



Critical Infrastructure Protection in the National Capital Region

**Risk-Based Foundations for Resilience and
Sustainability**

**Final Report, Volume 3:
Water and Wastewater Sector**

September 2005

University Consortium for Infrastructure Protection

Managed by the
Critical Infrastructure Protection Program
School of Law
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Final Report, Volume 3: Water and Wastewater Sector

Submitted in fulfillment of:

Department of Homeland Security Urban Areas Security Initiative (UASI) Grant 03-TU-03; and
Department Justice Office of Community Oriented Policing Services (COPS) Grant 2003CKWX0199

September 2005

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– **Notice** –

This research was conducted as part of the National Capital Region Critical Infrastructure Project, carried out by the University Consortium for Infrastructure Protection, managed by the Critical Infrastructure Protection Program, George Mason University, John A. McCarthy, Director and Principal Investigator.

It was sponsored by the U.S. Department of Homeland Security's Urban Area Security Initiative grant #03-TU-03, and by the U.S. Department of Justice Community Oriented Policing Services Program grant #2003CKWX0199, under the direction of the Senior Policy Group of the National Capital Region.

The views expressed are those of the authors, and do not necessarily reflect the views of the Department of Homeland Security, the Department of Justice, or the Senior Policy Group of the National Capital Region.

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Water Sector Report

Executive Summary

The water sector in the National Capital Region (NCR) is complex because it comprises many water supply and wastewater utilities. These utilities range in scale from three utilities that each serves more than a million people to individual homeowners who have their own wells and septic systems.

With regard to formal vulnerability assessments, and perhaps risk management, the water infrastructure is ahead of some other critical infrastructure sectors as a result of the federal government's mandate that water supply utilities conduct vulnerability assessments by June 2004. Although wastewater utilities were not required to complete these assessments, many did so.

Some professional organizations (e.g. American Water Works Association, Association of Metropolitan Sewerage Authorities), and government agencies (e.g. Sandia National Laboratory, US Environmental Protection Agency) developed vulnerability assessment tools used by these utilities to conduct vulnerability assessments. These assessment tools range from simple yes-no questions conducted by in-house employees, to sophisticated software systems that require significant amounts of data, and experts to run them. Two of the tools—Risk Assessment Methodology for Water Utilities (RAM-W) and the Vulnerability Self Assessment Tool (VSAT)—were more widely used than others in the NCR. The simpler tools are designed to assist a utility to identify potential vulnerabilities; more sophisticated tools, such as RAM-W, attempt to incorporate relative risk management. Although useful, each tool has limitations.

Discussions with relevant experts (see Appendices A and C) on the vulnerability assessments conducted in the NCR led to a set of recommendations to:

- Improve risk management tools for future use by water supply and wastewater systems
- Improve communication between the water sector and threat-identifying, law enforcement agencies
- Institute a regular schedule of risk assessments/reduction as part of an overall risk management plan
- Provide an effective mechanism for funding risk reduction that protects sensitive information about vulnerabilities from public disclosure
- Develop industry standards for risk management
- Develop practical measures of effectiveness to reduce risks
- Develop methods and tools to address dependencies across water utilities within the NCR
- Improve tools to address inter-sectoral dependencies better
- Institute regular tabletop exercises to illuminate and respond to intra- and inter-sectoral dependencies

1. Sector Background

1.1 Sector Profile

1.1.1 General

The water and wastewater infrastructure of the National Capital Region (NCR) includes facilities that are hundreds of years old (e.g. Georgetown’s sewers) as well as state-of-the-art treatment technologies for water supply, wastewater treatment, and increasingly, water reclamation for reuse. Further, this region’s water sector infrastructure system is complicated by the pace of growth and the multi-jurisdictional nature of the region. Many smaller service providers in the outlying regions of the NCR, in addition to the three major but separate water suppliers in the greater metropolitan area, are all involved.

Yet, these agencies/suppliers are remarkably different. For instance, they range in scale from small to enormous; and from facilities that are either old and in need of renewal/replacement to facilities that are state of the practice. From an operations standpoint, these agencies/suppliers range from low tech to highly automated. In addition, they range from financially prosperous with the ability to undertake new initiatives, to constrained and limited in future undertakings. Further complicating things, many of these agencies/suppliers, including the three major water suppliers in the region, cooperate or compete for water from the same source (Potomac River) for major portions of their supplies. Thus, these agencies/suppliers must and do work in concert during times of extremity, such as drought or emergencies.

The water and wastewater systems also exhibit key interdependencies. Specifically, flows into the wastewater stream are substantially derived from the water system, so failure of the water supply system directly impacts the wastewater system; and reclaimed water from one major wastewater treatment facility supplements water supply by discharging into a public water supply reservoir.

