NATIONAL INFRASTRUCTURE ADVISORY COUNCIL

WATER SECTOR RESILIENCE FINAL REPORT AND RECOMMENDATIONS

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ABOUT THE NIAC

The National Infrastructure Advisory Council (NIAC) provides the President of the United States with advice on the security and resilience of the critical infrastructure sectors and their functional systems, physical assets, and cyber networks. These critical infrastructure sectors span the U.S. economy and include the Water; Chemical; Commercial Facilities; Communications; Critical Manufacturing; Dams; Defense Industrial Base; Emergency Services; Energy; Financial Services; Food and Agriculture; Government Facilities; Healthcare and Public Health; Information Technology; Nuclear Reactors, Materials, and Waste; and Transportation Systems Sectors. The NIAC also advises the lead Federal agencies that have critical infrastructure responsibilities. Specifically, the Council has been charged with making recommendations to:

- Enhance the partnership of the public and private sectors in securing and enhancing the security and resilience of critical infrastructure and their functional systems, physical assets, and cyber networks, and provide reports on this issue to the President through the Secretary of Homeland Security, as appropriate.
- Propose and develop ways to encourage private industry to perform periodic risk assessments and implement risk-reduction programs.
- Monitor the development and operations of critical infrastructure sector coordinating councils and their information-sharing mechanisms, and provide recommendations to the President through the Secretary of Homeland Security on how these organizations can best foster improved cooperation among the sectors, the U.S. Department of Homeland Security, and other Federal Government entities.
- Report to the President through the Secretary of Homeland Security, who shall ensure appropriate coordination with the Assistant to the President for Homeland Security and Counterterrorism, the Assistant to the President for Economic Policy, and the Assistant to the President for National Security Affairs.
- Advise Sector-Specific agencies with critical infrastructure responsibilities, to include issues pertaining to sector and government coordinating councils and their information-sharing mechanisms.

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EXECUTIVE SUMMARY

Water is often called our most precious resource, and with good reason— clean drinking water and wastewater treatment services[1] sustain core functions of critical infrastructure, communities, and human life itself. Without water services, factories shut down, hospitals close, communities are disrupted, and most hotels, restaurants, and businesses cease operations. Water is a lifeline sector that serves businesses and communities on a daily basis and brings them back to normal after a disaster, which makes maintaining water services and quickly restoring them a priority. Because the sector has a track record of reliable service with few major disruptions, the infrastructure that delivers water often goes unnoticed and undervalued by decision-makers and the public-at-large.

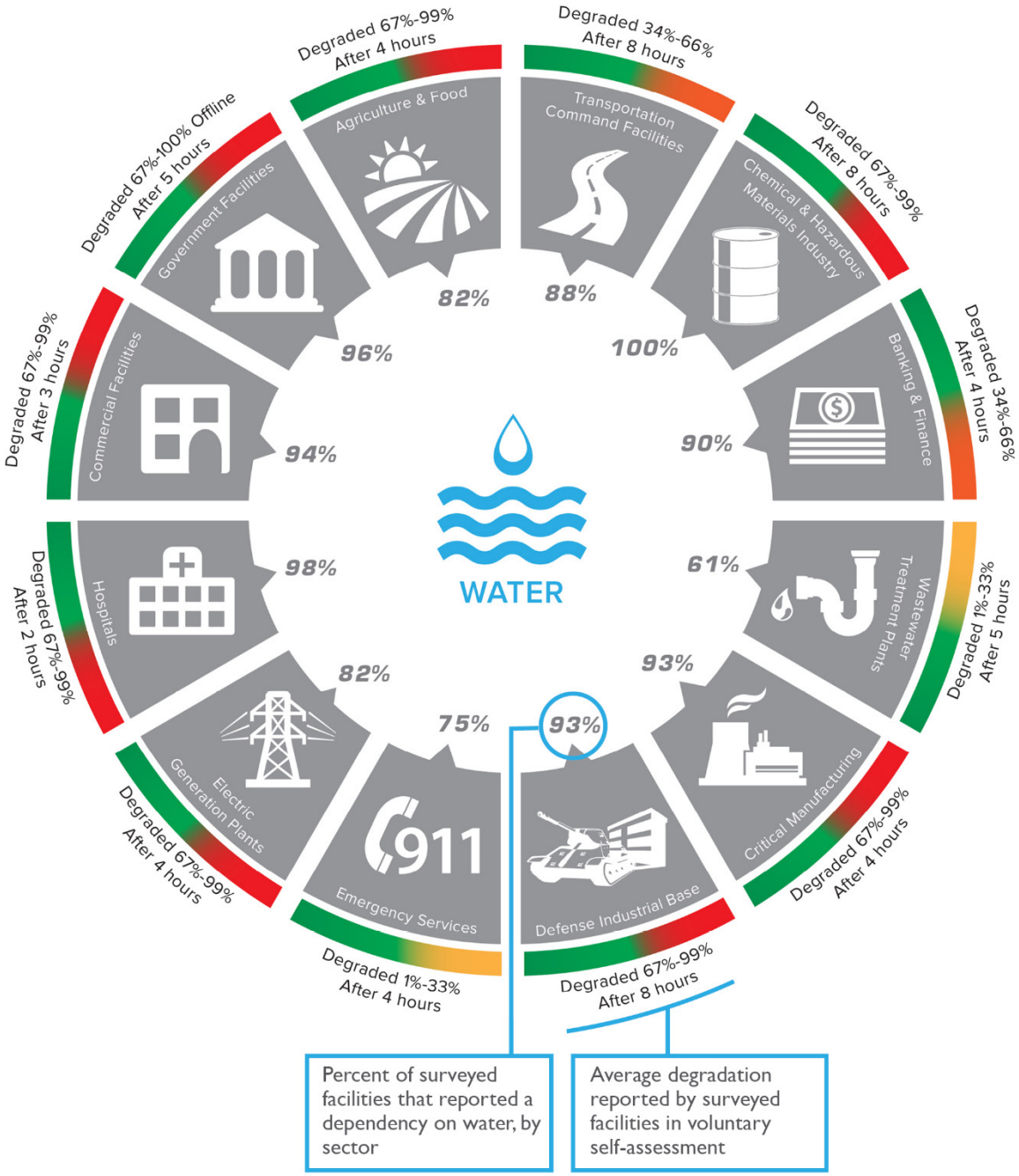
The National Infrastructure Advisory Council (NIAC) was asked to 1) assess security and resilience in the Water Sector, 2) uncover key water resilience issues, and 3) identify potential opportunities to address these issues. The Council formed a NIAC Working Group to examine water resilience using the framework developed in the NIAC's 2010 study on establishing resilience goals. This six-member group of NIAC members examined national-level issues related to water infrastructure systems based upon each of their own unique experience from across a myriad of sectors, numerous specific interviews with subject matter experts, and valuable input from the Study Group, support the findings and recommendations in the report.

> "What happened here is just an extreme example, an extreme and tragic case of what's happening in a lot of places around the country. We've seen unacceptably high levels of lead in townships along the Jersey Shore and in North Carolina's major cities. We've seen it in the capitals of South Carolina and Mississippi. And even, not long ago, lead-contaminated drinking water was found right down the street from the United States Capitol. So Flint is just a tip of the iceberg in terms of us reinvesting in our communities."
>
> *President Barack Obama, May 4, 2016 in Flint, Michigan*

The crisis in Flint, Michigan reveals how a loss of safe drinking water in a compromised water infrastructure can devastate a community. Yet this tragedy belies another critical risk: the loss of water services can cripple other critical infrastructures and trigger additional disruptions. An analysis of vulnerability assessments conducted by the U.S. Department of Homeland Security (DHS) Office of Cyber and Infrastructure Analysis (OCIA) revealed that among surveyed critical infrastructure that depend upon water for core operations, services are degraded 50 percent or more within eight hours of losing drinking water services (Exhibit ES-1).[2] The same holds true for a loss of wastewater treatment services. For example, the OCIA analysis noted that nearly all hospital functions could be degraded within two hours due to a loss of external wastewater discharge services. Yet, many infrastructure owners and operators do not have alternative sources of water or wastewater services. As a result, the full consequences of cascading failures from extended water service disruptions in critical sectors are not well understood.

[1] "Water services" are used throughout this report to refer to both drinking water and wastewater treatment services. It does not include upstream water resources and separate storm water systems. Chapter I. Introduction, Section A. Framing the Study describes the scope of this study in detail.
[2] DHS OCIA, *Sector Resilience Report*, 2014.

Exhibit ES-1. Critical Infrastructure Dependence on Water and Potential Function Degradation Following Loss of Water Services[3]



[3] The information provided in the graphic is based on a limited sample of 2,661 voluntary facility assessments conducted between January 2011 and April 2014 (DHS OCIA, *Sector Resilience Report*, 2014). (See pages 19-20 for more information.)

This study builds on the insights gained in our previous studies of resilience in the lifeline sectors of electricity and transportation. Although the Council found many similarities in the challenges, root causes, and opportunities facing these sectors, we also uncovered distinct challenges that the Nation's water infrastructure faces in building a more resilient sector:

- Community water systems are not typically connected to adjacent systems, unlike electricity and transportation infrastructure, which are interconnected into national networks.
- Roughly 85 percent of all water and wastewater systems are publicly owned and operated by municipalities and most are small; more than 80 percent of community water systems and publicly owned treatment works serve populations of less than 3,300.
- Most State and municipal decision-makers are constrained by long-held expectations by customers for water as a low-cost, affordable service that does not account for true life-cycle costs.
- Nearly all water infrastructure assets are out of sight and historically reliable, leading to an underappreciation of the criticality of water services and the infrastructure that deliver them.
- Like other sectors, water has an aging infrastructure that requires massive reinvestment to upgrade pipes, mains, and equipment. Many assets are nearing or beyond their expected lifespan, leading to roughly 240,000 water main breaks and between 23,000 and 75,000 sanitary sewage overflows per year in the United States. The estimated investment gap ranges from about $400 billion to nearly $1 trillion to maintain current levels of water service.
- Unlike the Energy and Transportation Sectors, which each have a Federal department and Cabinet position dedicated to their sectors and infrastructure, water has no corresponding Federal department dedicated to its sector. The U.S. Environmental Protection Agency (EPA), which serves as the Sector-Specific Agency (SSA) for the Water Sector, regulates and enforces the Clean Water Act and the Safe Water Drinking Act. While it has programs designed to improve the security and resilience of the Nation's drinking water and wastewater infrastructure, its primary mission is ensuring water quality.

WHAT WE FOUND

The affordability of systems—the ability of providers and their ratepayers to develop and maintain needed capabilities—is a cornerstone resilience issue. Too many jurisdictions do not account for the full life-cycle cost of building, maintaining, upgrading, and replacing systems; or are unable or unwilling to raise rates to pay for needed investment. Rates may simply reflect the least-cost path of patch and repair, ignoring longer-term problems and consequences, even under nonstressed conditions.

Over the course of this study, the importance of water services was underscored by the crisis that unfolded in Flint, Michigan. While the contamination of the Flint water supply was not the direct result of a failure in infrastructure resilience—and therefore beyond the direct scope of this study—it reveals the impact that compromised water services can have on communities, government, and families, and the breakdown in trust that Americans have placed in our water infrastructure.

Our findings highlight the criticality of water services, the need to address emerging risks, and the significant challenge of funding needed improvements to water and wastewater infrastructure.

- **Poor Understanding of the Criticality of the Water Sector**: The Water Sector is facing a dynamic and complex risk environment in which the full impacts of water disruptions and the potential cascading impacts are not fully understood among critical infrastructure operators, local and State leaders, and water service customers. As such, water and wastewater services are receiving inadequate attention in disaster planning, prevention, and response among public officials and dependent sectors.
- **Inadequate Valuation of Water Services**: Water services are often taken for granted because they have been highly reliable, inexpensive, and hidden from view. This makes it difficult to gain public support for needed upgrades and for decision-makers to justify rate increases needed to fund infrastructure improvements.
- **Wide Disparity of Capabilities and Resources**: Water utilities face a challenging risk environment for which many lack the required technical and financial capabilities to address all emerging risks, such as cyber risks. Utilities, especially small municipal agencies, often lack sufficient resources—including qualified staff, tools, and access to technical expertise and reliable information—to manage new risks.
- **Significant Underinvestment in Water Sector Resilience**: The large portion of public ownership within the sector and the current regulatory structure hinders long-term investment in resilient water infrastructure. Decaying infrastructure is mostly unseen, and problems are not elevated in the public eye until there are major failures.
- **Fragmented and Weak Federal Support for Water Resilience**: Resilience has not been substantially integrated into the actions of Federal agencies and resilient outcomes are typically not part of Federal programs and resources.
- **Regional Collaboration Not Broadly Applied:** Poor cross-jurisdictional collaboration can lead to stovepiped decisions that can be counterproductive to effective emergency response and recovery.

RECOMMENDATIONS

The Council recommends the following steps to improve resilience in the Water Sector. For each recommendation, we have identified specific actions that the Federal Government should take to implement these recommendations. (Chapter V. Findings and Recommendations, starting on page 35, includes a complete description of the recommendations and specific actions.)

Recommendation 1 — Analyze and map the complex risks of major water disruptions and develop mitigations.

The Federal Government should assist owners and operators in the Water Sector to uncover emerging cross-sector risks and develop mitigations for disruptions that could cascade into other sectors and regions or have the potential for national consequences. The Federal Government should commit funding and expert resources to help identify, analyze, and map

hidden risks that result from complex sector interdependencies, regional interconnections, and increased convergence of physical-cyber systems.

Recommendation 2 **Fortify Water Sector response and recovery capabilities.**

The Water Sector has a good track record of maintaining continuity of service and rapid response and recovery. However, because of the criticality of water and wastewater services, the Federal Government should take immediate actions to formalize and improve the response and recovery capabilities at every level of the Water Sector. The Federal Government should increase planning for extreme events, consolidate Federal response responsibilities, and increase funding for successful sector mutual aid efforts.

Recommendation 3 **Increase Federal funding, investment, and incentives to improve water infrastructure resilience.**

The Federal Government should establish new funding mechanisms, structures, and incentives to increase investment in resilience at the regional and local levels to counter historic underinvestment in infrastructure, and to remove obstacles that public agencies face in increasing rates, particularly when it impacts low-income communities.

Recommendation 4 **Increase technical and financial resources and expertise available to the Water Sector.**

The Federal Government should work with larger, well-resourced utilities to improve the technical and financial capabilities of smaller and less-resourced utilities by creating programs that link regional technical resources to local water utilities, and leverage established programs, expertise, and capabilities of universities. The Federal Government should also assist national and regional water associations to expand outreach to utilities to improve access to valuable tools and models. These efforts should emphasize improving the cybersecurity capabilities of water utilities that have limited cyber capacity.

Recommendation 5 **Strengthen Federal leadership, coordination, and support for Water Sector resilience.**

The President should strengthen Federal leadership on water infrastructure issues by directing a coordinated effort across Federal agencies to raise awareness about the importance of water, leveraging investment to create job opportunities and inclusion for local communities, and identifying and removing legal, regulatory, and policy barriers that impede investment and implementation of resilient measures.

MOVING FORWARD

The Council confirms what we found in our four previous studies of resilience: much of our most critical national infrastructure is crumbling and in major need of renewal and increased investment. The Water Sector is no different. Flint provides a stark example of what can happen to distort decision-making when resources are inadequate to do the job. But the same holds true for almost every major infrastructure failure in recent years—New Orleans levee breaches, Minnesota bridge

collapse, Washington Metro fires; they were all exacerbated by a lack of investment in system preservation.

Simply put, we have failed to make reinvestment in our infrastructure a top national priority. The condition of our infrastructure seriously lags behind in an increasingly competitive global economy, but we have been unable to generate the overall public interest, support, and political will to reinvigorate it. We have failed to recognize that investment in our infrastructure is also an investment in our people, our communities, and our economy. Cities and communities across the country face chronic unemployment and under employment, inequality, and affordability challenges that require urgent national action. Special attention must also be given to our most vulnerable populations in high needs communities. The weak levees in New Orleans and the corroding lead pipes in Flint drive home important lessons about the need for public/community engagement, greater accountability/transparency, and expanded partnerships in building and operating critical infrastructures.

New investments in smart, sustainable, resilient infrastructure is a catalyst for job creation, economic competitiveness, and an equitable and shared prosperity. To be sure, the risks are complex, the investments required are massive, and the task exceeds the capabilities of any one company, sector, or government agency. But we are beginning to see local support for ballot measures for major infrastructure investments, and projects at the local level that actively engage local communities, including a host of partners—business, government, community advocates, education, labor, and philanthropic organizations.

A great deal needs to be done to strengthen the security and resilience of critical infrastructure. Although much of the responsibility rests with the owners and operators who design, build, operate, maintain, and repair the infrastructure, the Federal and State governments are critical partners in this endeavor. Federal and State governments must make it easier for the owners and operators to invest in infrastructure improvements; they must identify and remove regulatory barriers that inhibit resilient behavior; they must help to identify and mitigate cross-sector risks that hide between the seams of interdependent sectors and regions; they must develop measurable standards and best practices to guide water agencies in their resilience efforts; they must leverage the science and engineering resources of national laboratories and universities to develop innovative technologies and bring them to market; and they must strengthen leadership and coordination among agencies across all levels of government. We believe this study, along with our previous ones, provides a practical template for action that can help ensure the long-term security and economic prosperity of the Nation's critical infrastructure.

I. INTRODUCTION

The National Infrastructure Advisory Council (NIAC)—a Federal advisory committee that advises the President on issues relating to the security and resilience of the Nation's critical infrastructure sectors and their supporting information systems—was charged with examining the resilience of the Water Sector in September 2015. Specifically, the NIAC was asked to 1) assess security and resilience in the Water Sector, 2) uncover key water resilience issues, and 3) identify potential opportunities to address these issues. The study found that many security measures—as defined in *Presidential Policy Directive 21 (PPD-21): Critical Infrastructure Security and Resilience*—are embedded in good resilience practices. Accordingly, the resilience focus of the report encompasses many aspects of security, defined in PPD-21 as "reducing the risk to critical infrastructure by physical means or defined cyber measures."[4]

This report presents the Council's findings and recommendations to the President, highlighting opportunities for the Federal Government to address key water resilience issues. Over the past seven years, the NIAC has examined resilience in four previous studies. In this work, the Council defined infrastructure resilience as "the ability to reduce the magnitude and/or duration of disruptive events" as determined by the "ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event." This definition directly parallels the definition in PPD-21: "the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions."[5] Simply put, resilient systems lose fewer functions during a disruption and require less time and resources to recover to normal operations.

NIAC AND RESILIENCE: A FOUNDATION FOR COLLABORATIVE SUCCESS

The NIAC examined resilience needs and practices, developing distinct recommendations in four studies:

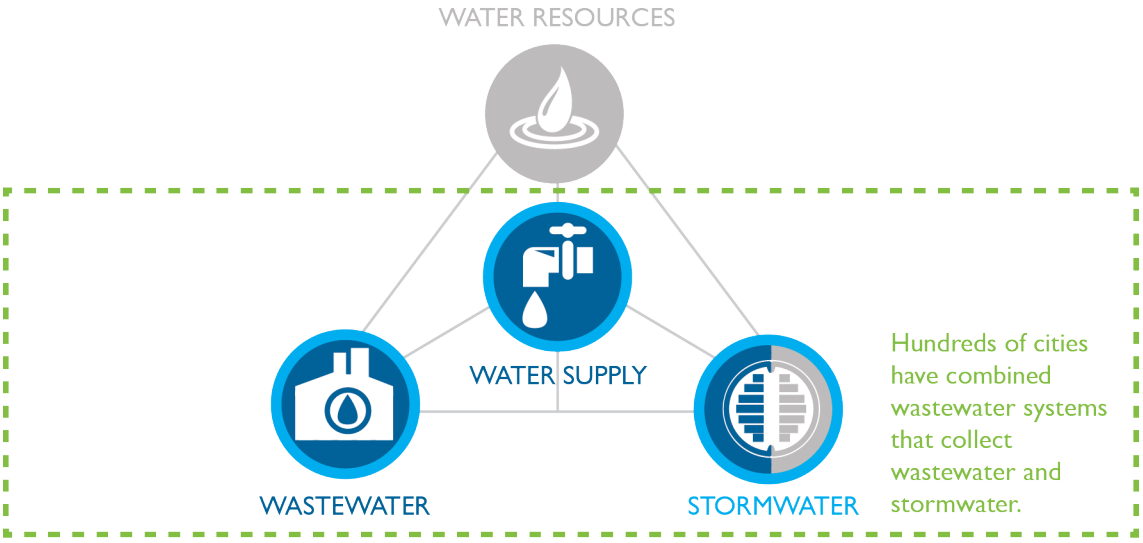
- *Critical Infrastructure Resilience* (October 2009) examined steps government and industry should take to best integrate resilience and protection into a comprehensive risk-management strategy.
- *A Framework for Establishing Critical Infrastructure Resilience Goals* (October 2010) developed a process framework for setting, testing, and improving resilience goals in the Electricity Sector that can be broadly applied to all lifeline sectors.
- *Strengthening Regional Resilience* (October 2013) examined the characteristics of critical infrastructure resilience in mitigating regional disruptions, finding that resilience in the lifeline sectors—energy, communication, water, and transportation—is particularly critical.
- *Transportation Sector Resilience* (July 2015) identified key actions that the Federal Government should take to strengthen the resilience of the Transportation Sector.

[4] The White House, PPD-21, 2013.
[5] Ibid.

A. FRAMING THE STUDY

Water infrastructure consists of the physical and cyber assets of drinking water and wastewater systems, as defined by Homeland Security Presidential Directive 7 (HSPD-7), the *2013 National Infrastructure Protection Plan* (NIPP 2013), and the *2015 Water and Wastewater Systems Sector-Specific Plan* (2015 SSP).[6] Exhibit I-1 illustrates the scope of the study, limiting the focus to water supply and wastewater, and indirectly stormwater as it affects combined wastewater treatment.

Exhibit I-1. Scope of NIAC Water Resilience Study



While water resources are critical, this study focused on the resilience of the Nation's water delivery infrastructure, rather than on the sufficiency of water resources. The Nation faces many water resource issues, including the drought in California, potential water shortages in the Southwest, and balancing flood control and water needs. These are all critical issues that impact the Water Sector, but are outside the direct scope of this study.

B. STUDY RESOURCES AND ACTIVITIES

To conduct this study, the Council formed the Water Resilience Working Group, consisting of NIAC members, to examine water resilience using the framework developed in our 2010 study on establishing resilience goals in the Electricity Sector. This six-member group of NIAC members convened to examine national-level issues related to water infrastructure systems based upon each of their own unique experience from across a myriad of sectors. The collective insights gained from the Working Group's expertise, extensive subject matter expert interviews, literature reviews, and findings and conclusions provided to the Working Group by a supporting Study Group—convened by the Working Group to look at specific technical, financial, and operational issues—provides the confidence that the Council's findings and recommendations are well grounded.

[6] The White House, HSPD-7, 2003; DHS, *NIPP 2013*, 2013; and EPA, *2015 SSP,* 2016.

More than 70 subject matter experts (SMEs) were interviewed as part of the study, representing a mix of utilities of different sizes, geographic locations, water association staff and members, consultants and academics, and representatives from government agencies with a role in in the Water Sector. These SMEs contributed knowledge about utility operations, sector risks, dependencies, planning and investments, severe weather, emergency management, cybersecurity, next-generation resilience, and financial solutions. Additional information can be found in appendices at the end of the report:

- Appendix A. Acknowledgements — A list of all study contributors and subject matter experts interviewed.
- Appendix B. Compendium of Information from Subject Matter Experts — A synopsis of the information provided during interviews.
- Appendix C. Disruption Scenario Case Study — An overview of the five disruptions evaluated by the Study Group.
- Appendix D. Study Group Findings and Conclusions — A list of the findings and conclusions developed by the Study Group.
- Appendix E. Compendium of Prior Recommendations — A review of prior recommendations and other sources most relevant to this study.

> "Water challenges are facing communities and regions across the United States, impacting millions of lives and costing billions of dollars in damages. Recent events, including record-breaking drought in the West, severe flooding in the Southeast, and the water-quality crisis in Flint, MI, have elevated a national dialogue on the state of our Nation's water resources and infrastructure. This dialogue is increasingly important as a growing population and changing climate continue to exacerbate water challenges."
>
> *The Executive Office of the President, Commitments to Action on Building a Sustainable Water Future, March 22, 2016*

II. WATER SECTOR OPERATIONAL SNAPSHOT

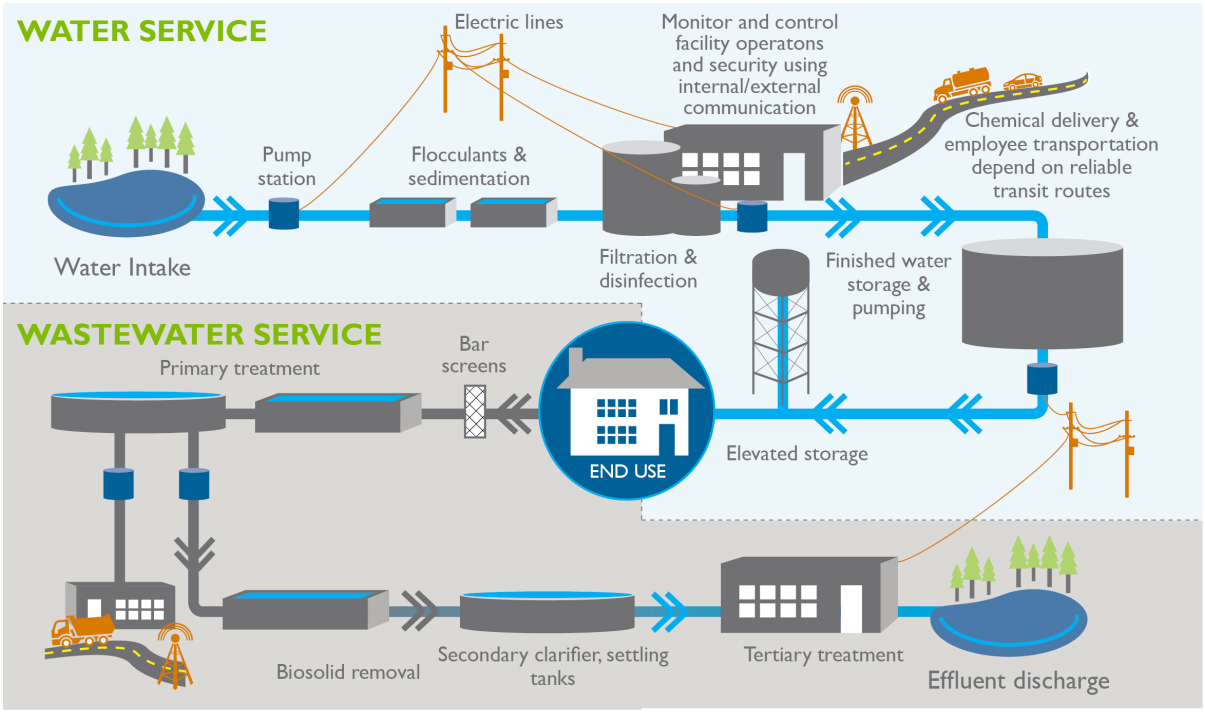
Most people do not think about what it takes for them to have clean water flow from their tap and wastewater removed. But these water and wastewater services rely on a vast network of infrastructure and assets from the pipes, water mains, and treatment plants; skilled facility employees; and information and technology networks that enable monitoring and communication. This Chapter provides a brief overview of the Water Sector.

A. KEY ASPECTS OF THE WATER SECTOR

There are thousands of water and wastewater treatment facilities in the United States, but the majority of the population is served by a small percentage of mostly large or very large systems. While individual utilities vary widely in size and complexity, Exhibit II-1 shows a typical design of both water and wastewater systems under normal operations.

Water and wastewater systems are predominantly owned and operated by municipal entities. In 2014, public entities provided water service to about 87 percent of people served by piped water.[7] This is consistent with surveys done by the U.S. Environmental Protection Agency (EPA) that found that most people receive their water from large, publicly owned community water systems.

Exhibit II-1. Typical Water and Wastewater Services Operation



[7] Food and Water Watch, *State of Public Water*, 2016.

WATER SECTOR SNAPSHOT

ASSETS & INFRASTRUCTURE

Water Supply

There are approximately **153,000 Public Water Systems** (PWSs) in the United States. PWSs provide **water for human consumption** through pipes and other constructed conveyances.

Community Water Systems (CWS)

A CWS is a PWS that provides residential water. **Less than 20% of CWSs serve 92% of the population that receive water from CWSs.** The remaining 8% of the population are served by CWSs that serve less than 3,300 people. The majority of CWSs are publicly owned. About 16% are privately owned and about 2,000 government entities contract with private companies. **There are more than 51,000 CWSs in the United States.**

Non-Transient Non-Community Water Systems

Schools, factories, office buildings, and hospitals that have their own water systems fall under this category. There are more than 18,000 of these systems.

Transient Non-Community Water Systems

Gas stations, campgrounds, or other places where people do not remain for long periods of time. There are approximately 84,000 of these systems.

Wastewater

Wastewater is predominantly treated by publicly owned treatment works. There are a small number of private facilities such as industrial plants.

Publicly Owned Treatment Works (POTW)

There are more than 16,500 POTWs in the United States. These systems provide wastewater service and treatment to more than 227 million people. POTWs are generally designed to treat domestic sewage, but some receive wastewater from industrial users. 79% of POTWs treat less than 1 million gallons per day and provide treatment to less than 23 million people (approximately 10% of the population served by POTWs).

Combined Sewer Systems (CSSs)

CSSs collect stormwater, domestic sewage, and industrial wastewater in the same pipe to transport it to a wastewater treatment facility. In general, CSSs have not been constructed since the mid-20th century and many existing CSSs are looking for ways to separate stormwater and wastewater. **CSSs serve approximately 40 million people in 772 communities.**

ELEMENTS OF WATER SERVICES

Water and wastewater utility assets can be characterized as physical, cyber, and human. The extent of these assets varies dramatically by utilities.

Physical

- Pipes and Related Components for Collection and Conveyance
- Treatment Facilities
- Distribution/Discharge Systems
- Sensors and Monitoring Systems

Cyber

- Industrial Control Systems
- Process Systems and Operational Controls
- Enterprise Systems

Note: Individual drinking water utilities will differ in the types of components used;

Human

- Personnel Availability and Capabilities
- Workforce Training and Education
- Vendors and Contractors

Source: EPA, 2015 Water and Wastewater Systems Sector-Specific Plan, (2015 SSP), 2016.

AFFORDABLE RATES DISGUISE CHRONIC UNDERINVESTMENT

The affordability of systems—the ability of providers and their ratepayers to develop and maintain needed capabilities—is a cornerstone resilience issue for the sector. Utilities use a variety of rate structures to recover the costs of operating systems, including charging a flat fee regardless of the amount of water used, block rates based on usage, and seasonal rates.[8] For utilities, there are several factors that come into play when setting rates: revenue, conservation, and affordability.[9] The rates charged must bring in enough revenue to maintain the system; however more and more customers are reducing the amount of water they use, decreasing revenue if rates are set based on usage.[10] Finally, utilities have to ensure that rates are affordable for disadvantaged customers, but do not encourage wasting of water.[11] In response, utilities are experimenting with different rate structures to try to balance these three factors.[12]

In general, too many jurisdictions do not account for the full life-cycle cost of building, maintaining, upgrading, and replacing systems (whose life cycles can span decades). Moreover, it appears from our research and discussions that some utilities are diverting money collected as water fees for general revenue purposes. This was found to be true in Flint, when half of the collected fees were diverted in this manner.[13] As a result, aging U.S. water infrastructure has suffered from generations of underinvestment and is now prone to failure. In its *2013 Report Card for the Nation's infrastructure*, the American Society of Civil Engineers (ASCE) gives both water and wastewater systems a "D" rating on an A to F report card scale.

State and local governments must increase investment into public water systems to meet stricter Federal water quality and drinking water safety standards—yet Federal appropriations for water infrastructure have declined between 2008 and 2012.[14] Often dominated by politics rather than engineering, decisions that set rates may simply reflect the least-cost path of patch and repair, ignoring resilience needs. This exacerbates longer-term problems and consequences, stretching the problems of a degrading infrastructure into future political cycles and generations of customers.

> "There is no more basic element sustaining human life than water. It's not too much to expect for all Americans that their water is going to be safe."
>
> *President Barack Obama, May 4, 2016, Flint, Michigan*

ATTRACTING AND MAINTAINING A HIGHLY SPECIALIZED WORKFORCE

A critical component of the Water Sector is its workforce—the men and women who operate and maintain water utilities every day. The number of employees and specialized nature of their work is

[8] EPA, "Water Sense: Understanding Your Water Bill," 2016.
[9] Walton, "Price of Water 2016," 2016.
[10] Ibid.
[11] Ibid.
[12] Ibid.
[13] Snider, "Flint's other water crisis: Money," 2016.
[14] ASCE, "Drinking Water: Conditions and Capacity," 2013; and ASCE, "Wastewater: Investment and Funding," 2013.

dependent on the type, size, and complexity of a utility. For example, larger facilities may employ chemists, engineers, microbiologists, public relations staff, systems analysts, security personnel, and other specialists who are highly trained in their individual roles and as a team.[15]

Most entry-level career paths in the Water Sector require a high school diploma while advanced positions typically require additional post-secondary education or on the job training.[16] Utilities also rely on outside contractors for engineering services, laboratory analyses, chemical deliveries, security, and other positions.[17] Because of the importance of water to other sectors, investments within the sector can have significant economic impacts on a community. A study of 30 water utilities in 25 geographic areas found that on average, for every $1 million these 30 utilities spent, five direct and 11 indirect jobs were supported.[18]

But a 2008 survey found that workforce planning was consistently cited as one of the top issues facing utilities.[19] Despite this concern, workforce planning may not receive the attention that regulatory or infrastructure issues receive.[20] Workforce could become an even greater issue for water utilities over the next several years. The Water Sector is in the midst of a concentrated retirement bubble—similar to other critical lifeline sectors—that is exacerbated by the specialized skills needed for the work, the localized nature of the sector, and eligibility for retirement after 30 years.[21] Between 2010 and 2020, the Water Sector is expected to lose between 30 and 50 percent of employees to retirement.[22] Many of these employees have worked at the same utility for the majority of their careers, compounding the impact of these retirements due to the loss of institutional knowledge.[23]

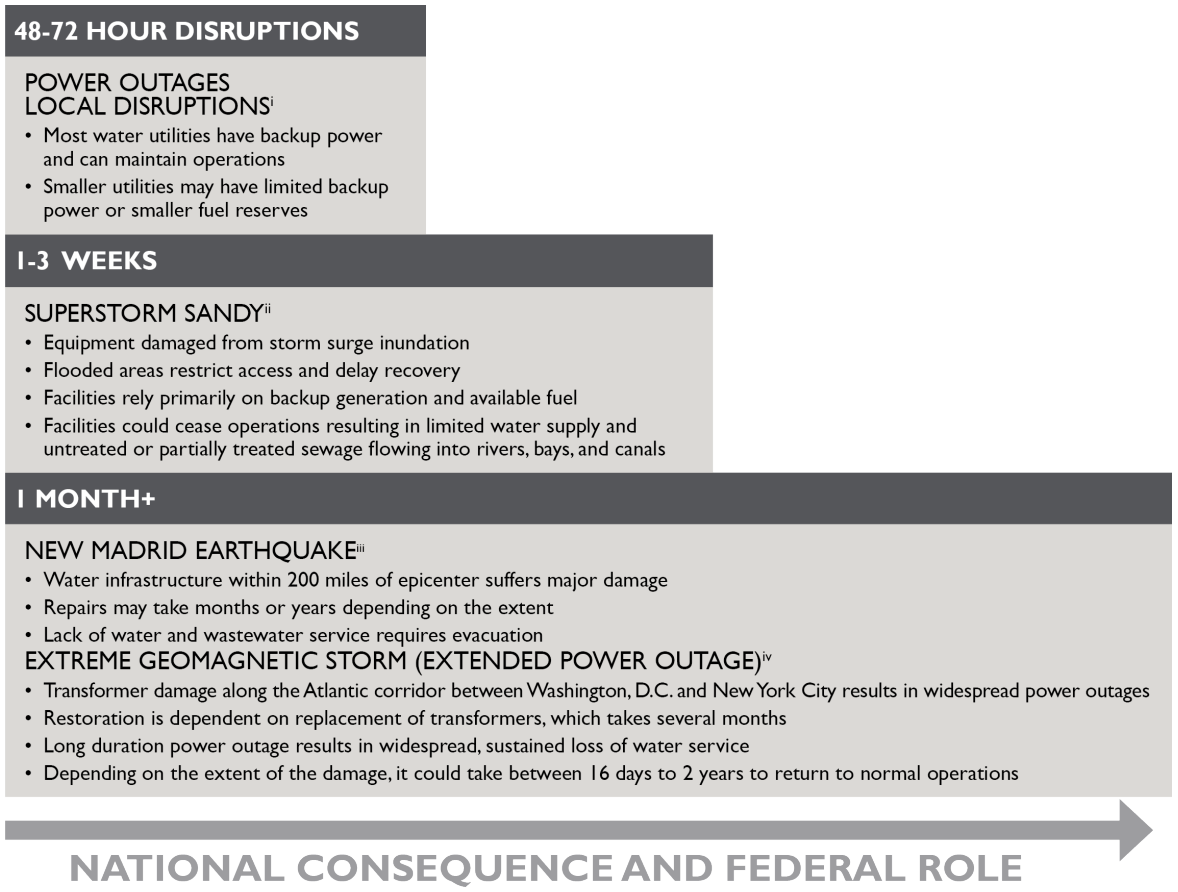
Partnerships and collaboration between utilities, educational institutions, and other partners for resource sharing and technical support will be crucial in addressing workforce development, planning, and knowledge transfer. This is particularly true for smaller utilities with fewer resources.

[15] EPA, *2015 SSP*, 2016.
[16] WRF and WERF, *National Economic and Labor Impacts of the Water Utility Sector*, 2014.
[17] EPA, *2015 SSP*, 2016.
[18] WRF and WERF, *National Economic and Labor Impacts of the Water Utility Sector*, 2014.
[19] WRF and AWWA, *Water Sector Workforce Sustainability Initiative*, 2010.
[20] Ibid.
[21] Ibid.
[22] Ibid.
[23] Ibid.

B. FEDERAL RESOURCES FOCUS ON RECOVERY AND WATER QUALITY

The Federal Government serves multiple roles in the sector, including regulator, enforcer, funder, and provider of critical aid and resources when service disruptions occur. This last role—providing critical aid and resources—is crucial during prolonged disruptions or shorter disruptions over a wide geographic area that can have national or regional consequences. Exhibit II-2 shows how the Federal role increases with the duration and scope of an event. Smaller utilities may be strained even during disruptions lasting from 48 to 72 hours, while larger utilities with deeper technical, personnel, and financial resources may need relatively little aid during shorter or intermediate disruptions, while. Virtually all systems will need aid for prolonged disruptions.

Exhibit II-2. Severity of Events and Increasing National Consequence and Federal Role



[i] DHS OCIA, *Sector Resilience Report*, 2014.
[ii] FEMA, *Hurricane Sandy FEMA After-Action Report*, 2013.
[iii] Mid-American Earthquake Center, Virginia Tech, *New Madrid Seismic Zone Catastrophic Earthquake Response Planning Project*, 2009.
[iv] Lloyd's and Atmospheric and Environmental Research, Inc. (AER), *Solar Storm Risk to the North American Electric Grid*, 2013.

The Federal Government's role is most prominent in the regulation of water and wastewater quality by EPA. The Safe Drinking Water Act (SDWA) provides the basis for drinking water security by protecting water quality and sources of drinking water. It applies to systems designed for the public to consume water through pipes and other constructed conveyances. Under the SDWA, the EPA sets and oversees the implementation of standards for drinking water quality.

EPA delegates primary enforcement responsibility (termed primacy) to States if they meet certain requirements. The majority of States and territories have received primacy. For jurisdictions that do not have primacy, such as the District of Columbia and Wyoming, an EPA regional office administers the drinking water program.

STATE ROLE

In addition to administering Federal regulations State agencies:

- Implement State initiatives and priorities
- Maintain inventories of drinking water and wastewater facilities
- Regularly inspect drinking water and wastewater facilities
- Provide technical assistance and training
- Maintain laboratory and operator certification programs
- Monitor compliance by reviewing analytical results
- Review and approve plans and specifications for new and expanded drinking water and wastewater facilities

(*Source: EPA, 2015 SSP, 2016.*)

The Clean Water Act (CWA), also implemented by EPA, governs the quality of discharges to surface and groundwater. It establishes national technology-based standards for municipal waste treatment and numerous categories of industrial point-source discharges (e.g., discharges from fixed sources). Under the National Pollutant Discharge Elimination System (NPDES) program, the permitting authority (either a State agency or EPA) designates the use for a body of water and then adopts water quality criteria to protect those uses, which inform the permitting of discharges from wastewater treatment facilities.[24]

EPA is the Sector-Specific Agency (SSA), or Federal lead, for the Water Sector under the designations identified in PPD-21.[25] Most of the current and projected programs of the Water Security Division for fiscal year 2016 focus on actions designed to support the implementation of one or more of the Water Sector's priority activities as outlined in the *2015 Water and Wastewater Systems Sector-Specific Plan* (2015 SSP). This includes enhancing communication and coordination among utilities and government partners, and fostering engagements to strengthen public-private partnerships and improve response and recovery capabilities.

EPA regularly communicates and coordinates with the U.S. Department of Homeland Security (DHS) on Water Sector security and resilience, and works with DHS to implement presidential directives, executive orders, and statutes. Other Federal agencies that share aspects of the water security and resilience mission include the U.S. Army Corps of Engineers (USACE) for control of water resource infrastructure; the U.S. Department of the Interior (DOI) for dams, reservoirs, and water quality assessments; and the U.S. Department of Energy (DOE) for the interdependency between water and energy.[26]

[24] EPA, *2015 SSP*, 2016.
[25] EPA, *2015 SSP*, 2016.
[26] Ibid.

Principal Federal funding available to States and municipalities is provided through two sources: EPA loans for water quality purposes and by the Federal Emergency Management Agency (FEMA) grants for emergency management. However, the pool of money available through FEMA is broader than just water and wastewater with FEMA grants going to a variety of qualified mitigation actions.

EPA's Clean Water State Revolving Fund (SRF) and Drinking Water SRF are partnerships between EPA and the States to provide low-interest loans for eligible water and wastewater projects. States operate their SRF programs and have the flexibility to target financial resources to specific community and environmental needs. As the money is paid back, the States are able to make new loans. The programs can provide different types of assistance under certain conditions, including refinancing, purchasing, or guaranteeing loan debt and purchasing bond insurance.[27] By comparison, the U.S. Department of Transportation (DOT) provides formula-driven grant dollars to States and transit agencies based on factors such as population, lane miles, and system condition. These transportation trust fund dollars provide certainty to States and local governments in planning their future investments. See Appendix F. Federal Policies, Agencies, and Activities for more information about the Federal role in funding, oversight, and resilience activities.

C. SECTOR PARTNERS OPERATE WITH A STRONG HISTORY OF COLLABORATION

Water utilities have a long, productive history of working together through associations and other collaborative mechanisms. This collaboration has produced a wealth of shared resources, including vital information, mutual-support relationships, planning processes, and analytical tools. The Federal Government built on this tradition of collaboration by using the partnership model, specified in HSPD-7, PPD-21, and NIPP 2013 to bring private and public sector participants into the planning and implementation of sector protection and resilience. EPA chairs the Water Government Coordinating Council (GCC), including Federal, State, and local entities, and the owners and operators of water utilities comprise the Water Sector Coordinating Council (Water SCC).

WATER SECTOR COORDINATING COUNCIL MEMBERSHIP

The Water Sector Coordinating Council membership is composed of water utility managers, two each appointed by the following representative associations: Association of Metropolitan Water Agencies (AMWA), American Water Works Association (AWWA), Water Research Foundation (WRF), National Association of Clean Water Agencies (NACWA), National Association of Water Companies (NAWC), National Rural Water Association (NRWA), Water Environment Federation (WEF), and Water Environment Research Foundation (WERF).

(*Source: Water SCC, "Charter of the Water Sector Coordinating Council," 2014.)*

The Water SCC member associations serve as the liaisons between the broader water services community and the government partners represented by the Water GCC.[28] The GCC—composed of Federal and State government representatives and national associations representing States—is

[27] EPA, "How the Drinking Water State Revolving Fund Works," 2015; and EPA, "Learn about the Clean Water State Revolving Fund," 2016.
[28] Water SCC, "Charter of the Water Sector Coordinating Council," 2014.

chaired by EPA and co-chaired by the DHS Office of Infrastructure Protection. The GCC coordinates policy, strategy, and activities across government entities within the Water Sector.

Through public-private partnerships, the private sector works with government entities to help foster the innovative financing and technology needed to build infrastructure, provide service and maintenance for operations, and develop advanced technologies to improve security and resilience. Examples of private sector involvement in the Water Sector include:

- Vendors typically provide cyber assets, and some cyber operations positions may be staffed by contractors.
- American Water, the largest publicly traded water and wastewater utility company, launched a digital initiative with GE to harness advanced data and analytics to improve water infrastructure. [29] American Water is also collaborating with ComEd, an energy delivery company, on an Advanced Metering Infrastructure project to better manage water usage and water quality. [30]
- WaterStart is an organization located in Nevada that works with domestic companies, water agencies, policy makers, and international entities to test promising water technologies to help bring them to market faster. [31]

In addition, nongovernmental organizations (NGOs), such as the One Drop Foundation, serve as key partners who can help bring attention, funding, and expertise to public-private partnerships. NGOs work both domestically and internationally to raise awareness, work collaboratively with public and private entities, raise funds for water infrastructure safety and preparedness, and help foster new technologies that can improve water supply and sustainability.

[29] American Water, "American Water COO Water Lynch Participates in White House Water Summit," 2016.
[30] Ibid.
[31] WaterStart, "What WaterStart Does," 2016; and Goldman, "Las Vegas is Betting It Can Become the Silicon Valley of Water," 2016.

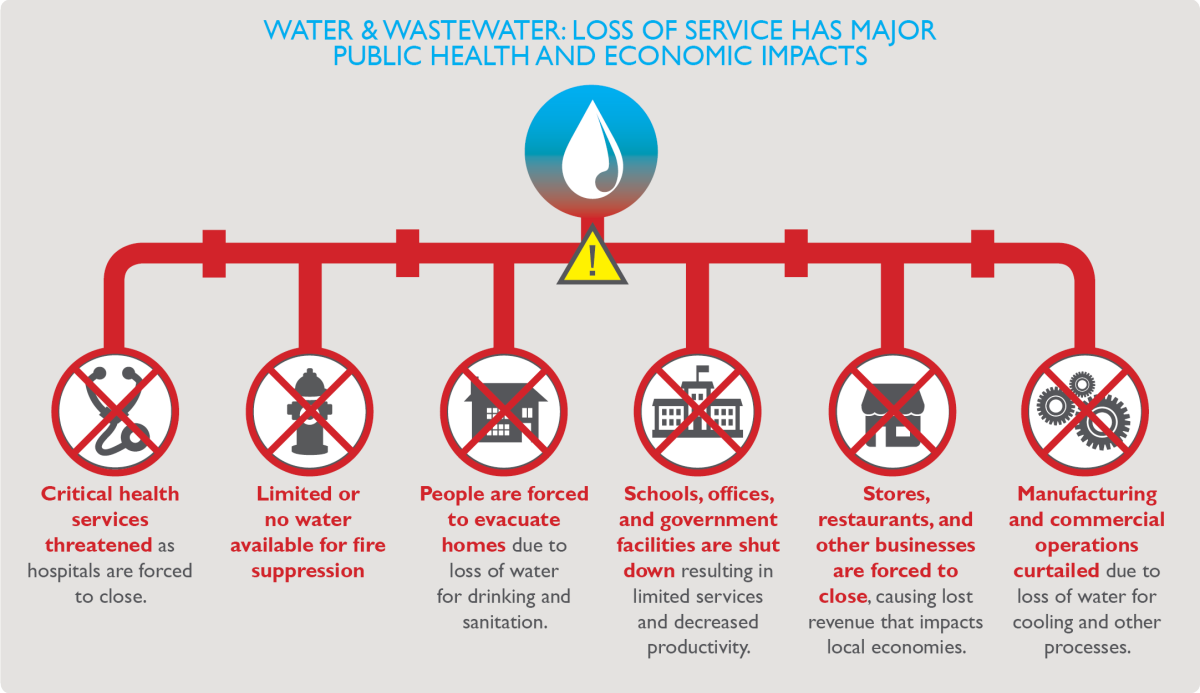
III. WATER SECTOR RISKS AND CRITICAL INTERDEPENDENCIES

Water services are essential to daily life, human health, and economic prosperity. Yet, these services are often misunderstood, undervalued, or taken for granted by both decision-makers and the public-at-large.

