com/techarticles/0912%20tech3.pdf>
- Combs, S. (2014). Texas Water Report: Going Deeper for the Solution. Texas Comptroller of Public Accounts. Retrieved from <http://comptroller.texas.gov/specialrpt/water/96-1746.pdf>

**Basis and Background Document:**  
**Climate Change Adaptation in the Water Supply Sector**

- Crook, J. (2015). Innovative Applications in Water Reuse: Ten Case Studies. *Water Reuse Association*. Retrieved from <https://watereuse.org/wp-content/uploads/2015/10/WRA-101.pdf>
- Diehl, T., Harris, M., Murphy, J., Hutson, S., and Ladd, D. (2013). Methods for Estimating Water Consumption for Thermoelectric Power Plants in the United States. Scientific Investigations Report 2013-5188. *USGS*. Retrieved from <http://pubs.usgs.gov/sir/2013/5188/pdf/sir2013-5188.pdf>
- Florida Department of Environmental Protection and University of Florida. (2009). Florida-Friendly Landscape Guidance Models for Ordinances, Covenants, and Restrictions. Retrieved from <http://www.dep.state.fl.us/water/nonpoint/docs/nonpoint/ffl-mo-ccr-1-09.pdf>
- Freas, K., Bailey, B., Munevar, A., & Butler, S. (2008). Incorporating climate change in water planning. *Journal American Water Works Association*, (100)6, 92-99. Retrieved from <http://www.jstor.org/stable/41312906>
- Gregg, R. M. & Hitt, J. L. (2012). *Water Supply Planning for Illinois* [Case study on a project of the Illinois State Water Survey]. Product of EcoAdapt's [State of Adaptation Program](#). Retrieved from CAKE: [www.cakex.org/case-studies/water-supply-planning-illinois](http://www.cakex.org/case-studies/water-supply-planning-illinois)
- Hansen, L., Gregg, R.M., Arroyo, V., Ellsworth, S., Jackson, L., & Snover, K. (2013). The State of Adaptation in the United States: An Overview. A report for the John D. and Catherine T. MacArthur Foundation. EcoAdapt. Retrieved from [http://resilientcities2015.iclei.org/fileadmin/RC2015/files/B3\\_ppt.Velasquez.pdf](http://resilientcities2015.iclei.org/fileadmin/RC2015/files/B3_ppt.Velasquez.pdf)
- Hayhoe, K. & Wuebbles, D. (2007) Water. *Climate Change and Chicago: Projections and Potential Impacts*. Retrieved from [http://www.chicagoclimateaction.org/filebin/pdf/report/Chicago\\_climate\\_impacts\\_report\\_Chapter\\_Three\\_Water.pdf](http://www.chicagoclimateaction.org/filebin/pdf/report/Chicago_climate_impacts_report_Chapter_Three_Water.pdf)
- Horton, R., Bader, D., Kushnir, Y., Little, C., Blake, R., and Rosenzweig, C. (2015). Climate Observations and Projections. New York City Panel on Climate Change 2015 Report. *Ann. New York Acad. Sci.*, (1336), 18-35. Retrieved from <http://onlinelibrary.wiley.com/doi/10.1111/nyas.12586/epdf>
- Horton, R., Gornitz, V., Bowman, M., & Blake, R. (2010). Climate observations and projections. *Ann. New York Acad. Sci.*, (1196), 41-62. doi:10.1111/j.1749-6632.2009.05314.x. Retrieved from <http://pubs.giss.nasa.gov/abs/ho08400z.html>
- Institute for Sustainable Communities (2014). Integrating Climate Change & Water Supply Planning In Southeast Florida. Southeast Florida Regional Climate Change Compact Implementation Guidance Series. Retrieved from <https://southeastfloridaclimatecompact.files.wordpress.com/2014/06/rcap-igd-water-supply-final-v-3.pdf>