Most of the very large wastewater treatment systems in the NCR discharge to the Potomac River below the fall line, or to its tidal tributaries. Generally speaking, this means that failures in the wastewater treatment infrastructure do not result in immediate concern for water supply. This, however, should not be interpreted to minimize the importance of maintaining a robust security apparatus surrounding the wastewater infrastructure. While major wastewater treatment plant failures may not directly affect drinking water, such disruptions would certainly cause substantial ecological damage, including damage to the commercial and recreational resources of the tidal rivers of the region.

Political jurisdictions—federal, state, and local—in the NCR, also complicate the water and wastewater infrastructure. These political boundaries, in general, do not match hydrologic or water resources boundaries, so typically, multiple jurisdictions are involved with any one water or wastewater agency.

1.1.2 Definitions

The water/wastewater infrastructure comprises physical, institutional and information subsystems associated with the collection, treatment and delivery of water for various uses by people, commerce, government and industry, as well as the collection, treatment and ultimate

disposal of wastewater from homes and industry. Each of these subsystems is complex and fully interdependent with the others.

The physical subsystem includes the aggregate collection of physical water collection, transport, treatment, and distribution networks and facilities, including dams, groundwater collection systems, aqueducts, water treatment plants, pumps, and pipe networks for water distribution. This subsystem also includes sewer collection networks, wastewater treatment plants, and treated-wastewater disposal facilities; electronic and computer control systems are also included in the physical subsystem.

The institutional subsystem includes the people and management structure that plan, design, construct, operate, and maintain the physical water and wastewater systems, and those who deal with billing and customer service. Typically, these are employees of the utilities, but may include regulators, investors and others.

The third subsystem is the information subsystem whose source, flow, transformation, and use of information are critical to the functioning of any organization. In particular, water infrastructure systems are especially dependent on information, and with automation are becoming even more so. The decision-making processes range from deterministic and elementary, to stochastic and sophisticated. In all cases, information is essential.

These three subsystems—physical, institutional, informational—are all critical to and essential parts of the water infrastructure system.

1.2. Sector Characteristics

1.2.1 Service Areas

The individual water or wastewater service area providers vary in size. For example, many people living in the NCR obtain water at their homes from wells on their property, and dispose of their wastewater through their own septic systems. While others obtain their water from a water utility, and they dispose of their wastewater through a sanitary sewer and treatment plant that serves 1.6 million other customers. Service areas for these providers range from a single homeowner's property to more than 1000 square miles.

1.2.2 Water Supply Companies, Employees, Customers

Summary information on the major utilities in the region has been collected by the Metropolitan Washington Council of Governments (WashCOG). This information is available at the utility web sites in several forms. The WashCOG web site has a static-version map showing service areas of public water suppliers (see Figure 1¹). The three major suppliers—Washington Aqueduct Division (WAD) of the US Army Corps of Engineers, Washington Suburban Sanitary Commission (WSSC), and Fairfax Water (FW)—deliver more than 90% of the water used in the region; the rest comes from all other sources.