A. CONSEQUENCES OF WATER SERVICE DEGRADATION AND LOSS

When water and wastewater services are lost, even for short periods, the consequences can be widespread and dramatic. When these services are lost for an extended period of time, the results can be catastrophic. (See Exhibit III-1).

Exhibit III-1. Consequence of Water and Wastewater Service Disruptions



Secure and resilient water and wastewater infrastructure is essential to daily life, ensuring the economic vitality of the Nation and maintaining public confidence in utility services. Maintaining these services has many challenges, including:

- The capability to manage loss of water services varies widely according to utility size, resource base, and other factors.
- The economic costs of preparation and response may mean that there are insufficient funds to prepare for and address risks ahead of time and to the level at which the risk requires.

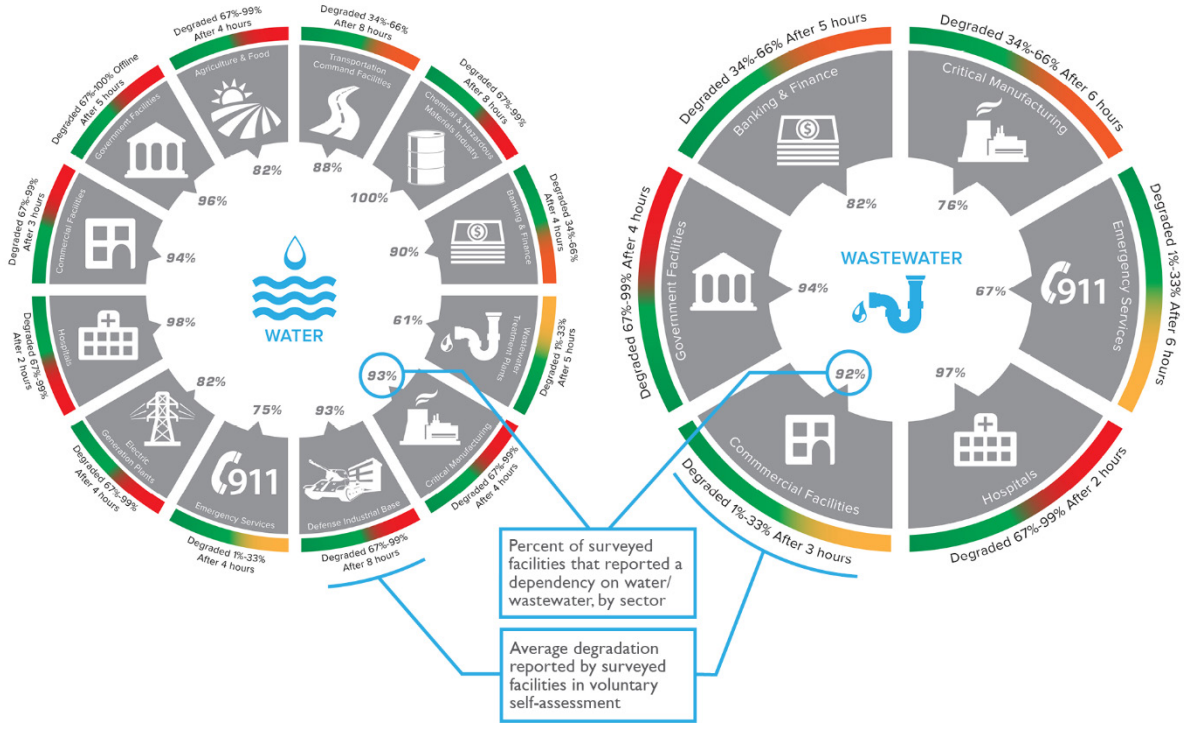
- An aging workforce that may result in loss of institutional knowledge and skills as employees retire.
- Reduced water consumption and conservation may result in less revenue available to maintain level of service and undertake infrastructure resilience projects.

While resilience—by nature—is a response to stressed conditions (natural or manmade disruptions to normal operating conditions), failures in nonstressed (normal) operating conditions may highlight underlying vulnerabilities that also affect resilience. The events such as those in Flint, Michigan show the underlying vulnerability of systems, and what can happen to a community when its water supply is disrupted. Resilience today in the Water Sector is very much a work in progress.
The following sections discuss sector risk and current practice, challenges facing the sector, and indicators of progress toward a more resilient future.

OTHER CRITICAL SECTOR SERVICES DEGRADE QUICKLY WITHOUT A FUNCTIONING WATER SECTOR

The Water Sector is considered one of the lifeline sectors because its functions are essential to core operations in nearly every other critical sector. When water services are lost for relatively short periods (less than eight hours), the functioning of multiple sectors is significantly degraded (see Exhibit III-2).

Exhibit III-2. Illustrative Impact of Water and Wastewater Disruption on Critical Sectors[32]



[32] The information provided in the graphic is based on a limited sample of 2,661 voluntary facility assessments conducted between January 2011 and April 2014. The number of facilities represent a small fraction of the infrastructure across the United States, and respondents may not be geographically dispersed. The graphic

WATER OPERATIONS DEPEND HEAVILY ON OTHER LIFELINE SECTOR SERVICES

While the Water Sector is critical to all sectors, it is interdependent with several key sectors. Exhibit III-3 provides an overview of the impacts to water and wastewater services when electricity, communications, and transportation are disrupted.

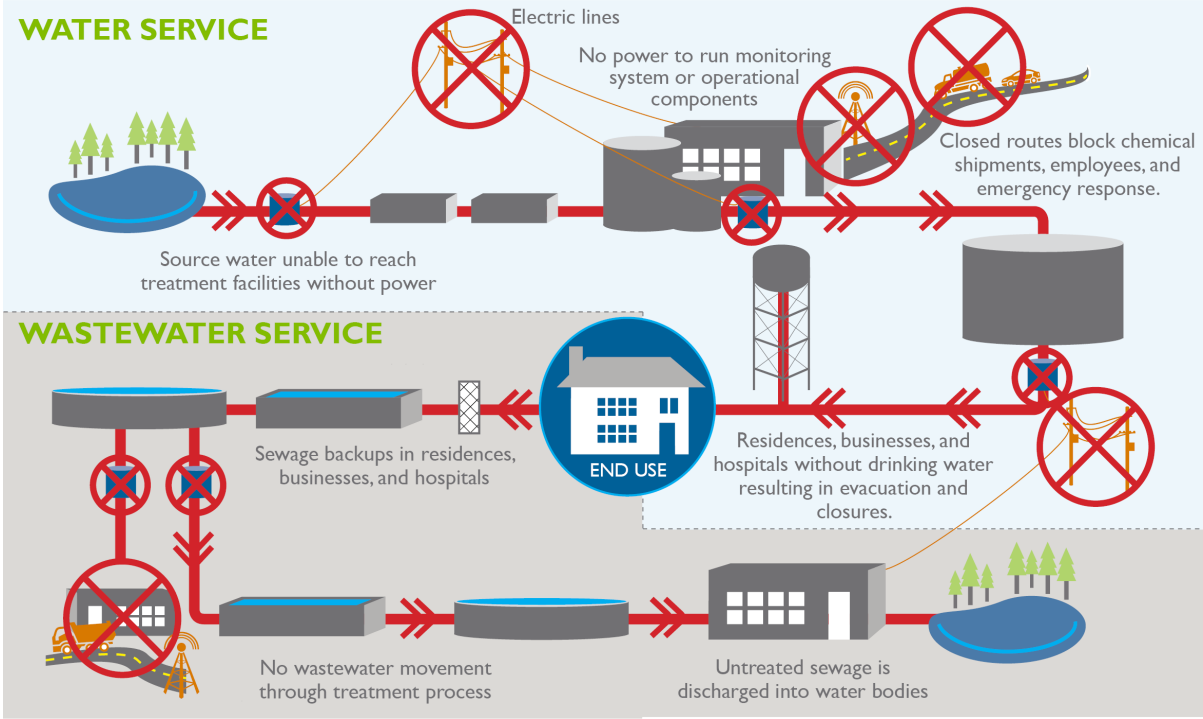
Significant points of interdependencies include:[33]

- **Chemical Sector**: Chemicals are required to operate water and wastewater treatment facilities and water is often necessary in chemical manufacturing processes.
- **Energy Sector**: The Energy Sector relies on water services for different aspects of energy production and generation. The Water Sector relies on energy, specifically electricity, to operate its pumps, treatment facilities, delivery systems, and processing. Long-term power outages can overwhelm a water utility's backup energy supply or deplete fuel reserves. This scenario is worsened if the outage is systemic, in that multiple energy utilities in a region are shut down or multiple water utilities in a region have to compete for scarce backup resources. In addition, energy prioritization—the order in which disrupted sectors obtain energy services—may be an issue for water utilities as they work to restore services.
- **Communications and Information and Technology (IT) Sectors**: These sectors rely on water services for equipment cooling and facility operations, while the Water Sector relies on communications and IT for their operations and control systems, monitoring systems, internal communications, and communications with the public and emergency responders.
- **Transportation Sector**: Chemicals and other supplies are delivered by truck and rail. Water Sector personnel also rely on transportation to get to and from work.

includes information on sectors where more than 60 percent of facilities within the group indicated a dependence on water or wastewater, and the percent degradation reported was the most frequent selection for the group—there may be other facilities that may be forced to evacuate after a certain amount of time within the sectors (DHS OCIA, *Sector Resilience Report*, 2014).

[33] DHS OCIA, *Sector Resilience Report*, 2014; and EPA, *2015 SSP*, 2016.

Exhibit III-3. Loss of Critical Infrastructure Services Effect on Water and Wastewater Services



Storing drinking water for short-term use to protect public health may seem almost routine—think of stocking up on water bottles and filling a bathtub before a major storm—yet it is impossible to store sufficient backup water or divert water resources to maintain water-intensive operations in places such as hospitals, office buildings, chemical plants, generators, and manufacturing facilities. Unlike electricity, water cannot easily be re-routed around disruptions, nor can facilities generate backup water onsite to maintain critical operations.

B. AGING INFRASTRUCTURE, CYBER DEPENDENCY, AND SEVERE WEATHER THREATS

Each water and wastewater owner and operator manages a unique set of assets and a distinct risk profile. Specific risks and risk-management priorities depend on utility size, location, assets and distinct risk profile. The following discusses three of the most significant, common risks faced by water and wastewater utilities.

DETERIORATING INFRASTRUCTURE IN A LIMITED-RESOURCE ENVIRONMENT

With the Nation's infrastructure suffering from chronic underinvestment, system failures and service shortfalls are becoming distressingly common. While this study focuses on the resilience of systems under stressed conditions, it does so with the understanding that improvements in resilience must go hand-in-hand with improvements to ensure consistent service under nonstressed conditions.

BY THE NUMBERS: AGING WATER INFRASTRUCTURE & INVESTMENT GAPS

- Inadequate capacity in wastewater systems creates as many as **75,000 sanitary sewer overflows per year**, discharging 3 billion –10 billion gallons of untreated wastewater and leading to as many as 5,500 different types of illnesses (EPA, *Impacts and Control of CSOs and SSOs*, 2004).
- Degrading assets contribute to an estimated **240,000 water main breaks per year** in the United States, a number that is likely to increase over the next 30 years (ASCE, "Drinking Water," *2013 Report Card*, 2013).
- Water infrastructure investment is not keeping up with the escalating need, creating an **investment gap that is expected to reach $105 billion by 2025** and continue growing over the coming decades (ASCE, *Failure to Act*, 2016).
- The EPA estimates that **$384 billion is needed to make necessary improvement**s for drinking water infrastructure between 2011 and 2030 (EPA, *Drinking Water Infrastructure Needs Survey and Assessment*, 2013).
- The EPA estimates that approximately **$271 billion is needed to maintain and improve** the Nation's wastewater infrastructure within the next five years (EPA, "EPA Survey Shows $271 Billion Needed for Nation's Wastewater Infrastructure," 2016).
- The American Water Works Association (AWWA) estimates it will cost **$1 trillion over the next 25 years** simply to maintain current levels of water service (AWWA, *Buried No Longer*, 2011).

The risks posed by systemic underinvestment in water infrastructure are being intensified by increasing vulnerability to extreme-weather events, cybersecurity challenges, and other threats. Current practice is often to patch and repair as incidents happen, at the expense of smart investment in resilient systems that has the potential to improve service at a cost below current practice.

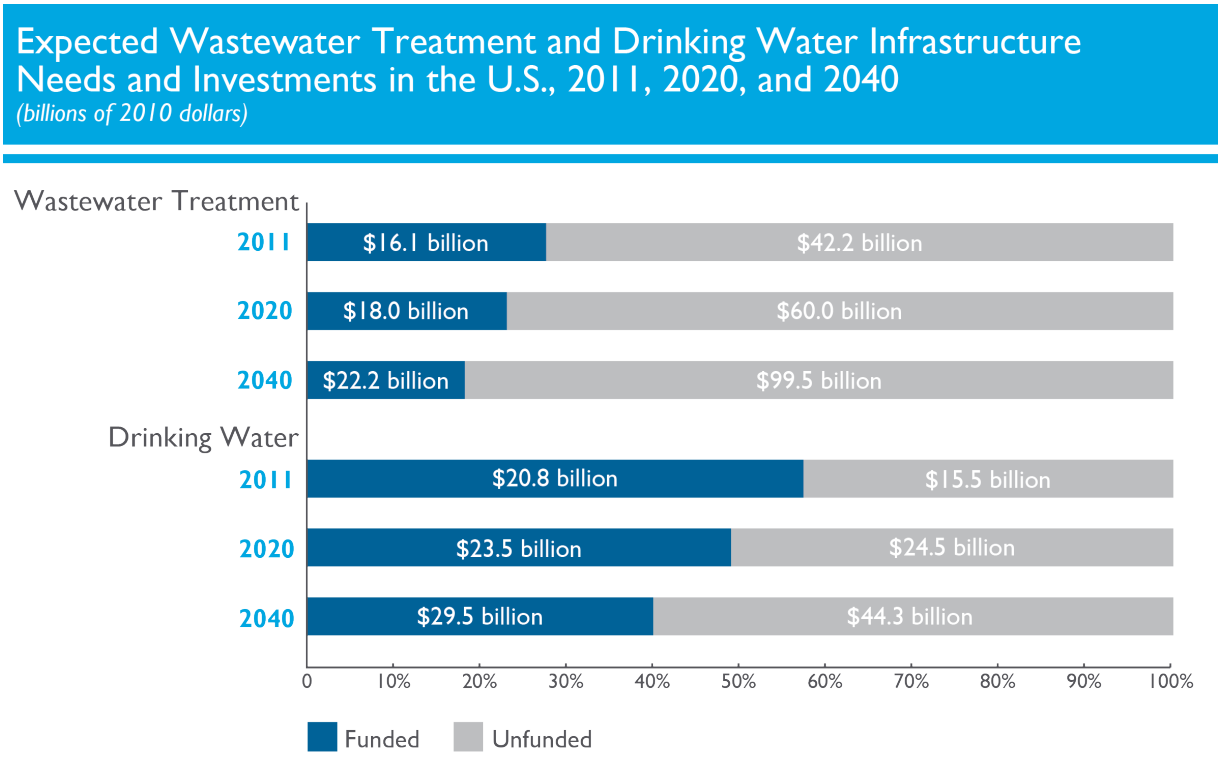
Aging infrastructure and limited resources for adequate response planning and resilience investments are inextricably linked, creating a complex risk. Much of the water infrastructure has or is approaching the age at which it needs to be replaced. For both drinking and wastewater systems, the useful life of component parts ranges from 15 to 95 years depending on the component and its materials. For example, mechanical and electrical components in treatment plants and pumping stations have an average useful life of 15 to 25 years while the concrete structures of treatment plants and pumping stations average 60 to 70 years for drinking water and 50 years for wastewater.[34] Wastewater mains have an average useful life of 25 years while drinking water trunk mains have an average useful life of 65 to 95 years.[35]

> "The impacts from having aging infrastructure are substantial and without action they will become critical. Because most of this infrastructure is out of sight and because many fine professionals work every day to keep it operating under difficult conditions, the full extent of the challenge we face is generally not understood by government officials, businesses, and the public."
>
> *Dr. Gerald E. Galloway, PE, Martin Institute Professor of Engineering at the University of Maryland; July 25, 2013 statement to the U.S. Senate Committee on Energy and Natural Resources, Subcommittee on Water and Power*

[34] ASCE, *Failure to Act*, 2011.
[35] Ibid.

Addressing this risk requires a massive investment in infrastructure. Estimates vary based on assumptions, time frames, and other factors; but it could cost several hundred billion dollars to as much as $1 trillion to address the Nation's infrastructure needs and maintain current levels of service.[36] Exhibit III-4 presents the American Society of Civil Engineers (ASCE) assessment of the sector's investments needs, specifically the gap between total need and the amount that is funded.

Exhibit III-4. Estimated Investment Gap for Water and Wastewater Infrastructure by ASCE[37]



SOPHISTICATED CYBER THREATS REQUIRE ADVANCED SOLUTIONS AND SPECIALIZED EXPERTISE

Water utilities increasingly use industrial control systems to continuously control treatment processes and delivery, remotely monitor operations, and control the pressure and flows in pipelines. These automated systems allow small teams of operators to efficiently and remotely manage complex physical processes using digital controls. Growing reliance on industrial control systems over the last decade has resulted in increased connectivity, a proliferation of cyber access points, escalating system complexity, and wider use of common operating systems and platforms—factors that increase cyber risk and require sophisticated cyber protections.[38]

Similar to companies in every sector, water utilities must protect their email, business systems, and billing systems from cyberattacks to protect sensitive business and customer data. Yet cybersecurity is even more imperative for the Water Sector's process control systems; a successful intrusion could

[36] AWWA, *Buried No Longer*, 2011.
[37] Chart recreated from ASCE, *Failure to Act,* 2011.
[38] Water SCC Cyber Security Working Group, *Roadmap to Secure Control Systems in the Water Sector*, 2008.

allow malicious actors to manipulate or disrupt water treatment and services, damage equipment, and compromise the safety of the water supply.[39] Attacks involving process control and monitoring systems could risk customer health and erode public trust in the water system.

These threats are no longer hypothetical. Hackers recently hijacked a water treatment plant's industrial control system and modified the levels of chemicals being used to treat water. In a March 2016 report, Verizon Security Solutions reported that it was investigating a data breach for an undisclosed water treatment facility, when it discovered that hackers who breached the payment system were also able to manipulate the controllers that manage the amount of chemicals used to treat the water supply.[40] The hack disrupted water treatment but did not affect the safety of the water—though it provided insight into the type of damage a more experienced or targeted hack could inflict. System knowledge also makes insider threats particularly insidious. For example, in 2001, a disgruntled ex-employee of an Australia software vendor hacked into a wastewater treatment plant and released 264,000 gallons of raw sewage into local rivers and parks.[41]

Cyber threats are not one dimensional; vulnerabilities stem from personnel, processes, and technology. As cyber threats grow and evolve, utilities will require broad-based knowledge and tools, and most importantly, experienced personnel to understand cyber threats and apply new processes, technologies, and best practices to secure cyber systems.

THE MANY DIMENSIONS OF THE CYBER THREAT

- Industrial control systems monitor and control highly distributed physical processes, including remote control of often unmanned facilities. Utilities require the tools and expertise to rapidly detect and recognize cyberattacks.
- Cyber and physical security is intimately linked. A cyber intrusion could give a hacker the ability to manipulate physical processes (such as chemical treatment and water flows), while insufficient physical security (such as an unsecured control room door) could give an individual unauthorized access to critical cyber controls.
- Utilities primarily rely on hardware and software vendors to develop secure control systems and patch vulnerabilities. Utilities need a strong understanding of cybersecurity requirements to procure secure technologies.
- Spearfishing attacks that aim to obtain operator credentials are a key threat. With the right credentials, even an inexperienced hacker can cause disruption or damage. Disgruntled employees with control system access also pose a threat.
- Increasing reliance on automated systems and growing sophistication of cyber threats requires a large increase in resources for staff training, cybersecurity advances, and knowledge acquisition.
- Smaller utilities often lack the resources and specialized personnel needed for cybersecurity improvements. For example, larger facilities may have the resources to maintain a separate, more-secure system for operational systems. This is rare in smaller utilities.

[39] Ibid; and DHS OCIA, *Sector Risk Snapshots*, 2014.
[40] Verizon Security Solutions, *Data Breach Digest: The Usual Suspects*, 2016.
[41] Godwin, "Water and Wastewater Cybersecurity," 2015.

NATURAL DISASTERS AND INCREASINGLY SEVERE WEATHER PATTERNS

Natural disaster can harm water quality, limit service availability, and damage infrastructure. Floods, hurricanes, earthquakes, and ice storms are of particular concern for water utilities, but the sector has centuries of experience managing such risks.[42]

The increased intensity and frequency of severe weather (e.g., major flooding) patterns linked to climate change threatens drinking water and wastewater infrastructure.[43] For example, most water facilities are located near bodies of water. Expected climate change impacts are sea level rise and higher storm surge, which can flood facilities, damaging equipment and halting operations. To prepare for this, facilities may need to move crucial equipment above expected flood levels. Increasing precipitation and drought can also degrade water quality, resulting in increased treatment needs to meet requirements.[44]

Black Sky Events

The Water Sector has a remarkable track record of maintaining water and wastewater services service during distressed conditions and minimizing the impact of disruptions that range from a few hours to a few weeks. The public is often unaware of the "near misses" that the sector has skillfully avoided. Disruptions are usually confined to local areas, but in rare cases—such as Superstorm Sandy—rise to a national-level event. But experts are predicting that far more serious incidents could take place in the near future. Often referred to as "black sky events," these high-impact, uncertain probability events could cause a combination of severe physical damage to infrastructure and widespread, long-duration power outages lasting months or even years. Without power, water service cannot be provided.

> "If we look at the experience of the Water Sector during Superstorm Sandy, the sector by and large did a terrific job of sustaining services. But a number of them were on the knife's edge of failure due to problems in the resupply of diesel fuel for stand-by generators, the burning out of generators and the scarcity of replacement spares, and other factors. I'm concerned that longer duration, wide area power outages in a black sky event would push us over that knife's edge and lead to serious disruptions in water and wastewater service."
>
> *Dr. Paul Stockton, Managing Director of Sonecon, LLC, and former Assistant Secretary of Defense for Homeland Defense*

Examples of potential black sky events, include:

- An earthquake in the New Madrid Fault Zone, which could cause extensive damage within 200 miles of the epicenter. A New Madrid earthquake was one of the five disruption scenarios the Study Group evaluated to assess Water Sector resilience during a high-impact event. (See Appendix C. Disruption Scenario Case Study for more details on the five disruption scenarios).

[42] EPA, *2015 SSP*, 2016.
[43] EPA, "Climate Change: Basic Information," 2016.
[44] NACWA and AMWA, *Confronting Climate Change.* 2009.

- High-magnitude earthquakes in sections of the San Andreas Fault, which experts indicate are overdue.[45] In 2008, the U.S. Geologic Survey examined the consequences of a major earthquake along this fault line in southern California. Despite the State's mitigation efforts, pipes that cross the fault line would be damaged or broken. In addition, due to the large area affected, there would not be enough replacement materials and pipes or people trained to install them quickly. It could take several weeks to up to six months to complete repairs and reestablish normal water and wastewater service. Recreating the water system may be necessary in the hardest hit areas, and for some pipelines, equipment and electronics, repairs could take up to five years to complete. The estimated cost to repair the water and sewer lines is $1 billion.[46]
- An extreme geomagnetic storm could also have widespread impacts that cross State lines and cause severe damage to transformers and other electrical equipment. A 2013 report by Lloyd's and Atmospheric and Environmental Research found that the greatest risk of this type of event is along the coast between Washington, D.C. and New York City, and that areas of the Gulf Coast and Midwest are also at high risk. The expected duration of the power outages could range from 16 days to up to two years depending on the availability of replacement electrical transformers.[47] The associated loss of water service can be expected to be of similar severity.

[45] Lin, "San Andreas Fault,'" 2016; and Jones, et al., *The ShakeOut Scenario*, 2008.
[46] Jones, et al., *The ShakeOut Scenario,* 2008.
[47] Lloyd's and Atmospheric and Environmental Research, Inc., *Solar Storm Risk*, 2013.

WHEN INFRASTRUCTURES FAIL

Major infrastructure failures often expose the true value of the safe, reliable service we expect from our critical sectors. The examples below illustrate how serious infrastructure failures—in transit, electricity, and drinking water—can have severe near- and long-term consequences, regardless of the cause.

- **Minneapolis Bridge Collapse**: On August 1, 2007, the I-35W Bridge in Minneapolis, Minnesota suffered a catastrophic failure and collapsed into the Mississippi River, killing 13 people and injuring 145 people. The bridge carried more than 140,000 vehicles each day and provided access to downtown Minneapolis, the University of Minnesota, and businesses. The economic impact for drivers that used the bridge was $400,000 per day. For the State, the loss of the bridge resulted in economic impacts of about $17 million in 2007 and $43 million in 2008 (NTSB, *Collapse of I-35W Highway Bridge*, 2008; Minnesota DEED and Mn/DOT, *Economic Impacts of the I-35W Bridge Collapse*, n.d.; Jones, "Friday Marks 7 years since I-35W Bridge Collapse," 2014).
- **Superstorm Sandy**: Hurricane Sandy made landfall on Oct. 29, 2012 near Atlantic City, New Jersey as a post-tropical cyclone with heavy rains, 80-90 mph winds, and storm surges along the East Coast. One week later a Nor'easter swept into the affected region with strong winds, rain and snow, and coastal flooding, giving Sandy the "superstorm" moniker. In New Jersey, more than 200 million gallons of water from the tidal surge engulfed one of the largest wastewater treatment plants in the United States, operated by the Passaic Valley Sewerage Commission. The 152-acre plant stood in four feet of water (with 15—30 feet of flooding in underground systems), sustained damage to critical machinery and lost power for three days. Extensive dewatering of sewage sludge and critical repairs to bring the plant back to operation cost an estimated $200 million—about $50 million more than the commission's total annual operating budget (NIAC, *Regional Resilience*, 2013).
- **2003 Northeast Blackout**: On August 14, 2003, a confluence of events triggered a cascading electric transmission failure that caused a blackout across Ohio, Michigan, Pennsylvania, New York, Vermont, Massachusetts, Connecticut, New Jersey, and the Canadian province of Ontario. The blackout lasted up to four days in some locations, left 50 million people without power, contributed to at least 11 deaths, and cost $4 billion--$6 billion. The U.S.-Canada Power System Outage Task Force found that the blackout was caused by deficiencies in corporate policies, lack of adherence to industry policies, and inadequate management of reactive power and voltage (Minkel "The 2003 Northeast Blackout—Five Years Later," 2008; U.S.-Canada Power System Outage Task Force, *Final Report on the August 14, 2003 Blackout*, 2004).
- **Flint Water Contamination Crisis**: In April 2014, the water source serving the City of Flint, Michigan—with a population of 99,000 people—was switched from Lake Huron (treated by Detroit Water and Sewerage Department) to the Flint River (treated by the Flint Water Treatment Plant). The more corrosive Flint River water required corrosion-control treatment, but it was not put in place when the switch occurred. The untreated water corroded the lead feeder pipes that connect homes to the underground water mains, causing lead to leach into the drinking water. The Flint Water Advisory Task Force found that a mismanagement of the drinking water supply caused Flint water customers to be exposed to toxic levels of lead and other hazards. Appendix H. The Flint Water Crisis provides a detailed examination of this failure of water services (Flint Water Advisory Task Force*, Final Report, 2016;* Adams, "Closing the valve on history," 2014; Edwards, "Test Update: Flint River water 19X more corrosive," 2015).

IV. WATER INFRASTRUCTURE RESILIENCE TODAY

Chronic underinvestment, system failures, and service shortfalls are becoming increasingly common in the Nation's infrastructure. Though this study focuses primarily on the resilience of systems under highly stressed conditions, resilience improvements must go hand-in-hand with strategies and practices to ensure reliable operations under normal, nonstressed conditions. There is a broad body of knowledge available today—principally from water associations—on resilience strategy and practices for water utilities. Translating resilience knowledge into widespread practice, however, is often limited by resource constraints and funding challenges that require innovative strategies and collaborative approaches to address. This Chapter reviews the current state of practices, major challenges to raising resilience in the sector, and key indicators of progress.

A. CURRENT PRACTICE

Each water and wastewater owner and operator manages a unique set of assets and operates under a distinct risk profile. As such, each utility's risk-management priorities depend on many factors, including utility size, location, assets, distinct risks, and perhaps most importantly, the resources and capabilities the utility can access.[48] Some serve growing populations with increasing resources, while others serve shrinking populations with declining tax bases that must maintain systems, which are now oversized for the population they serve. While each utility is responsible for its own risk management, sector-wide collaboration and information sharing plays a major role in boosting the resilience of individual systems and the sector as a whole.

Key aspects of resilience practices in the sector are outlined below; Appendix G. Baseline Resilience in the Water Sector provides a more extensive review of the sector's components, risks, and practices.

HIGHLY DIVERSE RESOURCES AND CAPABILITIES

Water and wastewater utilities are quite diverse; some develop and implement leading-edge practices while others lack access to essential information, knowledge, expertise, tools, and lessons learned. Despite the value of these resources among water utilities, adoption of successful practices and resources has not been fully realized across the sector. The adequacy of human capital within the Water Sector is a growing concern, particularly with regard to knowledge retention and talent acquisition. Challenges that require new skill sets and training—such as cybersecurity—constrain the ability of utilities to adapt to a changing environment. The loss of institutional knowledge due to retirements compounds this shortfall.

The relatively few very large systems in the Water Sector that serve the majority of the Nation's population —about 20 percent of water and wastewater systems serve more than 90 percent of the population—tend to have comparatively strong resilience measures in place. Smaller systems do not

[48] Water SCC, "Charter of the Water Sector Coordinating Council," 2014; and CIPAC Water Sector Strategic Priorities Working Group, *Roadmap to a Secure and Resilient Water Sector*, 2013.

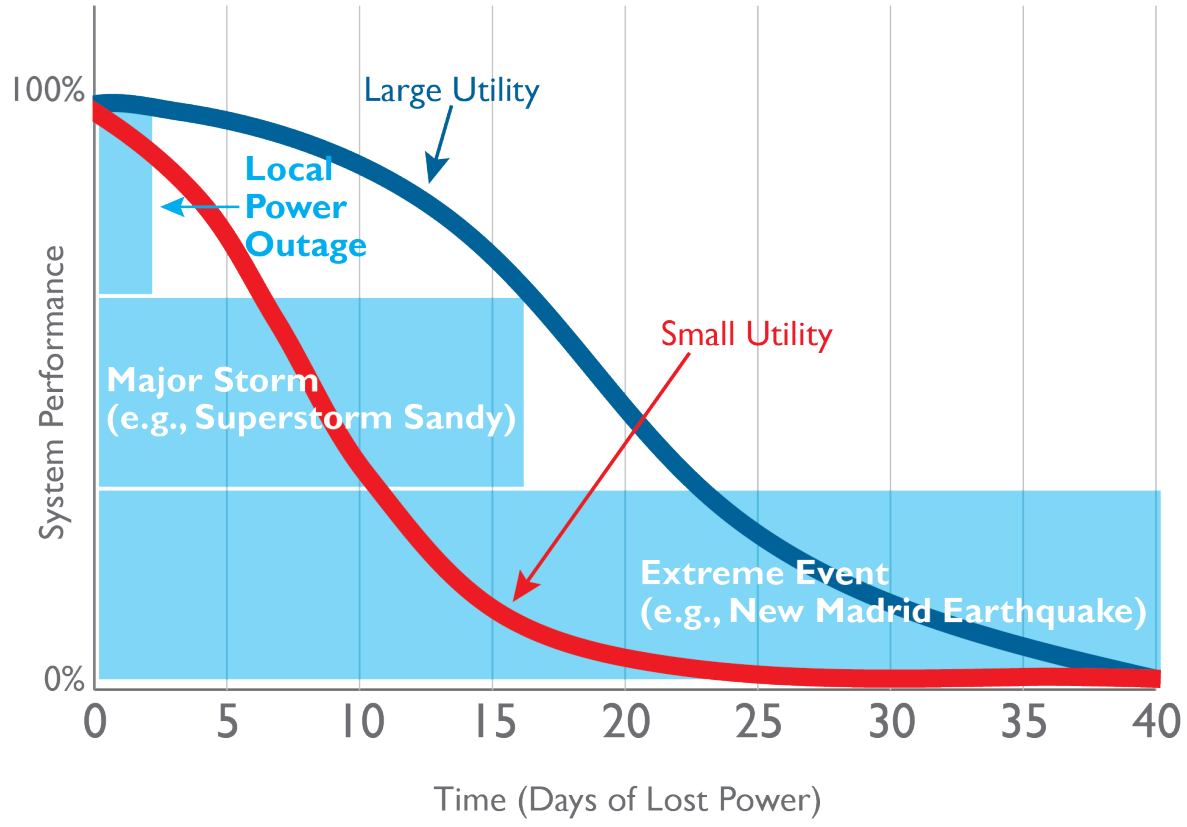
enjoy the same level of resources, and must rely on the transfer of knowledge and tools from other experts. Associations representing components of the Water Sector, aided by DHS and EPA, have been very active in developing and disseminating models, tools, and best practices, which are transferable to smaller systems. The *2015 Water SSP* includes many examples of this resilience-building approach.[49]

UTILITY RESPONSE CONSTRAINED BY SIZE AND RESOURCES

The Water Sector is adept at maintaining water services during short-term disruptions, such as a power outage lasting less than 24 hours. Beyond that time frame, the ability to maintain services depends largely on the size of the system, its location, and access to resources. For example, large utilities in a metropolitan region may have more robust backup and contingency resources, and depending on their location may have more options that allow them to "fail gracefully," such as access to mobile generators, access to nearby water utilities in the region that can provide aid, or relationships with other critical infrastructure partners that can share resources.

Exhibit IV-1 is a conceptual graph that shows how degradation of services can differ between large and small utilities. Larger utilities often are more equipped to handle power outages or other disruptions to critical infrastructure for several days or longer. But when disruptions stretch out into weeks or months, all systems—regardless of size—will need help maintaining services.

Exhibit IV-1. Conceptual Degradation Curve between Large and Small Utilities during Disruptions



[49] EPA, *2015 SSP,* 2016. Appendix 6, Table A6-1, pp. 47-49.

FEDERAL INVOLVEMENT

The Water Sector is facing a dynamic and complex risk environment in which the full impacts of water disruptions and potential cascading impacts are not fully understood among critical infrastructure operators, local and State leaders, and water service customers. As such, the history of major disruptions show that water and wastewater services are receiving inadequate attention in disaster planning, prevention, and response among public officials and interdependent sectors. The lack of widespread, cross-jurisdictional collaboration can lead to stovepiped decision-making that is counterproductive to effective emergency response.

As noted in Chapter II. Water Sector Operational Snapshot, the Federal Government's role in the Water Sector is primarily focused on water quality (EPA) and emergency response and recovery (FEMA). Resilience has not been substantially integrated into the actions of Federal agencies and resilient outcomes are not typically part of Federal programs and resources. In contrast to the Energy and Transportation Sector, the Water Sector does not have a cabinet-level department and there is no dedicated Emergency Support Function (ESF) for water.

Current authority for water is distributed across four ESFs and multiple Federal agencies, leading to uncertainty, leadership challenges, information-sharing complications, and an overtaxing of Water Sector response resources—all of which can impede water service recovery during disasters. In contrast, the Energy Sector has a dedicated ESF. In our 2009 report, *Framework for Dealing with Disasters and Related Interdependencies*, the Council recommended that the Water Sector should be elevated to an ESF within the National Response Framework (NRF) during the next revision cycle.[50] Despite the fact that the NRF was revised and released in 2013; the Water Sector remains disbursed across four different ESFs.[51]

EMERGENCY SUPPORT FUNCTION (ESF) AND THE WATER SECTOR

What is an ESF? ESFs provide the structure for coordinating interagency support in response to an incident. They are mechanisms for grouping common disaster response functions, with each ESF composed of multiple agencies performing similar functions as a single, cohesive unit. There are 15 different ESFs designed to improve emergency management and response.[52]

What is the relationship between ESF and the Water Sector? Responsibilities for emergency water service support is disbursed across four different ESFs: ESF 3 (Public Works and Engineering), ESF 4 (Firefighting), ESF 6 (Mass Care, Emergency Assistance, Housing, and Human Services), and ESF 8 (Public Health and Medical Services). Essentially, water and wastewater services are a subordinate function under four different ESFs, with each ESF having a different ESF Coordinator/Primary Agency responsible for that function. Under this design, water agencies do not have sufficient visibility with function leadership or the resources to support four different ESFs during an emergency.[53]

Water Sector	Energy Sector
• **ESF structure disbursed** across 4 different ESFs	• **Dedicated ESF structure**, ESF #12

[50] NIAC, *Framework for Dealing with Disasters and Related Interdependencies*, 2009.
[51] FEMA, *National Response Framework*, 2013.
[52] FEMA, *Emergency Support Function Annexes*, 2008.
[53] NIAC, *Framework for Dealing with Disasters and Related Interdependencies*, 2009.

COLLABORATION IN PLANNING

The Critical Infrastructure Partnership Advisory Council (CIPAC) Water Sector Strategic Priorities Working Group developed the *2013 Roadmap to a Secure & Resilient Water Sector* (2013 Roadmap) to prioritize activities to strengthen sector security and resilience. The 2013 Roadmap identified three top priorities for the Water Sector over the next five years: 1) advance the development of sector-specific cybersecurity resources; 2) raise awareness of the Water Sector as a lifeline sector and recognize the priority status of its needs and capabilities, and 3) support the development and deployment of tools, training, and other assistance to enhance preparedness and resilience.[54]

These priorities are currently being used by public-private partners in the Water Sector to focus on activities in a two- to five-year timeframe that can strengthen the sector's ability to plan for effective response and recovery, maintain resilience during a calamitous event, and garner support for both disaster and risk-mitigation cost recovery.

INFORMATION SHARING TO SUPPORT RESILIENCE

Information sharing plays an essential role in the security and resilience of the Water Sector. There are several key information-sharing methods extensively used in the sector. Associations play a fundamentally critical role in knowledge development and transfer, as well as in developing practices to share multiple types of resources during disasters. One of the most well-known and utilized mechanisms is the Water/Wastewater Agency Response Network (WARN), which is active in all 10 FEMA regions and Canada. In addition to providing mutual aid and assistance, WARN provides valuable after-action reports, such as the WARN *Superstorm Sandy After-Action Report*.

The Water Information Sharing and Analysis Center (WaterISAC) serves as an information-sharing arm of the sector. Members include hundreds of utilities serving more than 200 million people in the United States, as well as Federal, State, and local agencies and consulting firms.[55]

WARN: WATER UTILITIES HELPING WATER UTILITIES

The Water Sector is designated a lifeline critical infrastructure sector, meaning that other sectors depend on it to recover after a major disruption. Bringing disrupted water utilities back online to mitigate further disruption to other sectors and the community is a priority mission. To assist in this mission, AWWA led the creation of the Water and Wastewater Agency Response Network (WARN).

WARN is a network of utilities helping other utilities to respond and recovery from disruptions. Participating utilities can provide and receive emergency assistance (personnel, equipment, materials, and other critical services), as necessary, from other water or wastewater utilities. Mutual aid networks like WARN enable water utilities to:

- Secure sector-specific resources to quickly respond/recover from a disaster; and
- Build relationships with similar or nearby utilities that can be leveraged during preparedness, response, or recovery.

[54] CIPAC Water Sector Strategic Priorities Working Group, *Roadmap to a Secure and Resilient Water Sector*, 2013.
[55] National Council of ISACs, "Join Your Sector's Information Sharing and Analysis Center," 2015

B. CHALLENGES

Developing and sustaining effective risk-management practices comes with a broad range of challenges. While the challenges may vary according to a utility's size, resource base, and experience in risk management, the following challenges reflect common and critical challenges for water and wastewater utilities:

- **A Difficult Starting Point**. The Nation's water infrastructure is aging and needs reinvestment. Although there are certainly exceptions, too many systems are old, fragile, and have served well beyond their planned life spans. Restoring the long-term viability of these systems will be difficult—just to meet the demands of nonstressed conditions.
- **Support for Water as a Public Good**. Water services exist in a quasi-public-service world. While often considered a public good, they are nonetheless generally operated on a basis that does not account for the full life-cycle costs of systems. Inequities among wealthy and poor communities can exacerbate the affordability of clean water and create social justice concerns. A public good requires public investment.
- **Backing Solutions with Decisions**. An extensive array of knowledge, tools, and potential solutions has been developed by Water Sector professionals—in individual utilities and in professional associations. However, widespread improvement in resilience can only be achieved by adoption and funding of these potential improvements by decision-makers.
- **Enabling New Approaches**. Most State and municipal decision-makers are constrained by the long-held expectations by customers for water as a low-cost, affordable service that does not account for true life-cycle costs. This is particularly challenging in low-income areas with a shrinking tax base and limited economic opportunities. Political reluctance to opt for new technology, funding, and investment approaches –which may substantially differ from traditional ones and may constrain progress. With new challenges, the need for and value of new approaches must be understood.
- **Partnership and Champions.** The Federal Government involvement with services that are primarily delivered at the local level is understandably constrained. However, the government can assist by providing invigorated leadership with guidance, resources, incentives, and innovative approaches that leverage infrastructure investments into jobs. The challenge is simply too large for States and municipalities to go it alone.

C. INDICATORS OF PROGRESS

A number of concerted efforts by Water Sector partners have made progress in achieving the shared vision of a secure and resilient drinking water and wastewater infrastructure. This infrastructure provides clean and safe water as an integral part of daily life and ensures the economic vitality of and public confidence in the Nation's drinking water and wastewater service. Enhanced collaboration has yielded advances in areas such as the improved sharing of resources; the expanded use of new tools, knowledge, and training; and improved characterization of emerging threats, such as cyber intrusions and extreme-weather events.

Several examples of these collaborative successes are presented in Exhibit IV-2 and highlight both the critical role played by associations and the collaborative nature of successful endeavors. Appendix I. Collaborative Tools and Practices presents additional examples.

Exhibit IV-2. Examples of Collaborative Efforts for Improving Water Sector Resilience

RISK AND RESILIENCE MANAGEMENT OF WATER AND WASTEWATER SYSTEMS
AWWA developed standard J100-10 (R13), the first voluntary consensus standard encompassing an all-hazards risk and resilience management process for use specifically by water and wastewater utilities. It is a foundational, consensus-based standard that encompasses an all-hazards risk and resilience management process for use specifically by water and wastewater utilities.[56]
CIPAC WATER SECTOR CYBERSECURITY STRATEGY WORKGROUP: FINAL REPORT & RECOMMENDATIONS
The report recommends approaches to outreach and training to promote the use of the *National Institute of Standards and Technology* (*NIST) Framework for Improving Critical Infrastructure Cybersecurity;* identifies gaps in available guidance, tools, and resources for addressing this framework in the sector; and identifies measures of success that can be used by Federal agencies to indicate the extent of use of the framework in the Water Sector.[57]
ROADMAP TO A SECURE & RESILIENT WATER SECTOR
Developed by the CIPAC Water Sector Strategic Priorities Working Group, the roadmap establishes a strategic framework that articulates the priorities of industry and government in the Water Sector to manage and reduce risk. It also produces an actionable path forward for the Water Sector GCC, SCC, and government and private sector security partners in the sector to improve the sector's security and resilience within the next five years.[58]
CYBERSECURITY GUIDANCE & TOOL
Based on recommendations in the *2008 Roadmap to Secure Control Systems in the Water Sector*, AWWA's Water Utility Council developed a cybersecurity resource designed to provide actionable information for utility owner/operators based on their use of process control systems. The Use-Case Tool provides the foundation of a voluntary, sector-specific approach for adopting the NIST Cybersecurity Framework, created in response to Executive Order 13636 – Improving Critical Infrastructure Cybersecurity.[59]
EPA WATER INFRASTRUCTURE AND RESILIENCY FINANCE CENTER
In January 2015, EPA launched the Water Infrastructure and Resiliency Finance Center, which supports the government-wide Build America Investment Initiative. The center provides communities, municipal utilities, and private entities with information and technical assistance on how to effectively use existing Federal funding programs, access leading-edge financing

[56] AWWA, *AWWA J100-10 (R13) Risk and Resilience Management of Water and Wastewater Systems*, 2010.
[57] CIPAC Water Sector Cybersecurity Strategy Workgroup, *Final Report and Recommendations*, 2015; and NIST, *Framework for Improving Critical Infrastructure Cybersecurity*, 2014.
[58]CIPAC Water Sector Strategic Priorities Working Group, *Roadmap to a Secure and Resilient Water Sector*, 2013.
[59] AWWA, "Cybersecurity Guidance & Tool;" and AWWA, *Process Control System Security Guidance for the Water Sector*, 2014.

solutions, and develop innovative procurement and partnership strategies. Although relatively new, the center has already undertaken several initiatives including establishing a network of university-based Environmental Finance Centers that correspond to the 10 EPA Regions; hosting Regional Finance Forums to bring together municipal officials and interested stakeholders to facilitate peer-to-peer interactions, share best practices, and build relationships; and providing technical assistance and tools through its Community Assistance for Resiliency and Excellence (WaterCARE) program. The center, which is advised by EPA's Environmental Financial Advisory Board, also works closely with other Federal partners.[60]

TRANSFORMING COMMUNITIES THROUGH SUSTAINABLE INFRASTRUCTURE INVESTMENTS

Leading organizations are rethinking how investment in resilient infrastructure can be leveraged to create new opportunities to reinvigorate communities, increase inclusion, and stimulate local business investment. The San Francisco Public Utilities Commission (SFPUC) has created a Community Benefits Program that engages neighborhoods that are directly affected by the operation of its water, wastewater, and power enterprises. The program includes education, workforce development, economic development, land use, neighborhood revitalization, funding for the arts, localized professional services contracts, and philanthropic partnerships. SFPUC seeks to balance economic, environmental, and social equity goals to expand economic inclusion, create job opportunities, revitalize low-income neighborhoods and support climate change priorities.[61]

In the Transportation Sector, Secretary of Transportation Anthony Foxx recently issued a letter that encourages grantees and stakeholders to take advantage of opportunities to leverage $305 billion in Fixing America's Surface Transportation (FAST) Act funding to create new jobs, pointing out that every $1 billion invested in Federal highway and transit infrastructure would support 13,000 jobs. A new pilot program, for example, enables recipients of Federal highway and transit funds to use innovative contracting requirements designed to create jobs that may have traditionally been disallowed due to competition concerns. Another approach, the U.S. Employment Plan developed by the Jobs to Move America Coalition, contains a contractual provision that provides incentives for companies to create American jobs, locate facilities in the United States, and generate opportunities for unemployed workers through recruiting and training efforts.[62]

In essence, there is a great deal of information about the *mechanics* to solve the problem—what to do, how to do it, and who to work with—this is only the start of a solution. The *political challenge*, which spans the spectrum from developing public understanding to the willingness of elected officials to opt for investment, is daunting. The mechanics of a solution may well be easier than obtaining political will.