**Basis and Background Document:**  
**Climate Change Adaptation in the Water Supply Sector**

- Johnson, M., and Scott, J. (2015 Oct 20). Start Saving Water Now—ICC, ASHRAE Publish New Code Resource For Water Efficiency. *ASHRAE*. Retrieved from <https://www.ashrae.org/news/2015/start-saving-water-now-icc-ashrae-publish-new-code-resource-for-water-efficiency>
- Kendy, E. (2009). ELOHA: A New Framework for Determining and Managing Environmental Flows Over Large Regions. *The Nature Conservancy*. Retrieved from <https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/ELOHA/Documents/ELOHA%20overview-full%20w%20basic%20eflows.ppt>
- Kousky, Carolyn et al. (2011). The Role of Land Use in Adaptation to Increased Precipitation and Flooding: A Case Study in Wisconsin's Lower Fox River Basin. Retrieved from [http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-Rpt-Kousky%20etal%20GreatLakes%20\(2\).pdf](http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-Rpt-Kousky%20etal%20GreatLakes%20(2).pdf)
- Kennen, J., Henriksen, J., & Nieswand, S. (2007). Development of the Hydroecological Integrity Assessment Process for Determining Environmental Flows for New Jersey Streams. Scientific Investigations Report 2007-5206. *USGS*. Retrieved from <http://pubs.usgs.gov/sir/2007/5206/pdf/sir2007-5206-508.pdf>
- Kennen, J., Riskin, M., Reilly, P. & Colarullo, S. (2013). Method to Support Total Maximum Daily Load Development Using Hydrologic Alteration as a Surrogate to Address Aquatic-Life Impairment in New Jersey Streams. Scientific Investigations Report 2013–5089. *USGS*.
- Klein, G. (2005). California's Water – Energy Relationship, Final Staff Report. California Energy Commission. Retrieved from <http://energy.ca.gov/2005publications/CEC-700-2005-011/CEC-700-2005-011-SF.PDF>
- Metropolitan Water District of Southern California. (2015a). Turf Removal: Program Overview, Commercial Rebates. Retrieved from [http://socalwatersmart.com/commercial/?page\\_id=3085](http://socalwatersmart.com/commercial/?page_id=3085)
- Metropolitan Water District of Southern California. (2015b). Turf Removal: Program Overview, Residential Rebates. Retrieved from [http://socalwatersmart.com/?page\\_id=2967](http://socalwatersmart.com/?page_id=2967)
- Miller, K. & Yates, D. (2005). Climate Change and Water Resources: A Primer for Municipal Water Providers. *AWWA Research Foundation*. Retrieved from [http://www.isse.ucar.edu/water\\_conference/fulltext/ClimateChange\\_Final.pdf](http://www.isse.ucar.edu/water_conference/fulltext/ClimateChange_Final.pdf)
- Miller, R.B., G.A. Fox, C. Penn, S. Wilson, A. Parnell, R.A. Purvis, and K. Criswell. (2014). Estimating sediment and phosphorus loads from streambanks with and without riparian protection. *Agriculture, Ecosystems, and Environment (189)*, 70-81. doi: 10.1016/j.agee.2014.03.016. Retrieved from <http://www.sciencedirect.com/science/article/pii/S0167880914001352>