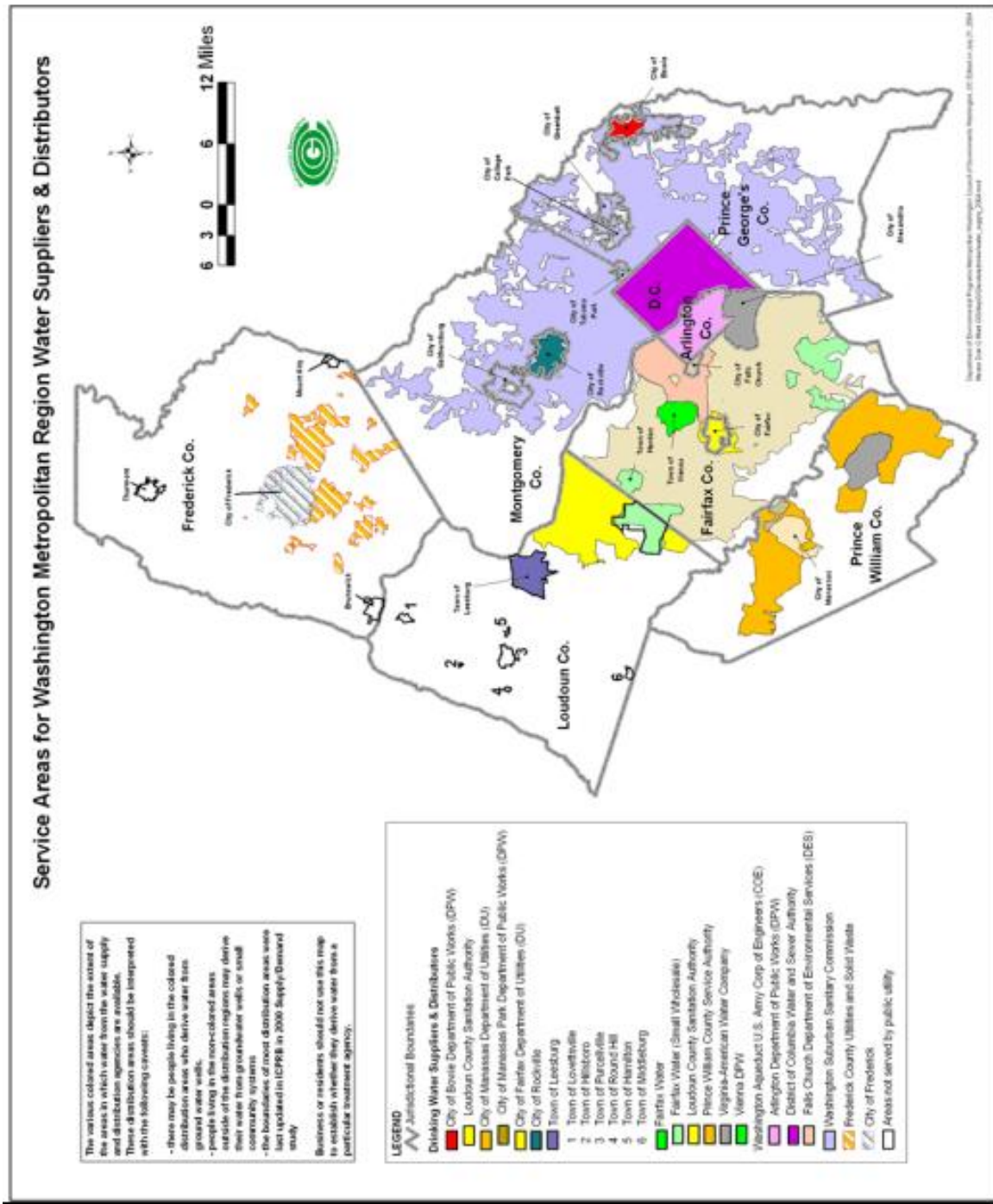


Figure 1: Service Area for Water Suppliers and Distributors

1.2.3 Water Supply Capacity and Demand

Public water utilities in the region produce and distribute an average of 445 million gallons per day (mgd), and have total treatment capacity of 1070 mgd. While some utilities supply water (meaning they obtain raw water from a source, treat it, and then deliver drinking water to customers), other utilities distributor purchased water directly from a supply utility (meaning

they do not have their own treatment facilities). Table 1 below contains a breakdown from WashCOG of the major suppliers² and distributors³ in the region.

Table 1. Water Suppliers and Distributors

Suppliers	Utility	Treatment Capacity [mgd]	Average Demand [mgd]	Maximum Daily Demand [mgd]	Approximate Number of Retail Customers
	Fairfax Water	262	135	221	210,000
	Washington Aqueduct Division	390			
	Washington Suburban Sanitary Commission	355	167	267	409,000 connections
	City of Bowie	5.2	2.3	4	25,000
	City of Fairfax	12	9	19	40-50,000
	City of Frederick	10.5	6.5	8.4	50,000
	Frederick County	8.6	4.5		9,600
	Town of Leesburg	5	3.2	5.2	27,000
	City of Manassas	14	10.5	14	> 10,000
	City of Rockville	8	5.3	10	50,000
Distributors	Arlington County		27	40	35,000 connections
	District of Columbia Water and Sewer Authority		140	210	
	City of Falls Church		17.5	29.4	33,000
	Loudoun County Sanitation Authority		10.4	19.9	31,000
	Prince William County Service Authority		16.5		> 60,000
	Town of Herndon		2.3	3.7	
	Town of Vienna		2.6	3.7	9,000
	Virginia American Water Company		20.6	32.2	43,000
	Total	1070	445	> 670	

1.2.4 Wastewater Collection, Transmission, Treatment, and Disposal Agencies

Services and infrastructure for the collection, transmission, treatment, and ultimate disposal of domestic wastewaters in the NCR are substantially more distributed than those serving comparable areas for public water supply. In some cases, municipal or county governments operate the collection systems, but obtain treatment services from regional authorities. In other cases, the local government may operate both the collection and treatment system(s), or may deliver wastewater to another jurisdiction for treatment. Finally, in the case of the major advanced wastewater treatment facility at Blue Plains in Washington, DC, wastewater is delivered to the plant from the District of Columbia, as well as from several suburban jurisdictions in both Maryland and Virginia.

1.2.5 Wastewater Treatment Capacity in National Capital Region

Table 2 shows the major local government, federal, and private sector agencies and companies that provide wastewater treatment services for flows of more than 1 mgd. Wastewater treatment systems and agencies with flows of less than 1 mgd have been omitted from the analysis and summary.

As seen in Table 2, several agencies in the region provide treatment capacity in excess of 50 mgd: Alexandria Sanitation Authority, Fairfax County Department of Public Works, Upper Occoquan Sewage Authority, Washington Suburban Sanitary Commission, and the District of Columbia Water and Sewer Authority.