[60] EPA, "About the Water Infrastructure and Resiliency Finance Center," 2016.
[61] SFPUC, "Community Benefits Program," 2013.
[62] Office of the Secretary of Transportation, "Letter to Transportation Stakeholders," 2016.

V. FINDINGS AND RECOMMENDATIONS

The Water Sector is a lifeline sector that is critical to the core operations of other sectors and essential to human health and daily life. The Water Sector faces a unique set of challenges due to services being historically reliable and low-cost, and out of sight of the public and decision-makers.

A. FINDINGS

Through interviews with Federal agency representatives and subject matter experts, extensive research, and the work of the Study Group, the Working Group identified six areas of findings that encompass the challenges, needs, and strategies for improving security and resilience within the Water Sector:

1. Poor Understanding of the Criticality of the Water Sector
2. Inadequate Valuation of Water Services
3. Wide Disparity of Capabilities and Resources
4. Significant Underinvestment in Water Sector Resilience
5. Fragmented and Weak Federal Support for Water Resilience
6. Regional Collaboration Not Broadly Applied

The findings highlight the criticality of water, the need to address emerging risks, and the significant challenge of funding needed improvements to water and wastewater infrastructure.

Finding 1: Water is not given appropriately high priority as a critical lifeline sector by public officials and dependent sectors during disaster planning, prevention, and response.

The Water Sector is facing a changing and complex risk environment, and critical infrastructure operations, State and local leaders, and customers often do not understand the full impacts of water service disruptions, including the potential cascading impacts of extended disruptions. As a result, the Water Sector may not receive the high priority it deserves to perform emergency restoration. For example, water utility employees often lack priority access to damaged assets during a disaster due to a misunderstanding of the steps needed to fully repair water systems and the time sensitivity of operational recovery in the sector.

1.1. Under the National Response Framework, water responsibilities are distributed across four Emergency Support Functions (ESFs) and multiple Federal agencies. This can result in water being excluded from unified command or interagency coordination, and can create confusion during response and recovery efforts that can impede water service recovery during disaster.

1.2. Water and wastewater utilities rely on electricity for operations, fuel for backup power and transportation, and chemicals for water treatment. While these dependencies are known to operators and emergency personnel, it is more difficult to track the changing risks within the interdependent sectors that supply critical products and services. These

dependencies and the associated risks are often not sufficiently addressed in practices, such as business continuity or response planning along supply chains or across dependent sectors.

Finding 2: Water services are often undervalued and taken for granted because they are typically highly reliable, inexpensive, and hidden from view.

This undervaluing makes it difficult to gain public support and necessary funding for infrastructure improvements, upgrades, repairs, and maintenance that would increase resilience and maintain the sector's excellent track record.

2.1 A significant portion of the infrastructure includes underground pipes and other assets that are invisible to the public eye. This location can mask the need for significant repairs, replacements, and upgrades as the infrastructure ages. Public perception of water infrastructure condition may not match the backlog of needed maintenance on many systems.

2.2 There are very few high-profile examples of major water infrastructure failures. As a result, weak public understanding and recognition of the critical nature of water services makes it difficult for public officials and decision-makers to justify the time and money required to make repairs following an incident, as well as fund key infrastructure improvements.

2.3 It is difficult for public officials to gain support to increase rates or allocate public funds for short- and long-term water infrastructure projects, particularly if disadvantaged or low-income populations would be harmed by rising water prices.

2.4 Investments in resilience can produce order-of-magnitude savings compared to expenditures for emergency response and repair.

Finding 3: Technical capabilities and resources vary widely among water utilities. Smaller utilities in particular often lack the qualified staff, tools, technical expertise, and reliable information needed to manage new risks.

An evolving risk environment requires utilities to prepare for a wide range of potential risks amidst day-to-day operations without loss of service levels. Such planning and preparation requires significant resources, including the technical and financial capability to manage long-term, risk-management decisions and "make the case" to decision-makers to address high-impact, low-frequency risks that must compete with other operational priorities.

3.1 As water utilities—particularly those that are under-resourced—balance day-to-day operations with long-term, risk-management decisions, they may lack the capabilities to adapt to a range of uncertain threats, such as extreme-weather events and rising sea levels. Water utility planners lack reliable projections, guidelines, or design standards from Federal agencies that would enable them to design, build, and maintain resilient infrastructure.

3.2 The increasing prevalence of cyber intrusions challenge business-as-usual practices for nearly all utilities. Strong cybersecurity awareness and practices among utility personnel is

often limited. The number of available Water Sector cyber experts is insufficient for current needs, and utilities are constrained in their ability to offer competitive hiring packages to attract top cybersecurity experts.

3.3 It is difficult to maintain, recruit, and train qualified personnel due to specialized job requirements and competition for skilled workers, leading to a loss of institutional knowledge and skills. Many utilities are unable to invest in enough engineering resources to assess existing and future infrastructure needs.

3.4 The technology, knowledge, and tools to promote resilience exist, but awareness of their availability and adoption does not appear to be spread widely throughout the sector, and knowledge transfer lags.

3.5 Water and wastewater utilities are diverse in the advancement of their operations—some are developing and implementing leading-edge practices, while others lack the information, expertise, and tools to do so.

Finding 4: There is significant, chronic underinvestment in water infrastructure and resilience due in part to widespread public ownership and a reluctance to raise rates.

The estimated investment gap ranges from $400 billion to almost $1 trillion to maintain the current level of water service. The majority of Water Sector assets are publicly owned, making it difficult to gain approval for large infrastructure investments to improve resilience from the elected boards/commissions that set rates and approve capital projects. Without public support, it is difficult to create the political will necessary to fund forward-looking investments, especially if they increase the burden on low-income populations.

4.1 Public resources are often available for immediate short-term needs, such as emergency response; but historic patterns of inadequate investment have delayed needed maintenance and inhibited long-term improvement projects. This has created frequently distressed conditions that threaten reliable operations outside of emergency events.

4.2 Publicly owned utilities often use bonds to fund construction and rely on rate increases to recoup costs. The requirements for additional Federal or State funding to support an infrastructure project, such as State Revolving Funds, can make it difficult to access or use these sources.

4.3 The challenge of maintaining affordability for all customers, including low-income or at-risk customers, can make it difficult for some water and wastewater systems to implement full cost-of-service pricing.

4.4 Some publicly owned utilities do not adequately invest in pre-disaster mitigations because they believe that the Federal Government will provide significant resources to repair their system in the wake of a major disaster.

Finding 5: Resilience has not been substantially integrated into the actions of Federal agencies, and resilient outcomes are not part of Federal guidance and resources.

The Federal agencies and departments that oversee the Water Sector, such as EPA and State primacy agencies, are primarily focused on public health and environmental protection measures, and resilience programs are often voluntary.

5.1 Some Federal regulations inhibit utilities from taking steps to improve resilience or build in redundancy, such as building and operating cost-effective power generation or allowing for different water quality standards to be met during an emergency.

Finding 6: Limited regional coordination across jurisdictions and water systems leads to inefficient, siloed decision-making that can hamper resilience.

Although there are notable exceptions, water utilities within a region tend to plan and operate independently, leading to a lack of visibility and understanding of infrastructure system dependencies within metropolitan areas and regions. Multiple local and/or State jurisdictions tend to complicate cross-jurisdictional coordination and may cause utilities to react to an event independently without consideration for a regional, collaborative solution that would yield quicker and more cost-effective results.

6.1 The lack of a broadly accepted framework for regional goals, resource-sharing criteria, and performance metrics hinders the development of a shared approach to disruption. The framework should apply to all phases of resilience, not just response.

6.2 Water disruptions primarily affect local communities, but can have a significant impact on local and regional lifeline sectors. Insufficient attention is given to the risk and impact of a large-scale national disruption.

6.3 The sector has made in-roads in this area through its Water/Wastewater Agency Response Network (WARN). The interstate, volunteer-based network provides mutual aid between member utilities following a disaster to aid in expedited restoration of services.

B. RECOMMENDATIONS

The Water Sector has made progress in the area of resilience by actively planning and collaborating on key efforts, such as the *2013 Roadmap to a Secure and Resilient and Water Sector* and the *CIPAC Water Sector Cybersecurity Strategy Workgroup: Final Report and Recommendations*. But as the findings suggest, much more needs to be done. Marshalling political will and public support is a protracted process that requires communication, collaboration, and unfailing dedication: champions are needed at all levels of government.

During each of our last two studies, the Council witnessed disasters that provided examples of how infrastructure can fail under stress. We witnessed the destruction brought by Superstorm Sandy and the 2012 derecho during our *Regional Resilience* study, and the effects of West Coast port shutdowns and winter storms that crippled the Boston transit system and caused a dangerous freight derailment in West Virginia during our *Transportation Resilience* study. The Flint water crisis that unfolded during our current study provided us with insights of how mismanagement, poor

governance, and infrastructure shortcomings can converge to wreak havoc on the daily lives of citizens of a small city. While our study is not focused on the Flint situation, we believe that our recommendations closely align with some of the underlying failings that led to the problems in Flint.

The Council recommends the following steps be taken to improve resilience in the Water Sector. For each recommendation, we have identified specific actions that the Federal Government should take to ensure the success of these recommendations. Many of these recommendations have been presented in previous studies by the Council or other organizations. Appendix E. Compendium of Prior Recommendations provides a list of these recommendations most relevant to this study.

Recommendation 1: Analyze and map the complex risks of major water disruptions and develop mitigations.

The Federal Government should assist owners and operators in the Water Sector to uncover emerging cross-sector risks and develop mitigations for disruptions that could cascade into other sectors and regions, particularly if they have the potential for national consequences. To accomplish this, the Federal Government should commit funding and expert resources to help identify, analyze, and map hidden risks that result from complex sector interdependencies, regional interconnections, and increased convergence of physical-cyber systems.

Specific Actions

1.1 The DHS National Protection and Programs Directorate (NPPD)—in coordination with EPA; DOE; DOT; U.S. Department of Health and Human Services (HHS); State, Local, Tribal, and Territorial Government Coordinating Council (SLTTGCC); and other Federal and State partners—should conduct joint tabletop exercises, across jurisdictions and interdependent sectors, to test the resilience of the water infrastructure during major incidents, such as cyberattacks and large-scale power outages. The joint exercise should be conducted within 12 months of the release of this report.

1.2 The Federal Government should identify existing user-friendly models that would help emergency managers and planners better understand systems and interdependencies at the metropolitan and regional level. The evaluation should identify best practices and data needed to improve existing models. The Federal agencies best positioned to improve and distribute models should work with the water associations on outreach and distribution of the models and best practices so they can be applied more broadly across the sector.

1.3 Within one year, the Federal Government, in partnership with the Water Sector, should identify analytic tools, guidelines, and check lists for assessing cross-sector and cyber vulnerabilities to be part of a series of pilot projects at selected sites across the water infrastructure. The pilots should leverage existing tools and guidance, and the results of the pilots should be used to encourage the application of successful tools and best practices more broadly across the sector by providing decision-makers with the evidence and data they need to justify investments.

1.4 The Federal Government, working with the Water Sector, should identify analytic tools (including those for assessment of cross-sector vulnerabilities and dependencies); guidance for mitigation, and associated best practices (including those from other sectors) to provide water utilities with measureable, actionable information they need to prepare for emerging threats and risks, particularly as they make decisions related to planning and capital investments (e.g., hardening assets, protecting or building facilities).

Recommendation 2. Fortify Water Sector response and recovery capabilities.

The Water Sector has historically maintained continuity of service during events and provided rapid response and recovery despite obstacles. However, because of the criticality of water and wastewater services, the Federal Government should take immediate actions to formalize and improve the response and recovery capabilities at every level of the Water Sector. To accomplish this, the Federal Government should increase planning for extreme events, consolidate Federal response responsibilities, and increase funding for successful sector mutual aid efforts.

Specific Actions

2.1 The National Security Council (NSC) should direct the Water Sector and Government Coordinating Councils to create a government-industry playbook for managing extreme events. The playbook, which could be modeled after the Electricity Sector Coordinating Council Playbook, should clearly define the roles and responsibilities of agencies and utilities to help sustain operations during a severe event and help prioritize activities, such as providing fuel for emergency generators and re-supply of crucial chemicals.

2.2 The Secretary of Homeland Security should direct the administrator of FEMA to consolidate Federal emergency response roles and responsibilities for water into a single ESF within the Annex to the National Response Framework. This would improve coordination and reduce confusion, improve information sharing and communication, and alleviate over-taxing of resources within the Water Sector.

2.3 EPA should increase funding to expand the successful mutual aid program, WARN, to facilitate regional collaboration of events that extend across jurisdictions and reinforce the program as a successful model for addressing the full spectrum of resilience and physical and cyber asset challenges.

Recommendation 3. Increase Federal funding, investment, and incentives to improve water infrastructure resilience.

The Federal Government should establish new funding mechanisms, structures, and incentives to increase investment in resilience at the regional and local levels to counter historic underinvestment in infrastructure, and to remove obstacles that public agencies face in increasing rates, particularly when they impact low-income communities.

Specific Actions:

3.1 EPA, under existing or newly established authorities, should work with HHS to create a Federal financial assistance program (similar to the Low Income Home Energy Assistance Program) to reduce the financial burden on low-income communities from water rate increases and allow communities to make necessary infrastructure investments and set rates that reflect the true cost of providing services. To launch the financial assistance program, EPA should work with the major water associations to implement a pilot with five water utilities within 12 months of this report's release.

3.2 Create a disaster deductible for allocating Stafford Act funding to incentivize communities to make investments to increase resilience. In recent years, the Federal Government has stepped in on numerous occasions following an event to provide post-disaster relief. This has created a moral hazard—communities are not investing in measures that could mitigate the impacts of a low-frequency, high-consequence event because they expect the post-disaster funds will be available, if needed. The effects of disasters often cross jurisdictions and impact entire regions; because of this, the deductible should have a regional focus.

- The NSC, DHS, and FEMA should develop resilience criteria that takes into account the multiple factors that can affect investment by water utilities and recognizes utilities that provide mutual aid and support.
- Mitigation and resilience actions would be credited toward a region's deductible. If they do not take certain steps, in the event of a disaster, there would be a certain amount of covered assistance that they would be responsible for paying.

> "For publicly-owned infrastructure there is actually a disincentive for investing in measures that mitigate risk of disruption whether it be from naturally occurring or manmade events, because local and State officials can be almost certain that when these low-probability, high consequence events happen, the Federal Government will come in afterward with significant resources to make them whole."
>
> *Dr. Stephen Flynn, Professor and Co-Director of the George J. Kostas Research Institute for Homeland Security at Northeastern University*

3.3 Identify and promote innovative financing options that fast track and streamline investments in water infrastructure and resilience, including public-private partnerships and century bonds; new or expanded use of the State Revolving Funds, as recommended by the Environmental Financial Advisory Board; or new ways to leverage other Federal grant programs, such as those available through the U.S. Department of Housing and Urban

Development, the U.S. Department of Agriculture, DOE, and FEMA. EPA's Water Infrastructure and Resiliency Finance Center appears well-positioned to lead this effort and can also conduct the necessary outreach, share best practices, provide technical assistance, and serve as a clearinghouse for effective mechanisms.

3.4 DHS, Science and Technology Directorate should reduce the risk of implementing innovative technology and funding mechanisms by developing cost-share pilot projects with water utilities to speed adoption of better and more cost-effective approaches to service delivery. Successful demonstrations should include an evaluation of whether the mechanism is applicable to other sectors.

3.5 Federal critical infrastructure investment should be repositioned to catalyze economic development; encourage smart, sustainable, and resilient systems; and create job opportunities and inclusion at the local level that will build public awareness and support for infrastructure investment. To achieve this, the President, through the Office of Management and Budget (OMB) and in coordination with the NSC, should direct the heads of all Federal departments and agencies responsible for critical infrastructure investment, as identified in PPD-21, to:

- Identify and report annually to OMB, all current and planned department/agency investments in critical infrastructure for which they have oversight;
- Design innovative programs and approaches that create job opportunities and local community benefits using Federal infrastructure investments; and
- Establish multiyear goals and performance milestones for critical infrastructure investments and include them in department/agency strategic plans.

Recommendation 4. Increase technical and financial resources and expertise available to the Water Sector.

The Federal Government should work with larger and well-resourced utilities to help improve the technical and financial capabilities of smaller or less-resourced utilities by creating programs that link regional technical resources to local water utilities and leveraging the established programs, expertise, and capabilities of universities. The Federal Government should also assist national and regional water associations to expand their outreach efforts that increase utility access to valuable tools and models. These efforts should emphasize improving the cybersecurity capabilities of water utilities that have limited cyber capacity.

Specific Actions

4.1 Create a network of land grant universities to build localized technical capabilities, services, and expertise for water utilities that can be leveraged with private funding, and help train the next-generation workforce. The initial program should start with 10 geographically dispersed universities that meet certain criteria, such as access to State funding, existing subject matter expertise, applicability to selected research topics, and their location.

4.2 The Secretary of Homeland Security should direct funding to water associations to increase outreach efforts of financial tools and life-cycle assessment models that help utilities justify necessary infrastructure investments and support improved asset management practices.

4.3 NSC and DHS should expand cyber resources, expertise, and workforce training for the Water Sector. This should include sharing best security practices and applications through outreach and leveraging existing programs such as the Protective Security Advisor's cybersecurity initiative.

Recommendation 5: Strengthen Federal leadership, coordination, and support for Water Sector resilience.

The President should strengthen Federal leadership on water infrastructure issues by coordinating across Federal agencies, raising awareness about the importance of water, leveraging investment to create job opportunities and inclusion for local communities, and identifying and removing legal, regulatory, and policy barriers that impede investment and implementation of resilient measures.

Specific Actions

5.1 Establish a temporary high-level Federal coordinating body led by DHS—with senior-level representatives from major agencies that have a role in water—to proactively lead collaboration across Federal, State, and local governments and the Water Sector, with particular emphasis on extreme and national-level events. To avoid creating another level of bureaucracy, the coordinating body should be limited to two years.

5.2 The focus on water at the Federal level has traditionally been on clean water (EPA), control of water resource infrastructure (USACE), and emergency response (FEMA), with little emphasis on proactive resilience and security. One of the first tasks for the Federal coordinating body should be to identify barriers to resilience and rapid recovery in existing Federal oversight, laws, and regulations through analysis.

> "Right now, the way [environmental laws and regulations] are being applied, is like taking a 1965 Ford Mustang manual and trying to fix a Prius."
>
> *Patricia Mulroy, senior fellow in the Metropolitan Policy Program at Brookings*

- The review should result in recommendations for statutory reforms that could promote resilient activities, encourage innovation, and provide flexibility in regulatory compliance during emergency situations.
- The review should also ensure that rules do not overlap or overrule each other.

5.3 The Federal coordinating body, working with national water associations and the Water Sector SCC and GCC, should initiate a national public outreach campaign to increase awareness about the importance of water services.

5.4 Within one year of issuance of this report, the NSC, in coordination with the Council of Economic Advisors, should convene a national public-private philanthropic leadership forum with representatives from business, government, community advocates, education, labor, and philanthropic organizations to determine the best approaches for leveraging Federal infrastructure investments to increase economic opportunities and build public support for Water Sector investment.

C. NEXT STEPS

Our message is clear: we can no longer ignore the deterioration of the Nation's water infrastructure in the face of emerging and uncertain risks. Water utilities have done a remarkable job of keeping the water flowing in the face of disasters and budget challenges. But growing interdependencies among lifeline sectors, and the vital role that water plays in nearly all human endeavor, demands more proactive steps.

Building and sustaining a resilient water infrastructure must be a top national priority. It will require stronger Federal leadership, more funding, and collaboration, commitment, and perseverance among all Water Sector partners. Investment in infrastructures must also be tied to investment in our people, our communities, and our economy. Cities and communities across the country face chronic unemployment and under employment, inequality, and affordability challenges that require urgent national action. Special attention must be given to our most vulnerable populations in high needs communities. The weak levees in New Orleans and the corroding lead pipes in Flint drive home important lessons about the need for public/community engagement, greater accountability/ transparency, and expanded partnerships in building and operating critical infrastructures.

Fault lines in the Nation's water infrastructure have been slow to emerge and virtually invisible to most of us. Reversing this trend will not be easy. The risks are complex and the challenges in investment, workforce development, and managing extreme threats will strain even the most capable utilities, and overwhelm smaller ones. We must not simply rebuild old and failing systems; we must build-in resilient characteristics by leveraging the capabilities of all partners.

To succeed in this endeavor, we must generate strong public interest, support, and the political will to reinvigorate crumbling infrastructure. New investments in smart, sustainable, resilient infrastructure must be used as a catalyst for job creation, economic competitiveness, and an equitable and shared prosperity. New investments in communities will translate into greater support for the infrastructures that serve them. Simply put, when infrastructures serve people, people will support infrastructure.

Strengthening the security and resilience of our critical infrastructure exceeds the capabilities of any one company, sector, or government agency. Water associations, NGOs, academia, and the private sector, particularly CEOs, must be engaged and committed to progress. Much of the responsibility rests with the owners and operators who design, build, operate, maintain, and repair the infrastructure, but Federal and State governments are critical partners in this endeavor. The government must make it easier for the owners and operators to invest in infrastructure improvements; they must identify and remove regulatory barriers that inhibit resilient behavior; they must help to identify and mitigate cross-sector risks that hide between the seams of

interdependent sectors and regions; they must develop measurable standards and best practices to guide water agencies in their resilience efforts; they must leverage the science and engineering resources of our national laboratories and universities to develop innovative technologies and bring them to market; and they must strengthen leadership and coordination among agencies across all levels of government.

We believe this study, along with our previous ones, provides a practical template for action that can help ensure the long-term security and economic prosperity of our Nation's critical infrastructure.

APPENDIX A.
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APPENDIX B.
COMPENDIUM OF INFORMATION FROM SUBJECT MATTER EXPERTS

This appendix synthesizes information from Working Group interviews and Study Group panel discussions and interviews with Federal agency representatives and subject matter experts (SMEs) in water and wastewater systems and critical infrastructure. It is organized into six sections:

- Water Sector Risks and Barriers to Resilience
- Cross-Sector Dependencies and Interdependencies
- Risk-Management Policies and Practices
- Infrastructure Investments and Funding
- Making the Business Case
- Leadership and Coordination

I. WATER SECTOR RISKS AND BARRIERS TO RESILIENCE

In the Water Sector, resilience focuses on minimizing water and wastewater service outages and recovering services as soon as possible following a disruption. To do this, utilities need to have the capacity to maintain operations despite challenges to the system, such as stressors, incidents, or disruptions. However, there is no consistent definition of resilience used throughout the sector. Note that while the engagements with SMEs focused on resilience, the security of systems—reducing the risk to critical infrastructure by physical means or cyber defense measures—is embedded in many aspects of resilience. Some highlights on Water Sector resilience:

- Utilities tend to focus on response after a major incident (e.g., severe drought) and not on resilience before an incident occurs.
- Shifting to a next generation resilience strategy will change how utilities manage risks.
- All-hazards preparedness perspective is key to resilience.
- Utilities need to plan for emerging threats. Such threats for the Water Sector include increasingly severe weather events, capacity issues stemming from changes in customer demographics and movement patterns (e.g., increased movement toward urban environments and coastlines), and cybersecurity.
- Utilities should examine infrastructure criticality, potential failure consequences, single points of failure that could cause significant problems, and ways to mitigate against each.
- Resilience is entirely voluntary for utilities, and must be balanced against other priorities, such as regulatory compliance, available funding, demographic shifts in customer base, and aging infrastructure.

There are five key barriers to resilience:

- Governance structure is not organized to advance resilience. It's organized around narrow political jurisdictions (e.g., local, county, State, Federal. However, infrastructure is increasingly regional, metro-regional, and interdependent.
- Limited training and education are focused on resilience. This makes it a challenging to have a workforce that can understand the complexities of resilience.
- Sectors have limited understanding of infrastructure systems, their vulnerabilities, interdependencies, and the hazards that will disrupt them.
- Infrastructure systems are generally not designed for resilience. They are designed for efficiency, safety, and security. This does not account for the fact that infrastructure will likely fail at some point and need to recover.
- There is a lack of economic incentives for sectors to invest in resilience, and sometimes there are disincentives for investing in resilience. This is particularly pronounced in the Water Sector.

The U.S. Environmental Protection Agency (EPA) has identified four critical components or core elements of resilience:

- Risk assessments to outline risks and what assets are at risk
- Emergency response planning
- Training and exercises
- Recovery

Within each of these, EPA set basic and advanced benchmarks, but they are optional to implement. Other components to resilience include:

- Having an emergency resource plan, including backup power and supplemental employees to operate facilities in an emergency.
- Establishing multiday water storage capabilities
- Finding mutual aid and assistance
- Revising the National Incident Management System (NIMS) to prioritize Water Sector
- Examining what finances a facility has available for recovery

Long-term threats to water infrastructure include infrequent/uncertain hazards and extreme weather events, limited funding and flexibility, and aging infrastructure.

- Hazards are well-established risks, but are infrequent and uncertain. This uncertainty generates inaction.
- Organizations need to establish what level of risk they are comfortable with and create response plans. While it may be impossible to prevent all impacts of an event, planning

shortens recovery time. Utilities have to build risks into planning, particularly with securing major equipment.

- Utilities and local governments are planning for resilience at a local level. However, threats such as extreme weather cross jurisdictional boundaries. The Water Sector needs to plan for infrequent hazards and justify expenditures that mitigate against these threats.
- Limited funding for infrastructure investments threatens resilience. The current price of water is not sustainable for full recovery of the cost of service.
- Aging infrastructure including the physical degradation of infrastructure is a major issue, particularly for wastewater utilities. Aging infrastructure can lead to public health problems.

Black sky events are natural and manmade forces that are high-impact but have an uncertain probability. These could cause a power outage more extensive and more severe than those that occurred during Superstorm Sandy.

- Black sky events have uncertain probability, but are not low-frequency. Risks are growing, especially in terms of manmade hazards.
- Black sky events cause wide area power outages that may extend for months, with the twin effects of long duration of power loss and physical damage to Water Sector infrastructure.
- Manmade hazards, cyber, kinetic, and electromagnetic interference attacks pose a substantial threat to the electric and natural gas industries, with cascading effects on the Water Sector.
- The United States is overdue for a catastrophic earthquake in the New Madrid Seismic Zone on scale with the 1812 earthquake. This would cause a massive electric and natural gas infrastructure failure.

Utilities have built some resilience for black sky events, but additional preparedness is needed.

- Utility chief executive officers (CEOs) will decide what constitutes prudent investments against black sky hazards. Focusing on black sky preparedness is important, but incremental preparedness for less intense events is also useful. Practical, step-by-step improvements could improve overall preparedness. Water executives could focus on incremental improvements for power outages.
- Sector-Specific Agencies (SSAs) for the Energy and Water Sectors have a vested interest in advancing resilience and addressing dependencies in the event of large-scale power outages. The *Resilience for Black Sky Days* report (conducted on behalf of the National Association of Regulatory Utility Commissioners) contains catastrophic scenarios for regulated utilities. The report examines the cost associated with not preparing for these low-probability, high-consequence events.
- It is important to examine resilience data, understand where we are today, and identify preparedness gaps.
- There is a lack of cross-system visibility for how black sky factors could disrupt functions.

Power failure is the largest risk dependency to the Water Sector and can generate regional and national impacts.

- There is a lack understanding about how a long-term power outage would disrupt municipal functions. If electricity is down for an extended period of time, utilities would not process wastewater effectively, if at all, crippling the city and leading to evacuations.
- Advanced systems—such as wastewater treatment systems that are highly mechanized and reliant on energy—are more vulnerable to disruption.
- For large plants, available generators may not be large enough to address power requirements.

Cybersecurity vulnerabilities of most concern include spearfishing; insider threat; the cyber-physical nexus; and impacts of an attack on operations, automated systems, supervisory control and data acquisition (SCADA) systems, and public confidence.

- Cybersecurity is not a one-dimensional problem; there are vulnerabilities in personnel, processes, and technologies.
- Control rooms can be vulnerable to spearfishing, inadvertent attacks, or undetected or unauthorized system access.
- Distributed systems make understanding cyber vulnerabilities difficult. The operator may not see the cyberattack (as they would a physical attack) because of distributed systems or because the attacker wants to remain undetected long enough to incur significant damage.
- IT security consequences, risks, and vulnerabilities are different on the operations side than in billing or program management systems. Security measures should be different depending on the environment.
- A cybersecurity failure in the Water Sector could have cascading effects across multiple sectors because of interdependencies.
    - For example, data centers depend on huge amounts of water to cool systems. If their water source is compromised, data centers cannot function without adequate alternative water sources. This would affect the operations of many interdependent sectors.

The Water Sector's cybersecurity challenge is complex and cybersecurity capabilities vary depending on resource availability and utility size.

- A variety of stakeholders in the Water Sector are connected to cybersecurity—vendors, engineers, owners/operators—and risk can generate from anywhere in this chain. Exchanging information is critical.
    - Cybersecurity principles are often not embedded throughout an entire organization.
    - Vendors may not have the cybersecurity tools a utility needs. However, vendors can adapt their practices to industry norms.

    - Comprehensive cybersecurity training and resources is necessary to ensure that personnel, across the sector, are up-to-date on cybersecurity solutions and practices.
    - There is an opportunity for adopting/adapting cybersecurity practices from the private sector. Expanding public-private sharing of information regarding cyber threats and incidents would be helpful.
- Utilities need more guidance on how to conduct cybersecurity risk assessments and prioritize assets. Although excellent guidance is available through associations, its application remains comparatively limited.
- Vendor cyber vulnerabilities, such as limited cybersecurity in products sold to water utilities, can create Water Sector cyber insecurity.
- SCADA systems are not standardized between facilities and do not have consistent interoperability with other water-automation programs. This leads to varying levels of cybersecurity risk.
- Smaller systems often lack resources and specialized personnel for large-scale cybersecurity improvements. Some large facilities have the resources to separate their Internet connectivity and infrastructure between operations. Smaller systems generally lack this capacity, resulting in more risk exposure.

Maintaining and enhancing a viable workforce is a core challenge for the Water Sector.

- Experienced personnel are a crucial part of the safe and reliable operation of water utilities. As risk evolves and new risks emerge, new or improved skill sets are required, and sometimes training commensurate with these risk areas is costly.
- Retirements and attractive pay outside of the Water Sector can result in a loss of institutional knowledge.
    - About 30 percent of the Water Sector workforce is eligible for retirement. The sector is actively working to respond, including examining how it can compete with private sector employment.
    - Obtaining and retaining cyber expertise is a particular challenge.
- Training, development, and recruitment are opportunities where the Federal Government can help. Industry can partner with the Federal Government on retraining the industry.

Water utilities must prepare for a variety of weather events and develop tools for comprehensive extreme weather planning.

- Severe storms, flooding, drought, changing weather patterns (e.g., El Niño, more frequent severe storms), and earthquakes are the natural events of most concern to utilities. Such events are difficult to plan for and can lead to loss of pumping capacity, limited access to critical resources (e.g., chemicals), and power outages. The following provides context for these extreme weather events.

- 2016 El Niño is resulting in sea levels 6 to 10 inches higher than normal. “King tides” are becoming more threatening to coastal combined systems.
- Severe, prolonged drought is particularly challenging because it may not follow predictable weather patterns.
- During severe heat and wind events, the risk for water disruptions increases. For instance, water supply goes down because of water used to fight fires.
- Major natural disasters, such as blizzards or hurricanes, are a major concern because they also affect the workforce required to operate the systems.

- Efforts to address extreme weather events include:
  - Working with regional partners to diversify the water supply to limit the effects of severe drought.
  - Studying extreme weather events and determining how they might impact infrastructure and what projects are needed (e.g., stormwater capture).
  - Understanding risks and vulnerabilities. Oftentimes, third-party organizations (e.g., nonprofit, private) can find vulnerabilities that were not anticipated by the owners and operators.
  - Investing in preparedness, such as ensuring equipment is available for long-term use. Systems with generators require adequate fuel to run the generators or backup power.
- Climate change will affect water infrastructure in different ways depending on the region’s vulnerabilities. The combination of aging infrastructure, population growth, and potential storm surge magnifies the effects of sea level rise for East Coast utilities. Consequences may include flooded sewer lines and salt water intrusion. In the Western United States, utilities experience water scarcity issues.

II. CROSS-SECTOR DEPENDENCIES AND INTERDEPENDENCIES

There are critical interdependencies between the Water Sector and other lifeline sectors. These are often not fully understood until after an incident occurs. In addition, sectors may lack visibility into the vulnerabilities of other sectors. This may be compounded by a reluctance to share information on vulnerabilities, both inside sectors and among interdependent sectors.

Dependencies and interdependencies exist along the Water Sector supply chain. The Water Sector has dependencies on sectors such as the Energy, Chemical, and Transportation. It has interdependencies with most sectors (e.g., Healthcare and Public Health are dependent on water).

- Water and wastewater utilities rely heavily on access to chemicals, transportation networks, and energy supplies.

- Personnel that know the system and that are trained in recovery processes are critical to resilience. Both within the Water Sector and along the supply chain, they are critical to maintaining operations. Personnel are needed to implement procedures.
- Challenges for addressing dependencies include:
    - Cascading failure analysis helps to identify and evaluate dependencies. However, sectors do not commonly share vulnerabilities.
    - Water distribution and collection systems may be inadequately addressed during analysis since they are located outside the central utility.
    - Technological and regulatory barriers can prevent utilities from securing onsite energy supplies.
    - The Water Sector needs to coordinate with the Energy Sector to restore power after a long-term loss of power. Priority customers rely on both water and energy, so the sectors should coordinate restoration based on the criticality of customers.

Action is needed to better understand cascading impacts (including regionally) and vulnerabilities throughout the sector. There is a need to break down silos and focus resources to address governance barriers.

- The vulnerabilities of larger supply chain systems, such as those outside of the Water Sector, are a major concern to local water utilities. There is a need for better dialogue on these vulnerabilities.
    - The Water Sector prides itself on silent service (i.e., reliable, consistent service). As a result, facilities may not fully understand or be reluctant to share their vulnerabilities.
    - Utilities are impeded by the limited sharing of vulnerabilities along the supply chain and are unable to conduct adequate cascading failure analysis and supply chain vulnerability identification.
- The Water Sector needs to examine Energy Sector dependencies. Water utilities could operate "off the grid" (e.g., use co-generation and onsite generation to ensure continuity of operations).
    - However, the utility will be treated as an energy generator and not as a water facility (and will become subject to energy regulations). This adds significant costs, which must be justified to customers and stakeholders.
- The Federal Government can support coordination between dependent sectors.

Although every water system has a unique set of assets/processes and operations are individualized, there is an increasing emphasis on creating system interconnections, where possible to allow greater flexibility. This enhances resilience, particularly for severe, long-term events such as droughts.

- System interconnectedness has driven utilities to consider a regional utility system. A hub would provide wholesale service to smaller utilities while all utilities are networked.

However, there is a concern that such a network would transmit cascading failures during disruptions.

- Organizations are focused on understanding dependencies among water systems and addressing cross-jurisdictional challenges. More attention is being directed to coordinated, long-term management of water resources.

III. RISK-MANAGEMENT POLICIES AND PRACTICES

The Water Sector maintains a key focus on effective all-hazards risk-management policies and practices. However, additional work is needed to ensure policies and practices are responsive to the risk environment and promote resilience. Adopting a comprehensive resilience framework that is forward thinking, focused on aging infrastructure and asset management, coordinated and inclusive of cybersecurity would advance resilience. In addition, those outside the Water Sector should recognize the sector as a lifeline sector during emergency response.

Utilities are moving toward an all-hazards emergency management approach, implementing a variety of risk-management solutions to combat a range of risks. However, investments in improved Water Sector response and recovery are needed.

- Examples of preparedness include training, planning for incidences beyond what is traditionally expected, using new technology and tools (e.g., flood inundation maps), and conducting large-scale drills on Unified Command.
- Depending on the utility size, infrastructure, and provided service, utilities may have difficulty in locating resources to facilitate a rapid recovery.
    - Many communities will be asking for the same equipment and supplies at once.
    - Navigating "red tape" and the logistics of getting equipment are challenges. Guidance, planning, and region-specific depots would provide much needed assistance.
    - Investing in backup energy equipment is costly, and it is difficult to provide an effective return on investment. Getting the ratepayer to understand investment needs is challenging, as ratepayers may have never experienced a utility losing all sources of power at once.
    - Replenishment of fuel stocks is a problem, especially during major events. If there was a widespread incident, fuel would be hard to get everywhere.
    - Backup needs could be registered with the 249th Engineering Battalion (Army) with dimensions, sizing, and fitting measurements to help utilities obtain replacements quickly.
    - Utilities could connect with other utilities that have similar equipment.
- The Water Sector would benefit from its own Emergency Support Function (ESF). Emergency management agencies train and include other government agencies, but they do not perform enough outreach to utilities. Incorporating the private sector is critical to response efforts.

    - The Emergency Management Assistance Compact (EMAC) structure can be leveraged to secure water-specific resources. This mutual aid structure can be tested through a coordinated exercise.

- The Water Sector should improve partnership and information-sharing capacity internally, and with other sectors and government agencies. It can do so by:
    - Developing utility partnerships to work through emergency planning challenges, providing training from more experienced utilities, and regularly conducting cross-jurisdictional exercises.
    - Participating in information-sharing networks (e.g., Water/Wastewater Agency Response Network (WARN), Information Sharing and Analysis Center (ISAC)) to ensure that a broader population is aware of threats and resources. These networks aggregate information from many sources.
    - Strengthening partnerships with local/State emergency management and law enforcement agencies. Emergency managers can train utilities in emergency management. Exercises and discussion forums will provide an opportunity to uncover gaps and understand roles/responsibilities.
- Many utilities have an emergency response plan for the organization, but not a response plan for a large-scale, regional incident. Hosting exercises—whether regional or all-hazards—ensures that organizations understand their responsibilities and provides an opportunity to test emergency response plans.

Improving risk-management solutions and considering effective response/recovery solutions enable utilities to navigate major disasters and prolonged disruptions and to mitigate cascading consequences.

- Many communities will be asking for the same equipment and supplies at once.
- Business continuity planning is critical; it may be necessary to release water at a lower quality rather than to have sewage leaks. Flexibility for quick solutions is needed.
- There needs to be better scenario planning rather than just growth-based planning.
- Response personnel should understand the Water Sector has unique characteristics, such as cascading effects on schools and hospitals. A Water Sector event can quickly escalate into a major event and potentially into a political one.
- At Battery Park City during Hurricane Sandy, various buildings needed onsite treatment. The area's distributed infrastructure (e.g., water treatment, systems) included 80 natural water facilities affected by the event. Facilities were up and running 24 hours after Sandy because they were not in flood-prone areas and energy back-up was obtained within a day. This enabled utilities to maintain services throughout the disaster.

The Water Sector needs to adopt an inclusive resilience framework that is forward thinking and that enables faster recovery after major disasters. After each disaster, rebuilding infrastructure up to higher standards means utilities will come back online quicker.

- The U.S. Water Alliance is focused on "one-water framework" for water resource management (e.g., drinking water, storm water, and wastewater) as a way to improve community outcomes.
- Based on past extreme weather events, some utilities have developed more robust resilience plans, such as detailed plans that addresses severe and long-term drought patterns.
- Workforce management and access is an issue that needs to be addressed. Skilled workers—already in short supply—must be able to reach facilities and have adequate resources to operate safely for extended periods.
- The sector needs a common set of performance metrics for resilience and green infrastructure.
- A comprehensive regional risk-management plan that should incorporate all sectors in the region.
- Revising the EPA Needs Survey for wastewater and water utilities should be examined. Surveys are based on specific statutory criteria. The Needs Survey should capture evolving needs related to preparedness and resilience.

Due to aging water infrastructure, utilities should implement an asset management programs.

- Asset management enables utilities to be efficient and better anticipate when equipment replacement will be needed. Effective asset management programs can provide more reliable and resilience service with comparatively small investment.
- Utilities should include these measures as part of an asset management program:
    - Inventory, track, and assess key system components with respect to age, application, and condition.
    - Ensure they have two sources of water supply to maintain drinking water availability, water pressure, and fire capability.
    - Examine storm water capture systems and how to use alternative sources of water.
    - Identify key accounts for prioritized restoration, depending on water service criticality.
    - Consider prioritizing service to areas that were already stressed before the shock/incident (especially for disadvantaged populations).
- Utilities are making investments in storm water management—being able to use water within their systems and not just pumping water out. Water can be stored and used for emergencies.

Cybersecurity practices at utilities have increased to focus on planning, understanding the physical-cyber nexus, coordinating across the supply chain, balancing budget priorities, and integrating components.

- Cybersecurity requires well-thought out plans, but not all utilities have included cyber in their risk-management plans.
- Utilities must understand both cyber and physical risks. Combining cyber and physical security processes and assets could simplify security infrastructure management, making it easier to detect and prevent security incidents and improving response and recovery efforts.
- Designers, vendors, and owners/operators must collaborate to find solutions for the sector. Vendors should understand new devices (including new technologies) and the requirements for integration into new systems. However, it can be costly to pay for multiple vendors to be onsite and remain updated.
- While utilities are used to investing in physical infrastructure with long life cycles, the life cycle of IT is short, and often misunderstood by utility management. For example, risk assessments are used to prioritize investments, which requires policy decisions related to specific aspects of SCADA and cyber system engineering. Decision-makers may not have the necessary expertise or understand the difference between IT and physical security.
- Sometimes heterogeneity and noncentralization of technology is an asset. In an attack, the operator may not have access to the entire system because the utility is segmented.
- EPA and the American Water Works Association (AWWA) have issued beneficial cybersecurity guidance to help improve water utility cybersecurity practices.

Although cybersecurity practices have improved, additional investment in cybersecurity is necessary.

- Investing in cybersecurity information sharing is critical to preventing, responding to, and recovering from a cybersecurity incident.
    - The WaterISAC is used to collect threat information, conduct analysis, and share information with partners. However, some information requires further research and vetting by the utility.
- A cybersecurity mutual aid network (e.g., WARN network) or knowledge sharing would help address cybersecurity challenges.
    - There is no functional equivalent for cyberattack mutual aid in the Water Sector. Personnel specially trained for cybersecurity, but deployable to partner utilities, may be worth developing.
- The sector needs leadership, unified security protocols, and common cybersecurity specification requirements for products/processes used in the Water Sector.
    - Leadership buy-in would empower cybersecurity programs. The Water Sector has a top-down security culture and cybersecurity programs should take this into account.

- Building cyber resilience into all aspects of water utility business and improving security measures (e.g., vendor-managed security processes) along the supply chain would help to address cybersecurity challenges.

Water is often not recognized as a lifeline sector during emergency response. Water infrastructure and the critical nature of its services should be a priority both before and after an incident.

- The Water Sector was successful in sustaining service during the Sandy outage, but many utilities were on the brink of failure due to lack of backup power, limited fuel for generators, or generators burning out from running too long.
    - Water was not given priority when fuel for generators or equipment was delivered.
    - Employees were unable to access facilities to help restore services, and in some cases had to find ways around police barricades.
- Although some Emergency Operation Centers (EOCs) have increased representation from the Water Sector during emergencies, this needs to be applied more consistently to ensure water is incorporated into response efforts.
- The Water Sector needs to identify and set realistic goals for a long-duration power outage to maintain services and to reduce the need for mass evacuations. Playbooks need to be created to achieve those goals, and targeted investments are needed to carry out the playbooks. The playbooks should outline what the utilities can do to help themselves and what partners can do to maintain service.
    - Water utilities can use advanced planning to provide service continuity for the highest priorities in their communities (e.g., lowering water pressures, limiting the service area).
    - Water Sector partners can prioritize distributing diesel fuel to water utility backup generators, providing extra parts, and resupplying chemicals during an extended power outages.
    - Military agencies (including the U.S. Army Corps of Engineers (USACE) and the Defense Logistics Agency) are integral to these efforts.

IV. INFRASTRUCTURE INVESTMENTS AND FUNDING

Infrastructure investment and funding levels may not be sufficient to address the Water Sector's resilience needs. Water systems planning should consider future system needs, and investment decisions should consider risk assessment results. Next generation resilience financing is driven by funding availability, affordable and responsible rate structures, and informed decision-making. However, resilience investment challenges exist and must be addressed in order to achieve next generation Water Sector resilience.

Water systems should be planned to ensure performance of systems against current and emerging threats. This entails building a robust set of planning and decision-making tools to help resilience.

- Water utilities will see increased costs in regions with high population increases. However, per capita water use is decreasing and revenues are flat. Infrastructure investments mean significant rate increases, because sales are flat. This issue only gets worse as infrastructure ages.
- Utilities are unsure what level of response to prepare for and how much to invest for each risk. Utilities focus on allocating resources to assets directly impacted by an event but not on preparing the whole system for future events.
    - There are limited resources (e.g., time, information, funding) devoted to resilience—most of the focus is simply on responding to the disruption and not on mitigating or preventing it.
- Capital improvements can be used to address aging infrastructure and to mitigate vulnerabilities.
- Utilities should leverage Federal resources, capabilities (e.g., the U.S. Department of Homeland Security (DHS), U.S. Department of Energy (DOE)), exercises, and resilience assessments against the utility's highest infrastructure priorities.
- Effective planning models from outside the sector can be leveraged for infrastructure investment.
    - The private bond market has model for natural disaster and risk assessment.
    - If you look at the insurance industry, two weeks of disruption is a key number. If you're out more than two weeks, small businesses have difficulty returning to normal operations. Defining this temporal endpoint would be helpful. There is also a distinction between manmade (terrorist) and natural hazard events, in terms of investment.

Investment decisions should be based on risk assessment results. A stronger link between asset management planning and day-to-day operations is needed.

- A risk assessment-informed investment approach would take the unique hazards of every region's water preparedness needs (e.g., flood, hurricane, earthquakes) into account.
- More perspectives are needed for future investment decisions
    - Managers should collect information from utility workers.
    - The customer should be at the center of the business model.
- Priority should be given to infrastructure projects that incorporate resilience.
- Utility managers should plan for population growth.

Improving information sharing would provide a better understanding of the risk environment for utilities, government agencies, and the public.

- There is a need for more information sharing from the Federal Government to quantify the probability of certain risks, including potential terrorist attacks.
- One barrier to information sharing and assessments is that utilities consider risk information to be proprietary.
- Partnerships sponsored by the Federal Government would enable utilities to share resources for mitigation and resilience.
- The information-sharing environment remains challenged by limited information and that utilities may not fully understand how to act on that information.
    - The industry does not self-report, so they don't have aggregated data to share. There is a lack of reporting outside of regulatory requirements.
    - Consequence analysis information is limited.
    - More data on trends related to evolving threats (e.g., cybersecurity) are needed.

Factors that drive next generation resilience financing include financing portfolio variability, affordable and responsible rate structures, and informed decision-making.