**Basis and Background Document:  
Climate Change Adaptation in the Water Supply Sector**

- Massachusetts Climate Change Adaptation Advisory Committee. (2011). Massachusetts Climate Change Adaptation Report. Retrieved from <http://www.mass.gov/eea/docs/eea/energy/cca/eea-climate-adaptation-report.pdf>
- Meyer, Scott C. et al. (2012). Northeastern Illinois Water Supply Planning Investigations: Opportunities and Challenges of Meeting Water Demand in Northeastern Illinois. Retrieved from <http://www.isws.illinois.edu/pubdoc/CR/ISWSCR2012-03sum.pdf>
- New Jersey Department of Environmental Protection. (2011). Outdoor Landscape Water Conservation Model Ordinance Description. Retrieved from [http://www.sustainablejersey.com/fileadmin/media/Actions\\_and\\_Certification/Actions/NaturalResources/WaterConservationModelOrdinance.doc](http://www.sustainablejersey.com/fileadmin/media/Actions_and_Certification/Actions/NaturalResources/WaterConservationModelOrdinance.doc)
- New Jersey Department of Environmental Protection Office of Science. (2012). Water Supply. *Environmental Trends Report*. Retrieved from <http://www.nj.gov/dep/dsr/trends/pdfs/watersupply.pdf>
- New Jersey Department of Labor and Workforce Development. (2012). Population and Labor Force Projections for New Jersey: 2010 to 2030. Retrieved from <http://lwd.state.nj.us/labor/lpa/dmograph/lfproj/sptabl.htm>
- New Jersey Water Savers. (2015). The Need for Water Conservation. Retrieved from <http://njwatersavers.rutgers.edu/The%20Need%20for%20Water%20Conservation.html>
- New Jersey Water Supply Authority. (2016). Source Water Protection. Retrieved from <http://www.njwsa.org/html/preservation.html>
- New York City Department of Environmental Protection. (2014). Toilet Replacement Program (TRP) FAQs. Retrieved from [http://www.nyc.gov/html/dep/html/ways\\_to\\_save\\_water/toilet\\_replacement\\_program\\_faq.shtml](http://www.nyc.gov/html/dep/html/ways_to_save_water/toilet_replacement_program_faq.shtml)
- Ntelekos, A. A., Oppenheimer, M., Smith, J. A., & Miller, A. J. (2010). Urbanization, climate change and flood policy in the United States. *Climatic Change* 103(3), 597-616. DOI: 10.1007/s10584-009-9789-6. Retrieved from <http://www.learningace.com/doc/5902392/071bd963e0b64625ffc086a5fa16ff29/ntelekos-et-al-2010-urbanization-climate-change-and-flood-policy-in-the-united-states>
- Philadelphia Water Department. (2016). Green Stormwater Infrastructure Programs. Retrieved from [http://www.phillywatersheds.org/what\\_were\\_doing/green\\_infrastructure/programs](http://www.phillywatersheds.org/what_were_doing/green_infrastructure/programs)
- Poff, L. et al. (2010). The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards. *Freshwater Biology* (55) 3, 147-



**Basis and Background Document:**  
**Climate Change Adaptation in the Water Supply Sector**

170. Retrieved from <http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2427.2009.02204.x/pdf>
- Poff, L., et al. (2011, July 7). Ecological Limits of Hydrologic Alteration: Environmental Flows for Regional Water Management. Retrieved from [https://www.conservationgateway.org/Documents/brochure-english\(1\).pdf](https://www.conservationgateway.org/Documents/brochure-english(1).pdf)
- Rosenzweig, C. et al. (2007, April 3) Managing climate change risks in New York City's water system: Assessment and adaptation planning. *Mitig. Adapt. Strategies Global Change* (12), 1391-1409, doi:10.1007/s11027-006-9070-5.
- Schaefer, S.C. & M. Alber. (2007). Temperature controls a latitudinal gradient in the proportion of watershed nitrogen exported to coastal systems. *Biogeochemistry* (85), 333-346.
- Seavy, N., Gardali, T., Golet, G., Griggs, F., Howell, C., Kelsey, R., Small, S., Viers, J., and Weigand, J. (2009). Why Climate Change Makes Riparian Restoration More Important than Ever: Recommendations for Practice and Research. *Ecological Restoration* (27) 3, 330-338. Retrieved from [http://www.remarkableriparian.org/pdfs/pubs/Climate\\_Change\\_Riparian\\_Restoration.pdf](http://www.remarkableriparian.org/pdfs/pubs/Climate_Change_Riparian_Restoration.pdf)
- Shaw, S. et al. (2011). Water Resources. *Responding to Climate Change in New York State*, 79-120. New York State Energy Research and Development Authority. Retrieved from <http://www.nysrerda.ny.gov/-/media/Files/Publications/Research/Environmental/EMEP/climaid/ClimAID-Water-Resources.pdf>
- Sustainable Jersey. (2015). Participating Communities. Retrieved from <http://www.sustainablejersey.com/actions-certification/participating-communities/>
- Taylor, D. (2012, April 9). Locals Tout Improved Water Quality After Desalination. *NJTV News*. Retrieved from <http://www.njtvonline.org/news/video/locals-tout-improved-water-quality-after-desalination/>
- U.S. Climate and Natural Resources Working Group (CNRWG). The U.S. Council on Climate Preparedness and Resilience. (2014). Priority Agenda: Enhancing the Climate Resilience of America's Natural Resources. Retrieved from [http://www.whitehouse.gov/sites/default/files/docs/enhancing\\_climate\\_resilience\\_of\\_americas\\_natural\\_resources.pdf](http://www.whitehouse.gov/sites/default/files/docs/enhancing_climate_resilience_of_americas_natural_resources.pdf)
- U.S. Environmental Protection Agency. (2012). Climate Ready Utilities Adaptation Strategies Guide. Retrieved from <http://water.epa.gov/infrastructure/watersecurity/climate/upload/epa817k11003.pdf>
- U.S. Environmental Protection Agency Climate Ready Water Utilities. (2015, July 15). Camden, New Jersey: Water Utility Climate Adaptation Planning. Retrieved from <https://www.youtube.com/watch?v=w9Omq3ZMQg&feature=youtu.be>