Table 2. Domestic Wastewater Treatment Capacities in the NCR (Source: MWCOG)

Jurisdiction and Agency		Capacity (mgd)
Virginia	Alexandria Sanitation Authority	54
	Stafford County Utilities Dept.	6
	Arlington County Division of Environmental Services	30
	Dale Service Corporation	6
	Prince William County Service Authority	24
	Town of Leesburg	5
	Loudoun County Sanitation Authority	12*
	DC Department of Corrections	2
	Fairfax County Public Works Department	54
	Town of Purcellville	1
	United States Marine Corps Base Quantico	2
	Upper Occoquan Sewage Authority	54
	Virginia Total:	250
Maryland	Frederick County Department of Public Works	6
	Town of Bowie	3
	Frederick City Public Works Dept.	8
	U.S. Army	2
	Charles Co. Dept. of Public Works	15
	Town of Thurmont	1
	Washington Suburban Sanitary Commission	74
Maryland Total:	109	
District of Columbia	District of Columbia Water and Sewer Authority	370
	District of Columbia Total:	370
National Capital Region		729

Notes: *Projected completion of the Broad Run Water Reclamation Facility is 2007

1.3 Review of Authorities

1.3.1 Policy

A lengthy statutory history exists concerning water infrastructure and its security. With regard specifically to security, Presidential Decision Directive 63, *Protecting America's Critical Infrastructures*, promulgated in May 1998, is perhaps the starting point. Its goal is:

No later than the year 2000, the United States shall have achieved an initial operating capability and no later than five years from the day the President signed Presidential Decision Directive 63 the United States shall have achieved and shall maintain the ability to protect our nation's critical infrastructures from intentional acts that would significantly diminish the abilities of:

- the Federal Government to perform essential national security missions and to ensure the general public health and safety;
- state and local governments to maintain order and to deliver minimum essential public services;
- the private sector to ensure the orderly functioning of the economy and the delivery of essential telecommunications, energy, financial and transportation services.

Any interruptions or manipulations of these critical functions must be brief, infrequent, manageable, geographically isolated and minimally detrimental to the welfare of the United States.⁴

PDD 63 identified critical infrastructure sectors, including water. The US Environmental Protection Agency (EPA) was designated as the lead federal agency for the water sector. PDD 63 addressed cyber and physical security in the federal government and required the federal government to be the model for the rest of the country for attaining critical infrastructure protection. Information Sharing and Analysis Centers (ISACs) were proposed for each of the critical infrastructures to facilitate communications through the sector.

The Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (PL 107-188) requires water supply utilities serving more than 3,300 people to:

- Conduct a vulnerability assessment (VA);
- Certify that the VA is completed;
- Submit a copy of the VA and the certification to EPA;
- Revise or develop an Emergency Response Plan (ERP) based on lessons learned in the VA; and
- Certify that the ERP was appropriately revised to EPA.

Those systems required to submit VAs account for approximately 94% of the people nationally who served by public water supplies. Deadlines for submission of these assessments to the EPA were:

March 31, 2003	for systems serving more than 100,000 people
December 31, 2003	for systems serving more than 50,000 people
June 30, 2004	for systems serving more than 3,300 people

The ERP was to be complete within six months of the submission of the Vulnerability Assessment.

1.3.2 Statutes

The USA Patriot Act (Uniting and Strengthening America by Providing Appropriate Tools Required to Intercept and Obstruct Terrorism Act) was signed into law in 2001, and covered a wide array of issues, some of which relate to the water sector. This Act includes the definition of critical infrastructures, and the inclusion of the water sector as one of these. Among the findings of the Critical Infrastructure Protection Act (section 1016 of the USA Patriot Act) is: “Private business, government, and the national security apparatus increasingly depend on an interdependent network of critical physical and information infrastructures, including telecommunications, energy, financial services, *water*, and transportation sectors.”

The Homeland Security Act of 2002 created the Department of Homeland Security, merging parts of more than thirty agencies into a new department. The lead federal agency for the water sector remains the Environmental Protection Agency (EPA) but the Department of Homeland Security oversees EPA activities. The Support Anti-Terrorism by Fostering Effective Technologies Act (SAFETY Act, PL 107-296) was enacted as part of the Homeland Security Act of 2002. This Act created systems of risk management and litigation management to facilitate the development and use of anti-terrorism technologies. Moreover, SAFETY creates certain limitations on liability from the use of approved anti-terrorism technologies in the case of a terrorist attack. At present, few if any water related technologies have qualified for this limitation.

The Intelligence Reform and Terrorism Prevention Act of 2004 reformed the US intelligence community, partially in response to the National Commission on Terrorist Attacks Upon the United States (911 Commission). Section 1016 creates an Information Sharing Environment that facilitates the appropriate sharing of information among government agencies and the private sector to enhance anti-terrorist activities. This may have implications for the already established water Information Sharing and Analysis Center (ISAC). Other sections require water agencies receiving federal funds to adopt the Incident Command System, and the Department of Homeland Security to report to Congress its progress in completing risk assessments of, and protection and response plans for the nation's critical infrastructure.