- The portfolio for financing options differs depending on the community—e.g., metropolitan communities have more options available than small communities. Options also access depend on staff expertise and utility risk tolerance.
    - For large, credit-worthy, prosperous communities options include: cash funding of capital, public issuance of bonded debt (fixed vs. variable rate). Other funding source include State Revolving Fund loans and private capital (less common in the United States than the rest of world).
    - Smaller systems have less financial flexibility, which can put them at risk since they are less able to make adjustments to respond to emerging risks. They often focus on resolving day-to-day issues.
    - Utility needs, assets, and communities served vary across the sector. Utilities can select the "right" financing mechanism based on their environment.
    - Associations (e.g., National Association of Clean Water Agencies (NACWA)) have taken a key role in socializing public-private or private-exclusive funding options.
- Pricing and funding levels are largely variable throughout the sector. Examining how to raise rates in an affordable and responsible way and improving the cost-of-service dialogue are needed to improve resilience investments. This includes:
    - Securing community buy-in for investments is crucial and difficult.
    - Political pressure keeps rates and charges to customers low, and impedes the case for resilience investment.

    - Alternatives should be examined for how costs should be allocated. Some resilience costs can be allocated based on a normal water utility model, but some of the costs can be allocated in a new way (e.g., based on taxable property value).
    - In the future, utilities may move from a variable to a fixed model. The revenue streams will be more stable, but the variable model will put pressure on low water users (which are also low income users).
    - Utilities can price service for minimum health and sanitation needs and then use nonrate revenues to provide support for nonessential needs.
- Sharing best practices and success stories across the Water Sector would improve knowledge regarding resilience infrastructure investments.
    - In San Francisco, there was a $4.8 billion investment in seismic reliability. There was limited pushback because people understood the need for investing in this reliability.
    - The Smart Grid energy project is an example of successfully investing in resilience and raising rates.
    - Flint, Michigan, is an example of what not to do—the decision to switch water sources was an economic decision that was not cost-effective because it did not account for risks and potential disruptive events.

Resilience investment challenges include addressing increased rate and resilience investment justification challenges, institutional barriers, and available insurance solutions.

- Some utilities may divert significant portions of water-service feeds to other purposes (e.g., use as general funds.)
- Servicing low-income or disadvantaged communities is a challenge. Utilities need to move forward without further disadvantaging people.
    - More robust affordability models and support programs are critical.
    - Utilities are not willing to raise the rates to make capital improvements.
- Rates and charges to customers need to keep pace with investment, especially absent of any significant Federal and State government investment in local infrastructure.
    - Justifying resilience investments is difficult because customers do not see anything new—it is insurance for a future event. The utility is not getting new customers or providing a higher level of immediate service. Utilities may not think the investment is worthwhile.
    - If you make investments and reflect that cost in the rates, the cost of service becomes a challenge.
    - Utilities that successfully implemented rate increases under the full-cost pricing model phased rate increases over several years and conducted significant public outreach to explain the increase, what the money was needed for, and the plans for making the investment in the systems.

- The Water Sector has many financing options. The private sector has flexibility and interest in investment but there is no open dialogue to discuss options.
- Regulatory restrictions and targets may limit smart investments. Many utilities who invested in supply reliability are still being held to water supply reductions/conservation cuts—the sector is painted with a broad brush.
    - By using rigid pricing models, States may hinder the ability of utilities to invest in resilience.
- More work needs to be done to examine how best to allocate large infrastructure investment expenses efficiently. Long-term capital planning could be incorporated into budget processes.
- Utilities are interested in resilience-oriented insurance but innovative insurance solutions are limited.
    - The current way of thinking is an obstacle—State/local governments know they have the safety net of the Federal Emergency Management Agency (FEMA). Utilities need to move from being reactive to proactively building resilience.
    - Catastrophe bonds are worth exploring, as they make response and recovery resources available immediately. They also provide certainty that funds will arrive, allowing the bond holder to set up contracts/assistance ahead of time to speed recovery.

Existing funding levels and mechanisms do not sufficiently address Water Sector resilience.

- There is a large deficit between the projected funding need for water infrastructure repairs, and the funding that is expected to be available.
    - The Federal Government used to be the main supplementary source of funding to local water authorities but recently State governments have taken on more of the burden. Tax and rate increases are often the result of this change. These revenue streams can be negatively perceived by the public if they are not properly framed.
- The State Revolving Funds (SRF) do not include resilience investments. Adaptation will cost billions of dollars, and there is not current path forward to pay for it. While some of it will be funded by rate payers, this is not sustainable over time.
    - Aging infrastructure intensifies investment needs, resulting in a larger funding gap than if resilience investments were instituted earlier.
    - More public outreach should communicate the need for resilient infrastructure.
    - More money is spent on mitigation than on adaptation. The Federal Government can support the shift away from event-driven financing.
- Resilience funding is a challenge, due to uncertainty in calculations and lack of understanding. For instance, many utilities do not know how to operationalize climate change analysis data to make the necessary investments.

- Existing mechanisms (e.g., FEMA Hazard Mitigation Funds) are not viable options to fund the necessary capital projects related to resilience.
    - Competing interests on who gets money and priorities are challenges.
    - Incentives to look at resilience and implement backup systems could be valuable.
    - Examine Federal highway funds allocation related to drinking/driving. This could be an example of matching investments to ensure appropriate resilience is considered.
    - The Federal Government can work to implement community behavior incentives, promote community engagement, and address resilience governance issues.

Additional Federal funding and mechanisms, and innovative funding solutions are needed for infrastructure investment.

- The Federal Government can create a pool of money for utilities to tap into for resilience investments.
- The Federal Government can leverage the Low Income Home Energy Assistance Program (LIHEAP) model for the Water Sector. This would enable infrastructure investments to move forward without further disadvantaging customers.
- SRFs are particularly helpful for smaller issuers that have difficulty with market access. However, the funding comes with many Federal requirements, which can make the program difficult or costly to use.
- The Federal Government should update Federal funding conditions to require risk mitigation, recovery, and adaptation. Whenever there are incentives, the Federal Government should examine how to leverage that to get desired behaviors.
- The Federal Government should create a tiered structure for the Stafford Act to address the issue of relying on Federal after-the-fact aid instead of investing in resilience.
    - Tier I: Keeps current level of funding, but is conditioned on certain criteria.
    - Tier II: Reduced funding, if criteria is not met.
- Create incentives for States to take action on infrastructure resilience.
- FEMA issued an Advance Notice of Proposed Rulemaking to receive comments on the agency establishing a Disaster Declaration for its Public Assistance Program. If communities take certain actions focused on mitigation and resilience, those efforts would be credited toward their deductible. If they do not take certain steps, in the event of a disaster there would be a certain amount of covered assistance that they would be responsible for paying.
- In addition to improved Federal funding mechanisms, public-private partnerships can encourage creative arrangements that benefit both the public and private sector and are a way to leverage existing resources.

Mitigation and recovery are key components to resilience. FEMA Mitigation Programs and the Public Assistance Program under the Stafford Act can help resilience investments.

- Pre-Disaster Mitigation Grant Program: The grant program assists communities with small-scale pre-disaster mitigation projects.
- The Hazard Mitigation Grant Program (HMGP) funds projects to reduce or eliminate long-term risks, consistent with State or local mitigation plans, following a Presidential major disaster declaration.
- Public Assistance Program allows for repair and replacement of damaged public infrastructure (e.g., if a wastewater treatment facility or pumping station was damaged). During rebuilding, if those facilities decide to implement cost-effective mitigation measures, they could be covered up to 75 percent.

V. MAKING THE BUSINESS CASE

Resilience practices take time and capital investments to institute. Utilities need dedicated funding based on justification resilience investments. This requires that the customers and political decision-makers are is aware of the value of water, resilience, and the financial and planning tools necessary to forecast and plan for myriad hazards.

The Water Sector may need to consider a new business model to encourage next generation resilience.

- Water infrastructure is invisible to customers. As a result, water functions are taken for granted until systems fail. The public is also not aware of what is required to maintain infrastructure, making it more difficult to explain the value of additional funding.
- Utilities need consistent messaging at the State and local level to ensure customers are aware of the value of water. Extensive community outreach and public education are needed to increase awareness and educate customers about their role in demand management and conservation.
- The relatively low cost of water in the United States makes it difficult to secure the necessary funding for large-scale water infrastructure projects. There is a disconnect between current rates and the true cost of maintaining water service. Structuring the value of these projects to nonmarket benefits makes the argument stronger.
- Private sector funding can be a potential solution. For example, in Corpus Christi a company determined that the local water supply was not resilient enough, so they are building their own desalination plant.
- Special consideration for low-income communities is needed. They are often affected first and the most by extreme weather. Legislation can direct requirements for resources to low-income communities.
- The sector must adopt resilient-design principles and convince decision-makers to fund future investments that lead to resilience.

- The old systems approach, based on historical data, is the cost of protection versus the cost of failure. This should change.
- If we do not value or are not willing to pay for flexibility in capital investments, then it will be hard to know the required design criteria for facilities.
- The sector should examine flexible infrastructure solutions (i.e., infrastructure that serves more than one purpose) and avoid generalizing risk—an individual utility-level approach is needed, structured around a sector resilience framework.

- Create a market around resilience, build tools, and emphasize a cross-sector approach
- Regardless of the business model (e.g., public versus private, single municipal owner versus multiple), utilities need customer support for rates, flexibility to respond, and fast and nimble solutions to disruptions. Examples include Lower Manhattan discussing the value proposition of major investments and the loss to commerce relative to hardening infrastructure and the U.S. Global Change Program.
- The Water Sector should build on green infrastructure practices to add resilience. It takes time for the government and customers to change their perceptions, and include security and resilience in infrastructure are new practices.
  - Green infrastructure is a relatively new concept to utility customers. The community needs to understand the *value* of sustainability, beyond additional costs. Additional grey infrastructure is more expensive.
  - Examples of green infrastructure investment include managing stormwater at the source, using solar panels, or implementing a green jobs program to help economically stressed areas.
  - The Green Infrastructure Calculating Tool shows how many gallons green infrastructure can capture and conveys it in an easily understandable way. Spatial information/data is always effective (e.g., showing things on a map is helpful).
  - Major cities are adopting green infrastructure. The NYC Green Infrastructure Plan is a tool used to manage storm water. In San Francisco, a regional nonprofit planning group (as a neutral broker) convened stakeholders and city departments to talk about green infrastructure being a collective opportunity for the city.
  - The U.S. Water Alliance is making the economic value argument about green infrastructure. The sector needs to talk about the benefits of integrated storm water management and to build collective ownership.

Tools, modeling, and research enable risk-based, financial, and planning decisions.

- Risk investments need to be well-informed to justify costs.
  - Utilities recognize they have to make smarter decisions and not just spend money on today's needs. Zero risk is unachievable and getting close to it is expensive.
  - Critical infrastructure interdependency tools (e.g., short-term, event-based modeling or examining water demands) are needed to enable decision-making.

- A consistent, locally and sector informed definition of risk is needed, along with standards and guidelines.
- Models to estimate economic impact may be a good Federal investment.
- The Federal Government can provide risk assessment and consequence expertise.
- Modeling tools in the insurance industry could be leveraged for use in the Water Sector.
- Science and engineering needs to be incorporated into water resilience planning and infrastructure improvements. One way to accomplish this is to integrate resilience into standards.
- The Water Sector needs to have a more holistic approach for designs systems to better withstand challenges, recover, and adapt. Part of this is investing in sustainability.
- Metropolitan-regional mapping should be conducted to understand infrastructure system dependencies that can also aid faster recovery in the event of failures.

- The frequency and intensity of extreme weather events require a new way of thinking. More "outside the box" scenario planning is needed. As the risk landscape changes, utilities have to plan for unusual/unpredictable events (e.g., a major cyber incident).
  - Extreme weather planning needs supportive funding structures, as current rate structures only cover regular operations and basic projects. Utilities have to justify investments.
  - Utilities have to balance risk acceptance. After an unusual event, utilities may be asked to install resilient solutions (e.g., generators) that can be costly and come with no guarantee that they will be used in the future.
  - Tools are good for short-term modeling, but are not as accurate in the long term, which is different from real-time feedback provided in the power industry.
  - There are effective models that forecast the direction, timing, and strength of storms. The National Hurricane Center forecast capability has improved noticeably over the last 20 to 25 years. They depend on satellite data, and aging satellite infrastructure is a concern.
  - The Water Sector must enable short-term and long-term planning. Short term planning includes how quickly snow melts and how to manage it. Long-term planning includes examining climate variables relating to runoff, which is more problematic.
  - In the long term, there is a need for good forecast capability (for supply of water) and scenario-based forecasting.
  - While there is scientific evidence regarding high-impact events (e.g., earthquakes, floods, and other natural disasters), an underlying impediment to implementing long-term solutions is local community opposition to permanent infrastructure built

in their area. We need decision-makers to present science in the clearest way possible.

  - Federal agencies, including EPA and USACE, have internal models and publicly available tools and models that can conduct forecasting both in the short term and long term. Modeling evaluates hydrology, the effects of demographic shifts, and cascading impacts on infrastructure to assist in accurately capturing future scenarios to aid in planning and preparation.
  - Disaster resilience uses different time scales. Some hazards (e.g., climate change, mega droughts) unfold over longer time frames and it is difficult to predict outcomes in order to fully justify investments.
  - Improved modeling and new technologies that combine sensor and historical data will enhance utility preparedness.
  - Government agencies often work together to ensure their climate change modeling and information is consistent. USACE works with other Federal agencies, such as the National Oceanic and Atmospheric Association (NOAA), and universities, to ensure that assumptions and modeling is consistent when they apply it to tools and resources. One example of this is their sea level change calculator, which is available to the public, and focused on USACE projects.
  - Modeling software and Water Sector-specific training support is needed.

- Financial/Decision-making tools:
  - Resilient infrastructure requires major costs, which can impede resilience. One way to address this is to consider the current financial environment and calculate costs over planning windows that make sense to decision-makers.
  - Many hazards occur infrequently, but could cripple regions. Because of this, you have to convince people must be convinced the hazard is important. Hazard analysts need to make results comparable to the traditional planning windows used to make financial decisions.
  - The Water Sector should support research and technological development by disseminating success stories and best practices and collaborating with the research community (e.g., how to annualize costs for water infrastructure).
- More informed resilience activities, such as scenario planning tools, response exercises, employee training on automated technological solutions, and tools that account for the "human side of resilience," need to be deployed throughout the Water Sector.
  - Dealing with complex systems requires experience. Models do not always include the complexity/characteristics to capture the true nature of a system.
  - During major disasters (e.g., an earthquake or pandemic), the effects of the event on the workforce will be a major challenge to overcome.
  - About 25 to 30 percent of the workforce is approaching retirement. Utilities are conducting market-based benefits analysis on how to compete with the private

sector. This will allow the utilities to competitively re-staff 50 percent of the workforce in the next five years. The industry is also evolving into more specialized work and needs knowledgeable staff.

- Research needs to:
    - Focus on energy efficiency and smaller-scale effective treatment operations.
    - Fund technologies that will limit future damage.
    - Encourage cross-discipline collaboration for better models.
    - Address snow-pack melting; cities are dependent on water imported from miles away.
    - Address seawater intrusion on local water supplies.
    - Examine the transportation-water connection.
- Utilities often struggle with making the business case for cybersecurity investments.
    - As cyber threats increase in frequency and intensity, customers will want to know what cybersecurity measures or programs have been implemented. However, the regular rate-paying customer is oblivious to potential disruptions from cybersecurity, as a consequence of the Water Sector's success in providing "invisible service."
    - Management may think cybersecurity solutions are too expensive.
    - Sector-specific cybersecurity tools that are sensitive to implementation cost issues are needed.

The Federal Government can support resilience in the Water Sector by focusing on affordability and providing funding, conducting risk analysis, sharing best practices, and helping utilities "make the case" for resilience.

- The Federal Government can provide support through analytic work and risk analysis. Utilities do not have the capacity to downscale global climate models; national labs can help provide the tools to guide utility decision-making.
- Utilities had to implement security upgrades after the September 11th attacks, and the public understood the need for this. If the Federal Government mandates a greater level of resilience and includes a resilience model for what infrastructure should look like, then utilities and the public will be better able to understand the need for changes and the costs associated with them.
- The Federal Government can support a group of professional associations or research foundations to examine these tools. National Institute of Standards and Technologies (NIST) committees can also help facilitate this kind of tool.

- The Federal Government can help promote resilience solutions as best practices:
    - The Center for Neighborhood Technology works with local finance organizations to address water incidents by convening communities and financing infrastructure adaptation.
    - Los Angeles and Philadelphia embrace decentralized activities and collaboration.
    - Texas has diversified its water supplies to mitigate a system shut down because they were dependent on one supply.
    - San Francisco leverages its technology boom to secure resilient solutions and private sector investments.
- EPA's Water Security Division conducts outreach and provides technical assistance to water utilities. The division provides electronic software tools, including an in-process tool called the "Route to Resilience" to help facilities develop risk assessments by answering a series of questions (similar to online tax software). The division facilitates connections with water/wastewater facilities across the United States and conducts tabletop exercises and risk assessments. The training also helps foster relationships between agencies in the Federal Government. The division provides direct technical assistance, including helping with risk assessments.
- EPA's State Revolving Funds are a potential vector for funding to help communities achieve resilience.
- Following Hurricane Katrina, the USACE was part of a large-scale hydraulic modeling effort with the U.S. Department of Defense (DOD), universities, NOAA, and representatives from across the Nation and globe. The effort involved modeling physical features of the area, developing thousands of potential scenarios for the next probable maximum flood, and developing design criteria for New Orleans and Southeast Louisiana.
    - Following Superstorm Sandy, the effort was expanded and real-time flood inundation information is available to States to assist in decision-making. Other tools include coastal modeling and sea level rise calculators that can be applied in community planning and development decisions.
- The North Atlantic Coast Comprehensive Study's tools are publicly available and are being used to help communities across the Nation define their risks.
- WaterSMART (Sustain and Manage American Resources for Tomorrow) is a Bureau of Reclamation program that looks at the Nation's changing landscape and assists in determining whether modifications are needed to maintain a sustainable water supply. Factors such as climate change and population shifts yield recommendations such as conservation and water source shifts.
    - The Bureau also examines the risk of long-term dam failure. As the condition of the dam itself changes, the risk assessment is continually reviewed to identify necessary repairs.

- The Regional Resiliency Assessment Program (RRAP) is a cooperative assessment of specific critical infrastructure within a designated geographic area and a regional analysis of the surrounding infrastructure. To improve the efforts in the RRAP, metro area dependencies should be examined and an implementation plan should be proposed.

VI. LEADERSHIP AND COORDINATION

There is a need for resilience at the regional level and for resilience across all sectors—not just the Water Sector—due to dependencies. Planning for and responding to all types of catastrophic events requires developing partnerships and acting regionally; major disasters should be seen from a regional perspective, not from local needs or the service area. However, a shift to a regional approach requires a new paradigm for how the systems are operated (i.e., not just on individual utility assets, but on operating systems based on regional needs). Coordination is needed between governments and utilities in the region, and should include hosting joint exercises and preparedness meetings.

Collaboration between levels of government and the Water Sector has focused efforts and resources on defining a collective vision for resilience and identifying roles and responsibilities. Proven results have included creating local resilience strategies and ensuring water systems perform during situations more severe than planned.

- The greatest resilience progress is realized when jurisdictions/regions have mechanisms for collaboration. They convene multiple actors and take a regional approach.
    - In New York City, the "Big U" plan started out with fortifying lower Manhattan from storm surge. It evolved into a green infrastructure project, called Dry Line, designed to build resilient infrastructure that can generate private sector funding/investment.
    - In one State, when a small facility is unable to meet water quality standards, Health and Human Services is brought in to give guidance to drinking water constituents. In some cases, the utility is forced to merge with a larger utility in order to help finance projects.
    - Southern Nevada collectively defined the disaster response vision for the region.
    - Other examples include California and West Coast (seismic activity), South Carolina (floods), Contra Costa Regional Capacity Study (water transfer), Bay Area Regional Reliability (BaRR) project, and Lake Oswego (joint funding and planning water supply for the region).
    - Concepts of enterprise zones have been set up in the past and some are now considering resilience zones.
    - Mississippi River: planning, construction, and collaboration built into the system meant that the river performed successfully for situations that were much more severe than planned.
- Political will is required to collaborate with other regions, especially on the benefits to the State and region of resilience investments.

- Los Angeles Mayor Garcetti issued a water order to organize the region around "one water."
- New York City Mayor Bloomberg included a "One NYC" resilience chapter in "Plan NYC" to help manage dependencies, especially based on lessons learned from Superstorm Sandy.

- Managing dependencies and interdependencies between sectors must be a priority for sectors, government agencies, and regional organizations. There is major interest in strengthening the connection between water, energy, and climate issues. Coordination exists but needs to be improved.
  - Inefficiencies are created by not looking at lifeline sectors (Transportation, Energy, Communications, and Water Sectors) as interdependent systems.
  - In California, State, regional, local partners examined Water Sector supply chain dependencies and interdependencies (e.g., identified vulnerabilities and what/who should build the redundancy into the system). The State is also building shared capabilities across local utilities to create local resilience, meaning the utilities are not just dependent on the State.
  - Utilities are examining next generation resilience practices from outside the sector.
  - The Water Sector needs to examine how to prioritize the allocation of scarce resources needed to sustain service during major events. There will be political perspectives on which systems will need to be prioritized first.
  - The scarce supply of fuel will be a major challenge. Multisector disruptions will draw heavily on the Energy Sector.
  - There is a growing amount of data from NOAA on climate change, and the ability to predict climate change effects is improving. However, there are data gaps for groundwater. Water management is very local and data may be difficult to obtain.
  - Governments expressed the need for integrated water management approaches to better prepare for resilient systems, particularly for extreme weather events.
  - Creating regional organizations that are united by factors such as customer base and water source can spread out costs on improvement/risk-management and storage projects, help avoid utility hikes (especially for small companies), and result in a more regional approach to water.

Although change is occurring at the local level, the overall vision for resilience must come from the Federal level. Action is needed in laws, regulations, authorities, and standards; policy and funding; risk and vulnerability assessments; cybersecurity practices; response and recovery practices; and coordination across sectors and regions.

- The Federal Government can support resilience by communicating the need for resilient infrastructure. This includes leading a "clean water revolution" (supporting investments, funding, and research).

- Federal laws and regulations should be evaluated to determine what currently applies, what should be modified, where overlaps exist, and how they should be modified to allow for new technologies and new ways to improve Water Sector security and resilience.
    - Laws and regulations such as the Clean Water Act, Safe Drinking Water Act, and Endangered Species Act were effective when they were first enacted more than 40 years ago. Today, however, they are making it difficult for agencies to adapt to the changes that are needed because of climate change.
    - Flexibility in water quality would allow stressed systems to recover faster. Short-term discharge of impaired water and delivery of less-than-drinking-water quality water for other uses than human consumption could facilitate a staged recovery. However, a realistic assessment on what is practical in extreme weather emergencies is needed.
    - Regulatory approval processes to build infrastructure can be lengthy and expensive. One solution could be a multiagency project team with representatives across Federal departments to facilitate collaborative problem solving.
    - Regulations on co-generation should enable water utilities to set up energy resilience programs without barriers. This issue is not specific to the Water Sector; other facilities (e.g., hospitals, police stations, community centers, evacuation centers) could benefit from regulatory.
    - If a high-level position is established at the White House to coordinate water issues, the position requires statutory authority over budget, training, and agency activities to be effective.
- Resilience varies between utilities. Federal resilience polices should be written to allow flexibility to capture these variances and to address unique needs. Guidance, tools, and information do not always reach the local level.
    - For example, water utilities are often located in flood plains and are built to sustain once-in-100-year floods. Superstorm Sandy nearly topped a wall built to withstand a 500-year flood. Standards need to be adjusted.
    - A Federal guidance document (e.g., an EPA best practices compilation) should allow organizations to identify ways to address resilience at the local level.
    - Federal agency (e.g., FEMA, U.S. Department of Housing and Urban Development (HUD), EPA, and USACE) standards need to be reconciled.
- Federal financial assistance should require recipients to meet conditions that encourage innovation and resilience (e.g., incentives using scoring criteria and measures).
    - The concepts of preparedness and flexibility need to be introduced into State, regional, and local systems. Otherwise, investments may be hard to defend.
    - EPA has clarified eligibility for certain funding streams, such as the State Revolving Funds, to include resilience projects.

- Federal funding driving resilience is only one issues as smaller/rural utilities do not use Federal funding streams. Procurement policies (at all levels of government) need to be updated to allow for easier transition to newer/resilient practices and vendors.

- Programs should aid low-income customers:
  - Utilities should be transparent about how service fees are used, including what rate increases will finance and the schedule of improvements.
  - A program like the Low Income Home Energy Assistance Program (LIHEAP) could be implemented in the water industry.
  - Current program examples include waiving a portion of service fees, providing discounts, and accepting voluntary donations to reduce the cost of water for low-income individuals:
    - The U.S. Department of Health and Humans Services (HHS) Office of Community Services (OCS) programs provide capital assistance for utilities with low-income customers.
    - The American Water Company of Pennsylvania and the Baltimore, Maryland Department of Public Works both have low-income assistance programs.
    - Detroit, Michigan has a grassroots program that collects donations that help people who have problems paying their water bills.
    - Information on smart meters, retro fitting old devices, and other conservation efforts should be provided.

- The Water Sectors should address issues that impact multiple sectors or a region, such as risks and cascading failures.
  - After the September 11th attacks, to address concerns about the security of water/wastewater facilities, EPA issued a series of requirements for facilities to conduct vulnerability assessments. This is an example of Federal activity affecting the local level, which resulted in regular assessments.
  - The Dams Sector identified a need for a common baseline to compare different risk environments. As a result, the *Federal Guideline for Dam Safety Risk Management* was created to set industry standards.
  - The Hydrologic Engineering Center (HEC) software programs can inform local municipalities and impart confidence about water surface elevation. That is useful for local emergency plans, enabling them to forecast events.

- Cybersecurity is a multidimensional challenge that cannot be resolved by one utility. The Federal Government can promote effective cybersecurity best practices and ways to mitigate risk throughout the sector, while supporting a coordinated sector approach to cybersecurity. All sectors need to modernize systems and increase cybersecurity.

- Federal cybersecurity capabilities are helpful and additional resources (e.g., tools, guidance) are needed. Examples include DHS risk assessments, Control Objectives for Information and Related Technology (COBIT), IT Infrastructure Library (ITIL) security management, the DHS Daily Open Source Infrastructure Report, and DOD programs/capabilities.
- The Federal Government can develop and socialize solutions to reduce system penetration from external sources. This may entail establishing a front-line of defense against immediate threats (e.g., situational awareness of network vulnerabilities, threats, and events), increasing countering capabilities and supply chain security for key information technologies, expanding cyber education, coordinating research and development, and defining and developing strategies to deter malicious cyber activity.
- A vulnerability assessment for smaller companies can help to determine their current level of cybersecurity risk.
- Vendors address security differently and a consolidation of vendor cybersecurity practices would be helpful, particularly in addressing international vendors—what is acceptable in Germany may not be acceptable in the United States.

- The Water Sector should support cross-agency and cross-sector collaboration. Resilient water systems are a shared endeavor.
  - It is a challenge to unify Federal, State, and local government efforts.
  - Changing the approach to look at the whole system could make emergency response and recovery funding easier to obtain.
  - The FEMA administrator is a centralized role that could take on more pre-event planning. During Hurricane Sandy, the FEMA Administrator kept governors updated on restoration, planning, and operations efforts. This practice should continue to ensure coordination of all key players.
  - National, State, and regional plans needs to outline pre-event collaboration with water and wastewater utility owners.
  - Federal agencies (e.g., EPA, Bureau of Land Management (BLM)), the Water Sector Coordinating Council (SCC) and Government Coordinating Council (GCC), and trade associations could jointly lead collaboration and disseminate resilience guidelines and best practices. EPA is disseminating guidance on what constitutes a robust resilience plan.
  - There is a need for regional joint capacity planning with the Water and Energy Sectors to manage the assumption that each other's supply will always be there.
  - The U.S. Department of Transportation (DOT) and EPA could jointly provide regional planning.

- Federal and State governments can partner with local utilities. Communities are willing to do more, but they need guidance and information (e.g., hearing about best practices, including from the private sector).

- The Defense Industrial Base Sector can support efforts to mitigate effects to public health and safety.
  - Federal, State, and local emergency managers should lead response efforts and facilitate dialogue with any military response.
  - The National Guard can mitigate the effects of a Black Sky Event by providing drinking water and addressing other immediate public health needs. When there is a wide-spread attack on infrastructure a State's governor can call on the Quartermaster Corps within the National Guard to supplement replacement facility parts.
  - Military installations regularly rely on close collaboration with the utilities, and mutual understanding is critical. The National Guard has systems that can convert raw water to water and transportation support capabilities, and can conduct debris removal work. There are opportunities for DOD to support industry.
  - There is ambiguity on what authority has decision-making power on water rights. Individual States believe they have final say in water rights. But the Federal Government believes it has Federal Reserve water rights. Constitutional tension could affect water supply in a crisis.
  - Water and water infrastructure is extremely complex because most owners are local municipalities. As a result, there is not a direct Federal role.
  - The USACE's involvement is often in response to disasters. USACE focuses on a systems approach with Federal and civilian infrastructure working in tandem. Following Superstorm Sandy, the Federal Government was operating under the National Response Framework. As the lead for ESF#3, the Corps was working closely with EPA to help a wastewater treatment facility return to operations.

- FEMA plays a key role in response and recovery:
  - FEMA is chair of a group established under Presidential Policy Directive 8 (PPD-8). This Mitigation Framework Leadership Group is an interagency group that also has State and local representatives. It is tasked with using the Federal Government's resilience and mitigation approach. The group works to establish standards, including executive orders related to Flood Standards (EO 13690), Seismic Standards, and Wild Urban Interface related to fire.
  - Projects built with the help of Federal investments must be built to withstand future events. FEMA can ensure the projects meet standards.
  - FEMA should make sure there is flexibility in the recovery process so that communities can rebuild in a manner that promotes resilience.

APPENDIX C.
DISRUPTION SCENARIO CASE STUDY

In order to help inform the National Infrastructure Advisory Council's (NIAC) Working Group recommendations to the full Council, the Study Group was tasked with assessing resilience during a high-impact scenario to identify challenges and opportunities. To that end, the Study Group designed a case study workshop that assessed water system resilience under five different disruption scenarios encompassing various regions and levels of disaster scale (local, State, and regional) and both manmade and natural hazards. The five disruption scenarios were selected due to their applicability to the Study Group's task and information learned during the Study Group's discussions, as well as being consistent with risk areas identified in the *2015 Water and Wastewater Systems Sector-Specific Plan* (2015 SSP).

Workshop participants included Study Group members and additional subject matter experts with experience in sector and cyber-physical dependencies, cybersecurity, natural disaster response and planning, and information sharing. To enable a robust discussion, participants were provided with comprehensive background information on the disruption scenarios and common resilience themes across the scenarios. The disruption scenarios covered the following risk areas: natural disasters, cybersecurity, and energy disruptions. The following five disruption scenarios were discussed during the workshop:

- **Natural Disasters**
  - Midwest Floods of 2008
  - Superstorm Sandy
  - New Madrid Earthquake
- **Cybersecurity**
  - Cyber-based Attack
- **Energy Disruptions**
  - Northeast Blackout of 2003

Section I of this appendix summarizes the results of the workshop. Section II provides the analysis of the five disruption scenarios in greater detail, including an examination of disruption impacts, dependencies, gaps and challenges, and opportunities.

I. WORKSHOP RESULTS

The workshop focused on identifying common resilience themes and uncovering gaps, challenges, and opportunities. This section highlights information learned from the workshop discussion, providing insights and perspectives on Water Sector resilience issues. It is organized by five major themes of Water Sector resilience:

- Priority as a Critical Sector and Valuation of Water Services
- Greater Investment in Resilience
- Changing Risk Environment

- Regional Disaster Preparedness
- Federal Support for Resilience

PRIORITY AS A CRITICAL SECTOR AND VALUATION OF WATER SERVICES

- Water utilities should be a "tier 1" priority for power restoration after a disruption.
- After a large-scale disaster, supply chain challenges proliferate and there is no formal prioritization of resources (generators, pumps, fuel) to support the Water Sector. The situation is further complicated by disrupted sectors connected to the Water Sector supply chain; for instance, transportation (e.g., transporting equipment for recovery) and chemical (e.g., chemical procurement challenges).
    - Resource prioritization is a direct output of the partnership model. Some utilities work with the State emergency management office, Federal Emergency Management Agency (FEMA), U.S. Army power teams, and adjacent utilities to receive prioritized resources.
    - Local/State emergency managers should champion both prioritization and holding cross-sector workshops and exercises.
- Robust communication (i.e., with the public, media, local government, local utilities) is important to not only convey information during times of emergency but also the overall value of water services.

GREATER INVESTMENT IN RESILIENCE

- More advanced water utilities should develop emergency resource request templates for and build information-sharing relationships with smaller, local utilities.
- Personnel represent a critical point in response/recovery and greater personnel investment is needed. Employee assistance programs (e.g., interest free home preparedness loans, food/gas/toll support) enable personnel to report to work during times of disruption.
- Greater investment in the sectors with a nexus to water infrastructure is needed (e.g., investing in the power grid, or facilitating public health sector exercises on water outages).
- Within the past 15 years, there has been a major push for earthquake preparedness causing earthquake preparedness gaps to close. Earthquake science has also improved and there is a better understanding of the risk. This success can be applied to other risk areas.
- Typically, utilities plan for a three to seven day power outage. There is a need for utilities to plan for short-, medium-, and long-term power outages.
- Utilities can invest in infrastructure resilience using the worst historical case; however, the risk environment changes and as such, utilities should consider investing/building-in resilience beyond the worst case.

CHANGING RISK ENVIRONMENT

- One water utility designed two-way lines of communication between the utility and State/local emergency management agencies. It is intended to expedite resources and de-conflict emergency response activities.
- Utilities need an appropriate framework to help them examine short- and long-term risks.
- Improved risk communication (e.g., flood risk) is needed.
- Water facility access issues significantly complicate recovery operations. These include access control and credentialing for water utility personnel, security infrastructure losing power, and transportation issues.
- The following represents information related to water cybersecurity issues:
    - The Water Sector can leverage cybersecurity lessons learned from the Energy Sector, for example their cyber-physical exercises.
    - Cybersecurity awareness throughout the utility (e.g., for all engineers, operators, and decision-makers) is limited.
    - Utilities do not have clear governance related to the management of cyber systems and incident preparedness and response roles/responsibilities.
    - Control system engineers see cybersecurity as "redundant" (i.e., ensuring continuity) and not "resilience" (i.e., preventing cyber incidents).
    - There are many systems and cyber processes and people supporting them; and as such, there are many points of vulnerability to control.
        - The U.S. Department of Homeland Security (DHS) can assist water utilities with identifying vulnerabilities.
    - Depending on information access levels (e.g., clearances), utilities may be information-rich (bordering on inundation) or information-poor. However, all utilities struggle with operationalizing cyber threat information and generating concrete threat-response actions.
        - Some utilities are also reluctant to share vulnerability and incident-learned information or join information-sharing networks.
        - There is a limited group of personnel intersecting the understanding of water utilities and cybersecurity. If there is a major, coordinated cyberattack on utilities there may not be enough available personnel to respond.
        - Utilities are unable to offer competitive packages to attract top cybersecurity experts.
    - Water utilities would greatly benefit from conducting cyberattack disruption exercises, during which they have to run their utilities manually.
    - Technology changes rapidly, resulting in frequent updates and increased opportunities for building-in resilience into cyber systems or falling farther behind.

REGIONAL DISASTER PREPAREDNESS

- Regional natural disasters (e.g., major floods) are infrequent and utilities are not able to assure power supply (e.g., fuel storage limitations and electricity is perishable).
    - Preparations are difficult.
    - Everyone needs the same resources, at the same time.
- Utilities should conduct the following regional event preparedness actions:
    - Establishing relationships with adjacent utilities for resources (e.g., personnel, equipment) during an emergency.
    - Pre-identifying resource needs, such as resources for minimum operations, and developing contracts to secure those needed resources.
    - Issuing purchase orders in advance to pre-approved vendors, enabling the vendor to move quickly.
    - Meeting with stakeholders (e.g., customers, local government, communities, emergency services) to communicate water utility recovery objectives and system outages, in the event of a major disruption.
- Additional exercises are needed within the Water Sector and in coordination with other sectors, in particular those that the Water Sector depends on (Chemical, Energy, Communication, and Transportation Sectors). This enables utilities to understand roles/responsibilities and identify 'choke points' in the system and system risk.
    - Exercises can be convened through the following: Local interdependent utilities convening themselves, local city/county emergency management, State lifeline infrastructure resilience councils, or FEMA.

FEDERAL SUPPORT FOR RESILIENCE

- The Water Sector's ability to construct dedicated power-generation sources is also constrained by investment challenges. Utilities are supporting generation equipment for something infrequent, which competes against dollars for aging infrastructure and more immediate needs.
- Regulatory flexibility is critical to navigating disruptions. During emergencies, water utilities need to maximize their operations to minimize down-stream disruption impacts (e.g., public health impacts).
    - There is a need to continue the dialogue regarding regulations that prohibit 'smart' emergency responses.
- A lot of cybersecurity information is shared with the sector, but utilities need more actionable information and guidance on what to do with this information.

II. DISRUPTION SCENARIO ANALYSIS

In support of the Study Group's tasking to consider Water Sector resilience related to a high-impact scenario, an assessment was conducted on available high-impact scenarios. Scenarios were selected based on their strong applicability to the Study Group's charge, as well as relevancy to key Water Sector resilience issues uncovered during Study Group panel discussions. This section summarizes the disruption scenarios which were examined, highlights common resilience themes across all five scenarios, and provides a synopsis of the core disruption aspects for each scenario.

DISRUPTION SCENARIO SUMMARY

Natural Disasters

Midwest Floods of 2008 (Actual Scenario)[63]

Hazard Type: Natural Disaster, Flooding

Key Characteristics: Heavy rainfall generates flooding exceeding historic flood levels in Idaho and southern Wisconsin, with some areas falling outside of the 100-year floodplain. Four wastewater facilities in Southern Wisconsin were examined.

Superstorm Sandy (Actual Scenario)[64]

Hazard Type: Natural Disaster, Hurricane/Superstorm

Key Characteristics: In October 2012, Superstorm Sandy made landfall in New Jersey. The storm surge rapidly inundated infrastructure, particularly wastewater sites. Relevant information from three New Jersey wastewater facilities, District of Columbia Water and Sewer Authority (DC Water, combined drinking water and wastewater treatment facility), New York City Drinking Water, and other water utilities participating in water response networks were examined.

New Madrid Earthquake (Fictional Scenario)[65]

Hazard Type: Natural Disaster, Earthquake

Key Characteristics: A major earthquake (7.7 magnitude) strikes the Central U.S. region—a region with un-reinforced infrastructure and a concentration of lifeline infrastructure. In areas within approximately 200 miles from the epicenter, drinking water and wastewater infrastructure is destroyed and service is unavailable to the vast majority of hospitals, government buildings, and communities, as well as for fire suppression.

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[63] FEMA, *Midwest Floods of 2008 in Iowa and Wisconsin*, 2009.
[64] FEMA, *Hurricane Sandy in New York and New Jersey*, 2013; *City of New York, A Stronger More Resilient New York*, 2013; and AWWA, *WARN: Superstorm Sandy After-Action Report*, 2013.
[65] Mid-America Earthquake Center, *Earthquake Hazard and Impact in the New Madrid Region*; and Mid-America Earthquake Center, *Impact of New Madrid Seismic Zone Earthquakes on the Central USA*, 2009.

Cybersecurity

Cyber Storm IV: Evergreen (Fictional Scenario)[66]

Hazard Type: Manmade, Cyberattack

Key Characteristics: A cyberattack targeting infrastructure at the local level was exercised across 16 States; focusing on State-level response and examining escalation from internal discovery to national information-sharing and remediation considerations.

Energy Disruption

Northeast Blackout of 2003 (Actual Scenario)[67]

Hazard Type: Manmade, Energy Disruption

Key Characteristics: A cascading outage of electric transmission and generation facilities produced a blackout of most of New York, as well as States in the Northeast and Midwest and Canada. A water supply district in Cleveland, Ohio—providing drinking water to 1.5 million people—was examined.

COMMON RESILIENCE THEMES

The following are key themes that crosscut the five scenarios.

- The **energy-water nexus** and its potentially adverse impacts on water utilities during a disruption is the most common theme across both manmade and natural disasters.
- **Elevating the priority status of the Water Sector** is a common after-action need, particularly as it relates to the energy-water nexus.
- **Energy, Transportation, and Communications** Sectors are ones that water utilities depend on for disruption response and recovery. The public health sector experiences the greatest downstream impacts from water disruptions.
- Major disruptions were beyond the capacity of the water utility to exclusively resolve and as such, water utilities relied on external resources and coordination with other water utilities, sectors, and emergency management. Across all disruptions, it was evident that additional pre-event **relationship-building, exercising, and understanding roles/responsibilities** would have improved disruption management.
- **Timely, accurate information sharing** to the public, media, and emergency management liaisons is critical to ensure public health and safety, mitigate panic, and facilitate response. Risk communication is essential.
- Utilities will experience major impacts if their infrastructure is not **built to withstand impacts** from a low-probability, high-impact event (e.g., major flooding).
- **Water facility access issues** significantly complicated recovery operations. These include access control and credentialing for water utility personnel; security infrastructure losing power; and transportation issues.

[66] DHS NCCIC, *Informing Cyber Storm V: Lessons Learned from Cyber Storm IV*, 2015.
[67] Center for Infrastructure Protection and Homeland Security, GMU, *Blackout*, 2013.

- **Personnel represent a potential point of failure** in response and recovery, as they can also be significantly impacted by major disruptions and unable to reach the facility. Once at a facility, they must be assured of personal safety along with food and drinking water.

OVERVIEW OF DISRUPTION ASPECTS

This section examines the five scenarios with response to four topics:

- **Scenario Impacts** – Key scenario information, inclusive of economic and physical infrastructure effects.
- **Dependencies** – Points of failure in processes, communication, or infrastructure leading to disruption in the Water Sector
- **Gaps and Challenge**s – Complications and obstacles experienced or uncovered during or after the Water Sector disruption
- **Opportunities** – Lessons learned information or expert-suggested actions, which could improve Water Sector security and resilience

Scenario Impacts

2008 Midwest Floods – Region: SE Wisconsin

- Iowa and Wisconsin reported billions in economic and agricultural losses
- One wastewater facility sustained $2 million in damages
- Flooding occurred above record stage and outside 1-percent-annual-floodplain-chance
- Plant inundation (from surface flows and river flooding) generated a complete plant shutdown
- It took two days to remove floodwaters from wastewater facilities; they were able to operate on permanent power two weeks later
- Personnel abandoned sites for safety; some facility access roads were impassable
- Emergency generators could not run due to water inflows, shut off fuel supplies, and transport issues

2012 Superstorm Sandy – Region: Northeast (NY, NJ, DC)

- Over 8.5 million people with no power; estimated $71 billion in damages; at least 162 dead
- Transportation corridors, roads, tunnels flooded—causing fuel shortages
- Power restored within hours to days but damaged power systems caused recovery delays; e.g., in Howard County, MD, loss of power resulted in release of 25 million gallons of raw sewage
- 10 of 14 New York City wastewater plants released partially treated/untreated sewage into local waterways; 42 of 96 pumping stations damaged
- Storm surge rapidly inundated wastewater sites, preventing planned actions (e.g., de-energizing plants)
- Equipment and systems damaged by floodwater, delaying recovery

New Madrid Earthquake – Region: Central U.S. (Fictional Scenario)

- 2.6 million households without electricity and 1.1 million households without water
- Within 200 miles of epicenter, drinking water and wastewater service unavailable to the vast majority of hospitals, government buildings, and communities
- 86,000 casualties and 3,500 fatalities
- 425,000 breaks to utility pipelines; nearly 715,000 damaged buildings; over 3,500 damaged bridges
- $300 billion in direct economic loss
- More than 730,000 people permanently displaced
- Limited medical, firefighting, and law enforcement services

Cybersecurity Incident (Fictional Scenario)

- *Not Available – impact information not disclosed in public report*

2003 Energy Blackout – Region: Cleveland, OH

- Large portions of Ohio, Michigan, Pennsylvania, Massachusetts, New York, Connecticut, New Jersey, and Ottawa, Canada were without power
- 50 million people affected
- Economic impact is estimated to be $4 billion to $6 billion for affected regions
- In the greater Cleveland area, it took 30 hours to restore power; and in NYC, it also took 30 hours
- Approximately 80 percent of the Cleveland water distribution system experienced partial outages
- Boil advisories are issued, impacting a majority of service customers

Dependencies

2008 Midwest Floods – Region: SE Wisconsin

- Transportation
- Energy
- Public Health (downstream disruption)
- Emergency Services to navigate access challenges
- Communications to disseminate information

2012 Superstorm Sandy – Region: Northeast (NY, NJ, DC)

- Energy-particularly electricity and fuel supply
- Transportation corridors
- Communications

New Madrid Earthquake – Region: Central U.S. (Fictional Scenario)

- Nearly all critical infrastructure, particularly: Energy, Transportation, Communications, Public Health (downstream), and Information Technology

- Personnel are unable to reach the facility, taking care of their own families

Cybersecurity Incident (Fictional Scenario)

- Internal/external system (e.g., cyber, physical) dependencies
- Communications

2003 Energy Blackout – Region: Cleveland, OH

- Energy-water utilities were disrupted due to a massive cascade of external failures
- Information Technology
- Communications
- Personnel

Gaps and Challenges

2008 Midwest Floods – Region: SE Wisconsin

- Wastewater facilities are located in low-lying areas prone to flooding
- Flooding recurrence levels are difficult to predict
- Transportation challenges in accessing flooded water facilities
- Fuel challenges—local fuel stations were out of service
- Power generation challenges—original and back-up generators were flooded, inoperable; offsite power utilities were disrupted
- Backup equipment had been installed below base flood elevation

2012 Superstorm Sandy – Region: Northeast (NY, NJ, DC)

- Wastewater facilities are located in flood zones, near major bodies of water
- Unprecedented storm surge and debris was beyond the capacity of the sewer/wastewater system to perform
- Essential and backup equipment had been installed below base flood elevation
- Permanent generators (in-place) were uncommon
- Lack of support for power and fuel requests
- Loss of electricity meant water supplies could not move through high-rises
- Radio/communication lines were temporarily lost
- Key transportation corridors, access roads were flooded
- Access control issues limited utility personnel's damage assessment and repairs

New Madrid Earthquake – Region: Central U.S. (Fictional Scenario)

- Entire water infrastructure within 200 miles of epicenter suffers major damage
- Water storage tanks collapsed and limit planned water supplies
- Wastewater overflows into buildings and spills into nearby water bodies
- Impassable roads and highways block access to many facilities
- Communications are all but eliminated

- Local equipment to repair infrastructure are damaged
- Chemical storage tanks and piping have ruptured, creating hazardous materials spills
- Large numbers of water and wastewater personnel are not at work because they are dealing with family issues and the loss of homes and schools

Cybersecurity Incident (Fictional Scenario)

- Major system dependencies exist, and taking systems down or bringing them up requires major coordination and collaboration
- There was uncertainty regarding when to communicate, what to communicate, and with whom
- Legal and authority questions challenge public and private interactions
- Escalating cyber emergencies
- Resource allocation procedures absent or inadequate
- Federal emergency response authorities unclear during a major cyber event
- Gaps in communication, responses plans, and resources were identified

2003 Energy Blackout – Region: Cleveland, OH

- Dependence on national power grid is a major vulnerability and there is a lack of understanding of the grid's complexities and connections
- Offsite networks and IT systems had to be powered down due to danger of overheating
- Back-up generators were limited and what exactly was connected to them was unknown
- Logistical issues (establishing a chain of command in decision-making, overworked personnel, deploying staff to field offices, availability of knowledgeable staff onsite) had to be quickly overcome
- Security gates lost power

Opportunities

2008 Midwest Floods – Region: SE Wisconsin

- Locate critical facilities outside 2-percent-annual-chance flood hazard area; if not possible, protect equipment to that level
- Use flood damage-resistant material and construction practices to reduce losses and facilitate cleanup
- Reduce direct inflows to prevent overwhelming operational equipment
- Coordinate with major users to reduce demand on facility
- Issue information bulletins to encourage the reduction of water use and sewage flows
- Develop emergency operations plans and checklists (e.g., contact information) for all facilities
- Plan to stage emergency equipment (e.g., pumps, generators, fuel) outside of mapped flood hazard area
- Place stronger emphasis on flood risk communication

2012 Superstorm Sandy – Region: Northeast (NY, NJ, DC)

- Improve Energy Sector communications; coordinate with utilities to improve reliability
- Make Water Sector power restoration a priority for all power providers
- Establish Water Sector support and define roles/responsibilities for Emergency Operations Centers (EOCs)
- Form pre-defined response teams for various events; determine roles
- Protect key infrastructure to a higher risk, lower probability flood event (e.g., 500-yr flood)
- Develop a flood protection strategy for all facilities (central, offsite)
- Conduct pump-station power loss exercises
- Develop a plan to secure critical equipment (trucks) and fuel after storm
- Invest in staff support (food, gas/toll support, temporary shelter)
- Work with local/State/regional planners and responders
- Federal response partners to ensure water utility personnel have site access
- Increase participation in Water/Wastewater Agency Response Network (WARN) and Emergency Management Assistance Compact (EMAC)
- Develop a more systematic process to gain utility operation status
- Address communication system interoperability issues; ensure internal/ external communications

New Madrid Earthquake – Region: Central U.S. (Fictional Scenario)

- Implement and support a continuous planning and exercise event cycle for major regional events
- Continue the interregional and Federal planning effort
- Focus on senior leadership involvement in catastrophic planning
- Develop a comprehensive lifelines recovery strategy
- Continue disaster air operations planning
- Examine emerging technologies to enhance recognition, warning, and post-event information sharing

Cybersecurity Incident (Fictional Scenario)

- Define dependencies in advance, identify critical systems, and develop communication/ coordination planning
- Clearly define roles/responsibilities and an incident command structure
- Ensure cyber plans include: response and recovery processes/procedures, contingency plans, coordination guidance, prioritization of mission critical systems, and information-sharing protocols
- Increase familiarity and exposure to cybersecurity issues (e.g., threats)
- Promote ongoing training to keep staff knowledge levels current
- Identify and understand available resources prior to an incident

2003 Energy Blackout – Region: Cleveland, OH

- Share information on national power grid dependencies
- Identify options for dedicated service, priority service, and other agreements with power suppliers
- Define decision-making process and roles/ responsibilities
- Establish an EOC for each offsite facility
- Develop protocols and ready-made templates for internal, external and public/media communications
- Ensure sufficient equipment for handling logistics and communications
- Have an EPA or State representative onsite to provide the 'other side' of disruption impacts
- Develop protocols and ready-made templates for internal, external and public/media communications
- Establish a public call center and regular communication with media
- Address security concerns (e.g., backup power for security gates) and establish procedures to avoid dissemination of critical facility information

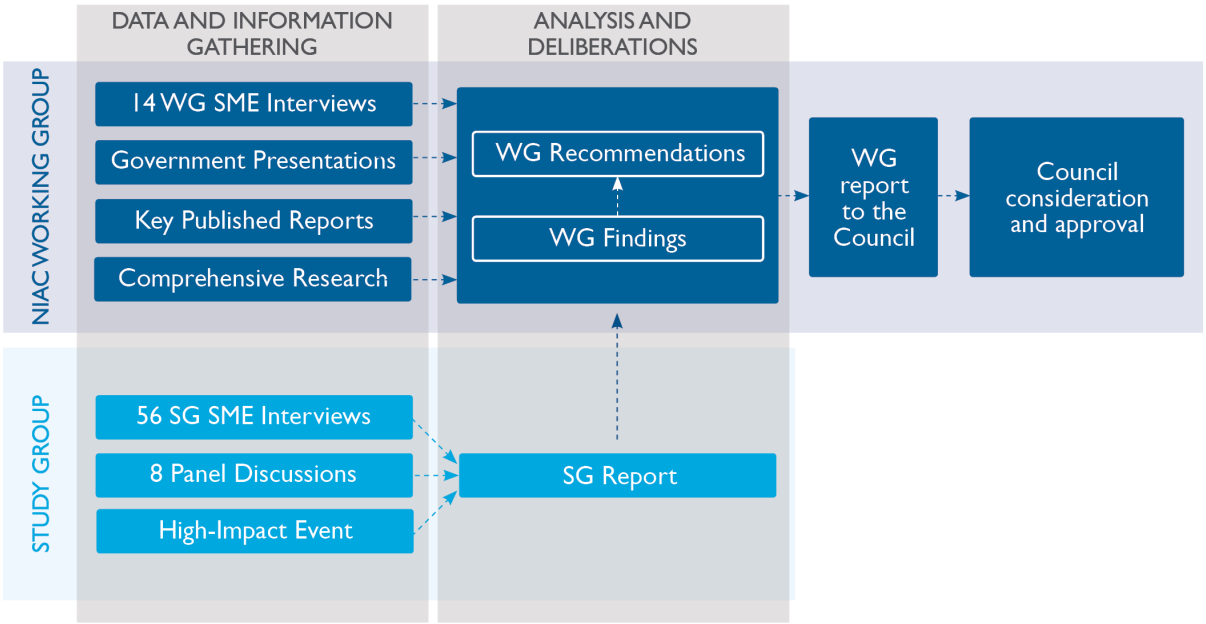
APPENDIX D.
STUDY GROUP FINDINGS AND CONCLUSIONS

The Working Group formed a non-NIAC-member Study Group to examine specific technical, financial, and operational issues. Specifically, the Study Group was tasked to:

- Identify baseline resilience of the sector
- Identify the risk profile of the sector including current, emerging, and long-term risks and the strategies and practices the sector is implementing to mitigate them
- Identify unique factors within the sector that influence risk mitigation, including investments and operational decisions
- Identify gaps in resources and practices, and opportunities to remedy them
- Summarize research and interviews into key findings and conclusions
- Prepare a summary report of Study Group findings and conclusions to the Working Group

Exhibit D-1 shows the formal entry point for the Study Group report that was invaluable during the analysis and deliberations phase. This Study Group input, in addition to the Working Group's expertise and experience, interviews with subject matter experts, extensive literature reviews, and comprehensive research resulted in a well-documented report.