**Basis and Background Document:**  
**Climate Change Adaptation in the Water Supply Sector**

- U.S. Environmental Protection Agency Water Sense. (2010). New Jersey Water Fact Sheet. Retrieved from [http://www3.epa.gov/watersense/docs/new\\_jersey\\_state\\_fact\\_sheet.pdf](http://www3.epa.gov/watersense/docs/new_jersey_state_fact_sheet.pdf)
- U.S. Global Change Research Program. (2009). Global Climate Change Impacts in the United States. Retrieved from <https://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf>
- U.S. Green Building Council. (2015). LEED BD+C: New Construction, v4- LEED v4: Water Efficiency. Retrieved from <http://www.usgbc.org/credits/new-construction/v4/water-efficiency>
- U.S. Interagency Climate Change Adaptation Taskforce. (2011). National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate. Retrieved from [https://www.whitehouse.gov/sites/default/files/microsites/ceq/2011\\_national\\_action\\_plan.pdf](https://www.whitehouse.gov/sites/default/files/microsites/ceq/2011_national_action_plan.pdf)
- U.S. Water Resources and Climate Change Adaptation Workgroup (2015). 2014 Highlights of Progress and 2015 Implementation Plan for the National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate. Council on Climate Change Preparedness and Resilience. Retrieved from [http://acwi.gov/climate\\_wkg/nap\\_fy1415-version9\\_hw\\_clean\\_final508c.pdf](http://acwi.gov/climate_wkg/nap_fy1415-version9_hw_clean_final508c.pdf)
- Van Abs, D. (2013). Water Resources Baseline Assessment Report. *Together North Jersey/ NJ Future*. Retrieved from <http://togethernorthjersey.com/wp-content/uploads/2013/11/Water-Resources-Baseline-Report-Final-Clean-11Sept2013-small.pdf>
- Virginia Department of Conservation and Recreation. (2015). Virginia's Conservation Reserve Enhancement Program. Retrieved from <http://www.dcr.virginia.gov/soil-and-water/crep>
- Wallis, M.J., Ambrose, M.R., & Chan, C.C. (2008). Climate Change: Charting a water course in an uncertain future. *Journal American Water Works Association*, (100)6, 70-79. Retrieved from <http://www.jstor.org/stable/41312904>
- Water Research Foundation. (2009). Integrated Water Resource Management. Retrieved from <http://www.theclimatechangeclearinghouse.org/UtilityOperations/IWRM/Pages/default.aspx>
- Zimmerman, R. and Faris, C. (2010). Chapter 4: Infrastructure impacts and adaptation challenges. *Annals of the New York Academy of Sciences*, 1196: 63–86. doi: 10.1111/j.1749-6632.2009.05318.x Retrieved from <http://onlinelibrary.wiley.com/doi/10.1111/j.1749-6632.2009.05318.x/epdf>