1.3.3 Regulations

The EPA is the lead federal agency overseeing security in the water sector. This agency implements mandates from the policies and statutes previously described. Consequently, the EPA required water utilities nationwide to complete vulnerability assessments and emergency response plans, and NCR utilities fully complied. Not only does the EPA store these response plans securely, it is also a source of funds to support the conduct of the vulnerability assessments, and continues to be a source of funds to support efforts by these utilities to reduce vulnerabilities. To that end, the EPA fostered development of vulnerability assessment tools, in cooperation with Sandia National Laboratory, the Association of Metropolitan Sewerage Agencies (AMSA), and the American Water Works Association Research Foundation (AWWARF). Further, the agency supported the establishment of the Information and Sharing Center (ISAC) for the water sector; the goals of the center are to improve communication in the water sector for notification of threat alerts, to improve notification of accidents, and to improve information-sharing beneficial to community water systems. In addition, EPA supports research on biological and chemical contaminants that may be associated with the water sector.

1.3.4 Roles and Responsibilities

The EPA is the lead federal agency overseeing security of the water infrastructure. In this role, it promulgates regulations, monitors performance of water utilities, and supports research to improve water security.

The water utilities/agencies are the public or private entities that produce and deliver potable water; and collect, treat and dispose of sanitary wastes. Each of these is independently operated and responds to EPA oversight, its own board of directors, and any local or state regulation.

Local and state regulators are actively involved in the operations of water utilities. Regulators license operators, set and monitor standards of performance, inspect facilities, hold hearings to

set rates for some utilities, and sometimes appoint members to the boards of directors of the utilities. Other quasi-public organizations, like the Metropolitan Washington Council of Governments (WashCOG), also support the water sector in the National Capital Region. These local organizations facilitate communication between water utilities in the region, and support regional initiatives to resolve problems that may cross political boundaries.

Professional associations and organizations are important in the water sector. The American Water Works Association (AWWA), the Association of Metropolitan Water Agencies, and the Association of Metropolitan Sewerage Authorities (AMSA) are examples at the national level. These organizations help to set industry standards of performance; facilitate communication within the sector; represent the industry to local, state, and federal regulators; and sponsor research and development of new techniques to support the industry.

1.4 Mapping of Interdependencies

The water sector is dependent on all seven of the other critical infrastructure systems included in the present study: banking/finance, emergency services, energy, health, postal/shipping, telecommunications, and transportation. More importantly, the water sector is dependent on all 13 of the current sectors identified nationally.⁵ Conversely, all of these other systems are dependent on water, although the time to effect and the intensity of the impact differ. The impacts are nonlinear, which means that if an event causes damage to two other sectors, the overall effect on the water sector will not necessarily be the sum of the individual effects expected from each of the other sectors.

The results of tropical storm Isabel's impact on the National Capital Region in 2003 are illustrative of the kinds of impacts that can occur. Due to high rains and loss of electricity in the region, some sewers and wastewater treatment plants overflowed and released untreated wastes into the environment. Most importantly, Fairfax Water lost the ability to treat and pump water to its more than one million customers for 12 hours due to the loss of electric supplies to all of its facilities. Thus, an energy failure led directly to the loss of the water supply.

Cascading impacts on other sectors soon followed. For instance, the local gas company cools some of its equipment with water, and without water and electricity, its ability to deliver natural gas was becoming compromised. Additionally, local hospitals need substantial quantities of water to launder linen; with the 12 hour loss of water supply, the lack of clean linen was becoming a problem. Because of winds and rain associated with the storm, some internal telecommunications were degraded; either the Supervisory Control and Data Acquisition (SCADA) system was down, or communication lines were down, resulting in managers making decisions with less information than usual. Also, communication with employees was degraded because cell phone circuits were busy, and/or land lines were down. Communication with the public was degraded because the number of inquiries was exceptionally large; one third came in the form of email, and personnel had to be redirected to respond. Indeed, this one incident was severe but illustrates the interdependencies between sectors.

1.4.1 Upstream sectors

Examples of the impacts of upstream sectors on the water sector are provided in Table 3. The most important short-term upstream sectors are energy, transportation, telecommunications, and emergency services.