Exhibit D-1. Overview of Working Group and Study Group Efforts



The Study Group has developed six main findings:

- Water is not given appropriately high priority as a critical sector.
- Water services are undervalued.
- Greater investment is needed to improve Water Sector resilience.

- A dynamic risk environment requires sustained research and analysis to support risk management.
- Regional collaboration is highly valuable but effectiveness requires expanded support.
- Federal program support for resilience is fragmented and weak.

These findings and their related conclusions are presented below.

Study Group Finding 1: Water is not give appropriately high priority as a critical sector.

The Water Sector's role as a lifeline sector is not sufficiently recognized—and acted upon—by the majority of stakeholders at the local, State, and national levels. This is a fundamental failing, as multiple sectors are critically dependent on water, and water is arguably the single most important resource for community health and well-being. Enhanced coordination across sectors on planning and prioritization of resources needed during restoration is needed to support the sector as a national priority.

Specific challenges include:

- Continuity of water services requires a full spectrum of resilient activity rather than simply focusing on response. This is not yet fully understood by the public or decision-makers.
- Planning for larger-scale (multicommunity, multijurisdiction) supplies of emergency drinking water is inadequate; the capability of individual States to effectively deliver needed water is limited.
- Cascading effects of disruptions among critical sectors are not fully understood or valued, particularly during major disasters when all critical services are being stressed.
- Service restoration requires improvement in coordination and communication between the Energy and Water Sectors.
- Current authority for water is distributed across four Emergency Support Functions (ESFs) under the National Response Framework and multiple Federal agencies, leading to uncertainty, leadership challenges, information-sharing complications, and an overtaxing of Water Sector response resources—all of which can impede water service recovery during disasters.

Study Group Conclusions: Opportunities to Increase the Priority of Water

A. Treat water and wastewater services as a first-tier national priority across the full spectrum of for preparedness—prevention, protection, response, mitigation, and recovery—as defined in Presidential Policy Directive 8 (PPD-8).

B. Examine the Federal/State capability in providing emergency water supplies under emergency conditions, particularly given recent events in Michigan, Ohio, and West Virginia.

C. Build a shared understanding among critical interdependent sectors of assumptions, plans, capabilities, and prioritization of resources.

D. Facilitate coordination between water utilities, fuel and chemical providers, and law enforcement and emergency managers to increase awareness of and improve service restoration processes.

E. Strengthen Federal coordination during emergencies and improve sector response, by streamlining and coordinating Water Sector emergency support functions (e.g., consolidating Federal assistance for the Water Sector under a single ESF).

Study Group Finding 2: Water services are undervalued

Water Sector services are often undervalued, if not simply taken for granted. Understanding, recognition, and support for the value of resilient water services is lacking by both the public-at-large and decision-makers. Proactive investments in resilience can produce order-of-magnitude savings compared to expenditures for emergency response and repair. However, this requires decision-makers who are willing to champion and fund resilience priorities, combined with underlying public support.

Specific challenges include:

- The lack of appreciation is an underlying contributor to lack of support for infrastructure investment.
- Decision-makers at every level need to support system upgrades that build resilient capacity and encourage system redundancy.
- Public outreach and education is critical to build the case for investment. Improved understanding by the public—and elected leaders—is fundamental to taking effective and sustained action for resilience.
- The challenge of raising rates to meet actual short- and long-term needs—including resilience—is enormous.

Study Group Conclusions: Opportunities to Appropriately Value of Water

A. Conduct a full life-cycle cost/benefit analysis to demonstrate the overall value of infrastructure investment—in health, convenience, economic prosperity, and overall quality of life—and the payoffs associated with investment now to avoid more costly impacts later.

B. Provide water utility decision-makers with specific and validated information to value water appropriately, about the positive cost/benefit characteristics of resilience investments, and to support and defend investments in system resilience.

Study Group Finding 3: Greater investment is needed to improve Water Sector resilience.

Enhancing resilience requires strategic investments in infrastructure, technology, and expertise, yet many water and wastewater systems are constrained making such investments, particularly in smaller utilities. While resources are often available for short-term operational needs, such as emergency response, investment in preventative measures has often been inadequate to ensure reliable service delivery under distressed conditions. Constraints include a lack of focus on full life-cycle costs for building resilient infrastructure, a deepening shortage of experienced personnel, a lack of awareness or availability of tools and information, and a concern by political leaders about

the impact of rate increases on low-income populations. Enhancing the ability of the Water Sector to make improved strategic investments can build resilience while complementing short-term operations.

Specific challenges include:

- While capital is available to most systems, incorporating a full accounting of risk is difficult because rate-setting is often a political process.
- Water and wastewater utilities are highly diverse; some develop and implement leading-edge practices while others lack information, knowledge, expertise, tools, and lessons learned. Despite the criticality of sharing these resources, adoption of successful practices and resources has not been fully realized.
- Information and tools to understand risks and conduct risk assessments are available and valuable, but are currently underutilized throughout the sector due to lack of awareness.
- The adequacy of human assets within the Water Sector are a growing concern, particularly with regard to knowledge retention and talent acquisition. Challenges that require new skill sets and the costs of training constrain the ability to adapt to a changing environment. The loss of institutional knowledge due to retirements compounds this shortfall.
- The affordability challenge makes it difficult for some communities to have full-cost-of-service pricing.

Study Group Conclusions: Opportunities to Increase Investment in Water Resilience

A. Incorporate risk into financial decisions and capital investments in building and sustaining resilient systems as cost-effective solutions that balance short- and long-term needs with normal and distressed operations.

B. Facilitate partnerships between water utilities, associations, and the private sector to educate and promote resource sharing and knowledge transfer (e.g., best practices and resilience case studies).

C. Encourage mentorships between leading edge utilities and less-mature utilities—such as between large and small utilities—and facilitated by associations.

D. Invest in the implementation (e.g., streamlining and increasing awareness) of currently available tools, especially standardized risk-analysis tools that inform capital project design and investment decisions, and ensure Federal agencies collaborate on tools to avoid duplication.

E. Invest in job and training programs and technical assistance—in partnership with higher-education providers, nongovernmental organizations, and veteran's services—on the use of information and tools.

F. Authorize and fund a financial assistance program, similar to the Low Income Home Energy Assistance Program (LIHEAP), to address the affordability challenge for disadvantaged populations.

G. Utilize asset management tools and green infrastructure approaches to increase investments in critical assets.

Study Group Finding 4: A dynamic risk environment requires sustained research and analysis to support risk management.

Water Sector partners recognize that planning for historic patterns of disruption do not fully account for changing and emerging risks. This situation is not exclusive to the Water Sector, as new and/or expanding threats (e.g., cyberattacks, aging and moving populations, and increasingly severe weather events) are becoming more prominent for all critical infrastructure. A dynamic risk environment requires continued research and analysis to improve confidence in long-term risk-management decisions, even while utilities struggle to meet the current demands of day-to-day operations. The cybersecurity challenge in particular will test the capabilities of risk-management processes, with the acquisition and retention of human-capital assets of particular concern.

Specific challenges include:

- Despite the increasing unpredictability of extreme-weather events, systems may lack the advanced capabilities to adapt to a range of potential threats (e.g., rising sea levels, expanding populations in coastal areas, and more severe storms).
- Sector dependencies, while generally well-understood, may not be adequately addressed in practice. Planning may not address either the extent of the need for supplies or their actual availability. For example, the duration of events may be underestimated, and the existing supply chain planning for electricity, critical chemicals, and fuels may in fact be inadequate. In addition to underestimating need, shortfalls may reflect transportation difficulties as well as difficulties at the point of production or origin. Disasters are not single-sector events, and joint lifeline-sector planning is essential.
- While a broad range of information, tools, analysis, and research are available to utilities, broad use across the sector to manage risk lags due to the lack of investment in consolidation and awareness of these resources.
- The increasing prevalence of cyber intrusions challenges business-as-usual practices. Cybersecurity awareness throughout utility personnel (e.g., for engineers, operators, and decision-makers) is often limited. In addition, the number of available Water Sector cyber experts is insufficient for current needs; utilities are constrained in offering competitive packages to attract top cybersecurity experts.

Study Group Conclusions: Opportunities to Increase Research and Analysis for Risk Management

A. Assist water utilities in adapting to potential threats by research and providing actionable information (e.g., better understanding of emerging cyber threats and how to respond), access to analytic tools (e.g., for assessment of cross-sector vulnerabilities and dependencies), and best practices and guidance.

B. Develop and update regularly a compendium of lessons learned, best practices, expert knowledge, and tools to support effective preparation and response for all threat types. Consolidate and broadly market these resources into a one-stop-shop for easy access by utilities.

C. Connect applied research to utilities, particularly in the areas of new technologies to support resilience and applying methods and technologies successful in other sectors to the Water Sector.

D. Develop and offer to water utilities exercises on cyber disruption and manual operation to determine cyber system management governance and incident roles/responsibilities.

Study Group Finding 5: Regional collaboration is highly valuable but effectiveness requires expanded support.

Regional-level planning and response is a highly effective approach for enabling resilience through joint action. While there are some notable exceptions, systems within a region containing multiple local and/or State jurisdictions tend to plan and operate independently. Improved understanding of, and support for, effective joint action is needed among local, State, and national leadership. Collaborative planning, relationship building, resource sharing, and knowledge transfer can aid individual utilities while simultaneously contributing to shared resilience improvements and an integrated approach to preparedness.

Specific challenges include:

- The lack of a broadly accepted framework for regional goals, resource-sharing criteria, and performance metrics hinders the development of a shared approach to disruption; such a framework is needed for all phases of resilience, not simply response.
- Although the consequences of a disruption of water and wastewater services are primarily local and regional, insufficient attention is given to the risk and impact of a large-scale, national disruption.

Study Group Conclusions: Opportunities to Improve Regional Collaboration

A. Develop and offer joint exercises—across jurisdictions and interdependent sectors, including chemical, energy, and transportation—to test and strengthen a regional resilience framework.

B. Reinforce successful mutual aid and assistance models—such as the WARN—as mechanisms to address the full spectrum of resilience and physical and cyber asset challenges.

C. Support knowledge transfer and resource sharing for the management of emerging threats and cyber vulnerabilities, such as through the WaterISAC.

D. Analyze the risk, impacts, and required actions associated with 1) a large-scale water or wastewater service disruption that requires the evacuation and relocation of large populations or 2) a widespread, coordinated cyberattack on utilities that stresses the capacity of cyber experts to respond.

Study Group Finding 6: Federal program support for resilience is fragmented and weak.

While resilience is well established in Federal policy (e.g., PPD-8), it has not been substantially integrated into the actions of Federal agencies. Resilient outcomes are not part-and-parcel of Federal guidance and resources. Reviewing statutes and regulations to support resilience, incentivizing resilience, and leading coordination are measures the Federal Government can take to actively implement resilience practices in accordance with Federal policy.

Specific challenges include:

- Federal authorities, regulations, reporting requirements, and funding mechanisms currently do not promote a unified response to the resilience needs of the sector.
- The sector's flexibility to operate during emergencies (e.g., water quality, power-generation sources) is constrained by regulatory requirements.

Study Group Conclusions: Opportunities to Strengthen Federal Support for Water Resilience

A. Focus resources, eliminate redundancy, and rationalize appropriate guidance, funding, and regulatory processes by examining the current structure of Federal authorities.

B. Review current statutory and regulatory structures with the intent to promote, rather than impede, resilient activity, and encourage innovation and flexibility in regulatory compliance. For example, coordinate and streamline the permitting of resilience projects (such as advocated in Title XLI of the Fixing America's Surface Transportation (FAST) Act) to enable more timely and effective planning and investment decisions.

C. Provide utilities with the regulatory flexibility needed during emergencies to discharge water of a less-than-permit specification quality, or to generate power without having to operate as both a regulated water and power utility.

D. Coordinate an approach across Federal agencies for nonregulatory programs that support resilience—such as grant funding requirements, streamlined project guidance, and education and knowledge transfer.

E. Increase authorizations and appropriations for resilience activities through existing Federal programs such as the Clean Water State Revolving Fund (SRF), Drinking Water SRF, Water Infrastructure Finance and Innovation Act (WIFIA), and Water Resources Reform and Development Act (WRRDA).

F. Continue tax-exempt status for municipal funding.

G. Incentivize or reward resilience in local and State planning and investment decisions—based on State and local input—to provide a common foundation for resilience at local, State, and regional levels.

H. Support pilot and demonstration projects that test innovative technology and provide funding mechanisms that reduce the risk to local, State, and regional decision-makers in adopting promising, yet unproven, innovations that could offer newer, better, and more cost-effective approaches to service delivery.

I. Proactively lead collaboration among local, State, and Federal agencies and the Water Sector.

J. Visibly support outreach and education efforts by informing citizens of the value/importance of water and water investments in a manner similar to fire-prevention and public health campaigns. Partnering with industry leaders and Water Sector associations would be a highly effective means of accomplishing this.

APPENDIX E.
COMPENDIUM OF PRIOR RECOMMENDATIONS

This appendix provides a listing of recommendations—previously released by the NIAC and other organizations—related to resilience in the Water Sector. The Council leveraged the knowledge and expertise of these organizations for the current NIAC study by identifying potentially significant insights from several associated studies. Exhibit E-1 provides a timeline of prior recommendations that are most closely tied to the recommendations submitted by the Council in this study. These recommendations are further detailed in this appendix, organized into seven main themes:

- **Cross-Sector Interdependencies**
    - Identifying Interdependencies
    - Cross-Sector Engagement and Partnerships
- **Strategically Improving Water and Wastewater Infrastructure**
    - Adopting Existing Frameworks for Resilience
    - Addressing Regulatory Policies Affecting Recovery
    - Focusing on Regional Needs
    - Facilitating Infrastructure Investments and Incentives
- **Complementary Public and Private Resilience Building**
    - Improving Public-Private Partnerships
    - Fostering Senior Executive-Level Partnerships
- **Emergency Planning and Response**
    - Conducting Cross-Sector Emergency Planning Exercises
    - Enhancing Critical Infrastructure Simulations and Analysis
    - Facilitating Regional Resilience Planning
    - Incorporating Lifeline Sectors in Emergency Operation Centers
    - Developing Access-Credentialing Solutions
- **Information Sharing**
    - Improving Intelligence Information Sharing
    - Understanding Infrastructure Intelligence needs
- **Cybersecurity**
- **Capabilities to Address Emerging Issues**
    - Examining Social Media Capabilities
    - Developing Simulation and Modeling Tools
    - Developing Design Standards and Best Practices

Exhibit E-1. Prior Recommendations from NIAC and Other Water Sector Sources

Prior NIAC Recommendations

Prior Water Sector Recommendations

2010

DHS IP should lead a national effort to improve the understanding of resilient activities and how they are implemented in support of combined infrastructure and community resilience.
(NIAC, Recommendation 1, Optimization of Resources, 2010, p. 19)

The NIAC should prepare a follow-up report to the July 2009 Framework for Dealing with Disasters and Related Interdependencies and progress on the recommendation for DHS to elevate water services to its own ESF within the NRF to achieve higher prioritization of water systems during emergency response
(NIAC, Recommendation 6, Optimization of Resources, 2010, p. 24)

2013

The Secretary of Homeland Security should facilitate efforts with governors, mayors, and local government officials to identify or develop regional, public-private, cross-sector partnerships, led by senior executives, to coordinate lifeline sector resilience efforts within a given region.
(NIAC, Recommendation 2, Regional Resilience, 2013, p. 5)

State and local emergency operations centers must establish clearly defined roles and responsibilities for Water Sector support. Representation can be physical or virtual, but should include a member from WARN.
(AWWA, Recommendation 6, WARN: Superstorm Sandy After Action Report, 2013, p. 3)

Raise awareness of the Water Sector as a lifeline sector and recognize the priority status of its needs and capabilities, and support the development and deployment of tools, training, and other assistance to enhance preparedness and resiliency.
(CIPAC Water Sector Strategies Working Group, Roadmap to a Secure and Resilient Water Sector, 2013)

2014

Determine the role of policies, regulation, and consolidation within industries and its impact on resilience, security, innovation, and resilience.
(NIAC, Recommendation 1.3, CISR R&D Plan, 2014, p. 25)

Federal agencies and utilities should work together to better inform the public and communities about the need for resilience in water systems.
(AMWA and NACWA, Recommendation 3.a, Water Resilience Summit, 2014, p. A-4)

Document Federal agencies with responsibilities for resilience, as well as existing partnerships involving Federal agencies and local utilities and communities. Analyze the Federal landscape for potential redundancies in resilience efforts and identify potential areas for collaboration.
(AMWA and NACWA, Recommendation 4.a, Water Resilience Summit, 2014, p. A-4)

Federal and State agencies and utilities must look more holistically at regulations to ensure flexibility for resilience and to leverage opportunities that capitalize on multiple benefits for innovation (e.g., biosolids for energy).
(AMWA and NACWA, Recommendation 2.a, Water Resilience Summit, 2014, p. A-4)

2015

Incorporation of CEO-relevant roundtables to sector-specific or national exercises which will assist them to identify decisions or issues that their companies, and a sector as a whole, will need to manage from a financial, regulatory, operational, and reputational corporate risk level.
(Recommendation 8.4. CEO Engagement, 2015, p. 30)

I. CROSS-SECTOR INTERDEPENDENCIES

The understanding of sector interdependencies—how events impacting one sector can cascade across other sectors, often in unexpected ways—is essential component for preparing for large-scale events. This area covers the identification of interdependencies, and the cross-sector engagements and partnerships to build the understanding needed to address these interdependencies.

IDENTIFYING INTERDEPENDENCIES

- The President should task the NIAC to identify the highest-priority cross-sector risks affecting national security and resilience and produce a written report to the President within 18 months recommending potential executive-level, cross-sector action. (NIAC, Recommendation 1.3. *Regional Resilience*, 2013, p. 5)
- Emphasize cross-sector interdependencies and collaboration through the Sector Partnership Model:
    - The U.S. Department of Homeland Security (DHS) and other Federal organizations should increase resources to conduct cross-sector studies and analysis, guided by private sector knowledge of infrastructure operations.
    - Increase understanding of cross-sector interdependencies and capabilities, led by the sectors that have a well-established partnership and a strong security posture. (NIAC Recommendation 6 (with selected bullet point), *CI Partnership Strategic Assessment*, 2008, p. 11)
- The national laboratories should focus their interdependency modeling and research on the regions and sectors whose failure would have the highest impact on the economy and national security. The Study Group suggests starting with modeling the telecommunications and energy sectors and the interdependencies among them and other critical infrastructure. In addition, existing research and development (R&D) studies need to be indexed and cross-referenced so that these materials are accessible to appropriate parties. (NIAC, Recommendation 9, *Cross Sector Interdependencies*, 2004, p. 11)
- The DHS Office of Infrastructure Protection (IP) should expand the provision of scalable, low-cost tools and techniques for community-level identification and assessment of infrastructure interdependencies. (NIAC, Recommendation 3, *Optimization of Resources*, 2010, p. 21)
- The NIAC should prepare a follow-up report to the July 2009 Framework for Dealing with Disasters and Related Interdependencies and progress on the recommendation for DHS to elevate Water Services to its own Emergency Support Function (ESF) within the National Response Framework (NRF) to achieve higher prioritization of water systems during emergency response (NIAC, Recommendation 6, *Optimization of Resources*, 2010, p. 24)
- The interoperability of communication systems needs to see continued consideration based on vulnerability to service outages that can compromise operations and response effectiveness. This includes maintaining radio communication networks such as 900-MHz

systems. (American Water Works Association (AWWA), *Water/Wastewater Agency Response Network (WARN): Superstorm Sandy After-Action Report*, 2013, p. 4)

CROSS-SECTOR ENGAGEMENT AND PARTNERSHIPS

- The Secretary of Homeland Security should facilitate the development of cross-sector partnerships within selected regions to improve the regions' resilience to very large-scale events that could impact national security, resilience, and economic stability. (NIAC, Recommendation 2.1, *Regional Resilience*, 2013, p. 5)
- Document Federal agencies with responsibilities for resilience, as well as existing partnerships involving Federal agencies and local utilities and communities. Analyze the Federal landscape for potential redundancies in resilience efforts and identify potential areas for collaboration. (Association of Metropolitan Water Agencies (AMWA) and National Association of Clean Water Agencies (NACWA), *Water Resilience Summit: Summary & Next Steps*, 2014, p. 4)
- Develop an intergovernmental partnership to address Water Sector adaptation and resilience needs in the face of changing weather patterns. (NACWA, W*ater Resources Utility of the Future: A Call for Federal Action*, 2013, p. 3)

II. STRATEGICALLY IMPROVING WATER AND WASTEWATER INFRASTRUCTURE

Strategic decisions about the development, implementation, and application of regulations and investments directly impact the sector's resilience. Recommendations in this category recognize the complexity of this decision-making, and are organized into four focus areas:

- Adopting existing frameworks for resilience
- Addressing regulatory policies affecting recovery
- Focusing on regional needs
- Facilitating infrastructure investments and incentives

ADOPTING EXISTING FRAMEWORKS FOR RESILIENCE

- Promote the use of the NIAC-developed framework for setting resilience goals in the critical infrastructure and key resources (CIKR) sectors and for providing a common way to organize resilience strategies within the Federal Government, State governments, and CIKR sectors. (NIAC, Recommendation 5, *Establishing Resilience Goals*, 2010, p. 52)
- Fortify government policy framework to strengthen critical infrastructure resilience:
    - The President should adopt the NIAC definition for resilience for development of resilience policy.

- Government should establish a collaborative dialogue with CIKR owners and operators in each sector to develop a commonly agreed-upon set of outcomes-focused goals for each sector.
- The President should issue a Homeland Security Presidential Directive (HSPD)-level authority to develop a national policy on resilience in a manner similar to and consistent with the HSPD-7 policy for protection, but also ensure the authorities under this guidance and public-private infrastructure protection partnership is retained. (NIAC, Recommendation 1 (with selected bullet points), *Critical Infrastructure Resilience*, 2009, pp. 16–18)

- All critical infrastructure sectors should consider adopting the industry self-governance model exemplified by the Institute of Nuclear Power Operations and the North American Transmission Forum to enable the private sector to collaborate on industry-wide resilience and security issues outside the regulatory compliance process. (NIAC, Recommendation 4, *Establishing Resilience Goals*, 2010, p. 52)
- Ensure that the implementation of the U.S. Environmental Protection Agency's (EPA's) Integrated Planning & Permitting Framework fully accounts for Utility of the Future (UOTF)-type activities. (NACWA, *Water Resources Utility of the Future: A Call for Federal Action*, 2013, p. 3)

ADDRESSING REGULATORY POLICIES AFFECTING RECOVERY

- A process for identifying and addressing statutory, regulatory, and policy impediments to recovery:
  - DHS should institutionalize processes and provide funding as needed to systematically develop and maintain at the Federal, State, and local (especially major metropolitan) government levels, catalogs of specific laws and regulations that may need to be suspended or modified during different disaster scenarios to improve CIKR recovery efforts.
  - The Executive Branch should work with Congress and State legislatures to pass legislation with provisions that allow the executive branches in government, at the Federal and State levels, to grant blanket waivers for statutes and regulations identified as impeding recovery efforts during an emergency or disaster-type event. (NIAC, Recommendation 1 (with selected bullet points), *Framework for Dealing with Disasters and Related Interdependencies*, 2009, pp. 20–21)
- Potential Federal, State, and local action to address statutory, regulatory, and policy impediments to disaster recovery/preparedness:
  - To address the lengthy waiver process for Environmental Impact Statements (EIS), DHS should ask Congress to validate the "Alternative Arrangements" rule the Council on Environmental Quality has used to expedite EIS requirements during emergencies.

- DHS should work with the relevant Sector-Specific Agencies (SSAs) and regulators to identify a process for emergency waivers for document filing deadlines with regulatory agencies on processes that need to be expedited during a disaster.
- DHS should ask Congress to consider legislation authorizing the waiver of Federal and State restrictions on the interstate movement of motor vehicles responding to a disaster.
- The Federal Emergency Management Agency (FEMA) and DHS IP should collaborate to develop a structured, commonly applicable best practices decision-making process for authorities to use for credentialing CIKR workers and granting access to a disaster area during an emergency. (NIAC, Recommendation 2 (with selected bullet points), *Framework for Dealing with Disasters and Related Interdependencies*, 2009, pp. 21–23)

- Determine the role of policies, regulation, and consolidation within industries and its impact on resilience, security, innovation, and resilience. (NIAC, Recommendation 1.3, *CISR R&D Plan*, 2014, p. 25)
- The Water Infrastructure Network (WIN) recommends Congress pass legislation and the President sign it, and provide funding for its provisions that:
  - Creates a long-term, sustainable, and reliable source of Federal funding for clean and safe water.
  - Authorizes capitalization of the next generation of State financing authorities to distribute funds in fiscally responsible and flexible ways, including grants, loans, loan subsidies, and credit assistance.
  - Focuses on critical "core" water and wastewater infrastructure needs and nonpoint source pollution.
  - Streamlines Federal administration of the funding program and encourages continuous improvement in program administration at both the Federal and State levels.
  - Adequately finances strong State programs to implement the Clean Water Act and the Safe Drinking Water Act.
  - Establishes a new program for clean and safe water technology and management innovation to reduce infrastructure costs, prolong the life of America's water and wastewater assets, and improve the productivity of utility enterprises.
  - Provides expanded, targeted technical assistance to communities most in need. (WIN, *Water Infrastructure NOW: Recommendations for Clean and Safe Water in the 21st Century*, 2001, p. 4)
- Federal/State/local policy for emergency management must clearly elevate the Water Sector to top-level priority for response and recovery as recommended by the NIAC. Water utilities should continue to work with their critical response partners and customers to ensure that Water Sector response activities are coordinated, awareness exists with regard

to backup power and fuel needs, and coordination of credentialing and site access controls is done in advance. (AWWA, *WARN: Superstorm Sandy After-Action Report*, 2013, p. 3)

- Federal and State agencies and utilities must look more holistically at regulations to ensure flexibility for resilience and to leverage opportunities that capitalize on multiple benefits for innovation (e.g., biosolids for energy). (AMWA and NACWA, Recommendation 2.a, *Water Resilience Summit*, 2014, p. A-4)
- The President of the United States should consider issuing an Executive Order that (a) creates a Federal Interagency Task Force on Water Reuse to coordinate all Federal water reuse initiatives, and (b) sets a goal for minimum percentages of reclaimed water for all new Federal installations (similar to the Federal goal for recycled paper). (NACWA, Water Environment Research Foundation (WERF), and Water Environment Federation (WEF), *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 18)
- Support a Congressional Clean Water Technology & Innovation Caucus that can bring a focus to UOTF priority issues. (NACWA, WERF, and WEF, *Water Resources Utility of the Future: A Call for Federal Action*, 2013, p. 3)
- Consider and explore a new 21st Century Watershed Act that can drive the Water Sector toward the emerging UOTF model. (NACWA, *Water Resources Utility of the Future: A Call for Federal Action*, 2013, p. 3)
- Support an Executive Order on water reuse/recycling that coordinates Federal reuse policies and programs, and stimulates innovation. (NACWA, *Water Resources Utility of the Future: A Call for Federal Action*, 2013, p. 3)
- Make the case for streamlined permitting requirements and flexibility in addressing regulatory requirements with Federal agencies, including lengthened permit terms, to allow for longer term resilience planning. (AMWA and NACWA, *Water Resilience Summit: Summary & Next Steps,* 2014, p. 4)
- Congress should relax the private-use test for publicly owned and operated energy recovery or production projects as long as the issuer first satisfies 100 percent of its own energy needs before selling excess production. (NACWA, WERF, and WEF, T*he Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 16)
- With Congressional authorization as needed, EPA and the States should reform the Total Maximum Daily Load (TMDL) process to achieve reliable, least-cost loadings reductions regardless of source and/or other in-stream actions to restore ambient water quality goals, with appropriate financial support where needed, monitoring, and enforcement. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 13)
- EPA should amend its TMDL regulations and guidance to formally incorporate adaptive management as part of the TMDL approach. Until it does, EPA should issue guidance to State regulators that encourages States to pursue these voluntary processes based on the Wisconsin model. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 14)

- Congress should support greater adoption of watershed-based solutions by explicitly encouraging trading in the Clean Water Act and extending permit terms for facilities that are participating in these processes. Similarly, EPA should work with delegated States to promote viable and flexible trading programs. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 13)
- Congress should consider three amendments to the Clean Water Act to acknowledge water recycling and reuse where it is feasible and desirable locally: 1) redefine publicly owned treatment works (POTW) to identify its ability to be a resource provider, 2) extend permit terms for projects that employ resource recovery activities such as water recycling, 3) name water reuse as eligible for Federal financial assistance. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, pp. 17-18)
- Support statutory changes to the Clean Water Act and Safe Drinking Water Act that bolster the important role recycled water can play in public health and safety. (NACWA, *Water Resources Utility of the Future: A Call for Federal Action*, 2013, p. 3)
- EPA should revise the March 2011 sewage sludge incineration rule to exclude sewage sludge incinerators that use biosolids to generate energy. More broadly, EPA should work with clean water authorities to formulate procedures that account for multimedia assessment of energy and resource recovery alternatives at their facilities, so that future rules can take a broader, more holistic perspective of all environmental benefits and risks. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 15)
- Using materials that they have already developed, EPA should support local stormwater management entities in initiatives designed to educate the public about the value of, and equitable ways to pay for, stormwater management as one component of integrated management plans for all water resources within local watersheds. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 19)
- Consistent with the findings of the National Academy in its recent study on water reuse, Congress should amend the Safe Drinking Water Act to make explicit certain safeguards (e.g., advanced treatment, increased monitoring) that are needed to assure that potable reuse can indeed be safe. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 17)
- An appropriate organization of the 50 States such as the Council of State Governments should formulate a program of reciprocal technology certification, where once tested and permitted in one State, the burden of proof to deny a permit for that technology in any other State falls to the regulatory agency based on guidelines agreed by all 50 States. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 25)
- State legislatures should amend their Renewable Portfolio Standard (RPS) eligibilities to include energy recovery projects from biosolids. To help legislatures understand why such changes would generate triple bottom-line benefits, the wastewater industry should educate State legislatures on this matter. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 16)

- States should clarify use rights associated with, and rules governing groundwater storage of, reclaimed wastewater so that private developers and public agencies would have stronger incentives to engage in nonpotable reuse of wastewater. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 17)
- States in which additional water reuse would help meet future demand for water supplies safely and at least cost should amend State Revolving Fund (SRF) eligibilities to include wastewater reuse. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 17)

FOCUSING ON REGIONAL NEEDS

- The President should require that Federal agencies: a) explicitly consider and address the differences among regions when promulgating security and resilience rules, programs, or guidance; and b) expressly state how they have customized implementation to each region if there is not generic applicability. (NIAC, Recommendation 3.3, *Regional Resilience*, 2013, p. 6)
- The President should designate the Energy, Communications, Water and Wastewater Systems, and Transportation Systems Sectors as lifeline sectors and direct SSAs to examine their policies, procedures, and programs to determine the extent to which they recognize the priority of the lifeline sectors and the individuality of regions, amending or revising those that do not. (NIAC, Recommendation 3, *Regional Resilience*, 2013, p. 6)
- The Secretary of Homeland Security should initiate a pilot program with State and local governments in select regions to conduct regional joint exercises, develop risk maps of critical sector interdependencies, and extract lessons learned on regional needs and gaps for government and sector partners. (NIAC, Recommendation 2.2, *Regional Resilience*, 2013, p. 5)
- There is a need for better information regarding the scope and magnitude of forecasted disasters impacting potable water:
    - It would be beneficial to promote State-wide and regional exercises that specifically consider water outages.
    - Multiagency emergency water supply plans should include an assessment as to recovery periods being extended due to critical spare parts not being available for long durations and the time periods for restoring critical infrastructure to functional condition. (EPA, *Planning for an Emergency Drinking Water Supply*, 2011, p. 31)
- Regional governments should consider creating joint water/wastewater/stormwater utilities that can manage all water within their jurisdictional boundaries as a single resource. Further, these unified water management enterprises would be better equipped to coordinate more effectively with land-use, transport, housing, energy, and other local authorities that use or affect water. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 20)

- State and local emergency operations centers must establish clearly defined roles and responsibilities for Water Sector support. Representation can be physical or virtual, but should include a member from WARN. (AWWA, *WARN: Superstorm Sandy After-Action Report*, 2013, p. 3)

FACILITATING INFRASTRUCTURE INVESTMENTS AND INCENTIVES

- Explore the potential for creating tax incentives or other instruments to incentivize the private sector to enhance the resilience of critical infrastructure. (NIAC, Recommendation 8, *Cross Sector Interdependencies*, 2004, p. 11)
- To help fill the relative cost gap and generate other economic and environmental benefits of wastewater reuse, the wastewater industry should advocate for wastewater reuse investment tax credits to attract private investment, expanded grants to cover costs of facility feasibility studies, and/or loan guarantees for reuse projects that serve rural or low-income communities that could not afford to repay market rates. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 26)
- Develop, clarify, and expand tax credit and incentive programs that will encourage clean water agencies and their private sector partners to engage in UOTF-related activities, especially in energy conservation and production, water reuse, resource recovery, and green infrastructure. (NACWA, *Water Resources Utility of the Future: A Call for Federal Action*, 2013, p. 3)
- The President should direct the Council of Economic Advisors and the Office of Science and Technology Policy to work with Federal agencies to create a strong and enduring value proposition for investment in resilient lifeline infrastructure—and its underlying physical and cyber systems, functions, and assets—and accelerate the adoption of innovative technologies in major infrastructure projects. (NIAC, Recommendation 6, *Regional Resilience*, 2013, p. 7)
- Within one year, U.S. Department of Energy (DOE), in conjunction with the Council of Economic Advisors and the White House Office of Science and Technology Policy, should complete a pilot analysis of the value proposition for investment in infrastructure grid modernization and recommend any incentives or alternative mechanisms for cost recovery that may be needed to encourage long-term investment in the modernization of lifeline infrastructure. Using the Energy Sector as the vanguard, all lifeline-sector SSAs should work with their sector partners to establish the value proposition for investment and financing in other critical sectors. (NIAC, Recommendation 6.1, *Regional Resilience*, 2013, p. 8)
- DHS should work through Federal research organizations, academic institutions, and the national laboratories to develop Applied Centers of Excellence for Infrastructure Resilience to provide an operating environment to test and validate innovative technologies and processes that build resilience into new large-scale infrastructure projects, integrate next-generation R&D, and share results with other designers in other regions. By partnering with lifeline sector owners and operators, these centers will leverage opportunities for real-world

testing, raise awareness of new capabilities, and speed commercialization of emerging technologies. (NIAC, Recommendation 6.3, *Regional Resilience*, 2013, p. 8)

- Encourage resilience using appropriate market incentives:
    - Government should partner with CIKR owners and operators to leverage their understanding of market forces, incentives, and disincentives in order to apply appropriate action that will strengthen infrastructure resilience. (NIAC, Recommendation 5 (with selected bullet point), *Critical Infrastructure Resilience*, 2009, pp. 26–27)
- Research and analyze the labyrinth of regulations and policies across all levels of government that impede and dis-incent investments in security and resilience. (NIAC, Recommendation 1.1, *CISR R&D Plan*, 2014, p. 24)
- Identify essential elements of enabling policies and regulations that would encourage and facilitate owner and operator investment and gain public acceptance of such investments, particularly for many of the lifeline sectors, for which rates and return on investment are determined through State and Federal commissions. (NIAC, Recommendation 1.2, *CISR R&D Plan*, 2014, p. 25)
- Identify and establish the elements for business and public justification for investments from lessons learned. (NIAC, Recommendation 2.1, *CISR R&D Plan*, 2014, p. 25)
- Develop an effective model of shared industry funding. (NIAC, Recommendation 2.2, *CISR R&D Plan*, 2014, p. 26)
- Create a program for early stage technology and innovation investment for the Water Sector similar to programs that exist in the energy sector. (NACWA, *Water Resources Utility of the Future: A Call for Federal Action*, 2013, p. 3)
- Advocate leveraging existing Federal funds from agencies with programs that benefit drinking water and clean water utilities for projects that advance resilience goals (e.g., SRFs, Water Infrastructure Finance and Innovation Act (WIFIA), Farm Bill, U.S. Department of Energy (DOE) grants and U.S. Department of Housing and Urban Development (HUD) Community Block Grants). (AMWA and NACWA, *Water Resilience Summit: Summary & Next Steps*, 2014, p. 4)
- Congress should establish and fund Advanced Research Projects Agency (ARPA)-W to work with industry to define high-risk, high-reward R&D needs, solicit proposals from public and private enterprises that had solutions at various stages of commercialization, and manage information flow about the research for the benefit of the industry and the Nation. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 23)
- Congress should establish within ARPA-W, a special development facility for consortia of clean water agencies, universities/research centers, and technology developers, who together would jointly apply for federally subsidized private insurance that would offset utility costs in the event that piloting innovative technologies was unsuccessful. This facility also could provide tax credits to private corporations that partnered with a grant recipient

to help offset risks associated with developing and commercializing its technology. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action, 2013*, p. 24)

- Clean water agencies should take advantage of any unobligated grant funds and to the extent they are eligible, loans from the 29 States that established revolving loan funds using State Energy Program (SEP) grants. On the basis of strong performance of the 2009 American Recovery and Reinvestment Act (ARRA) funding, the wastewater community should advocate for continued funding under these programs, with explicit acknowledgement that clean water agencies should be priority recipients of funding assistance. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, pp. 21-22)
- The Bureau of Reclamation should focus Federal grants on reuse projects, without which returns would be insufficient to attract private co-investment and where they deliver high net economic and social benefits. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action, 2013*, p. 21)
- Refocus existing Federal grant programs to support UOTF initiatives. (NACWA, *Water Resources Utility of the Future: A Call for Federal Action*, 2013, p. 3)
- The wastewater community should advocate for a continuation, if not an expansion of these EPA programs. Continued Federal funding not only preserves the intergovernmental partnership embedded within the Clean Water Act, it creates jobs and accounts for the "public goods" benefits that all clean water utilities deliver when they ship cleaner water to downstream users; reduce greenhouse gas emissions through energy efficiency, methane reduction, and renewable energy production; and reduce runoff from green infrastructure. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 22)
- The U.S. Department of Agriculture (USDA) should take steps to assure that a greater proportion of their conservation program assistance funds nutrient reduction programs. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 23)
- Create and support market-based approaches to efficiently and more equitably address watershed-scale water quality challenges. (NACWA, *Water Resources Utility of the Future: A Call for Federal Action*, 2013, p. 3)
- The Water Sector should work with Congress to examine these programs to assure that they do not exclude or limit their participation and where it does or can, they should work with Congress to amend authorizing language to ensure that private investors have every incentive to partner with clean water authorities to extract energy from wastewater and biosolids, and to ensure that renewable energy from these facilities however generated is eligible to participate in markets for renewable energy. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 15)
- There are multiple ways to prevent these negative consequences described in this report. Possible preventive measures include spending more on existing technologies, investing to

develop and then implement new technologies, and changing patterns in where and how we live. All these solutions involve costs. Separately or in combination, these solutions will require action at the national, regional, and private levels, and will not occur automatically. (American Society of Civil Engineers (ASCE), *Failure to Act: The Economic Impact of Current Investment Trends in Water and Wastewater Treatment Infrastructure*, 2011, p. 42)

III. COMPLEMENTARY PUBLIC AND PRIVATE RESILIENCE BUILDING

Achieving critical infrastructure security and resilience requires close collaboration between the public and private sectors. Sectors cannot singularly understand, prepare for, or manage the complexities inherent in securing and making the Nation's interdependent and complex infrastructure more resilient. The recommendations in this category include practical ways to address the need for resilience on a massive scale, and are organized into two focus areas: improving public-private partnerships and fostering senior executive-level engagement.

IMPROVING PUBLIC-PRIVATE PARTNERSHIPS

- Clarify roles and responsibilities of critical infrastructure partners:
    - Review current incident management documents including the National Response Framework (NRF) and the National Incident Management System (NIMS) and identify opportunities to expand training and outreach activities to CIKR owners and operators. Such activities provide Federal, State, and local entities a better understanding of the components of resilience during an event and allow for increased information sharing.
    - CIKR owners and operators and DHS should identify a mechanism to monitor and measure resilience at the CIKR sector level. This process should include establishment and support of a feedback mechanism to address CIKR owner and operator concerns in all critical infrastructure sectors and should specifically assess the adequacy of the supply chain to meet response and recovery needs. This process should be analogous to and in coordination with the National Infrastructure Protection Plan annual reporting process.
    - Government should develop a better understanding of the role that repair and maintenance funding can have on CIKR and prioritize funding for these activities, both as a component of its resilience activities and part of its broader funding support of public infrastructure. (NIAC, Recommendation 3 (with selected bullet points), *Critical Infrastructure Resilience*, 2009, pp. 19–21)
- Strengthen and leverage public-private partnership:
    - Government should collaborate with CIKR executive decision-makers throughout the resilience policy development process. Development must be an iterative process featuring bidirectional communication and a clear understanding of how to reach consensus.

- Government should use the existing Sector Partnership Model to plan and implement resilience efforts in coordination with, and addition to, current protection activities.
- DHS should implement the NIAC's recommendations contained within the *Framework for Dealing with Disasters and Related Interdependencies* that support needed changes for CIKR operator regulatory relief during a national crisis or incident, CIKR worker credentialing and access to a disaster area, and clarification of disaster recovery priorities and roles. This improved coordination among CIKR sectors and government will provide faster recovery times and more focus on restoring operations, order, and public safety.
- Government should endeavor to better understand the role of design and construction in infrastructure resilience. Application of this understanding will help to shape the policy, R&D funding, and incentives that can spur technological innovation as well as the robust design and construction of critical infrastructure needed for resilience. (NIAC, Recommendation 4 (with selected bullet points), *Critical Infrastructure Resilience*, 2009, pp. 21–26)

- Increase flexibility in the sector partnership to better accommodate diverse sector needs:
  - DHS should encourage Sector Coordinating Councils (SCCs) to develop strategic roadmaps to enable sectors to articulate a variety of sector needs, identify sector priorities, and implement protection and resilience strategies. (NIAC, Recommendation 5 (with selected bullet point), *CI Partnership Strategic Assessment*, 2008, pp. 10–11)
- The Secretary of Homeland Security should facilitate efforts with governors, mayors, and local government officials to identify or develop regional, public-private, cross-sector partnerships, led by senior executives, to coordinate lifeline sector resilience efforts within a given region. (NIAC, Recommendation 2, *Regional Resilience*, 2013, p. 5)
- DHS IP should lead a national effort to improve the understanding of resilient activities and how they are implemented in support of combined infrastructure and community resilience. (NIAC, Recommendation 1, *Optimization of Resources*, 2010, p. 19)
- Federal agencies and utilities should work together to better inform the public and communities about the need for resilience in water systems. (AMWA and NACWA, Recommendation 3.a, *Water Resilience Summit*, 2014, p. A-4)
- Working more closely with the design engineering community to understand new stochastic approaches to performance and design of advanced technologies including biological nutrient reduction (BNR), State, and Federal permit writers need to incorporate results into new permits to assure that they have more realistic parameter limits that are still protective of the environment, but achievable at more appropriate costs. (NACWA, WERF, and WEF, *The Water Resources Utility of the Future: A Blueprint for Action*, 2013, p. 25)

- Increase participation in Water/Wastewater Agency Response Network (WARN) and representation in local and State emergency operation centers (EOCs). (AWWA, *WARN: Superstorm Sandy After-Action Report*, 2013, p. 2)
- Develop consistent damage assessment and system status criteria for use at the local, State, and Federal level in partnership with WARNs. Information requests from response partners for systems status should be connected with utility requests for resources to restore operations to support situational awareness and coordination of resources needed to repair the systems. (AWWA, *WARN: Superstorm Sandy After-Action Report*, 2013, p. 4)
- Increase awareness of Emergency Management Assistance Compact's (EMAC's) applicability in supporting Water Sector needs. (AWWA, *WARN: Superstorm Sandy After-Action Report*, 2013, p. 2)
- Water Sector requests for generator and fuel support must be shared with the WARN and the Emergency Support Function 3 – Public Works (ESF 3) desk in the EOC. In addition, the DOE must make restoration of power to Water Sector assets a top priority for all power distribution providers. Utilities should continue to assess their energy management strategies to continue normal operations after a power failure. A diverse set of strategies exists for utilities that should be customized for their specific conditions. (AWWA, *WARN: Superstorm Sandy After-Action Report*, 2013, p. 3)

FOSTERING SENIOR EXECUTIVE-LEVEL PARTNERSHIPS

- The President should direct the heads of the appropriate SSAs to form partnerships with senior executives from lifeline sectors, using a process modeled after the government's successful executive engagement with the Electricity subsector. (NIAC, Recommendation 1, *Regional Resilience*, 2013, p. 4)
- Within six months, the President should direct the heads of appropriate SSAs to convene a meeting with chief executive officers (CEOs) or other owner/operator leadership with equivalent decision-making authority from each lifeline sector to explore the formation of a partnership to address high-priority risks to the sector's infrastructure. (NIAC, Recommendation 1.1, *Regional Resilience*, 2013, p. 5)
- Incorporation of CEO-relevant roundtables to sector-specific or national exercises which will assist them to identify decisions or issues that their companies, and a sector as a whole, will need to manage from a financial, regulatory, operational, and reputational corporate risk level. (NIAC, Recommendation 8.4, *CEO Engagement*, 2015, p.30)

IV. EMERGENCY PLANNING AND RESPONSE

When a disaster occurs, effective emergency planning and response can mean the difference between life and catastrophic loss. While the NIAC framework for resilience, developed in the NIAC's 2010 study on establishing resilience goals, emphasizes a spectrum of activities—including planning, preparation, recovery and adaptability—the Council has frequently developed recommendations focused specifically on improving emergency planning exercises and operations

to support Federal, State, local, and private sector efforts. Recommendations in this category are organized into five focus areas:

- Conducting cross-sector exercises
- Enhancing simulation and analysis tools
- Facilitating regional resilience planning
- Incorporating lifeline sectors in EOCs
- Developing access-credentialing solutions

CONDUCTING CROSS-SECTOR EMERGENCY PLANNING EXERCISES

- The Secretary of Homeland Security should facilitate efforts with governors, mayors, and local government officials to identify or develop regional, public-private, cross-sector partnerships, led by senior executives, to coordinate lifeline sector resilience efforts within a given region.
    - DHS should initiate a pilot program with State and local governments in select regions to conduct regional joint exercises, develop risk maps of critical sector interdependencies, and extract lessons learned on regional needs and gaps for government and sector partners. Each regional partnership should conduct a regional cross-sector exercise, with full participation by public and private sector partners at the executive and operational level, to simulate a catastrophic event across a large geographic region. The exercise should be led by the regional partners and supported by DHS experts, processes, and tools as needed. Such an exercise will allow participants to "experience" unprecedented events, identify coordination and communication challenges, and help expose hidden physical and cyber risks due to lifeline sector interdependencies. The results of the exercise should be used to create an action plan to address needs and gaps. (NIAC, Recommendation 2 (with selected bullet point), *Strengthening Regional Resilience*, 2013, p. 43)
- DHS IP should lead a continuing effort to enhance the transfer of expertise and lessons learned from national-level infrastructure planning and analysis to regional and community-level systems.
    - DHS IP should sponsor a series of regional exercises devoted specifically to the issue of the distribution of goods and services during a major event affecting community resilience. The purpose of these exercises is to bring together officials at all levels of government and private sector owners and operators to identify the specific resources that may be needed in such an event, where the resources may be available, and how they are to be distributed under emergency conditions. The results of these exercises should be compiled into a report and widely distributed as part of FEMA's community outreach program to aid in community resilience planning. (NIAC, Recommendation 4, *Optimization of Resources for Mitigating Infrastructure Disruptions*, 2010, p. 21-22)

- Implement government enabling activities and programs in concert with critical infrastructure owners and operators:
    - Engage CIKR owners and operators to conduct more cross-sector emergency planning exercises to identify interdependencies, improve preparedness, and establish relationships between sectors, local government, State government, and the Federal Government. Results of these exercises should be accessible to all related sectors and facets of government, regardless of whether or not they participated in the exercise, so that the full benefits of resilience and business continuity planning can be realized. (NIAC, Recommendation 6 (with selected bullet point), *Critical Infrastructure Resilience*, 2009, p. 27)

ENHANCING CRITICAL INFRASTRUCTURE SIMULATION AND ANALYSIS

- Develop and integrate modeling and simulation tools.
    - Develop, scale and integrate interdependency and consequence modeling, and simulations to support operational decisions to predict and prevent cascading failures. Research and development should be performed to develop a comprehensive and functional simulated environment that can be used to analyze the effects of infrastructure failure in the wake of a disaster. This environment will allow users to see how clear and present threat scenarios would affect infrastructure, and how the disruption of those essential services would affect other vital services. Such a tool would be utilized by communities and institutions and government at all levels for planning, coordination, and focused investments to act on lessons learned and improve preparedness. (NIAC, Recommendation 4 (with selected bullet point), *CISR R&D Plan*, 2014, p. 29-30)
- DHS IP should expand the provision of scalable, low-cost tools and techniques for community-level identification and assessment of infrastructure interdependencies. Many effective tools and techniques are widely used on a national level to assess interdependencies and their potential impacts. Further development and transfer of infrastructure-based tools could demonstrably increase the ability of communities to establish and maintain an improved understanding of infrastructure assets and the associated community and infrastructure interdependencies. In turn, understanding of these interdependencies can improve the planning and use of resources in the event of disruptions. (NIAC, Recommendation 3, *Optimization of Resources for Mitigating Infrastructure Disruptions*, 2010, p. 21)
- DHS should support modeling and analysis studies of the cross-sector economic impacts of CIKR failures using tools such as input-output analysis. Many of the CIKR sectors are highly interconnected, which can improve resilience but also create new opportunities for problems to cascade across sectors, regions, and economic systems. Understanding the impact of sector failures is becoming more important as infrastructures become increasingly

interconnected. (NIAC, Recommendation 6, *A Framework for Establishing Critical Infrastructure Resilience Goals*, 2010, p. 52-53)

FACILITATING REGIONAL RESILIENCE PLANNING

- DHS IP should lead a national effort to improve the understanding of resilient activities and how they are implemented in support of combined infrastructure and community resilience.
    - DHS IP collaborating with FEMA should encourage regional organizations to develop Regional Infrastructure Protection Plans (RIPP) to support the coordination of regional all-hazards planning for catastrophic events. Regional plans should include the development of integrated protocols and procedures to manage a catastrophic event. An important component of regional plans should be the linkage of response operations and available resources. The NIAC encourages regional organizations to seek funding for RIPPs through the DHS Regional Catastrophic Preparedness Grant Program. (NIAC, Recommendation 1 (with selected bullet point), *Optimization of Resources for Mitigating Infrastructure Disruptions*, 2010, p. 19)

INCORPORATING LIFELINE SECTORS IN EMERGENCY OPERATIONS CENTERS

- The President should designate the Energy, Communications, Water, and Transportation Sectors as lifeline sectors, and direct SSAs to examine their policies, procedures, and programs to determine to what extent they recognize the priority of the lifeline sectors and the individuality of regions, amending or revising those that do not.
    - The FEMA National Response Coordination Center, Federal agencies, and State and local governments should modify their processes and plans for emergency operations to include the co-location of representatives of lifeline sectors in their EOCs during major disasters. The practice of including operational personnel from energy, communications, and other lifeline sectors in EOCs during Superstorm Sandy improved situational awareness, streamlined communications, and expedited response and recovery. (NIAC, Recommendation 3 (with selected bullet point), *Strengthening Regional Resilience*, 2013, p. 44)

DEVELOPING ACCESS-CREDENTIALING SOLUTIONS

- The Secretary of Homeland Security, working with heads of appropriate Federal agencies, should launch a cross-agency team within 60 days to develop solutions to site access, waiver, and permit barriers during disaster response and begin implementing solutions within one year. (NIAC, Recommendation 5, *Regional Resilience*, 2013, p. 7)
- DHS IP and FEMA should collaborate with State, local, tribal, and territorial governments and owners and operators to develop a commonly applied process or system to credential lifeline sector owners and operators and grant them access to disaster areas more effectively. (NIAC, Recommendation 5.1, *Regional Resilience*, 2013, p. 7)

- DHS should work with State and local government and infrastructure owners and operators to catalog the waivers and permits commonly required during a variety of disaster scenarios and develop a streamlined process for rapidly issuing those permits and waivers at the Federal, State, and local level. (NIAC, Recommendation 5.2, *Regional Resilience*, 2013, p. 7)
- The Water Sector should continue to work with Federal, State, and local response partners to ensure water utility crews are properly recognized and allowed access to their facilities. (AWWA, *WARN: Superstorm Sandy After-Action Report*, 2013, p. 3)

V. INFORMATION SHARING

Information sharing is an essential role of public-private partnerships across the entire spectrum of preparedness. Without sufficient information sharing, collaboration between various levels of government and critical infrastructure owners and operators would not work. Given the complexity of this issue, the NIAC and other organizations have spent considerable time assessing the various means and effectiveness of public-private information sharing. The recommendations in this category address information-sharing needs in two focus areas:

- Improving intelligence information sharing
- Understanding infrastructure intelligence needs

IMPROVING INTELLIGENCE INFORMATION SHARING

- Direct that DHS and the Office of the Director of National Intelligence (ODNI), in collaboration with other members of the U.S. Intelligence Community and the SSAs, prepare a quadrennial report on the state of intelligence information sharing for infrastructure protection and resilience. (NIAC, Recommendation 4.1.c, *Intelligence Information Sharing*, 2012, p. 44)
- DHS, with the guidance and aid of ODNI, should establish core teams of 3-4 intelligence specialists for each sector, as well as a team that focuses on cross-sector information issues. These specialists should 1) be drawn from the members of the Federal Intelligence Community, 2) have expertise in both intelligence processes and sector business and risk-management processes, and 3) be responsible for fusing varied intelligence information streams into products useful for owner and operator planning and decision-making. (NIAC, Recommendation 4.2.c, *Intelligence Information Sharing*, 2012, p. 46)
- Senior executive information-sharing mechanism: Develop a voluntary executive-level information-sharing mechanism between critical infrastructure CEOs and senior intelligence officers. (NIAC, Recommendation 1, *Public-Private Sector Intelligence Coordination*, 2006, p. 22)
- The Federal Government should ensure the availability of qualified, vetted security professionals. (NIAC, Recommendation 4, *Implementation of EO 13636 and PPD-21*, 2013, p. 18)

UNDERSTANDING INFRASTRUCTURE INTELLIGENCE NEEDS

- Direct the Federal Intelligence Community to consider infrastructure protection and resilience as a national priority; collect infrastructure intelligence needs; and prepare a National Intelligence Estimate to evaluate terrorist targets in the 18 critical infrastructure sectors and assess vulnerability to such attacks, including cross-sector interdependencies and risks. (NIAC, Recommendation 4.1.b, *Intelligence Information Sharing*, 2012, p. 44)
- The NIAC recommends that DHS work with each SSA to implement, for all 18 critical infrastructure sectors, a robust intelligence requirements process that 1) meets the information needs of owners and operators, 2) delivers these requirements to appropriate elements of the Intelligence Community, 3) is consistent with existing Intelligence Community processes, and 4) supports advocacy for critical infrastructure priority within the Intelligence Community. (NIAC, Recommendation 4.3, *Intelligence Information Sharing*, 2012, pp. 46–47)
- Within key intelligence agencies throughout the Intelligence Community, create "sector specialist" positions at both the executive and operational levels, as applicable. (NIAC, Recommendation 5, *Public-Private Sector Intelligence Coordination*, 2006, p. 25)

VI. CYBERSECURITY

Managing cyber risks to operations has become an increasing component of water utilities' security and resilience portfolios. The Federal Government's role in aiding utilities is broad, and includes increasing awareness and planning, developing secure control system standards, incentivizing technology development and investments, examining and sharing information about cyber risks and vulnerabilities, and pursuing cyber criminals. The recommendations in this category address these roles.

- Use the Federal Government's procurement power to encourage information technology suppliers to develop cybersecurity framework–compliant hardware and software. (NIAC, Recommendation 3, *Implementation of EO 13636 and PPD-21*, 2013, p. 17)
- The Federal Government should leverage its purchasing power to incentivize enhanced security and resilience in core cybersecurity systems and programs (e.g., Information Technology, Industrial Automation, and Telecommunications Sectors). (NIAC, Recommendation 7.2, *Implementation of EO 13636 and PPD-21*, 2013, p. 19)
- The Federal Government should develop policies and apply resources to pursue and discourage global cyber criminals from attacking critical infrastructure facilities. (NIAC, Recommendation 7.4, *Implementation of EO 13636 and PPD-21*, 2013, p. 19)
- Recommendations for security as an enabler:
    - The President should establish a goal for all critical infrastructure sectors that no later than 2015, control systems for critical applications will be designed, installed, operated, and maintained to survive an intentional cyber assault with no loss of critical function.

- DHS should promote uniform acceptance across all sectors that investment in control systems cybersecurity is a priority. For sectors with regulatory oversight of earnings and investments, DHS should promote inclusion of the costs of control systems cybersecurity as legitimate investments and expenses that deserve approval by their regulatory bodies. (NIAC, Recommendations for Security as an Enabler (with selected bullet points), *Convergence of Physical and Cyber Security*, 2007, p. 18)

- Recommendation for market drivers:
  - DHS and the SSAs should encourage the application of existing security and security-relevant standards and criteria in the development and implementation of secure control systems. (NIAC, Recommendations for Market Drivers (with selected bullet point), *Convergence of Physical and Cyber Security*, 2007, p. 20)
- Recommendation for executive leadership awareness:
  - To improve executive leadership awareness of the cyber risk to control systems, the NIAC recommends that DHS work with SSAs to implement a program for control systems cybersecurity executive awareness outreach. (NIAC, Recommendations for Executive Leadership Awareness (with selected bullet point), *Convergence of Physical and Cyber Security*, 2007, p. 22)
- Recommendation for information sharing:
  - DHS should enhance existing program activities to create the ability to integrate and track understanding of the cyber risk for critical infrastructure control systems using all available sources.
    - This collaborative program should collect, correlate, integrate, and track information on the following:
      - Threats, including adversaries, toolsets, motivations, methods/mechanisms, incidents/actions, and resources.
      - Consequences, including potential consequences of compromise to sector, industry, and facility-specific control systems.
      - Vulnerabilities in control systems or their implementations in the information technology infrastructure that adversaries could exploit to gain access to critical infrastructure control systems.
    - This capability is a DHS operations function, and it will include input and expertise from the following: critical infrastructure owners and operators and other relevant parties in the private sector regarding consequences and vulnerabilities, the Intelligence Community regarding threats, Carnegie Mellon's Computer Emergency Response Team Coordination Center and other sources regarding incidents, and DHS (including the United States Computer Emergency Readiness Team) regarding cyber vulnerabilities.

        - DHS will communicate resulting warning information to control systems owners and operators to ensure protection of U.S. critical infrastructure. (NIAC, Recommendation 6, *Convergence of Physical and Cyber Security*, 2007, p. 27)

- Direct lead agencies to work with each of the critical sectors to more closely examine the risks and vulnerabilities of providing critical services over network-based systems. (NIAC, Recommendation 1, *Prioritizing Cyber Vulnerabilities*, 2004, p. 10)
- Direct DHS to sponsor cross-sector activities to promote a better understanding of the cross-sector vulnerability impacts of a cyberattack. (NIAC, Recommendation 4, *Prioritizing Cyber Vulnerabilities*, 2004, p. 10)
- Direct Federal agencies to include cyberattack scenarios and protective measures in their disaster recovery planning. Encourage sector coordinating groups to include cyberattack scenarios and protective measures in their disaster recovery planning. (NIAC, Recommendation 5, *Prioritizing Cyber Vulnerabilities*, 2004, p. 11)
- Security should be designed to be built in to systems, rather than layered on top of systems. (NIAC, Recommendation 7.1, *Implementation of EO 13636 and PPD-21*, 2013, p. 19)
- Develop real-time cybersecurity risk-analysis and management tools. (NIAC, Recommendation 3.1, *CISR R&D Plan*, 2014, p. 27)
- Establish new architectures to "bake in" self-healing and self-protected cyber systems. (NIAC, Recommendation 3.2, *CISR R&D Plan*, 2014, p. 27)
- Develop automated security analysis and data collection tools and methods. (NIAC, Recommendation 3.3, *CISR R&D Plan*, 2014, p. 28)
- Understand cross-sector connections that could cause cascading effects. (NIAC, Recommendation 3.4, *CISR R&D Plan*, 2014, p. 28)
- Measure the effectiveness of security. (NIAC, Recommendation 3.5, *CISR R&D Plan*, 2014, p. 28)

VII. CAPABILITIES TO ADDRESS EMERGING ISSUES

Resilience occurs in a dynamic environment. The Nation enhances resilience through a continual process of implementation, review, and improvement. Recommendations in this category highlight evolving capabilities and tools to address emerging issues related to resilience, organized into three focus areas:

- Examining social-media capabilities
- Developing simulation and modeling tools
- Developing design standards and best practices

EXAMINING SOCIAL-MEDIA CAPABILITIES

- FEMA and the Federal Communications Commission (FCC) should convene a task force of senior emergency managers from lifeline sector SSAs and representatives of leading private sector social media and technology firms—such as Twitter, Facebook, and Google—to examine how new and emerging social media apps, platforms, and capabilities can be used to support emergency notification and response and provide greater value to the public. The task force should publish its findings in a report on best practices. (NIAC, Recommendation 4.1, *Regional Resilience*, 2013, p. 6)

DEVELOPING SIMULATION AND MODELING TOOLS

- Scale risk assessment and, management decision support tools for local communities and individual institutions. (NIAC, Recommendation 4.1, *CISR R&D Plan*, 2014, p. 28)
- Develop, scale and integrate interdependency and consequence modeling, and simulations to support operational decisions to predict and prevent cascading failures. (NIAC, Recommendation 4.2, *CISR R&D Plan*, 2014, pp. 28-29)
- Continue research and development for managing "big data." (NIAC, Recommendation 4.3, *CISR R&D Plan*, 2014, p. 29)

DEVELOPING DESIGN STANDARDS AND BEST PRACTICES

- Determine design standards and best practices for the replacement, upgrading, and maintenance of critical infrastructure systems. (NIAC, Recommendation 2.3, *CISR R&D Plan*, 2014, p. 26)
- Identify innovative, cost-efficient, and accelerated approaches to "People Readiness" in developing a skilled workforce. (NIAC, Recommendation 2.4, *CISR R&D Plan*, 2014, p. 26)
- Determine factors and approaches to accelerate recovery following a disaster. (NIAC, Recommendation 2.5, *CISR R&D Plan*, 2014, pp. 26-27)
- Establish resilience metrics. (NIAC, Recommendation 2.6, *CISR R&D Plan*, 2014, p. 2)

APPENDIX F.
FEDERAL POLICIES, AGENCIES, AND ACTIVITIES

This appendix outlines the Federal agencies interacting with the Water Sector and describes Federal policy and actions that address Water Sector resilience. First, it identifies Federal policies related to water and wastewater system resilience, examining examples of Federal law, presidential directives and executive orders and other guidance. Second, it outlines the primary Federal agencies involved in the Water Sector. Third, it describes Federal programs and activities related to resilience in the Water Sector. Lastly, it provides an overview of the components of Federal funding.

I. FEDERAL POLICIES

A number of laws, statutes, directives, and guidance inform Federal policies related to Water Sector resilience. Federal policies then inform the initiatives, programs, projects, and activities designed to strengthen protection and resilience within the sector's infrastructure. There are two primary laws governing Water Sector systems and enforcement to protect human health and the environment: Safe Drinking Water Act and Clean Water Act.[68] Presidential directives and executive orders—such as PPD-21 Critical Infrastructure Security and Resilience—build on the pursuit of critical infrastructure security and resilience. In addition, Federal guidance and major funding mechanisms further support Water Sector resilience initiatives, programs, projects, and activities carried out by Federal agencies.

FEDERAL LAWS

There are four Federal laws that most impact water resilience. Two focus on water resilience and two address emergency response.

Safe Drinking Water Act (SDWA)

Established in 1974, the SDWA provides the basis for drinking water security by protecting water quality and underground sources of drinking water. It applies to public water systems, including pipes and other constructed conveyances. The SDWA authorizes the U.S. Environmental Protection Agency (EPA) to set national standards for drinking water quality and oversees the State, local, and water utility implementation of those standards. Under the SDWA, the National Primary Drinking Water Regulations (or "primary standards") set enforceable maximum levels for particular contaminants in public water systems. These primary standards include requirements for water systems to test for these contaminants and to ensure standards are achieved. In addition to setting these standards, EPA provides guidance and assistance on drinking water, collects data, and oversees State drinking water programs in pursuit of SDWA requirements.

The law allows States to request drinking water programs, giving them the authority (or "primacy") to oversee the program within its borders. Of the 50 States, 49 have "primacy", in addition to the Commonwealth of Puerto Rico, and the Navajo Nation. EPA regional offices administer the drinking

[68] EPA, *2015 SSP*, 2016.

water programs for Wyoming, the District of Columbia, the Virgin Islands, Guam, America Samoa, and the Commonwealth of the Mariana Islands.

Federal Water Pollution Control Act (Clean Water Act)

The Clean Water Act (CWA) regulates the discharge of pollutants into waters and regulates surface water quality standards. It establishes standards for municipal waste treatment and numerous categories of industrial point-source discharges (e.g., discharges from fixed sources). It requires States and some tribes to enact and implement water quality standards in order to achieve designated water-body uses, address water pollutants, and regulate dredge-and-fill activities and wetlands. EPA and States with permitting authority have a number of enforcement authorities.[69]

Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act)

Typically, States are able to assist utilities during a major disruption but they may not have the resources to assist larger systems or regional outages. For large disasters, States seek assistance under the Stafford Act.[70] This Act provides the statutory authority for most Federal disaster activities. The Act authorizes the delivery of Federal technical, financial, logistical, and other assistance to States and localities during declared major disasters or emergencies. Federal assistance is provided if an event is beyond the combined response capabilities of State and local governments.[71]

Public Health Security and Bioterrorism Preparedness and Response Act

Title IV of this Act required drinking water facilities serving more than 3,300 customers to conduct a vulnerability assessment and develop an Emergency Response Plan (ERP) that addresses assessment findings. Facilities must identify plans, procedures, and equipment that can be used in event of a terrorist or intentional attack, or used to prevent or mitigate an attack. It also calls on EPA to conduct research studies in prevention, detection and response to intentional or terrorist acts that potentially disrupt drinking water supply or infrastructure.[72]

PRESIDENTIAL DIRECTIVES AND EXECUTIVE ORDERS

In addition to the abovementioned laws and statutes, the following presidential directives inform Federal policy related to critical infrastructure security and resilience.

Homeland Security Presidential Directive 5, Management of Domestic Incidents (February 28, 2003)

HSPD-5 directs the Secretary of Homeland Security to develop and administer a National Incident Management System (NIMS) to provide a consistent nationwide approach for Federal, State, and local governments to work effectively and efficiently together to prepare for, respond to, and recover from domestic incidents, regardless of cause, size, or complexity. HSPD-5 also directs the Secretary to develop and administer a National Response Plan (NRP) to integrate Federal

[69] EPA, *2015 SSP*, 2016.
[70] EPA, *Planning for an Emergency Drinking Water Supply*, 2011.
[71] Ibid.
[72] EPA, *2015 SSP,* 2016.

Government domestic prevention, preparedness, response, and recovery plans into one all-discipline, all-hazards plan.

Presidential Policy Directive 8, National Preparedness (March 30, 2011)

PPD-8 calls on Federal agencies to work with the whole community to achieve the goal of a secure and resilient Nation through developed capabilities "to prevent, protect against, mitigate, respond to and recover from the threats and hazards that pose the greatest risk." It is organized around the following main elements: National Preparedness Goal (the end to achieve), National Preparedness System (the means to achieve the goal), National Planning Framework (describes how the whole community works together to achieve the goal), and National Preparedness Report (measures progress toward the goal).

Presidential Policy Directive 21, Critical Infrastructure Security and Resilience (February 12, 2013)

PPD-21 provides the national approach to protecting critical infrastructure. It defines critical infrastructure broadly, to include cyber, as well as physical structures. PPD-21 expands the view of critical infrastructure threats from the previous terrorism perspective to an all-hazards approach. It advances a national unity of effort to strengthen and maintain secure, functioning, and resilient critical infrastructure across the spectrum of prevention, protection, mitigation, response, and recovery.

Executive Order 13636, Improving Critical Infrastructure Cybersecurity (February 12, 2013)

EO 13636 addresses how the Federal Government will help prevent, mitigate, and respond to the rise of cyber intrusions into the United States' critical infrastructure while, at the same time, maintaining a cyber infrastructure that protects privacy and confidentiality.

Executive Order 13690, Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input (January 30, 2015)

EO 11988—Floodplain Management, issued in May 1977, requires Federal agencies to avoid—to the extent possible—long- and short-term adverse impacts associated with the occupancy of flood plains, in addition to avoiding direct/indirect support of floodplain development if there is a practicable alternative. It is designed to reduce the risk of flood loss; minimize the impact of floods on human safety, health, and welfare; and restore/preserve the flood plains. EO 11988 was amended by EO 13690 which established the Federal Flood Risk Management Standard (FFRMS) to improve resilience to current and future flood risks. It provides three approaches that Federal agencies can use to establish the flood elevation and hazard area for consideration in their decision-making: climate-informed science approach, adding two to three feet of elevation to the 100-year floodplain, and using the 500-year floodplain.

OTHER FEDERAL GUIDANCE

National Infrastructure Protection Plan 2013: Partnering for Critical Infrastructure Security and Resilience (NIPP 2013)

NIPP 2013 guides the national effort to manage risk to the Nation's critical infrastructure. NIPP 2013 builds upon previous plans by emphasizing the complementary goals of security and resilience for critical infrastructure. To achieve these goals, cyber and physical security and the resilience of critical infrastructure assets, systems, and networks are integrated into an enterprise approach to risk management. The national plan also establishes a vision, mission, and goals that are supported by a set of core tenets focused on risk management and partnership to influence future critical infrastructure security and resilience planning at the international, national, regional, State, local, tribal and territorial governments, and owner and operator levels. NIPP 2013 further organizes critical infrastructure into 16 sectors and designates a Federal department or agency as the lead coordinator—Sector-Specific Agency (SSA)—for each sector.[73]

National Response Framework (NRF)

The NRF is a component of the National Preparedness System mandated in PPD 8: National Preparedness of March 2011. PPD-8 defines five mission areas – prevention, protection, mitigation, response, and recovery – and mandates the development of a series of policy and planning documents to explain and guide the Nation's collective approach to ensuring and enhancing national preparedness. The NRF is a guide to how the Nation responds to all types of disasters and emergencies. It is built on scalable, flexible, and adaptable concepts identified in the NIMS to align key roles and responsibilities across the Nation.

The NRF is composed of a base document, Emergency Support Function (ESF) Annexes, Support Annexes, and Incident Annexes. The ESF Annexes describe the Federal coordinating structures that group resources and capabilities into functional areas that are most frequently needed in a national response. Support Annexes describe the essential supporting processes and considerations that are most common to the majority of incidents. Incident Annexes describe the unique response aspects of incident categories.

EPA participates in the NRF in multiple ways. EPA is the coordinator for ESF #10 – Oil and Hazardous Materials Response and is a support agency for several Emergency Support Functions, including:[74]

- ESF #3 – Public Works and Engineering
- ESF #4 – Firefighting
- ESF #5 – Emergency Management
- ESF #8 – Public Health and Medical Services
- ESF #11 – Agriculture and Natural Resources
- ESF #12 – Energy

[73] DHS, *NIPP 2013,* 2013.
[74] FEMA, *National Response Framework*, 2013.

- ESF #13 – Public Safety and Security
- ESF #14 – Long-Term Community Recovery
- ESF #15 – External Affairs

National Disaster Recovery Framework (NDRF)

The NDRF is a guide that enables effective recovery support to disaster-impacted States, Tribes, Territorial and local jurisdictions. The NDRF provides a flexible structure that enables disaster recovery managers to operate in a unified and collaborative manner. It also focuses on how best to restore, redevelop and revitalize the health, social, economic, natural and environmental fabric of the community and build a more resilient Nation.[75]

In September 2012, two-thirds of the United States was affected by drought. The President convened the White House Rural Council to address efforts to mitigate the impact of the drought by utilizing all resources. The NDRF was used to coordinate the response. In June 2013, the President released his Climate Action Plan. Later in that year the National Drought Resilience Partnership (NDRP) was formed as part of that effort.[76]

National Earthquake Hazards Reduction Program (NEHRP)

The National Institute of Standards and Technology (NIST) is designated by Congress as the Lead Agency for the NEHRP. The NEHRP Office oversees several programs and projects, including those seeking to understand the dynamic of earthquakes and their impact on critical infrastructure and to develop and deploy improved prescriptive seismic provisions in U.S. model building codes and standards. EPA works with NIST to help citizens prepare for an earthquake, with an emphasis on water safety and security.[77]

II. FEDERAL AGENCIES

In addition to State and local agencies, Federal agencies share in the mission to protect public health and the environment. This section outlines the primary Federal agencies that maintain relationships and interactions with the Water Sector. EPA has the predominant role, with responsibility for the enactment of the Clean Water Act and Safe Drinking Water Act. In addition, it serves as the SSA for the sector. EPA regularly communicates and coordinates with the U.S. Department of Homeland Security (DHS) on Water Sector security, and works with DHS to implement presidential directives, executive orders, and statutes. The Water Sector, EPA, DHS, and other Federal agencies share in the mission to protect public health and the environment through secure and resilient drinking water and wastewater infrastructure.

The Water Sector Government Coordinating Council (GCC)—composed of Federal and State government representatives and national associations—is chaired by EPA, with DHS serving as co-chair. In addition to EPA and DHS, the Federal agencies listed under Other Federal Partners, serve on

[75] FEMA, "National Disaster Recovery Framework," 2015.
[76] NIDIS, "National Drought Resilience Partnership."
[77] National Earthquake Hazards Reduction Program, "Background & History," 2016.

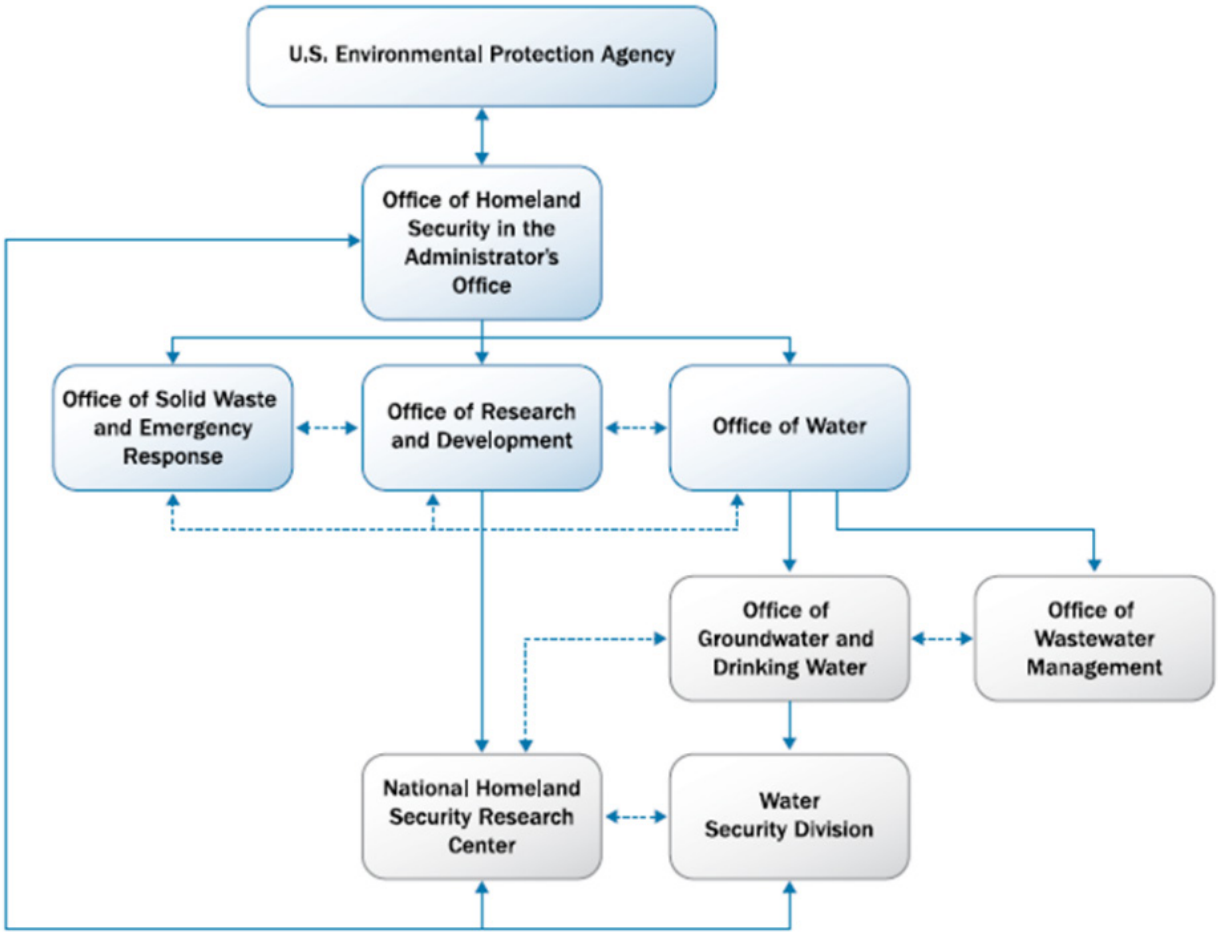
the GCC. These Federal agencies maintain relationships and interactions with the Water Sector in pursuit of Water Sector resilience, and are discussed in the following paragraphs.

The following sections discuss the roles of EPA and DHS—the GCC chair and co-chair along with the other agency representatives in the GCC.

U.S. ENVIRONMENTAL PROTECTION AGENCY

EPA is charged with executing SSA responsibilities for the Water Sector. Significant EPA components involved in Water Sector resilience include: EPA Headquarters, the Office of Water (OW), and the Office of Solid Waste and Emergency Response (OSWER). Exhibit F-1 shows the organizational structure for EPA, and where the Office of Water is located.

Exhibit F-1. EPA Organizational Chart for Water[78]



EPA Headquarters

Within EPA Headquarters, there are key offices which have programs related to Water Sector security and resilience. These include:

[78] EPA, *2010 SSP*, 2010.

Office of Homeland Security (OHS), which provides Agency-wide leadership and coordination for homeland security policy, including EPA's planning, prevention, preparedness, and response for homeland security-related incidents.[79] Programs administered by OHS are:

- Homeland Security Collaborative Network
- Homeland Security strategic planning
- Pandemic flu preparedness and response
- Nuclear Incident Response Team Interagency Agreement

Office of Policy (OP), which has special expertise in five areas: regulatory policy and management, environmental economics, strategic environmental management, sustainable communities, and climate adaptation.[80] OP programs most relevant to resilience comprise climate-resilience programs. Examples include:

- Mainstream climate adaptation planning into EPA's programs, policies, rules and operations to ensure they are effective under future climatic conditions.
- Support climate-resilient investments by States, tribes, and local communities by integrating climate adaptation criteria into financial mechanisms (grants, cooperative agreements, contracts, and technical assistance agreements).
- Chair the Federal Agency Adaptation Work Group established by the White House Council on Climate Preparedness and Resilience to support the development and implementation of all agencies' climate change adaptation plans.

EPA Office of Water

The Office of Water (OW) ensures drinking water is safe, and restores and maintains oceans, watersheds, and their aquatic ecosystems to protect human health, support economic and recreational activities, and provide healthy habitat for fish, plants and wildlife. OW is responsible for implementing the CWA and SDWA, and several other statutes.

Several offices within OW have important programs related to Sector security and resilience. These include:

- **Immediate Office of the Assistant Administrator for Water (IO)**, which produced a study on The Importance of Water to the U.S. Economy[81] and which addresses Climate Change in the Water Sector. EPA's climate change program is extensive and links to various aspects of the program may be found on the IO Climate Change Website.[82]
- **Office of Ground Water and Drinking Water (OGWDW)**, which has programs and projects dealing with Drinking Water Contaminants, Drinking Water Basics, Drinking Water Standards, Local Drinking Water, Public Drinking Water Systems, Small Public Drinking

[79] EPA, "About the Office of Homeland Security (OHS)," 2016.
[80] EPA, "About the Office of Policy (OP)," 2016.
[81] EPA, *The Importance of Water to the U.S. Economy*, 2013.
[82] EPA, "Addressing Climate Change in the Water Sector," 2016.

Water Systems, Source Water Protection, Sustainable Water Infrastructure, Underground Injection Control, Water Security, and Private Drinking Water Wells.[83] Within this office, the Water Security Division works to prevent, respond to, and recover from hazards, including maintaining a resilient infrastructure.

- **Office of Science and Technology (OST)**, which is responsible for developing sound, scientifically defensible standards, criteria, advisories, guidelines and limitations under the CWA and SDWA OST produces regulations, guidelines, methods, standards, science-based criteria, and studies that are critical components of national programs that protect people and the aquatic environment.
- **Office of Wastewater Management (OWM)**, which supports the FCWA, by promoting effective and responsible water use, treatment, disposal and management and by encouraging the protection and restoration of watersheds. Important programs managed by OWM include Biosolids, Combined Sewer Overflows and Sanitary Sewer Overflows, Green Infrastructure, Municipal Technologies, National Pollutant Discharge Elimination System (NPDES) program, Septic (Decentralized) Systems, Wastewater in Small Communities, Stormwater, Sustainable Water Infrastructure, and the WaterSense Program.[84]
- **Water Infrastructure and Resiliency Finance Center** identifies financing approaches to help communities make better informed decisions for drinking water, wastewater, and stormwater infrastructure that are consistent with local needs. The center seeks to accelerate and improve the quality of water infrastructure by promoting:
    - Effective use of Federal funding programs
    - Leading edge financing solutions
    - Innovative procurement and partnership strategies
    - Collaborative financial guidance and technical assistance efforts
    - Data and learning clearinghouses that support effective decision-making[85]

EPA Office of Solid Waste and Emergency Response (OSWER)

The OSWER provides policy, guidance, and direction for EPA's emergency response and waste programs. The Office develops guidelines for the land disposal of hazardous waste and underground storage tanks, as well as provides technical assistance to all levels of government to establish safe practices in waste management.[86] Emergency management and response is managed by OSWER. This important program is responsible for responding to oil spills, chemical, biological, radiological releases, and large-scale national emergencies under the National Response System. EPA also provides additional response assistance when State and local first-responder capabilities have been exhausted or when additional support is requested.[87]

[83] EPA, "About the Office of Water," 2016.
[84] EPA, "About the Office of Wastewater Management," 2016.
[85] EPA, "About the Water Infrastructure and Resiliency Finance Center," 2016.
[86] EPA, "About the Office of Land and Emergency Management (OLEM)," 2016.
[87] EPA, "Emergency Response," 2016.

EPA Regional Offices

EPA has 10 regional offices responsible for executing the agency's programs in States and territories.[88] Under the SDWA, States can request authority to oversee their drinking water programs, also known as primacy. There are 49 States, the Commonwealth of Puerto Rico, and the Navajo Nation have primacy. EPA regional offices administer drinking water programs for other entities that do not have primacy including other sovereign tribal nations, Wyoming, the District of Columbia, the Virgin Islands, Guam, American Samoa, and the Commonwealth of the Mariana Islands.[89]

U.S. DEPARTMENT OF HOMELAND SECURITY

EPA communicates and coordinates with DHS to implement presidential directives, executive orders, and statutes related to Water Sector security and resilience. The DHS Office of Infrastructure Protection is the primary point for EPA communication and coordination on critical infrastructure security and resilience activities.

EPA has a designated liaison to DHS, who helps to coordinate and share information between EPA, DHS, and other Federal sector partners on issues pertaining to drinking water and wastewater systems. The liaison helps to provide insight on vulnerability and consequence issues that directly impact Water Sector utilities. This coordination improves DHS' ability to interpret water-related threat information and to develop and distribute timely and accurate threat-warning products that are relevant to the Water Sector. The DHS Protective Security Advisors conduct assessments of nationally significant critical infrastructure, including those in the Water Sector, through security surveys, site assistance visits, and incident response. In addition, EPA and FEMA have close collaboration in a number of key areas, including activities within the NRF and the incorporation of sustainability and smart growth practices into communities' hazard mitigation and long-term disaster recovery efforts.[90]

OTHER FEDERAL PARTNERS

The following are the six Federal agencies that serve on the Water Sector GCC in addition to the EPA (chair) and DHS (co-chair).

Federal Bureau of Investigation (FBI)

The FBI interacts with the Water Sector through threat information sharing. The FBI works closely with EPA, DHS, and the WaterISAC to share intelligence and threat warnings related to physical and cyberattacks and to contamination incidents. Drinking water and wastewater utilities, as well as State agencies overseeing Water Sector activity, have been encouraged by EPA to coordinate security activities with local FBI offices nationwide.

U.S. Army Corps of Engineers (USACE)

The U.S. Department of Defense (DOD) primarily interacts with EPA through USACE. USACE is responsible for maintaining the Nation's commercial waterways and operates the dams and locks; a

[88] EPA, "About EPA," 2016.
[89] EPA, *2015 SSP*, 2016.
[90] DHS and EPA, *Memorandum of Agreement*, 2010.

large number of drinking water systems use dammed reservoirs as their primary water sources. Dam safety and protection is, therefore, a critical issue for the Water Sector. Employees of the USACE Engineering Research and Development Center sit on EPA National Homeland Security Research Center's Distribution System Research Consortium. Military facilities with their own drinking water and wastewater systems are regulated under the SDWA and CWA and, where applicable, must complete and submit vulnerability assessments to EPA.

U.S. Department of Agriculture (USDA)

The USDA provides funding and support for small, rural drinking water and wastewater utilities. With issuance of Homeland Security Presidential Directive 9 (HSPD-9): Defense of the United States Agriculture and Food, USDA expanded its role with EPA to build on and increase current monitoring and surveillance programs that provide early detection and awareness of disease, pest, and poisonous agents.

U.S. Department of Health and Human Services (HHS)

Water and wastewater utilities coordinate with public health agencies during emergency response and other water quality-related events, in addition to providing water services necessary for the operations of medical and other healthcare facilities. EPA has issued guidance for water utility emergency response plans, identifying healthcare facilities and hospitals as particularly critical users. Common practice entails water utilities and healthcare facilities working together to develop effective plans to sustain hospital functions when water supplies are disrupted.[91]

U.S. Department of the Interior (DOI)

EPA coordinates with DOI on dam security and water quality. The National Park Service (NPS) maintains drinking water and wastewater utilities, under their purview, that are regulated by the SDWA and CWA. The Bureau of Land Management (BLM) plays a role in managing the Western water supply—some drinking water sources reside on BLM-managed public lands.

U.S. Department of State

Several major rivers, which are used as drinking water sources in the United States, cross Canada and Mexico borders. In addition, some Water Sector utilities obtain their treatment chemicals from Canada. The U.S. Department of State collaboratively works with other countries to ensure the protection of Water Sector infrastructure and water sources with an international nexus.

III. FEDERAL ACTIVITIES

Federally supported resilience activities in the Water Sector support the Sector's vision, mission, goals and objectives for resilience, as well the priority activities described in the *2015 Water and Wastewater Systems Sector-Specific Plan* (2015 SSP).[92] EPA is the Sector-Specific Agency (SSA) for the sector and as such, most Federal resilience activities in the Water Sector take place under EPA.

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[91] CDC and AWWA, *Emergency Water Supply Planning Guide for Hospitals and Health Care Facilities*, 2012; and Welter, et al, "Cross-Sector Emergency Planning for Water Providers and Healthcare Facilities," 2010.
[92] EPA, *2015 SSP,* 2016.

EPA ACTIVITIES

The following describe major EPA activities related to resilience planning and assistance.

EPA Strategic and Programming Planning

EPA has several strategic and planning documents to advance its priorities and mission to protect human health and the environment. The fiscal year 2014-2018 Strategic Plan references resilience in support of the President's Climate Action Plan (June 2013); specifically, to build resilience for extreme weather events.[93] One of the five agency FY 2016-2017 Agency Priority Goals is to "advance resilience in the nation's water infrastructure, while protecting public health and the environment, particularly in high-risk and vulnerable communities." To achieve this, EPA will provide technical assistance and tools to 25 urban communities to advance green infrastructure to improve local climate resilience. EPA will also provide resilience tools and training (on regional-based threats) to 1,000 small water utilities.[94] In addition, the Water Security Initiative (WSi) is an EPA program that addresses the risk of contamination of drinking water distribution systems. Its implementation includes the development of practical guidance and outreach to promote voluntary national adoption of effective and sustainable drinking water contamination warning systems.[95]

National Water Program (NWP) 2012 Strategy: Response to Climate Change (December 2012)

The first EPA NWP Strategy was published in 2008 and identified more than 40 key actions that could be taken in the near-term to understand and address the potential impacts of climate change on water resources. The 2012 NWP Strategy describes long-term goals for the management of sustainable water resources and identifies strategic actions that would need to be taken to achieve those goals. As such, the 2012 Strategy is a roadmap to guide future programmatic planning within EPA.