Table 3. Effects on the Water Sector from Loss of an Upstream Sector

Upstream Sector	Effects on Water Sector from Loss of Upstream Sector
Banking/Finance	Payments to suppliers and employees may be stopped. Income from customers may be stopped. Loans to finance expansion of facilities may be unavailable.
Emergency Services	First responders—fire, police—for incidents at plants may not be available with resulting increased damage/injury. First responders may be unavailable to help monitor the widespread network of pipes, pumps, tanks, etc. that form the distribution and collection systems.
Energy	Loss of energy may result in degradation or complete loss of the water system, which depends on pumping and other intensive uses of energy.
Health	Ill employees will either not be available or will not be as effective.
Postal/Shipping	Bills, payments, and some parcels may be delayed. Some of these may be critical.
Telecommunications	Loss of telephony will cause difficulties communicating with employees and the public. Loss of Internet connectivity will cause difficulties communicating with the public via email and web sites and employees. Loss of internal communications of data through the Supervisory Control and Data Acquisition (SCADA) system may mean degradation of the water system.
Transportation	Difficulties with delivery of key chemicals or parts by surface transport may result in degradation or loss of the system. Difficulties with employee transportation may mean insufficient numbers of employees to operate key facilities, or inability to reach key facilities.
Water	Loss of wastewater treatment may result in release of untreated wastewater into streams that serve as the source of raw water for a water supplier. The degraded quality of the raw water source may degrade the water supplier's quality.

1.4.2 Downstream sectors

Most other sectors depend on water as a critical input, and shortages may quickly lead to important consequences. Loss of the normal water supply means that employees in all sectors must immediately have alternative drinking sources. In addition, sanitary waste disposal typically depends on water to flush toilets, or to rinse sinks. Therefore, alternative means for disposal of this waste must be found quickly. Certainly all sectors ultimately depend on water supplies and wastewater disposal. Examples of these dependencies are provided in Table 4.

Table 4. Effects on Downstream Sector from Loss of the Water Sector

Downstream Sector	Effects on Downstream Sector from Loss of Water Sector
Banking/Finance	Most functions could be relocated to other unaffected areas in the

	<p>long term. In the short term, offices may be closed.</p> <p>Electronic equipment may have temperature and humidity specifications that require water for cooling and humidity control.</p>
Emergency Services	<p>Loss of pressure or contamination of water supplies may limit the ability to fight fires. This reduction in fire fighting ability may impact all sectors because various facilities may be required to limit their use, or individuals may elect to limit their use of these facilities, until fire suppression capabilities are restored.</p> <p>Contaminated water used in fire suppression or other uses may spread the contamination, making it airborne.</p> <p>Scarce water supplies may require police to monitor/protect these supplies.</p>
Energy	<p>Water is used for cooling and loss of the water supply may result in loss or degradation of some portions of the energy system.</p>
Health	<p>Loss or degradation of water supplies is catastrophic. It affects drinking water, food preparation, laundry operations, surgery, dialysis, etc. Any of these could cause closure or limitations of use of health facilities.</p> <p>Contaminated water could pose a major health crisis with potentially large numbers of affected people, swelling the demand for health services in the region.</p> <p>Loss of the wastewater system may result in an inability to dispose of sanitary waste, with the resulting limitation on use of health facilities.</p>
Postal/Shipping	<p>Some functions may be impacted, especially if the facilities require water to operate equipment, or if loss of fire suppression systems limits use of the facilities.</p>
Telecommunications	<p>Some functions may be impacted, especially if the facilities require water to operate equipment, or if loss of fire suppression systems limits use of the facilities.</p>
Transportation	<p>Water is used not only by employees in the transportation sector but also by the machines and facilities of that sector.</p> <p>Transportation networks are directly impacted by water that is not drained from these facilities. Loss of drainage or increased water levels on or near transportation facilities may result in a loss of access to those facilities and/or loss of the facility.</p>
Water	<p>Loss of water supplies means that the amount of wastewater generated will decline. This may impact the wastewater collection and treatment system that are designed and managed to collect and treat a typical flow rate.</p>

1.4.3 Sidestream sectors – e.g. regulators, competitors

Local, state, and federal agencies oversee the water sector through licensing of key employees, by promulgating rules, setting standards of performance, and by monitoring and enforcing system performance. Professional associations provide support for the water sector in a variety

of ways: providing industry standards of practice, communicating with governmental agencies on behalf of the industry, and supporting research and development to enhance the water sector. (More details are found in section 1.2.3.)

Law enforcement is critical to the water sector. The FBI, state and local police, and other enforcement agencies collect and assess information about the types of threats and likelihood of threats to the water sector. This information is important when conducting a vulnerability assessment and during an incident.

1.4.4 Other dependencies – e.g. co-locations, rights of way

Water distribution and wastewater collection systems are often co-located with each other and with energy distribution, telecommunications, and road networks. In addition, because movement of water in the water supply system and in the wastewater system is energy intensive, there are necessary co-locations of significant energy facilities with treatment works and pumping stations.