Coordination with Emergency Management Agencies

EPA developed two documents to help further the coordination and integration of the Water Sector and emergency management community.

- *Coordination of the Water and Emergency Services Sector* discusses the value of water to the emergency management community, and provides recommendations on how utilities can work together with their local emergency management agency.[96]
- *Bridging the Gap* focuses on the relationships between State drinking water primacy agencies and State emergency management agencies.[97]

[93] EPA, *FY 2014-2018 EPA Strategic Plan*, 2014.
[94] EPA, Office of the Chief Financial Officer, *FY 2017 EPA Budget in Brief*, 2016.
[95] EPA, "Drinking Water and Wastewater Resilience," 2016.
[96] EPA, *Coordination of the Water and Emergency Services Sectors*, 2012.
[97] EPA and ASDWA, *Bridging the Gap*, 2013.

Water Infrastructure and Resiliency Finance Center Activities

The Center provides objective financial advice to help communities make informed decisions on financing drinking water, wastewater, and stormwater infrastructure projects. Current activities include:[98]

- **Regional Finance Forums**: These forums bring together communities with water infrastructure financing needs in an interactive peer-to-peer networking format. Attendees hear how local utilities have financed resilient water infrastructure projects and have the opportunity to meet key regional funding and technical assistance contacts.
- **WaterCARE Program**: The Community Assistance for Resiliency and Excellence (WaterCARE) program supports communities in developing resilient and sustainable finance planning strategies for drinking water and wastewater infrastructure to meet long-term local needs. Project successes are shared to support decision-making for other communities that have similar water infrastructure financing needs.
- **Innovative State Revolving Fund Financing**: The Center is launching a State Revolving Fund (SRF) Peer-to-Peer Learning Program with the Council of Infrastructure Financing Authorities (CIFA) and engaging in other SRF outreach on state-of-the-art practices.
- **Partnerships**: The Center is initiating a Water Infrastructure Public-Private Partnership Study and Local Government Training with the University of North Carolina Environmental Finance Center and West Coast Exchange. The Center is working with its partners to promote new tools such as EPA Region 3's "Community-Based Public-Private Partnerships Guide for Local Governments" to explore alternative market-based tools for integrated green stormwater infrastructure.
- **Stormwater Financing Clearinghouse**: The Center is focusing on stormwater financing by developing a clearinghouse of information to support communities to develop dedicated sources of revenue for stormwater programs.

EPA Water Security Division Activities

Most of the current and projected programs of EPA Water Security Division (WSD) for fiscal year 2016 focus on actions designed to support the implementation of one or more of the Water Sector's priority activities (as outlined in the 2015 SSP). These activities include:

- Supporting coordination with other sectors to improve relationships, develop mitigation and response plans, and improve response and recovery following an incident.
- Holding workshops and training focused on community-based water resilience, including how to use tools available to assess current levels of preparedness.
- Coordinating and facilitating exercises with WARN and at the State level to highlight the importance of cross-agency coordination and the criticality of water during a major incident.
- Working at the regional level with clusters of utilities facing a common hazard to implement mitigation measures.

[98] EPA, "About the Water Infrastructure and Resiliency Finance Center," 2016.

- Developing educational materials, training, and guidance for State primacy agencies, utilities, and decision-makers on cybersecurity and mitigation measures.

DHS COLLABORATION: SECTOR RESILIENCE ACTIVITIES

The following are key examples of major collaborative activities supported by DHS.

CIPAC Projects and Activities to Support a Secure and Resilient Water Sector (March 1, 2010)

The Critical Infrastructure Partnership Advisory Council (CIPAC) Emergency Preparedness, Response, and Recovery Workgroup produced a document of projects and activities to support Water Sector Strategic Planning Working Group priorities. The Workgroup identified some 35 projects and activities, including the following top ten:

- Improve Emergency Response Plan (ERP) Guidance
- Outreach Targeted to Utility Managers
- Fact Sheet(s) on ERP Requirements, Hazards & Consequences
- Checklist for Coordination with Local Emergency Management
- Develop an Enhanced Crisis Communication Workbook
- Produce Business Case for Preparedness
- Create an Emergency Operations Center (EOC) Water Desk Manual
- Improve Opportunities for Mutual Aid Across State Lines
- Fact Sheet on Utilities being First Responders
- All-Hazard Example Decision Trees for Specific Incidents

Contamination Warning System CIPAC Workgroup: Final Report (March 2012)

The CIPAC Contamination Warning System Workgroup produced a report of 10 findings, in addition to specific objectives and priorities, within two charge areas: 1) the structure of a national program to promote adoption of CWS practices, and 2) the gaps identified in the current development and understanding of CWS components. This document is a primary source of recommendations dealing with national contamination warning issues.

CIPAC Roadmap to a Secure & Resilient Water Sector (May 2013)

Developed by the CIPAC Water Sector Strategic Priorities Working Group, the Roadmap establishes a strategic framework that articulates the priorities of industry and government in the Water Sector to manage and reduce risk. It also produces an actionable path forward for the Water Sector Government Coordinating Council (Water Sector GCC), Water Sector Coordinating Council (Water SCC), and government and private sector security partners in the Sector to improve the Sector's security and resilience within the next five years. The 2015 SSP identifies this document as a blueprint to be used for enacting the priorities and goals with the Water Sector.

The Roadmap establishes three top priority activities for the Water Sector: 1) Advance the development of sector-specific cybersecurity resources; 2) Raise awareness of the Water Sector as a lifeline sector and recognize the priority status of its needs and capabilities; and 3) Support the development and deployment of tools, training, and other assistance to enhance preparedness and resilience. The Roadmap further describes the opportunities, challenges to implementation, efforts needed to achieve these goals, and roles and responsibilities within the Sector to successfully implement each of the priority activities.

CIPAC Water Sector Cybersecurity Strategy Workgroup: Final Report & Recommendations (April 2015)

The CIPAC Water Sector Cybersecurity Strategy Workgroup generated recommendations related to the *NIST Framework for Improving Critical Infrastructure Cybersecurity* (Cybersecurity Framework).[99] The report identifies gaps in available guidance, tools, and resources for addressing the Cybersecurity Framework in the Sector; and identifies measures of success that can be used by Federal agencies to indicate the extent of use of the Cybersecurity Framework in the Water Sector. It provides specific recommendations to achieve each of the four objectives above. Although EPA is responsible for regulating the security of critical infrastructure in the Water Sector, EPA believes that the voluntary partnership model is the best approach for implementing the Cybersecurity Framework in the Sector and therefore participated in and supported the CIPAC workgroup cybersecurity report.

Water and Wastewater Systems Sector-Specific Plan (2015 SSP)

The 2015 SSP addresses risk-based critical infrastructure protection strategies for drinking water and wastewater utilities, regulatory primacy agencies, and technical assistance partners. This includes processes and activities to enable the protection, and increased resilience, of the Sector's infrastructure. The 2015 SSP serves as a blueprint to be used for enacting the priorities and goals outlined within the *Roadmap to a Secure and Resilient Water Sector* and NIPP 2013, and provides an overarching framework for integrating sector critical infrastructure and key resource protection efforts into a unified program.

IV. FEDERAL FUNDING

There are two primary sources of Federal funds. EPA provides funding to address water-quality goals, and DHS through FEMA provides grants for disaster mitigation. For the latter, water services are only one of the many areas that qualify for support.

ENVIRONMENTAL PROTECTION AGENCY FUNDING

Clean Water State Revolving Fund

The Clean Water State Revolving Fund (CWSRF) is a partnership between EPA and the States to help States finance water infrastructure projects. Under the program, Congress appropriates funding to EPA that then provides grants to the States, which must contribute an additional 20 percent to

[99] NIST, *Framework for Improving Critical Infrastructure Cybersecurity*, 2014.

match the Federal grants. From this pool of money, the States finance low interest loans for eligible water infrastructure projects. As loans are repaid, the money goes into the State programs to finance new projects.[100] Using a combination of Federal and State funds, State CWSRF programs provide loans to eligible recipients to:

- Construct municipal wastewater facilities
- Control nonpoint sources of pollution
- Build decentralized wastewater treatment systems
- Create green infrastructure projects
- Protect estuaries
- Fund other water quality projects

Drinking Water State Revolving Fund

Similar to the CWSRF, the Drinking Water State Revolving Fund (DWSRF) is a partnership between the Federal Government and State governments to help finance water infrastructure projects focused on providing safe drinking water. Under the program, Congress appropriates money for the fund, EPA awards grants to each State. The grant amount is based on the results of the Drinking Water Infrastructure Needs Survey and Assessment. States must provide a 20 percent match of any funding received, and as loans are repaid they flow back into the pool of money used to fund additional loans and projects.[101] Eligible projects include:

- Improving drinking water treatment
- Fixing leaky or old pipes (water distribution)
- Improving source of water supply
- Replacing or constructing finished water storage tanks
- Other infrastructure projects needed to protect public health

Water Infrastructure Finance and Innovation Act (WIFIA)[102]

WIFIA (authorized in 2014) establishes a new financing mechanism for water and wastewater infrastructure projects under EPA. It was modeled after the Transportation Infrastructure Finance and Innovation Act (authorized in 1998, amended in 2005) and is designed to fill market gaps and leverage private co-investment.

Although separate from the SRF programs, the WIFIA program works in coordination to provide low-interest loans for up to 49 percent of the costs of projects that are nationally or regionally significant. It is intended to increase flexibility for non-Federal interests and leverage private sector investments to increase the effect of Federal funding. The new SRF provisions provide loan flexibility, lower interest rates and extended repayment periods of 30 years. Examples of

[100] EPA, "Learn about the Clean Water State Revolving Fund (CWSRF)," 2016.
[101] EPA, "How the Drinking Water State Revolving Fund Works," 2015.
[102] EPA, "Learn About the Water Infrastructure Finance and Innovation Act Program," 2015.

eligible projects include projects to enhance energy efficiency at drinking water and wastewater facilities, and desalination, aquifer recharge, and water recycling projects. Qualifications include:

- Funded projects must be nationally or regionally significant
- Individual projects must be reasonably anticipated to cost no less than $20 million

A. U.S. DEPARTMENT OF HOMELAND SECURITY FUNDING[103]

Hazard Mitigation Grant Program (HMGP)[104]

The HMGP assists States, Tribes, and local communities in implementing long-term hazard mitigation measures following a major disaster declaration. The program's objectives are to significantly reduce or permanently eliminate future risk to lives and property from natural hazards; provide funds to implement projects in accordance with priorities identified in State, Tribal, or local hazard mitigation plans; and enable mitigation measures to be implemented during the recovery from a disaster.

The HMGP can be used to fund projects to protect either public or private property, as long as the project fits within State and local government mitigation strategies to address areas of risk and complies with HMGP guidelines. Examples of projects include: acquiring and relocating structures from hazard-prone areas; retrofitting structures to protect them from floods, high winds, earthquakes, or other natural hazards, and constructing certain types of minor and localized flood control projects. HMGP funding is also available following a major disaster declaration if requested by the Governor.

Pre-Disaster Mitigation (PDM) Grant Program[105]

The PDM Grant Program is designed to assist States, territories, federally recognized tribes, and local communities in implementing a sustained pre-disaster natural hazard mitigation program. The goal is to reduce overall risk to the population and structures from future hazard events, while also reducing reliance on Federal funding in future disasters. This program awards planning and project grants and provides opportunities for raising public awareness about reducing future losses before disaster strikes.

[103] DHS, *Congressional Budget Justification (FY 2017)*
[104] FEMA, "Hazard Mitigation Assistance," 2016.
[105] FEMA, "Pre-Disaster Mitigation Grant Program," 2016.

APPENDIX G.
BASELINE RESILIENCE IN THE WATER SECTOR

Resilience is part of the Water Sector's culture, because the safe and reliable delivery of water and wastewater services, particularly under normal, nonstressed conditions, is ingrained in the sector's business model. However, throughout the sector there is wide variability in the degree to which Water Sector utilities have implemented specific resilience practices to respond to stressed conditions. Determining factors for resilience level include utility size, area of responsibility, and scale; complexity of the utility's operations; public versus private ownership; and the nature of perceived threats and risks.

This appendix includes an overview of the sector's components, risks, aspects of resilience, and resilience practices.

I. SECTOR OVERVIEW

The infrastructure of the Water Sector is complex, but its principal infrastructure can be grouped into drinking water and wastewater categories of varying sizes and ownership types.[106] This section provides an overview of drinking water and wastewater systems, the underlying value to the Nation's public health and economy, and the extensive role of collaboration in aligning public and private interests.

Most of the larger public drinking water systems and treatment works, which serve the major of Americans, are owned and operated by municipal entities. However, private water companies own nearly 16 percent of the Nation's Community Water Systems, and around 2,000 government entities contract with private companies to provide water and/or wastewater service in a public-private partnership.[107]

DRINKING WATER

Key infrastructure in the public drinking water systems of the Sector include:[108]

- **Raw Water Supply (e.g., surface water, groundwater)**: Surface water includes lakes, reservoirs, and rivers. Groundwater primarily includes water held in aquifers.
- **Raw Water Transmission (e.g., conduits, pipelines, catch basins)**: Conduits are covered tunnels and pipelines conveying raw water to treatment facilities. Pipelines include the entire system of pipes, interconnections, and valves that may be underground, above ground, or across rivers. Catch basins are used in combined sewer systems to catch excess wastewater and stormwater where it is held for later treatment and disposal.
- **Raw Water Storage (e.g., reservoirs, tanks)**: Reservoirs may be located in remote or urban areas, and vary widely in size. Storage tanks are also used to hold water prior to treatment.

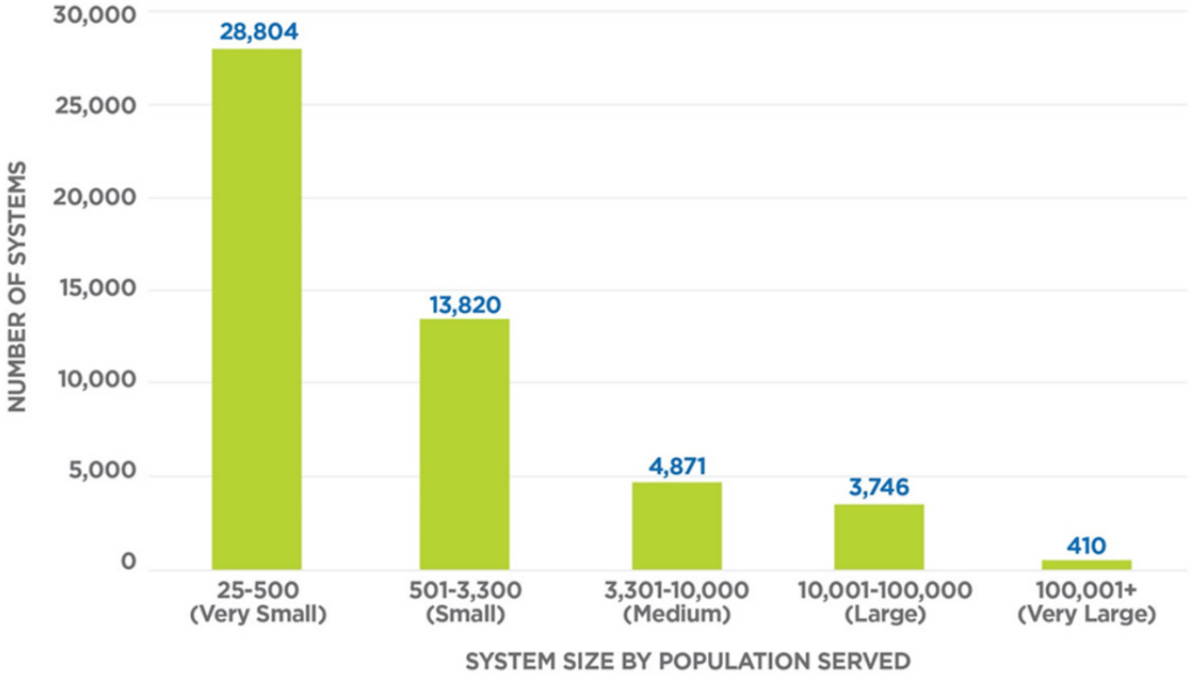
[106] EPA, *2015 SSP*, 2016.
[107] NAWC, "The Truth about Private Water Service Providers," 2010.
[108] EPA, *2015 SSP*, 2016.

- **Water Treatment Facility**: Includes a wide range of facilities that provide safe, potable water for domestic use; adequate water under sufficient pressure for fire protection and other emergencies; and industrial water for manufacturing. Steps to treat water include clarification, coagulation, sedimentation, filtration, and the use of chemicals in disinfection and fluoridation.
- **Treated/Finished Water Storage**: Includes water towers, standpipes, and covered and uncovered reservoirs that store treated water for a short period of time until it can be distributed to users.
- **Treated Water Distribution System**: Includes main water transmission pipes, water service lines to end users, water distribution pumping stations, fire hydrants, booster disinfection facilities to add additional disinfectant to treated water, backflow preventers to prevent contaminated water from entering the distribution network, and meters to track consumption of water.
- **Treated Water Monitoring System**: Includes facilities to monitor treated water quality for contaminants, and can include sensors to monitor water pressure and water quality.
- **Treated Water Distribution Control Center**: Includes central control facilities that monitor and operate the distribution system. Often, the facilities house supervisory control and data acquisition (SCADA) systems as part of an integrated control system. Some centers utilize electronic networks to connect monitoring systems and controls to a central display and operations room.

There are approximately 153,000 Public Water Systems (PWSs) in the United States.[109] These systems provide water for human consumption through pipes or other constructed conveyances to at least 15 service connections, or serve an average of at least 25 people, for at least 60 days annually. Community Water Systems (CWSs), which serve people year-round in their residences, is the largest group of service providers. Exhibit G-I shows the number of community water systems by size.

[109] EPA, *2015 SSP*, 2016.

Exhibit G-I. Number of Community Water Systems and System Size[110]



WASTEWATER

Key infrastructure in the public wastewater systems of the Sector include:[111]

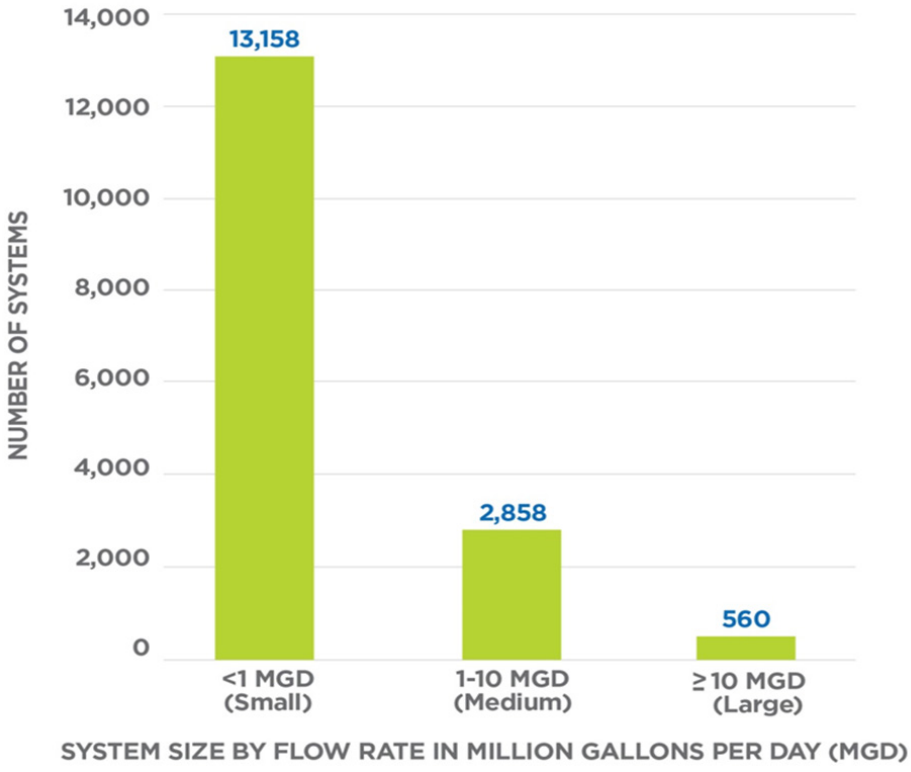
- **Wastewater Facility (e.g., wastewater collection systems, sewers, inverted siphons, manholes, combined sewer/overflow outfall locations, lift/pump stations, and catch basins)**: Wastewater collection systems are the network of pipes that conveys wastewater from the source to the treatment plant. In some older cities, the wastewater and stormwater collection systems are integrated (combined sewer systems). In these older systems, flooding can result in the combined effluent being discharged directly to the receiving body (e.g., river or bay), bypassing the treatment plant.
- **Wastewater Raw Influent Storage**: Includes facilities to store raw sewage prior to treatment, including tanks or impoundments.
- **Wastewater Treatment Plant**: Provide a combination of physical and biological processes that are designed to remove organic matter from solution and treat the water to a degree that it can be released to the environment. Processes include screening, grit removal, flotation, flocculation and sedimentation, aeration, clarification, disinfection, chemical coagulation, and filtration. The processes are applied to the plant influent to reduce pollutant levels to the concentrations specified in the National Pollutant Discharge Elimination System (NPDES) permit, in the case of a direct discharger, or other specified discharge limits, in the case of an indirect discharger.

[110] EPA, *2015 SSP*, 2016.
[111] Ibid.

- **Treated Wastewater Storage**: Includes facilities where treated wastewater is held prior to discharge.
- **Treated Wastewater Discharge System**: Includes facilities that discharge treated wastewater to a surface water body (directed discharger), or to a POTW collection system (indirect discharger).
- **Treated Wastewater Monitoring System**: Includes facilities that monitor a range of physical properties (e.g., flow rates and water-quality indicators) and detect levels of contaminants before, during, and after wastewater treatment.
- **Wastewater Control Center**: Includes central control facilities that monitor and operate the wastewater system. Some systems utilize electronic networks, often including wireless communication, to link the monitoring system and the controls for the treatment and distribution systems to a central display and operations room. SCADA systems are part of an integrated control system.

Wastewater is predominantly treated by Publicly Owned Treatment Works (POTWs); there are approximately 16,500 POTWs in the United States. There are also a small number of private facilities, such as industrial plants. The majority of wastewater utilities treat less than 1 million gallons per day and provide services to fewer than 23 million people in total. [112] Exhibit G-2 shows the number of publicly owned treatment facilities by size.

Exhibit G-2 Number of Publicly Owned Treatment Works and System Size[113]



[112] EPA, *2015 SSP,* 2016.
[113] Ibid.

THE VALUE OF WATER

Disruptions to drinking water and wastewater services have far-reaching public health, economic, environmental, and psychological impacts as shown in Exhibit G-3. These impacts demonstrate the need for improved understanding and support for Water Sector criticality and resilience efforts.

Exhibit G-3. Water Disruption Impacts

WHAT HAPPENS WHEN WATER SYSTEMS ARE DISRUPTED?

The Water Sector represents one of the critical lifeline sectors; safe and reliable water services are absolutely fundamental to our way of life. Disrupting these water systems would have far-reaching adverse public health, economic, environmental, and psychological impacts. Further, these impacts would not be confined to one location but would ripple across the Nation and threaten public confidence in the Nation's drinking water and wastewater service.

Without Water or Wastewater Services the following activities are not possible:

Individual Use

- Drink water.
- Brush your teeth or shower.
- Use toilet facilities.
- Prepare meals (e.g., boiling food, washing fruits and vegetables).
- Wash clothes and dishes.
- Maintain private pools and water tanks.
- Respond to medical emergencies (e.g., flushing skin/eyes with water to remove a toxin).
- Water lawns, plants, or gardens.

Public Supply Use

- Treat water and wastewater for any use.
- Maintain public pools, parks, gulf courses, nurseries, cemeteries, or provide water for any landscape-watering use.
- Operate critical public health and safety facilities, e.g., hospitals or firefighting capabilities.
- Keep public spaces (e.g., community centers, shopping malls), government offices, or businesses open.
- Irrigate for agricultural purposes. The animals (e.g., cows, chickens) depending on this food supply will also be affected.

Industry Supply Use

- Operate thermoelectric power facilities, including for power cooling.
- Maintain major commodity industries that use large amounts of water (food, paper, chemicals, refined petroleum, or primary metals).
- Incorporate water into any product, such as for processing, washing, diluting, cooling, or transporting a product.
- Extract minerals.
- Maintain livestock systems (watering, feeding, farm needs, sanitation, and waste-disposal).

(*Source: USGS, "Water Use in the United States," 2016.*)

Public Health Impacts

Without a safe, clean, and reliable water supply, public health will suffer. Impacts will vary depending on the cause of the disruption, such as contaminants in the water system or a lack of drinking water and wastewater services. The contaminant type or length of disruption are also key variables in the degree of health impact.

Case in Point

On January 9, 2014 in Charleston, West Virginia, about 10,000 gallons of a chemical called 4-methylcyclohexane methanol (MCHM) leaked from a storage tank into the Elk River. The chemical amount overwhelmed the filtration system in the West Virginia American Water (WVAW) treatment plant about a mile downstream.[114] Later that day, the WVAW issued a 'do not use' water order and the West Virginia Poison Center began receiving calls from people reporting rashes, nausea, vomiting, diarrhea, and other symptoms. Little is known about MCHM and its human health effects. Studies have only been conducted on animals and they show that when laboratory animals are exposed to high doses of MCHM, it causes problems with the liver, kidneys, blood, and the brain.

On January 21, 2014, it was discovered that another chemical (propylene glycol phenyl ether (PPH)), with health effects similar to MCHM, was part of the January 9 release. The most common way people were exposed to the contaminants was bathing, showering, washing hands, and other skin contact. A study of emergency department visits showed that 356 of 369 people were treated and released from the hospital between January 9 and January 23, 2014, with 3.5 percent or people hospitalized.[115] Long-term public health impacts are unknown. The incident is an example of the need to safely and reliably communicate public health risks.[116]

Economic Impacts

Businesses are unable to operate without a safe water supply or wastewater services. Facilities such as work places, restaurants, shopping malls, and public areas would be forced to shut down. This would result not only lost business revenue for the individual companies, but could generate larger adverse impacts to the local, State, or national economy.

Case in Point

Southern California water services are principally served by the California Aqueduct, which could be shut down due a major disaster (e.g., earthquake). In addition to the major disruption to water utility services, a 12-month shutdown of the aqueduct water supply would amount to economic losses of as much as 550,000 jobs and $55.6 billion in Gross Domestic Product (GDP) to the Los Angeles County Economy. A 24-month disruption could lead to a total two-year loss of 742,000 job-years of employment, $75 billion of GDP, and $135 billion of sales revenue for businesses in the county.[117]

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[114] Friend, "Water in American: Is It Safe to Drink?" 2014.
[115] WV DHHR, "Elk River Chemical Spill," 2014.
[116] Manuel, "Crisis and Emergency Risk Communication," 2014.
[117] Rose, et al., *Total Regional Economic Losses from Water Supply Disruptions to the Los Angeles County Economy*, 2012.

Environmental Impacts

Water disruptions have the potential to impact the broader environment through the pollution of water. For example, a sewage overflow or contaminant release can negatively impact plant and animal species, affecting the water quality, habitat, and species themselves.

Case in Point

Superstorm Sandy generated many critical infrastructure impacts. Due to the storm, power was lost, and approximately 80 sewage treatment systems in New Jersey were damaged. One system that was damaged was the Passaic Valley Sewerage Commission. During the five days the plant was out of commission, approximately 2.75 billion gallons of untreated waste flowed from the plant into the nearby bay.[118] From the hardest hit States, 11 billion gallons of untreated and partially-treated sewage flowed into the aquatic environment (rivers, bays, canals). Untreated sewage can negatively impact the aquatic ecosystem by depleting available oxygen, creating nutrient imbalance, and promoting sudden plant growth such as algae blooms, chasing away normal aquatic life.[119]

Psychological Impacts

A water incident does not have to generate major public health, economic, or environmental impacts to result in a major disruption. The loss of public confidence in the water services and the threat of spreading fear and panic in the community impacted and across the Nation would adversely impact the Water Sector. An unreliable, unclean, and unsafe water supply creates lasting fears (e.g., fears of an unknown contaminant's health effects). A prolonged incident could also affect the government's ability to maintain order, deliver public services, and ensure public health and safety.

Case in Point

In August 2014, Toledo was affected from a large algae bloom in Lake Erie, an event that has long-troubled the lake. Toxic levels of microcystin meant residents could not use the water supply since boiling the water only increased the concentration of toxin. Even after the "Do Not Drink" advisory was lifted, the confidence in the water supply did not bounce back. A year later (August 2015), another algae bloom threatened the area. Even though the microcystin levels were low and very manageable by the water treatment utility, residents began to stockpile bottle water and planned to not use tap water—a move that suggests damaged public confidence.[120] Toledo continues to build on efforts to regain public confidence; however, restoring public confidence (even with the appropriate decontamination) requires significant effort.

SECTOR COLLABORATION

Public water and wastewater systems are predominantly owned and operated by municipal entities, with the Federal Government role most prominent in the regulation of water quality. The sector has a long, productive history of collaboration through associations and geographic clusters of utilities. This collaboration has produced a wealth of information, mutual-support relationships, and tools. For example, the American Water Works Association (AWWA) developed standard J100-10 (R13)

[118] Manuel, "The Long Road to Recovery: Environmental Health Impacts of Hurricane Sandy," 2013.
[119] Kenward, et al., "Sewage Overflows from Hurricane Sandy," 2013.
[120] Henry, "Toxic algae struggles leave Toledo's reputation hanging in the balance," 2015.

Risk and Resilience Management of Water and Wastewater Systems, the first voluntary consensus standard encompassing an all-hazards risk and resilience management process for use specifically by water and wastewater utilities.

Water Sector Coordinating Councils

The Federal Government built on this tradition of collaboration by using the partnership model, specified in *Homeland Security Presidential Directive 7 (*HSPD-7*): Critical Infrastructure Identification, Prioritization, and Protection*, *Presidential Policy Directive 21 (*PPD-21*): Critical Infrastructure Security and Resilience*, and the *2013 National Infrastructure Protection Plan* (NIPP 2013) to bring public and private sector participants into the planning and implementation of sector protection. EPA organized the Water Government Coordinating Council (GCC) including Federal, State, and local entities; and the owners and operators of water utilities organized the Water Sector Coordinating Council (Water SCC).

WATER SECTOR COORDINATING COUNCIL MISSION

"The Water Sector Coordinating Council shall serve as a policy, strategy, and coordination mechanism and shall recommend actions to reduce and eliminate significant critical infrastructure security and resilience vulnerabilities to the Water and Wastewater Sector through the interactions with the Federal Government and other critical infrastructure sectors."

The GCC is co-chaired by EPA, the Water SSA, and DHS. The Water Sector GCC coordinates policy, strategy, and activities across government entities within the Water Sector, with membership drawn from Federal and State government representatives and leaders in water protection and resilience issues.[121] The Water SCC member associations serve as liaisons between the broader water services community and the government partners represented by the GCC. The current list of Water GCC and SCC member organizations is included in Exhibit G-4.

The Water Sector GCC and SCC often meet under the umbrella of the Critical Infrastructure Partnership Advisory Council (CIPAC), established by DHS to provide a forum in which the government and private sector entities, organized as coordinating councils, can jointly engage in activities to support and coordinate critical infrastructure security and resilience efforts. Under CIPAC, the Water Sector GCC and SCC have formed several working groups to address specific issues of security and resilience concern to the sector.[122] In 2015 these working groups included:[123]

- Cybersecurity Working Group
- Drinking Water Contamination Warning System Working Group
- Risk Assessment Methodology / Standard Examination Working Group
- Strategic Planning Working Group

[121] EPA, *2015 SSP,* 2016.
[122] EPA, "Water Sector Government Coordinating Council Charter," 2014; and Water SCC, "Charter of the Water Sector Coordinating Council," 2014.
[123] DHS, "Water and Wastewater Systems Sector Working Groups."

Exhibit G-4. Water Sector Coordinating Council and Government Coordinating Council Membership[124]

Water Sector Government Coordinating Council	Water Sector Coordinating Council
• Association of State Drinking Water Administrators • Association of State and Interstate Water Pollution Control Administrators • Association of State and Territorial Health Officials • Environmental Council of the States • National Association of County & City Health Officials • National Association of Regulatory Utility Commissioners • U.S. Department of Agriculture • U.S. Department of Defense • U.S. Department of Health and Human Services • U.S. Department of Homeland Security • U.S. Department of the Interior • U.S. Department of Justice • U.S. Department of State	• American Water • American Water Works Association • Artesian Water Company • Association of Metropolitan Water Agencies • Bean Blossom-Patricksburg Water Corporation • Boston Water and Sewer Commission • Breezy Hill Water and Sewer Company • California Water Service Co. • County of King (Washington) Department of Natural Resources and Parks • District of Columbia Water and Sewer Authority • National Association of Clean Water Agencies • National Association of Water Companies • National Rural Water and Sewer Authority • Northeast Ohio Regional Sewer District • Onondaga County Water Authority • Prince William County Service Authority • Spartanburg Water • Symantec Corporation • Trinity River Authority of Texas • United Water • Water Information Sharing and Analysis Center

II. RISKS TO THE WATER SECTOR

Secure and resilient water and wastewater infrastructure is essential to daily life and in ensuring the economic vitality of the Nation and public confidence in the Nation's drinking water and wastewater services. This level of criticality demands the need for effective risk management to successfully navigate a broad range of potential disruptions. In fact, emergency response planning is inherent to the sector; enabling continuity of such critical operations and sustaining public health and environmental protection.[125] In addition, each of the following risks may share other contributing factors, such as:

- Capabilities in managing an area-wide loss of water services may be deficient.
- Although the Water Sector is recognized as a lifeline sector, its lifeline criticality is not commonly recognized among all relevant stakeholders. This generates a challenging situation, as the lack of recognition can escalate consequences during area-wide events.

[124] DHS, "Water and Wastewater Systems Sector: Council Charters and Membership," 2016.
[125] EPA, *2015 SSP*, 2016.

- The economic costs of preparation and response may mean that there are insufficient funds to prepare for and address risks ahead of time and to the level at which the risk requires.
- Inadequate information sharing and resources for the full resilience spectrum of prevention, protection, mitigation, response, and recovery.
- An aging workforce, resulting in lost institutional knowledge as employees retire.
- Reduced water consumption and conservation results in less revenue available to maintain level of service and undertake infrastructure projects.

Drinking water and wastewater systems rely on a chain of linked components, each of which must function well if service is to be provided to the customer. If any of these components or operations is disrupted for more than a short period of time, the entire system will shut down. This makes water utilities highly vulnerable by nature, and the complexity of their interlinked operations make redundancy of many major components almost impossible.

The Water Sector is proactive in identifying and prioritizing risks to its infrastructure. This enables the sector to implement risk-reduction activities through a partnership approach whereby the government and the sector share the responsibility for improving Water Sector resilience by identifying joint priorities and engaging in coordinated action. At the national level, DHS produces risk assessments of the primary risks to each critical infrastructure sector to inform sector owners and operators in developing and implementing their risk-management activities. At the sector and national level, common significant risks include natural disasters and cyberattacks.

In 2013, the Water Sector Strategic Priorities Working Group identified the sector's most critical risks, organized into categories of most significant, high, and medium. The 2015 SSP reaffirmed the continued validity of these risks, as shown in full risk profile listed in Exhibit G-5. Only a few of the risks were covered in the body of the report. The risks are not limited to physical or cyber events, but rather encompass a much broader spectrum of risk that impacts the sector's overall security and resilience and its ability to provide needed water services to the Nation.

Exhibit G-5. Water Sector Risks[126]

MOST SIGNIFICANT RISKS

- Natural disasters (such as impacts on water quality and quantity from floods, hurricanes, earthquakes, ice storms, pandemic flu, and other geographic catastrophes)
- Economic implications of aging infrastructure
- Cyber events
- Capability in managing an area-wide loss of water
- Although the Water Sector has been defined as a lifeline sector, this is not commonly recognized among all relevant stakeholders, a situation that can escalate consequences during area-wide events.

HIGH RISKS

- Economic costs of preparation and response: The Water Sector can create a large economic risk in a disaster, but there are insufficient funds to prepare for and address risks ahead of time.
- Ignorance about the consequences of inaction and apathy from some stakeholders in utilities, the customer base, State and local government, Federal Government and Congress
- Inadequate coordination and information sharing during preparation, response, and recovery
- Intentionally malicious acts
- Limited resource availability: Many utilities are faced with competing needs (e.g., regulatory, aging infrastructure, environmental, and public health protection, and workforce succession requirements) that are immediate, concrete, and can limit resource availability for implementing preparedness and resilience improvements
- Unenforced and outdated requirements that do not address evolving threats

MEDIUM RISKS

- Lack of mutual aid agreements, effective education and outreach to emergency management, and lack of best practices for emergency response planning
- Technology interoperability issues that create information-sharing challenges during response
- Insufficient communication to water utility boards of the definition, management, and prioritization of critical assets and needs

DHS assesses the overall risk to the Water Sector as "vulnerable to a variety of all-hazard threats including contamination with deadly agents, insider threats, physical attacks using improvised explosive devices (IEDs), cyberattacks, and natural hazards. Successful attacks on a drinking water or wastewater system could result in large numbers of illness, casualties, and denial of service, which

[126] EPA, *2015 SSP,* 2016, Figure 4, p. 10.

could severely impact the Nation's public health and economic vitality."[127] DHS further identifies the most serious risks to the Sector:

- **Chemical, Biological, or Radiological (CBR) Contamination**. Most public water supplies are monitored and treated to prevent the distribution of contaminated drinking water. The risk of CBR contamination stems from both the terrorist threat to contaminate the U.S. water supply and the serious health impacts that could result from an undetected contaminant. These impacts could vary depending on the type of substance, route of exposure (ingestion, absorption, inhalation), and amount of time before the contaminant is detected.
- **Natural Hazards**. Natural hazards (e.g., hurricanes, tornadoes, floods, earthquakes, and drought) pose a serious and continuing risk for the Sector. Water infrastructure may be severely disrupted or destroyed by such hazards, which may further complicate an overall disaster emergency response due to multiple cross-sector interdependencies. Critical water shortages may also result from drought conditions and climate change, leading to water use restrictions and rationing.
- **Physical and Cyberattacks by Terrorists, Homegrown Extremists, or Disgruntled Insiders**. Physical attacks using improvised explosive devices (IEDs) on chemical storage tanks or other critical nodes in a drinking water or wastewater system could result in a release of hazardous materials or in a long-term loss of service should a single-point-of-failure be destroyed. Cyberattacks and intrusions on SCADA systems or other business systems pose a serious threat to the Water Sector, allowing malicious actors to manipulate or exploit control systems essential to operation of drinking water and wastewater utilities.

III. ASPECTS OF RESILIENCE

Improving resilience in the sector is perhaps best framed by two aspects: the activity and capability of the individual utilities and the development and sharing of information, tools, and practices through sector collaboration. The following discusses salient elements of each.

RESILIENCE AT THE UTILITY LEVEL

Resilience is part of the Sector's culture, because the dependable delivery of safe water and wastewater disposal services are inherent in the Sector's business model, whatever the size of the utility or jurisdiction managing its resources. The resilience of Sector assets and operations can never be taken for granted or allowed to lapse.

There is wide variability in the degree of resilience at the individual utility level, depending on such factors as the size of the utility or managing jurisdiction, its public or private ownership, and the scale and complexity of the individual system's operations. For example, the relatively few very large systems in the sector—serving the majority of the population—have strong resilience measures in place and are heavily monitored and regulated for safety and quality standards set by EPA and enforced by the States. However, smaller systems generally do not have access to the same level of

[127] DHS OCIA, *Sector Risk Snapshots*, 2014.

resources as large systems and are not monitored as closely for the enforcement of safety and quality standards.

Some of the most important resilience measures—based on policy, plans, strategies, recommendations, and models—are implemented on a regional or local level through regional water districts and local utilities. While these measures have proven to strengthen resilience at the local or regional level, the practices are not cohesive across the country. Greater emphasis on increasing sector-wide availability of resilience practices could further increase resilience both at the utility level and the sector level.

COLLABORATION FOR RESILIENCE AT THE SECTOR LEVEL

Because of the sector's complexity and the many dependencies that exist in the processes and operations providing the public with drinking water and wastewater treatment, the Water Sector has robust risk-management procedures and tools in place to ensure the resilience of the sector's many assets and systems. Partly because of the resilience differentiation between larger and smaller utilities, EPA and associations representing the Water Sector have been very active in trying to develop models, tools, and best practices which are transferable to smaller systems. There are many examples of this resilience-building approach, as reflected in the Water Sector success stories recorded in the 2015 SSP.[128] Some examples of these resilience-building activities include:

- Developed *How to Develop a Multi-Year Training and Exercise Plan* to assist utilities in creating multiyear plans that can lead to increased emergency preparedness.
- The Water Information Sharing and Analysis Center (WaterISAC) published *10 Basic Cybersecurity Measures to Reduce Exploitable Weaknesses and Attacks*.
- Published the *Weather & Hydrologic Forecasting for Water Utility Incident Preparedness and Response* document to provide hazardous weather and forecasting resources for utility awareness and preparedness.
- Leveraged the CIPAC framework to develop sector priorities, build partnerships, and increase collaboration among public and private sector stakeholders, including the *2013 Roadmap to a Secure & Resilience Water Sector*, which represents the Water SCC/GCC priorities.
- The Water Research Foundation, AWWA, and EPA developed *Business Continuity Planning for Water Utilities: Guidance Document*.
- Developed the interactive guidance document *Flood Resilience: A Basic Guide for Water and Wastewater Utilities* to help water utilities understand their flooding threat and identify practical mitigation options to protect their critical assets.

The sector identifies and prioritizes programs, projects, and activities which together can strengthen sector resilience in the future. As demonstrated in this and the previous section, the sector has set specific goals and objectives, identified in detail the infrastructure in the sector, determined how risks can be assessed and analyzed, completed and planned a vast array of activities designed to

[128] EPA, *2015 SSP*, 2016.

address and mitigate Sector risks, identified how to measure success in managing risk in the sector, and developed robust information-sharing mechanisms within the sector partnership. All of these steps combine to establish a solid baseline of resilience in the sector, while at the same time pointing to needed improvements that can be addressed on a priority basis.

Examples of resilience have been provided in this section in terms of the identification and prioritization of sector risks, which have been formalized and compiled by the CIPAC Water Sector Strategic Priorities Working Group in the *2013 Roadmap to a Secure and Resilient Water Sector*. Steps taken or to be taken by the sector in terms of its cybersecurity resilience have also been discussed above, in terms of the CIPAC Water Sector Cybersecurity Strategy Workgroup in its 2015 *Final Report & Recommendations.*

IV. RESILIENCE PRACTICES

The following highlights primary practices implemented at the utility and sector levels, along with specific challenges in fully realizing resilience. The practices are organized into categories consistent with components of the NIPP 2013 risk-management framework and core tenets: set goals and objectives, understand dependencies and interdependencies, assess and analyze risk, share information, and implement risk-management activities.

SET GOALS AND OBJECTIVES

The Water Sector is proactive in identifying and prioritizing goals to managing risks across the sector. Current goals and priorities driving the sector are derived from the *2013 Roadmap to a Secure & Resilient Water Sector* (2013 Roadmap) and the 2015 SSP. Commonalities across the documents include an increased focus on outreach and awareness campaigns; preparedness, recovery, and resilience strategies; and cybersecurity concepts and capabilities.

The 2013 Roadmap priorities are:

- Advance the development of sector-specific cybersecurity resources.
- Raise awareness of the Water Sector as lifeline sector and recognize the priority status of its needs and capabilities.
- Support the development and deployment of tools, training, and other assistance to enhance preparedness and resilience.

They are used by EPA and its public-private partnerships in the sector to focus on activities in a two to five year timeframe that can together strengthen the sector's ability to plan for effective response and recovery, maintain resilience during a calamitous event, and garner support for both disaster and risk-mitigation cost recovery.[129] The 2015 SSP's four strategic goals and 13 objectives are outlined in Exhibit G-6. They are used by the sector to develop, implement, and measure

[129] CIPAC Water Sector Strategic Priorities Working Group, *Roadmap to a Secure and Resilient Water Sector*, 2013.

progress of protection and resilience activities designed to prevent, detect, respond to, and recover from all hazards.[130]

Exhibit G-6. Water Sector Goals and Objectives[131]

Goal 1: Sustain protection of public health and the environment. The Nation relies on sustained availability of safe drinking water and on treatment of wastewater to maintain public health and environmental protection. To protect public and environmental health better, the Water Sector works to ensure the continuity of both drinking water and wastewater services.	
Objective 1	Encourage integration of both physical and cybersecurity concepts into daily business operations at utilities to foster a security culture.
Objective 2	Evaluate and develop surveillance, monitoring, warning, and response capabilities to recognize and address all-hazards risks at water systems that affect public health and economic viability.
Objective 3	Develop a nationwide laboratory network for water quality protection that integrates Federal and State laboratory resources and uses standardized diagnostic protocols and procedures, or develop a supporting laboratory network capable of analyzing threats to water quality.

Goal 2. Recognize and reduce risk. With an improved understanding of the vulnerabilities, threats, and consequences, owners and operators of utilities can continue to thoroughly examine and implement risk-based approaches to protect, detect, respond to, and recover from all hazards better.	
Objective 1	Improve identification of vulnerabilities based on knowledge and best available information, with the intent of increasing the sector's overall protection posture.
Objective 2	Improve identification of potential threats through knowledge base and communications—with the intent of increasing overall protection posture of the sector.
Objective 3	Identify and refine public health and economic impact consequences of manmade or natural incidents to improve utility risk assessments and enhance the sector's overall protection posture.

[130] EPA, *2015 SSP*, 2016.
[131] EPA, *2015 SSP,* 2016, Table 2, pp. 17-18.

Goal 3. Maintain a resilient infrastructure. The Water Sector will investigate how to optimize continuity of operations to ensure the economic vitality of communities and the utilities that serve them. Response and recovery from an incident in the sector will be crucial to maintaining public health and confidence.	
Objective 1	Emphasize continuity of drinking water and wastewater services as it pertains to utility emergency preparedness, response, and recovery planning.
Objective 2	Explore and expand implementation of mutual aid agreements/compacts in the Water Sector by encouraging utilities to join their State WARN. The sector has significantly enhanced its resilience through agreements among utilities and States; increasing the number and scope of these will further enhance resilience.
Objective 3	Identify and implement key response and recovery strategies. Response and recovery from an incident in the sector will be crucial to maintaining public health and confidence.
Objective 4	Increase understanding of how the Sector is interdependent with other critical infrastructure sectors. Sectors such as Healthcare and Public Health and Emergency Services are largely dependent on the Water Sector for their continuity of operations, while the Water Sector is dependent on sectors such as Chemical or Energy for continuity of its operations.

Goal 4. Increase communication, outreach, and public confidence. Safe drinking water and water quality are fundamental to everyday life. An incident in the Water Sector could have significant impacts on public confidence. Fostering and enhancing the relationships between utilities, government, and the public can mitigate negative perceptions in the face of an incident.	
Objective 1	Communicate with the public about the level of protection and resilience in the sector and provide outreach to ensure the public's ability to be prepared for and respond to a natural disaster or manmade incident.
Objective 2	Enhance communication and coordination among utilities and Federal, State, and local officials and agencies to provide information about threats by utilizing WaterISAC and other information-sharing networks.
Objective 3	Improve relationships among all Water Sector partners through a strong public–private partnership characterized by trusted relationships.