2. State of Risk Management

2.1 Awareness of Value of CIP and CIVA/RM

Water sector officials are aware of the value of critical infrastructure protection. By federal mandate, all water supply utilities were required no later than June 2004 to complete a vulnerability assessment, and by January 2005 to complete an emergency response plan. To ensure compliance, all utilities were required to submit their vulnerability assessments and emergency response plans to the US Environmental Protection Agency. These deadlines have been met in the NCR. Some wastewater utilities also conducted vulnerability assessments during this period. For example, the Washington Suburban Sanitary Commission, which serves 1.6 million customers in the NCR, conducted a full vulnerability assessment of its wastewater system simultaneously with its water system. Other wastewater utilities in the NCR have also conducted vulnerability assessments and have completed or are engaged in revising emergency response plans.

2.2 Availability of Appropriate Tools

Appropriate tools are available and have been used. Also, tools for small and large systems have been developed and are available. However, many of these tools focus more on the physical security of the system than on the people/institution or information subsystems, and consideration of cross-sector vulnerabilities has been limited.

Various tools have been proposed and/or developed to support vulnerability assessments and/or risk management regarding the water sector. Because vulnerability assessments were federally mandated to be completed by all water suppliers serving more than 3,300 customers prior to July 2004, there has been substantial experience using these tools in the water sector.

Most of the vulnerability assessment tools that have been developed include some consideration of cross-sector impacts, yet they are highly limited in addressing these cross-sector effects.

Vulnerability assessment is only one phase of a larger risk management process. In this process, an owner, operator or stakeholder of an infrastructure facility attempts to: identify threats, evaluate the consequences of the threat if it were to succeed, identify the vulnerabilities in the

system, and evaluate the risk associated with the threat. Based on all of these, a risk reduction plan is then formulated. The goal is to reduce the vulnerabilities and to reduce risk. Next, the plan is implemented. Then, the process is repeated to ensure that in a changing environment, new threats, vulnerabilities, and risks are identified, considered, and incorporated into the risk reduction plan.

An overall risk management strategy requires: identification of various threats to the sector, a method to measure the effects if that threat were to succeed, and an assessment of the probability of the threat succeeding. These can be used to compute the risk or expected value of the consequences of the threat, and if the whole array of possible threats is identified, an overall risk or expected value of consequences of all threats can be calculated. If a particular vulnerability is reduced (e.g. a fence is put around a pump house), then this process and calculation can be repeated to find the improvement or reduction in risk. Hence, a determination of whether the risk reduction warrants the change in vulnerability and cost of risk reduction action can then be made, considering the cost of the improvement.

Although several vulnerability assessment tools were developed for the water sector, two vulnerability assessment/risk management (VA/RM) tools are principally used in the water sector: the Risk Assessment Methodology for Water utilities (RAM-W), and the Vulnerability Self-Assessment Tool (VSAT). A brief review of RAM-W, VSAT, and other assessment tools is provided below.

RAM-W and VSAT are used extensively in the water sector for three principal reasons:

1. Quality: both were developed in cooperation with various water sector professional organizations, with funding from EPA.
2. Availability: both were available in time for water utilities to use to meet the deadline for submission of their vulnerability assessments.
3. Expertise: these tools included training by consultants for those utilities who required assistance to complete their vulnerability assessments by the deadline.

Vulnerability assessment tools require substantial inputs, some of which are difficult or impossible to provide accurately. These inputs include information about the physical system and its components, and may also include information about the people, information technology system, customers, and suppliers of the utility. Collecting and entering this information may be a significant task. In addition, these tools require identification of threats and the probability or relative likelihood of these threats. Some of these are easy to identify and estimate because there is some history of accidents occurring; however, identification of all the different ways that a disgruntled insider or organized outsider can threaten a system is difficult, and the probabilities that these threats will occur are difficult or impossible to estimate.

In cooperation with the EPA and various water sector professional organizations like the American Water Works Association Research Foundation, Sandia National Laboratory developed the RAM-W tool. Sandia is a Department of Energy National Laboratory and has a long history of risk assessment activities in the nuclear industry; they used this expertise to design a software tool that was appropriate to the water sector. RAM-W is designed to assist water utilities to assess the risks associated with vandals, terrorists, insiders, computer hackers, and others. The approach uses comparative analysis and relative rankings to assess which vulnerabilities are most critical. The tool requires significant data inputs and expertise to

perform an analysis. Virtually all large water suppliers nationwide, and all three of the large suppliers in the NCR, used RAM-W to comply with the federal mandate.

In collaboration with two consulting firms and with EPA funding, the Association of Metropolitan Sewerage Agencies (AMSA) developed VSAT, which is the other tool used extensively for vulnerability assessments. VSAT incorporates eight steps:

1. Asset categorization and identification
2. Criticality
3. Existing countermeasures
4. Vulnerability rating
5. Risk level
6. Risk acceptability
7. Identify and estimate cost of risk mitigation
8. Business continuity plan

This tool also requires significant data inputs. VSAT identifies qualitative risks; it supports users to prepare for incidents; and prepares users to respond and recover from them. Moreover, this tool can support water utilities that serve any number of customers. Several wastewater utilities in the NCR have used, or have attempted to use VSAT.