UNDERSTAND DEPENDENCIES AND INTERDEPENDENCIES

The level of resilience in the Water Sector is of fundamental importance to the Nation, because the sector is a lifeline sector. The lives and well-being of Americans and the efficient functioning of the U.S. economy depend on a continued and dependable supply of water and wastewater services. This fundamental importance can easily be seen in terms of the critical interdependencies between the Water Sector and other sectors. A more specific listing of how these sectors depend on each other is provided in the 2015 SSP.

Dependencies and interdependencies that exist between the Water Sector and other critical sectors have been identified and extensively documented in after-action reports on the cascading effects of past major events. The *2013 WARN Superstorm Sandy After-Action Report* serves as one of the most influential after-action reports for the sector, because it identified key actions related to dependencies that could reduce consequences and increase resilience in the Water Sector in the future. These recommended actions were organized into several categories: Interstate Mutual Aid & Assistance, Elevating the Priority Status of Water Infrastructure, Energy and Water Nexus in Disasters, Site Access, Coordination, Situational Awareness, and Communications.[132]

Interdependencies of the Water Sector with the Energy and Healthcare and Public Health Sectors are of most prominence during recent major events. For example, in collaboration with the Healthcare and Public Health Sector, the Water Sector has helped develop plans, protocols, and processes to assist the dependent sector to prepare for emergencies. Nonetheless, and as illustrated by the lack of clear understanding of all the ramifications of the Energy-Water nexus, there remains a critical need to further develop the methodologies to collect and analyze relevant data to be better able to manage these types of complex interdependencies. An excellent example of the specificity required to achieve this level of coordinated response is the sector's efforts to reach out and assist healthcare facilities with their emergency planning in the event of an emergency impacting their water supply. The following sections describe these interdependencies in greater detail.

Energy-Water Nexus[133]

The Energy and Water Sectors are closely linked with each other. Energy requires water in large quantities for mining, fuel production, hydropower, and power plant cooling. Water needs energy for pumping, treatment, and distribution of water and for collection, treatment, and discharge of wastewater. Estimates of the Nation's electricity contributing to moving and treating water and wastewater by public and private entities range between 4 and 13 percent, depending on how it is calculated. In some parts of the country, such as California, those estimates run as high as 19 percent.

As similar situation exists with the Energy Sector's need for water. Agriculture dominates U.S. water consumption at 71 percent; however, the Energy Sector (including biofuels, thermoelectric, and fuel production) is the second-largest consumer at 14 percent, while domestic and public uses are third at 7 percent. More than 80 percent of U.S. electricity is generated at thermoelectric facilities that depend on cooling water; these facilities withdraw 143 billion gallons of freshwater per day. In 2005, thermoelectric cooling represented 41 percent of water withdrawn nationally, and 6 percent of water consumed nationally. Water availability issues—such as regional drought, low-flow, or intense competition for water—are critical for hydroelectric and thermoelectric generation. However, the Energy Sector's need for water varies widely across the sector. In some cases, such as fuel production, the byproduct is wastewater. Wastewater (often saline) brought to the surface by oil

[132] AWWA, *WARN: Superstorm Sandy After-Action Report*, 2013.
[133] Copeland, *Energy-Water Nexus: The Water Sector's Energy Use*, 2014; and Carter, *Energy-Water Nexus: The Energy Sector's Water Use*, 2013.

and gas wells represent the largest byproduct of fuel production. Approximately 2.3 billion gallons are produced daily from onshore oil and gas wells in the United States.

A Congressional Research Service (CRS) study noted several areas requiring additional research before the energy-water nexus could be more fully understood. The research areas included:[134]

- Data that could help decision-makers and users fill what is now an incomplete picture of energy needs for water uses are lacking. This is apparent across sectors and also within individual sectors. Data that exist are scattered and often are not available at a scale needed by decision-makers.
- More integrated research is needed on water and energy operations. Standards for data collection, coordination, and quality control are lacking.
- Research is needed on advanced technologies that save energy and save water, and partnerships between government and the private sector that move research and development from bench-scale to implementation are needed.
- Better understanding is needed of linkages between energy, water, land, and agriculture and risks of climate change and extreme weather events on water availability and energy supply.
- Policies and approaches are needed to encourage the water and energy sectors to move toward integrated resource management.
- Analysis is needed of incentives, disincentives, and lack of incentives to investing in cost-effective energy or water efficiency measures. One area of interest is regulatory barriers to co-implementation of efficiency programs in the water and energy sectors.
- More education and outreach to all types of water users, the general public, and public officials are needed on the water-energy nexus and how improving efficiency involves the reciprocity of saving energy and saving water.

To address these and other issues surrounding the water-energy nexus, the U.S. Department of Energy (DOE) proposed a new energy-water nexus crosscutting activity for fiscal year (FY) 2016 that would analyze the relationships between energy and water use and conduct research on water and energy systems. DOE justified its new activity on the grounds that energy is a major user of the Nation's water and that extraction, distribution, and treatment of water requires large amounts of energy. Components of DOE participating in the crosscutting activity include several DOE offices: Energy Policy and Systems Analysis, International Affairs, Energy Efficiency and Renewable Energy, Fossil Energy, Indian Energy Policy and Programs, and Science.[135]

Water Supply and Healthcare Facilities

The energy-water nexus illustrates the close interdependencies between these two sectors. An example of a critical infrastructure sector dependency on water is the need for hospitals and healthcare facilities to access a reliable source of water during emergencies. Without water, the

[134] Ibid.

[135] Holt, *Energy and Water Development: FY2016 Appropriations*, 2015.

facilities will shut down, and the lives of individuals needing their care may be in jeopardy. To address this life-critical issue, the CDC and AWWA collaborated in the development of the *Emergency Water Supply Planning for Hospitals and Healthcare Facilities* and the *Drinking Water Advisory Communication Toolbox*. Both of these documents reflect Water Sector resilience efforts in conjunction with the needs of a dependent sector.

The *Emergency Water Supply Planning for Hospitals and Healthcare Facilities* report provides a four-step process and detailed guide for the development of an Emergency Water Supply Plan (EWSP):[136]

1. Assemble the appropriate EWSP Team and the necessary background documents for your facility;
2. Understand your water usage by performing a water use audit;
3. Analyze your emergency water supply alternatives; and
4. Develop and exercise the EWSP.

The Drinking Water Advisory Communication Toolbox provides a protocol and practical toolbox for communicating with stakeholders and the public about water advisories. It focuses on water systems and addresses the range of situations that generate drinking water advisories.[137] The Toolbox is based on more than 500 documents, protocols, regulations, and other resources related to the issuing of drinking water advisories, as well as nearly 100 interviews conducted with water systems, primacy agencies, and local public health departments in the United States and Canada. The toolbox includes instructions on how to prepare before an event, what to do during an event, templates and tools to use, and recommendations for follow-up actions and assessments after an event. The purpose of the toolbox is to enable water systems to communicate effectively with partners and the public in order to protect public health.

ASSESS AND ANALYZE RISK

The vulnerability of Water Sector systems, coupled with their essential life supporting services, necessitates that sector owners and operators (publicly and privately owned) pay exceptionally close attention to risk management in the sector. Historically, water and wastewater utilities have incorporated protection and emergency preparedness initiatives into their operating protocols, with a traditional goal of continuously improving their infrastructure protection, security, dependability, and resilience. The assessment of risk to individual utilities and their specific infrastructure is conducted primarily by the utilities themselves. However, there are challenges in providing vulnerability assessments to those outside the utility. Obstacles to the sharing of this kind of detailed vulnerability information has limited the Federal Government's ability to compile on a national level an accurate and complete assessment of the sector's security and resilience status.

Drinking water and wastewater utilities are encouraged to conduct or update risk assessments as well as to prepare or revise Emergency Response Plans (ERP) on a regular basis. EPA's Vulnerability Self-Assessment Tool (VSAT) provides Water Sector utility owners and operators with qualified and

[136] CDC and AWWA, *Emergency Water Supply Planning Guide for Hospitals and Health Care Facilities*, 2012.
[137] CDC, and et al., *Drinking Water Advisory Communication Toolbox*, 2013.

quantified risk assessment processes to measure risk at the asset and system level; prioritize utility investments and efforts to mitigate risk; and track utility risk-management performance and investment over time. VSAT uses consistent vulnerability, consequence, and threat information within the Risk Analysis and Management for Critical Asset Protection framework, also known as RAMCAP. EPA's Water Health and Economic Analysis Tool (WHEAT) is a generalized (threat-neutral) consequence analysis tool, designed to assist drinking water and wastewater utility owners and operators in quantifying public health consequences, utility-level financial consequences, direct and indirect regional economic consequences, and the downstream impacts of an adverse event that pose risks to the Water Sector. The WHEAT tool includes modules for drinking water and wastewater systems.

Examples of regional and local resilience measures, aimed at managing assessed risk, from the Los Angeles area include:

- The Metropolitan Water District of Southern California (MWD) assists local southern California communities to develop local sources of water and utilize groundwater banking and transfers. MWD also promotes and invests in conservation and water use efficiency programs as a way to help the region adapt to current and anticipated shortages of imported water from Northern California and the Colorado River.[138]
- Facing aging infrastructure of its system, the Los Angeles Department of Water and Power (LADWP) developed a Capital Improvement Program with a 10-year horizon to maintain and replace existing components of the water system, as well as substantial updates or construction of new facilities.[139]
- LADWP's water conservation programs includes providing incentives for installation of more than 1.8 million water-saving showerheads, more than 1.27 million water-efficient toilets, and more than 80,000 high efficiency clothes washers. Water saving from the more efficient toilets themselves save the City more than 14 billion gallons of water each year. As well as instituting a "Cash in Your Lawn" program, whereby residents of the City have replaced over 15 million square feet of traditional grass with low-water-using "California Friendly landscaping," saving 540 million gallons of water per year.[140]
- The City of Los Angeles adopted the "One Water LA 2040 Plan" (One Water LA). Coordinated by a multiagency implementation team, One Water LA is a collaborative approach to develop an integrated framework for managing the City's watersheds, water resources, and water facilities in an environmentally, economically, and socially beneficial manner.[141]

SHARE INFORMATION

Information sharing plays an essential role in the security and resilience of the Water Sector. The sector leverages the resources and capabilities of four primary information-sharing mechanisms to

[138] Metropolitan Water District of Southern California, *Integrated Water Resources Plan,* 2016.
[139] LADWP, "Water Infrastructure Plan," 2015.
[140] Ibid.
[141] City of LA, "One Water LA."

support resilience across the sector: the Water Information Sharing and Analysis Center (WaterISAC), Water/Wastewater Agency Response Network (WARN), and trade associations.

Water Information Sharing and Analysis Center (WaterISAC)

Established as a nonprofit organization in 2001, the WaterISAC is the primary information-sharing and operational arm of the Water Sector. Through a secure Webportal, twice-weekly e-newsletters, alerts, and Webinars, the WaterISAC delivers physical and cyber threat information; guidance on risk management, mitigation and resilience; contaminant databases; and other information. Members include hundreds of utilities serving more than 200 million people in the United States, as well as Federal, State, and local agencies and consulting firms.[142] The WaterISAC is supported by fees charged to its users.

- WaterISAC Pro-members receive a wide range of services, including a vast library of sensitive threat information, best practices, articles, exercise guides, vulnerability assessments, and other resources on security and emergency management; contaminant databases with information on health effects, treatment and lab methods; a bi-annual Water Sector threat analysis; urgent physical and cyber threat alerts; and free Webcasts on current water security and emergency response topics.
- BASIC members are granted access to a library of open-source information about security and emergency response and threat alerts.[143]

Water/Wastewater Agency Response Network (WARN)

WARN is an intrastate network of utilities helping utilities to respond to and recover from emergencies by sharing resources with each other. WARN enables participating agencies to maintain contact with one another for emergency purposes, providing expedited access to specialized resources, and facilitating training on resource exchange. WARNs are volunteer-based, utility-to-utility networks that prepare for disasters, and then help member utilities respond and recover more quickly by getting the specialized utility resources (e.g., equipment and personnel) whenever and wherever needed. AWWA hosts a WARN Webpage that provides contact information for WARN representatives around the Nation, as well as links to situational reports prepared by WARN during emergencies, such as Hurricane/Superstorm Sandy.[144] In 2014, there were a total of 50 WARNs in the United States and 2 WARNs in Canada.

Water Sector Associations

Water Sector associations play a vital role in the information-sharing aspects of resilience. Some of AWWA's efforts in this have already been mentioned: the 2013 Roadmap and support of the WARN Website. A few further examples of association activities which seek to enhance sector resilience include:

- The Association of State Drinking Water Administrators (ASDWA) in 2014 released a report documenting a yearly shortfall of at least $230 million between the resources available in

[142] National Council of ISACs, "Join Your Sector's Information Sharing and Analysis Center," 2015.
[143] WaterISAC, "About Water ISAC."
[144] AWWA, "Water/Wastewater Agency Response Network."

States (from all sources – both Federal and State) and those needed by States to administer minimum required programs.[145]

- The Association of Metropolitan Water Agencies (AMWA) has a program to assist publicly owned utilities to adapt to climate change. One example is its monthly Sustainability and Security Report.[146]
- The National Association of Clean Water Agencies (NACWA) is active in next generation Water Sector issues, such as the energy-water nexus, green infrastructure, watershed-based solutions, and water resources utility of the future.[147]
- The National Association of Water Companies (NAWC) has many programs supporting public and private investment in water infrastructure. Its State-by-State summary of water investments is a useful tool for both advocates as well as policy makers.[148]

IMPLEMENT RISK MANAGEMENT ACTIVITIES

As highlighted in the 2015 SSP sector partners develop and disseminate guides, tools, training, and exercises aimed at managing risk.[149] Several of these practices are organized below according to NIAC's definition of resilience: robustness in preparing for an event; resourcefulness through training, exercises, and drills; rapid recovery; and adaptability through incorporating lessons learned. Additional examples of resilience activities in the Water Sector can be found in Appendix I. Collaborative Tools and Practices.

Robustness in Preparing for an Event

- Published *Weather & Hydrologic Forecasting for Water Utility Incident Preparedness and Response* to provide hazardous weather and forecasting resources for utility awareness and preparedness
- Developed the interactive *Flood Resilience: A Basic Guide for Water and Wastewater Utilities* to help utilities know their flooding threat and identify practical mitigation options to protect critical assets
- Published *10 Basic Cybersecurity Measures to Reduce Exploitable Weaknesses and Attacks* (WaterISAC)
- Developing a method to coordinate cyber and physical risk-assessment tools to enhance management decision-making
- Updating the *All-Hazards Consequence Management Plan* to create a better understanding of current threats and vulnerabilities and strategies to reduce the impacts of an emergency event

[145] ASDWA, "Press Release: Insufficient Resources for State Drinking Water Programs," 2014.
[146] AMWA, "Sustainability and Security Report," 2016.
[147] NACWA, "Issues: Utility of the Future," 2016.
[148] NAWC, *State Data Sheet 2013*, 2013.
[149] EPA, *2015 SSP,* 2016.

- Developed *Business Continuity Planning for Water Utilities: Guidance Document* (Water Research Foundation, AWWA, and EPA)
- Enhancing engagement with utilities during smaller emergencies and planned maintenance to assess emergency response plans
- Harnessing existing tools and guidance to develop an overarching tool/resource that defines key actions and procedures to help utilities enhance their preparedness and resilience
- Developing incentives—through grants, insurance, standards, and certification—to increase investment in Water Sector infrastructure
- Periodically assessing available resources, identifying current needs and gaps, and improving existing resources or develop new ones

Resourcefulness through Training, Exercises, and Drills

- Conducted training workshops in EPA Regions 2 and 5 to educate drinking water utilities on the design and implementation of contamination warning systems, such as those implemented under the Water Security Initiative
- Developed *How to Develop a Multi-Year Training and Exercise Plan* to assist utilities in creating multiyear plans that can lead to increased emergency preparedness
- Developed the "Don't Get Soaked" video for utility managers, board members, and elected/appointed officials to help them understand the benefits of investing in preparedness, prevention, and mitigation activities
- Conducting State and local exercises, tabletop exercises, and workshops that improve understanding of Water Sector interdependencies, sector criticality, and impacts of loss of service during a disaster
- Developing and implementing an education and awareness campaign that helps utilities to communicate the importance of the Water Sector in emergency planning and to describe the costs and benefits of risk-reduction investments to States and public commissions using sector risk assessment and consequence analysis tools
- Developing and implementing public messaging to gain consumer support in addition to Federal, State, and local support for pre-disaster risk-reduction and resilience activities

Rapid Recovery

- Developed "Federal Funding for Utilities – Water/Wastewater – in National Disasters" (Fed FUNDS) tool to provide tailored information to utilities about applicable Federal disaster funding programs
- Published a report documenting the findings from an EPA evaluation of commercially available water quality event detection systems
- Determining the applicability of FEMA assistance criteria to address Water Sector needs and ensure the criteria are clear and well understood

- Integrating Water Sector considerations into all-hazards preparedness and response tools designed to support wide-area urban contamination incident response
- Developed the "How Can Water Utilities Obtain Critical Assets to Support Decontamination Activities" fact sheet
- Integrating Water Sector considerations into emergency response planning to ease access and credentialing issues for water utility personnel during an event

Adaptability through Incorporating Lessons Learned

- Performing after-action analyses after large events that highlight economic implications for the Water Sector
- Demonstrating the capabilities of existing tools and developing case studies to communicate their success
- Leveraging tools and best practices from interdependent sectors to understand their potential application to the Water Sector
- Developing Federal incentives for State drinking water programs and emergency management programs to support hazard mitigation investments
- Developing a tool consistent with the AWWA J100-10 standard to help utilities update all-hazards risk assessments, and then leverage them to update emergency response and risk-management plans; perform after-action analyses; and incorporate lessons learned following an event
- Examining climate change adaptation strategies to identify "no regret" measures that offer multiple types of benefits

APPENDIX H.
THE FLINT WATER CRISIS

Flint, Michigan—a city of about 99,000 people—lost access to safe, reliable drinking water due to a confluence of factors—"government failure, intransigence, unpreparedness, delay, inaction, and environmental injustice," according to the Flint Water Advisory Task Force Final Report.[150] The Flint water crisis underscores the importance of water to daily life, the impact on people who are unable to access safe drinking water, and the long-lasting consequences such contamination can have on residents, particularly children and other vulnerable members of the community.

For this study, the NIAC was tasked with assessing the security and resilience of water infrastructure, uncovering key resilience issues with that infrastructure, and identifying potential opportunities to address issues. The Flint water crisis demonstrates the underlying vulnerability of systems that are not properly maintained and managed.

Additional information is likely to emerge as the causes and consequences of the crisis are investigated. As of May 2016, there are multiple ongoing investigations including congressional hearings, the U.S. Environmental Protection Agency's (EPA) Flint Safe Drinking Water Task Force, and a multiagency investigation through the U.S. Attorney's Office with the Federal Bureau of Investigation. In May, the Michigan State Attorney General charged two State regulators and a city employee in connection with the incident.[151]

> "The bad news is that this should not have happened in the first place. And even though the scope of the response looks sort of like the efforts we're used to seeing after a natural disaster, that's not what this was. This was a manmade disaster. This was avoidable. This was preventable."
>
> *President Barack Obama, May 4, 2016, Flint, Michigan*

This appendix provides a brief overview of the facts of the incident, as they are known today; underlying deficiencies that contribute to infrastructure failures; and how the NIAC's recommendations, if implemented, could help prevent future situations like that in Flint.

I. INCIDENT OVERVIEW

The Flint crisis started in April 2014 when the city switched its water source from Lake Huron (treated by Detroit Water and Sewerage Department) to the Flint River (treated by the Flint Water Treatment Plant). The Michigan governor and President of the United States declared states of emergency to free up State and Federal resources to help in response.[152] Cases of bottled water and filters were distributed to residents and lawmakers have called for additional Federal funding to be provided to aid Flint and other cities with similar situations to replace the lead pipes and provide resources to support the people affected by lead contamination.

[150] Flint Advisory Task Force, *Final Report*, 2016.
[151] Householder and White, "3 Officials charged in Flint water crisis; more predicted," 2016.
[152] The White House, "President Obama Signs Michigan Emergency Declaration," 2016.

The Flint water crisis arose from contamination of the drinking water serving Flint, Michigan, when the water source was switched from Lake Huron water to more corrosive the Flint River water. [153] Required corrosion control treatment was never put in place when the switch was implemented, causing the untreated water to corrode the lead feeder pipes that connect homes to the underground water main, causing lead to leach into the drinking water.[154] After the contamination was brought to light, Flint re-connected to the Detroit Water and Sewerage Department in October 2015.

II. UNDERLYING DEFICIENCES

Although a rare incident, the features of the Flint water crisis are not unique. Underlying deficiencies such as planning and investment constraints, poor management, and insufficient government coordination and collaboration led to resilience failures. In the process, public confidence in the water supply erodes and public health and the environment is damaged. The underlying deficiencies revealed in the Flint water crisis are present throughout this report on Water Sector resilience. The information below describes these themes in relation to the Flint water crisis.

CONDITION OF INFRASTRUCTURE

America's water infrastructure is aging and is in dire need of reinvestment. Aging infrastructure is one of the main contributors to lead in the water supply.[155] In 1986, Congress banned new lead pipes—"use of any pipe, any pipe or plumbing fitting or fixture, any solder, or any flux, after June 1986, in the installation or repair of (i) any public water system; or (ii) any plumbing in a residential or nonresidential facility providing water for human consumption, that is not lead free."[156] However, some U.S. water distribution systems still contain lead pipes and fixtures (typically, those built before the 1980s) and some major cities still have 100 percent lead piping bring water from the water utility to the homes and businesses.[157] American Water Works Association (AWWA) estimates there are about 6.5 million lead service lines in the United States, while EPA estimates the number is closer to 10 million.[158] Comprehensive reinvestment in public drinking water and wastewater systems—not just for lead pipe replacement—is necessary for safe, clean, and resilience water services.

PLANNING AND INVESTMENT CONSTRAINTS

Declining populations and increased conservation of water can lead to a decline in revenue sources. The water system in Flint was built for a city of 200,000 people; however, today's population is half of that. As populations decline, the remaining people must share the full cost for water services and investment, while municipalities must make ends meet with a smaller tax base.[159] Infrastructure

[153] Adams, "Closing the valve on history: Flint cuts water flow from Detroit after nearly 50 years," 2014.
[154] Edwards, "Test Update: Flint River water 19X more corrosive," 2015; and Office of the Auditor General, *Questions and Answers to Senator Ananich*, 2015.
[155] EPA, "Basic Information about Lead in Drinking Water."
[156] EPA, "Section 1417 of the Safe Drinking Water Act," 2015.
[157] EPA, "Basic Information about Lead in Drinking Water."
[158] Householder and White, "3 Officials charged in Flint water crisis; more predicted," 2016.
[159] Semeuls, "A Tale of Two Water Systems," 2016.

cannot be easily downsized to meet the needs of a smaller population and acceptable level of services cannot be reduced to counteract the population decline.[160]

The residents of Flint also have some of the highest water rates in the nation, averaging $76 per month. Michigan law restricts city governments' ability to raise property and income taxes. As a result, the city government relied on its water and sewer revenues to counteract a reduced tax base and reductions in State funding.[161] As a result, the Flint residents were having to pay more to maintain operations, the funds that would have been available for infrastructure improvements were being diverted, and investment decisions were not being determined with long-term resilience in mind.

GOVERNMENT COORDINATION AND COLLABORATION

The Flint Water Advisory Task Force's Final Report highlights the government failures that precipitated and lengthened the water crisis:[162]

- The Michigan Department of Environmental Quality (MDEQ), which has primacy authority, failed to effectively enforce drinking water regulations, and dismissed efforts to bring issues of unsafe water, lead contamination, and increased cases of Legionnaires' disease to light.
- The Michigan Department of Health and Human Services (MDHHS) failed to adequately and promptly act to protect public health.
- With the City of Flint under State-appointed emergency management, the Flint Water Department rushed into full-time operation of the Flint Treatment Plant without applying corrosion control needed to use the Flint River.
- EPA delayed enforcement of the Safe Drinking Water Act (SDWA) and Lead and Copper Rule (LCR).
- The Governor's Office failed to reverse poor decisions made by MDEQ and emergency managers despite senior staff members raising concerns and suggesting intervention.

III. WATER RESILIENCE RECOMMENDATIONS APPLIED TO FLINT

The Flint water crisis reinforces the critical role that water plays in our lives and the devastating impact on communities when water services are compromised. This report makes several recommendations that if applied would improve resilience within the Water Sector, and help water and wastewater systems avoid situations like Flint.

The NIAC Resilience Framework encourages those who manage critical infrastructure create robust systems that can absorb the shock of an incident and continue to provide clean safe water;

[160] Hoornbeek and Schwarz, "Sustainable Infrastructure in Shrinking Cities," 2009.
[161] Snider, "Flint's other water crisis: Money," Politico, March 7, 2016,
[162] Flint Advisory Task Force, *Final Report*, 2016.

resourceful in managing an incident to continue to provide services; quickly restore compromised service and return to normal; and adapt to a changing environment and risks.

The NIAC's recommendations call on the Federal Government, its public and private sector partners, and water utilities to:

- **Analyze and map complex risks**. The NIAC recommends that the Federal Government work with the Water Sector to identify tools, guidance, and mitigation measures and increase distribution across the sector. By clearly understanding risks, and having access to tools, models, checklists, and other resources, decision-makers could have a better understanding of the impacts and consequences of actions, such as switching water sources.
- **Fortify response and recovery.** This recommendation calls on the Federal Government to formalize and improve response and recovery capabilities at all levels of the Water Sector. Flint was a manmade disaster, but the response is similar to what happens following a natural disaster (e.g., emergency declaration, Federal funding assistance). But in Flint, once the problem was identified, the response was delayed. Creating a more formal response and recovery process, including reinforcing effective mutual aid models such as WARN, can provide water utilities and communities with the skills, information, and resources they need to quickly respond following an incident (whether it's a natural or manmade disaster).
- **Increase Federal funding, investment, and incentives to improve water infrastructure resilience**. Water utilities must often balance day-to-day operations with long-term infrastructure investments. For Flint, and communities in similar situations, access to innovative financing options can help utilities make these needed investments. The NIAC also recommends the creation of a Federal financial assistance program to reduce the burden on low-income communities from water rate increases.
- **Increase technical and financial resources available to the Water Sector.** If utilities have access to technical resources, such as local universities, workforce training, tools and life-cycle assessment models, they will have the capabilities to prepare and respond to existing and emerging risks, and to improve resilience.
- **Strengthen Federal leadership coordination, and support.** As illustrated in Flint, there were failures of government at the Federal, State, and local level that have a role in oversight of water services. Better coordination and communication across all levels of government is crucial for maintaining safe and effective water services. This coordination starts at the Federal level.

APPENDIX I.
COLLABORATIVE TOOLS AND PRACTICES

Enhanced collaboration between Water Sector partners has accelerated progress in attaining secure and resilient drinking water and wastewater infrastructure. The success stories summarized below represent the benefits of greater collaboration from improved sharing of resources; expanded use of new tools, knowledge, and training; and the improved characterization of emerging threats such as cyber intrusions and extreme-weather events.

I. SHARING RESOURCES

The **Emergency Management Assistance Compact (EMAC)** is an interstate mutual aid agreement that facilitates the sharing of assistance among States during emergency events, including natural and manmade disasters. Ratified by the U.S. Congress in 1996, EMAC is the most widely adopted mutual aid arrangement in the United States; it has been adopted by all 50 States, the District of Columbia, Puerto Rico, Guam, and the U.S. Virgin Islands. It provides a structured approach through which a State can request aid—including personnel, services, equipment, and supplies—from other States during an emergency. EMAC establishes responsibility for reimbursement between States, and also addresses liability, compensation, and licensing issues for personnel deployed pursuant to an EMAC request.[163]

The **Water and Wastewater Agency Response Network (WARN)** is a network of utilities helping other utilities to respond to and recover from emergencies. Through this network, water/wastewater utilities that have sustained damages from natural or manmade events can obtain emergency assistance from other water/wastewater utilities. Assistance includes personnel, equipment, materials, and other associated services as necessary. Formalizing the existing capability to provide mutual aid and assistance provides the sector with a degree of resilience against natural or manmade disasters to ensure continuity of service to customers.[164]

To expedite communication of Water Sector resource needs during an incident, the American Water Works Association (AWWA) developed the **Water & Wastewater Mutual Aid & Assistance Resource Typing Manual**, which uses EMAC for interstate mutual aid deployments. This manual was developed with extensive input from water utility owners/operators and is based on the team/mission approach to incident response for intra- and interstate mutual aid and assistance.[165]

The **Virginia Pooled Financing Program**, established in 2003, provides financing to local governments for essential products. Pooled loan programs are a cost-effective mechanism for borrowers to participate in a larger transaction to access capital markets. Since the program's inception, more than 100 local governments in Virginia have utilized the program to finance/re-finance over $2 billion in infrastructure projects, including water projects.[166]

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[163] EMAC, "Homepage."
[164] AWWA, "WARN."
[165] AWWA, *Water & Wastewater Mutual Aid & Assistance Resource Typing Manual*, 2008.
[166] Virginia Resources Authority, "Virginia Pooled Financing Program."

II. ACCESSING TOOLS, KNOWLEDGE, AND TRAINING

The ***AWWA G430-14: Security Practices for Operations and Management*** guide can help utilities to develop a protective security program that promotes the protection of employee safety, public health, public safety, and public confidence. The guide defines standard, minimum requirements for a protective security program and builds on the long-standing practice among utilities of utilizing a multiple barrier approach for the protection of public health and safety. The requirements outlined in the standard are designed to support a protective utility-specific security program that results in consistent and measurable outcomes to address the full spectrum of risk management from organizational commitment, physical and cybersecurity, and emergency preparedness. The standard received SAFETY Act designation from the U.S. Department of Homeland Security (DHS).[167]

The ***AWWA G440-11 Emergency Preparedness Practices*** guide is one of several in a Utility Management series designed to cover the principal activities of a typical water and/or wastewater utility. It defines the minimum requirements for emergency preparedness for a water or wastewater utility and expands upon the requirements outlined in the AWWA G430 guides. Minimum practices include the development of an emergency response plan (hazard evaluation, hazard mitigation, response planning, and mutual aid agreements), the evaluation of the emergency response plan through exercises, and the revision of the emergency response plan after exercises.[168]

The ***Business Continuity Plans for Water Utilities: Guidance Document*** guide provides sector-specific guidance—jointly developed by the Water Environment Research Foundation (WERF), AWWA, and the U.S. Environmental Protection Agency (EPA) on behalf of the Water Sector Coordinating Council (Water SCC)—for utilities to develop a business continuity plan, including a Disaster Response Plan.[169]

The ***CIPAC Water Sector Cybersecurity Strategy Workgroup: Final Report and Recommendations*** recommends training and outreach approaches to promote the use of the *NIST Framework for Improving Critical Infrastructure Cybersecurity*;[170] identifies gaps in available guidance, tools, and resources for addressing this framework; and identifies measures of success that can be used to indicate the extent to which the framework is being used by the Water Sector. It also provides recommendations to achieve each of these areas.[171]

A number of agencies and organizations have developed stormwater and **Green Infrastructure Calculating Tools** to assist design professionals in stormwater management and green infrastructure planning, costing, and comparison of various best management practices. A compiled list of calculators currently available from EPA, Center for Neighborhood Technologies, Sustainable

[167] AWWA, *AWWA G430-14: Security Practices for Operations and Management*, 2015.
[168] AWWA, *AWWA G440-11 Emergency Preparedness Practices*, 2011.
[169] WERF, EPA, and AWWA, *Business Continuity Planning for Water Utilities*, 2013.
[170] NIST, *Framework for Improving Critical Infrastructure Cybersecurity*, 2014.
[171] CIPAC Water Sector Cybersecurity Strategy Workgroup, *Final Report and Recommendations*, 2015.

Technologies Evaluation Program, WERF, and State and municipal governments is available online from a manufacturer of interlocking concrete paver materials.[172]

Information Sharing and Analysis Centers (ISACs) help critical infrastructure owners and operators protect their facilities, personnel, and customers from cyber and physical security threats and other hazards. ISACs reach deep into their sectors, communicating critical information far and wide and maintaining sector-wide situational awareness. ISACs collect, analyze, and disseminate actionable threat information to their members and provide members with tools to mitigate risks and enhance resilience.[173] **WaterISAC**, a nonprofit organization established in 2001, is the information sharing and operational arm for water and wastewater utilities. The organization helps members strengthen their cyber and physical security, recover from natural and manmade disasters and improve overall preparedness and resilience. Through a secure Webportal, twice-weekly e-newsletters, alerts and Webinars, WaterISAC delivers a rich and thorough physical and cyber threat information; guidance on risk management, mitigation, and resilience; and contaminant databases. Members include hundreds of utilities serving more than 200 million people in the United States, as well as Federal, State, and local agencies and consulting firms.[174]

The **Water Environmental Research Foundation (WERF)**, an independent scientific research organization dedicated to wastewater and stormwater issues, provides tools and knowledge to water managers and urban planners.[175] One example is the **Integrated Urban Water Model (IUWM)**, a mass balance model that provides a tool for water managers to forecast water demand, waste, and associated costs for various water management scenarios. In addition, WERF developed an information brief, **Tools for Evaluating the Benefits of Green Infrastructure for Urban Water Management**, which provides overviews for two analysis methods gaining popularity in the urban planning field—life-cycle cost analysis and triple bottom line—as they apply to stormwater and urban water management.[176]

New York City's Green Infrastructure Program is a multiagency effort led by the Department of Environmental Protection (DEP) to design, construct and maintain a variety of sustainable green infrastructure practices for city-owned property (e.g., streets, sidewalks, schools, and public housing). The program promotes practices that mimic the natural flow of water to manage stormwater runoff from streets, sidewalks, parking lots and rooftops to engineered systems that typically feature soils, stones, and vegetation. This process prevents stormwater runoff from entering the city's sewer systems. DEP is also building green infrastructure in compliance with the New York Department of Environmental Conservation requirements to reduce combined sewer overflow discharges into the city's water bodies through the use of a separate storm sewer system.

The Green Infrastructure Toolkit, designed by the New York City DEP, educates homeowners, community gardeners, and others interested in stormwater management techniques to minimize the effects of rainfall on water bodies in cities with combined sewers and other places that

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[172] Uni-Group USA, "Green and Stormwater Calculators."
[173] National Council of ISACs, "About ISACs."
[174] WaterISAC, "About Water ISAC."
[175] Sharvelle, *Development of the Integrated Urban Water Management Too*l, 2012; and Weinstein, T*ools for Evaluating the Benefits of Green Infrastructure for Urban Water Management*, 2012.
[176] Weinstein, *Tools for Evaluating the Benefits of Green Infrastructure for Urban Water Management,* 2012.

experience flooding and storm water problems. The photographs, detail drawings, material lists, and text provide a starting point for those interested in utilizing these practices in their homes, gardens and communities. The toolkit also includes a printable version of green infrastructure techniques.[177]

Developed by the CIPAC Water Sector Strategic Priorities Working Group, the ***2013 Roadmap to a Secure & Resilient Water Sector*** establishes a strategic framework that articulates the priorities of industry and government in the Water Sector to manage and reduce risk, and also produces an actionable path forward for the Water Sector Government Coordinating Council, Water Sector Coordinating Council, and government and private sector security partners in the sector to improve the sector's security and resilience within the next five years. The roadmap establishes three top priority activities for the Water Sector: 1) Advance the development of sector-specific cybersecurity resources; 2) Raise awareness of the Water Sector as a lifeline sector and recognize the priority status of its needs and capabilities; and 3) Support the development and employment of tools, training, and other assistance to enhance preparedness and resilience.[178]

M19 Emergency Planning for Water Utilities, Fourth Edition, developed by AWWA, provides guidelines and procedures that can be used by utilities of any size to develop an emergency preparedness plan, identify vulnerabilities in the water system, and determine how a disruption would likely impact service. Originally issued in 1973 and updated most recently in 2001, revisions of the manual are in progress to reflect current the state of knowledge regarding emergency preparedness and the AWWA G440 guides.[179]

The **Water and Wastewater Treatment Technologies Appropriate for Reuse (WAWTTAR)**, a predictive program developed by Humboldt University, enables planners to select suitable water and wastewater treatment options appropriate to the material and manpower resources available to particular communities throughout the world. The localized performance and cost of a large number of possible systems can be estimated with WAWTTAR for any location and condition for which basic information on the problem to be solved is available. While the initial target audience was outside the United States, WAWTTAR has found considerable utility by engineers involved in small community project planning in the United States.[180]

The National Association of Clean Water Agencies (NACWA), the WERF, and the Water Environment Federation (WEF) collaborated on ***The Water Resources Utility of the Future: A Blueprint for Action***. This report captures a fundamental shift in the way clean water utilities in the United States define their role in society (i.e., from managers of waste to managers of valuable resources). The blueprint provides examples of initiatives in energy and materials recovery and reuse, water reuse, and green infrastructure, and a new openness on the part of clean water utilities to partner with developers of technology, design engineers, and the public and private finance community.[181]

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[177] NYC DEP, "NYC Green Infrastructure Program;" and Grow NYC, "Green Infrastructure Toolkit."
[178] CIPAC Water Sector Strategic Priorities Working Group, *Roadmap to a Secure and Resilient Water Sector*, 2013.
[179] AWWA, *M19 Emergency Planning for Water Utilities, Fourth Edition*, 2001.
[180] WAWTTAR, "Homepage."
[181] NACWA, et al, *Water Resources Utility of the Future: A Blueprint for Action*, 2013.

The **WaterLex Toolkit**'s budgeting tool assists development partners to develop a budget for their program to ensure that water and sanitation services are supplied in a financially sustainable manner. The tool focuses on assessing financial capabilities, developing a financing plan, and making decisions about capital and recurring expenditures.[182]

III. CHARACTERIZING EMERGING THREATS

The ***AWWA J100-10 (R13) Risk and Resilience Management of Water and Wastewater Systems (RAMCAP)*** guide documents a process for identifying and communicating security vulnerabilities and provides methods to evaluate the options for improving these weaknesses. It includes methodology to identify, analyze, quantify, and communicate the risks of specific terrorist attacks and natural hazards against critical water and wastewater systems. In addition, it establishes requirements for the risk and resilience assessment and management process that inform decisions on where to allocate resources to reduce risk and enhance resilience through countermeasures and mitigation strategies. This standard received SAFETY Act designation from DHS.[183]

The U.S. Water Alliance's **One Water Management** program supports and enhances a more holistic approach to water management. The approach—in both policy and practice—is expanding across the sector because it is recognized as necessary to support sustained sector-wide resilience. Examining water management in an integrated way across water sources and water uses is key to a sustainable and resilient water future. As such, the Alliance is building a network of leaders representing research foundations, national trade associations, Federal agencies, companies, and nongovernmental organizations to unite for integrated water management. The Alliance's One Water Management vision is closely aligned with and builds upon the extensive national and global work on Integrated Water Resources Management (IWRM).[184]

EPA National Homeland Security Research Center and AWWA prepared the ***Planning for an Emergency Drinking Water Supply*** report to respond to the 2002 Bioterrorism Act that directed EPA to conduct "a review of the methods and means by which alternative supplies of drinking water could be provided in the event of destruction, impairment or contamination of public water systems" (42 U.S.C. 300i-4 (b)." This report details options and plans to provide drinking water in situations where public water systems are compromised.[185]

Produced by AWWA, ***Process Control System Security Guidance for the Water Sector*** provides a consistent and repeatable course of action to reduce vulnerabilities in process control systems and identifies specific recommended cybersecurity practices for the sector.[186] It builds and expands upon the *2008 Roadmap to Secure Control Systems in the Water Sector*, developed by the Water Sector Coordinating Council Cyber Security Working Group with AWWA sponsorship.[187]

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[182] WaterLex, "Budgeting Tool: Budgeting sustainable water and sanitation services."
[183] AWWA, *AWWA J100-10 (R13) Risk and Resilience Management of Water and Wastewater Systems*, 2010.
[184] U.S. Water Alliance, "One Water Hub."
[185] EPA, *Planning for an Emergency Drinking Water Supply*, 2011.
[186] AWWA, *Process Control System Security Guidance for the Water Sector*, 2014.
[187] Water SCC Cybersecurity Working Group, *Roadmap to Secure Control Systems in the Water Sector*, 2008.

After-Action Reports (AARs) issued following a variety of disasters and emergencies share successes and areas for improvement. The ***WARN Superstorm Sandy After-Action Report*** is based on information shared by impacted utilities, State and Federal partners, and WARNs in the impacted States. High priorities for improvement in the sector, identified by this AAR, include intrastate mutual aid and assistance, interstate mutual aid and assistance, the need to elevate the priority status of water infrastructure, the energy and water nexus in disasters, site access, coordination, situational awareness, and communications.[188]

EPA has drawn upon the WARN AAR as well as other post-Sandy studies to improve its response to major events impacting the Water Sector. Other important AARs include:

- New York City, *Hurricane Sandy After Action* (May 2013)[189]
- DHS, *Lessons Learned: Social Media and Hurricane Sandy* (June 2013)[190]
- FEMA, *Hurricane Sandy FEMA After-Action Report* (July 1, 2013)[191]
- NERC, *Hurricane Sandy Event Analysis Report* (January 2014)[192]

AMWA and NACWA hosted a **Water Resilience Summit** in April 2014, convening key Federal and municipal agency leaders to outline the collaborative actions to address climate change and enhance resilience. The summit focused on how to ensure the Water Sector becomes more resilient, while allocating resources and mitigating some of the enormous costs more effectively than in previous post-disaster recovery and relief efforts. Participants of the summit identified opportunities for Federal agencies, States and utilities to influence progress on resilience through planning, funding, and financing; permitting and regulatory flexibility; public education and community outreach; and partnerships and coordination at all levels of government.[193]

[188] AWWA, *WARN Superstorm Sandy After-Action Report,* 2013.
[189] NYC. *Hurricane Sandy After Action*, 2013.
[190] DHS S&T, *Lessons Learned: Social Media and Hurricane Sandy*, 2013.
[191] FEMA, *Hurricane Sandy FEMA After-Action Report*, 2013.
[192] NERC, *Hurricane Sandy Event Analysis Report*, 2014.
[193] AMWA and NACWA, *Water Resilience Summit*, 2014.

APPENDIX J.
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APPENDIX K.
ACRONYMS

Acronym	Definition
AAR	After Action Report
ASDWA	Association of State Drinking Water Administrators
AER	Atmospheric and Environmental Research
AMWA	Association of Metropolitan Water Agencies
ANSI	American National Standards Institute
ARPA	Advanced Research Projects Agency
ASCE	American Society of Civil Engineers
ASDWA	Association of State Drinking Water Administrators
ASIWPCA	Association of State and Interstate Water Pollution Control Administrators
ASWM	Association of State Wetland Managers
AWWA	American Water Works Association
BLM	Bureau of Land Management
BNR	Biological Nutrient Reduction
CBR	Chemical, Biological, or Radiological
CBWR	Community-Based Water Resiliency
CEO	Chief Executive Officer
CDC	Centers for Disease Control and Prevention
CI	Critical Infrastructure
CIFA	Council of Infrastructure Financing Authorities
CIKR	Critical Infrastructure and Key Resources
CIPAC	Critical Infrastructure Partnership Advisory Council
CISR	Critical Infrastructure Security and Resilience
COBIT	Control Objectives for Information and Related Technology
CRS	Congressional Research Service
CSO	Combined Sewer Overflows
CWA	Clean Water Act
CWS	Commercial Water System
CWSRF	Clean Water State Revolving Fund
DEED	Minnesota Department of Employment and Economic Development
DEP	Department of Environmental Protection
DHS	U.S. Department of Homeland Security
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
DOT	U.S. Department of Transportation

Acronym	Definition
EIS	Environmental Impact Statements
EMAC	Emergency Management Assistance Compact
EO	Executive Order
EOC	Emergency Operations Center
EPA	U.S. Environmental Protection Agency
ERP	Emergency Response Plan
ESF	Emergency Support Function
EWSP	Emergency Water Supply Plan
FAST	Fixing America's Surface Transportation
FBI	Federal Bureau of Investigation
FCC	Federal Communications Commission
Fed FUNDS	Federal Funding for Utilities for Water/Wastewater in National Disasters
FEMA	Federal Emergency Management Agency
FFRMS	Federal Flood Risk Management Standard
FY	Fiscal Year
GCC	Government Coordinating Council
GDP	Gross Domestic Product
HEC	Hydrologic Engineering Center
HHS	U.S. Department of Health and Human Services
HMGP	Hazard Mitigation Grant Program
HSPD	Homeland Security Presidential Directive
HUD	U.S. Department of Housing and Urban Development
IDT	Infrastructure Data Taxonomy
IP	Office of Infrastructure Protection
ISAC	Information Sharing and Analysis Center
IT	Information Technology
ITIL	IT Infrastructure Library
IUWM	Integrated Urban Water Model
IWRM	Integrated Water Resources Management
LADWP	Los Angeles Department of Water and Power
LIHEAP	Lower Income Home Energy Assistance Program
MCHM	Methylcyclohexane methanol
MDEQ	Michigan Department of Environmental Quality
MDHHS	Michigan Department of Health and Human Services
Mn/DOT	Minnesota Department of Transportation
MWD	Metropolitan Water District of Southern California
NACWA	National Association of Clean Water Agencies
NAWC	National Association of Water Companies
NDRF	National Disaster Recovery Framework

Acronym	Definition
NEHRP	National Earthquake Hazards Reduction Program
NERC	North American Electric Reliability Corporation
NIAC	National Infrastructure Advisory Council
NIMS	National Incident Management System
NIPP	National Infrastructure Protection Plan
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Association
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NRF	National Response Framework
NRWA	National Rural Water Association
NSC	National Security Council
NTSB	National Transportation Safety Board
NWP	National Water Program
OCIA	Office of Cyber and Infrastructure Analysis
OCS	Office of Community Services
ODNI	Office of the Director of National Intelligence
OGWDW	Office of Ground Water and Drinking Water
OHS	Office of Homeland Security
OLEM	Office of Land and Emergency Management
OMB	Office of Management and Budget
OP	Office of Policy
OST	Office of Science and Technology
OSWER	Office of Solid Waste and Emergency Response
OW	Office of Water
OWM	Office of Wastewater Management
PDM	Pre-Disaster Mitigation
POTW	Publicly Owned Treatment Work
PPD	Presidential Policy Directive
PPH	Propylene glycol phenyl ether
PWS	Public Water System
R&D	Research and Development
RAMCAP	Risk and Resilience Management of Water and Wastewater Systems
RIPP	Regional Infrastructure Protection Plans
RPS	Renewable Portfolio Standard
RRAP	Regional Resiliency Assessment Program
SCADA	Supervisory Control and Data Acquisition
SCC	Sector Coordinating Council
SDWA	Safe Drinking Water Act

Acronym	Definition
SEP	State Energy Program
SFPUC	San Francisco Public Utilities Commission
SLTT	State, Local, Tribal, and Territorial
SMART	Sustain and Manage American Resources for Tomorrow
SRF	State Revolving Fund
SSA	Sector-Specific Agency
SSP	Sector-Specific Plan
TMDL	Total Maximum Daily Load
UOTF	Utility of the Future
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VRA	Virginia Pooled Finance
VSAT	Vulnerability Self-Assessment Tool
WARN	Water/Wastewater Agency Response Network
WAWTTAR	Water and Wastewater Treatment Technologies Appropriate for Reuse
WEF	Water Environment Federation
WERF	Water Environment Research Foundation
WHEAT	Water Health and Economic Analysis Tool
WIFIA	Water Infrastructure Finance and Innovation Act
WIN	Water Infrastructure Network
WRF	Water Research Foundation
WRRDA	Water Resources Reform and Development Act
Water SCC	Water Sector Coordinating Council
WSD	Water Security Division