The National Rural Water Association and Association of State Drinking Water Administrators, in collaboration with the EPA, developed the Security Self-Assessment Guide for Small Water Systems.⁶ This tool is designed for systems that serve fewer than 3,300 people and is more rudimentary than RAM-W or VSAT. Further, it is designed for small systems that have limited professional staff and may also represent limited target appeal. Its focus is on the security of the physical system and comprises a simplistic set of yes/no questions. *No* responses require some action that may include contacting the state's primary drinking water agency for assistance.

The National Rural Water Association developed the Security and Emergency Management System (SEMS) Software Program.⁷ This software is an automated tool based on the Security Self-Assessment Guide for Small Water Systems; it is intended for small systems up to 10,000 customers.

The Northeast Rural Water and National Rural Water Associations developed the Security Self-Assessment Guide for Small Wastewater Systems.⁸ This guide is a companion to the Security Self-Assessment Guide for Small Water Systems and is organized similarly. Its focus is the physical security of wastewater systems.

The New England Water Works Association developed the Vulnerability Assessment Tool for Small Systems.⁹ This tool is self-guided and designed to be used by drinking water systems that serve 3,300 to 50,000 people.

2.2.1 Vulnerability assessments

All water suppliers with more than 3,300 customers have conducted vulnerability assessments. Many smaller systems have conducted assessments using simpler tools. Further, many wastewater utilities voluntarily conducted assessments.

2.2.2 Compliance-oriented policies and procedures

Because of a federal mandate, vulnerability assessments were conducted; however, security has always been a fundamental principle of the water sector. This infrastructure is perhaps the most reliable of the critical infrastructures historically. Hence, the explicit inclusion of malicious activity to disrupt the water sector is becoming part of the overall security framework for the sector, just as drought, hurricanes, accidents, etc., already are, and standard procedures and tools used in this sector are now incorporating this type of threat.

2.2.3 Risk management methods

Some tools explicitly include some form of risk management (RAM-W, VSAT), while most others do not. More information is provided in section 2.2.

2.3 *Extent of implementation of CIP risk-reduction programs or options*

The vulnerability assessment process in the NCR water sector has led directly to lists of projects to reduce vulnerabilities for individual utilities. In general, these projects have affected the budgeting process. Utilities consider these projects for at least two reasons: (1) they take their mandate to provide highly reliable service seriously; and (2) they do not want to leave identified vulnerabilities unaddressed.

In response to the vulnerability assessments already conducted, significant allocations have been made to reduce vulnerabilities and risk. Evidently, the results of the vulnerability assessments were taken seriously. In some cases, budgeted amounts are large; in one case, close to \$100M was budgeted to address items identified through the vulnerability assessment process. In another case, a utility ranked the list of proposed projects beginning with largest relative-risk-reduction per unit cost. Relative-risk-reduction is a term derived from the RAM-W process that is intended as a surrogate for actual risk reduction; however, the units of relative-risk or relative-risk-reduction are not dollars but are without assigned units and are designed to support pair-wise comparisons. Those projects that showed large relative-risk-reduction per unit cost were considered obvious funding opportunities (“no-brainers” in the parlance of the utility). Accordingly, those with very small relative-risk-reduction per unit cost were considered low on the funding priority list, and probably would not receive funding; logically, those projects between these two extremes represented the “hard decisions.”

2.4 *Extent of evaluation of CIP effectiveness*

Evaluating the extent of effectiveness is a difficult issue, but can be divided into two parts. First, consider the quality or effectiveness of the vulnerability assessments that were already conducted. All evidence supports the importance placed on these efforts by the utilities, and the desire to perform them well. However, the time limitation imposed by federal law required the assessments to be completed very quickly, which may have degraded the quality of the final reports.

Second, knowledge of the vulnerabilities identified through the assessment process must be protected. The security of the vulnerability assessment reports is important. This is evident because the EPA is required to store reports in a secure facility with armed guards, and only a select group of officials with appropriate security clearance is allowed to view them. Therefore,

it is difficult to judge the extent to which subsequent resource allocations to reduce vulnerabilities and risks were effective.

It is likely that vulnerability assessments will become a part of utilities' planning process, yet there is no current statutory requirement that additional assessments be conducted.

3. Developing Risk Reduction Programs and Processes

3.1 Risk Reduction Project and Investment Recommendations

3.1.1 Tools and decision processes

Improve tools for future use for water supply systems: RAM-W was used by most utilities, and all large utilities, conducting vulnerability assessments. The choice of RAM-W was based largely on its availability because large water suppliers were essentially given a six-month window to conduct the assessment. Although, RAM-W was available, it was found to be lacking in certain key areas. For instance, it requires the identification of a utility's most serious threat scenario. The tool also requires some estimate of the probability of various types of attack, information which is often unknown or unknowable by a utility. RAM-W requires an enormous amount of data (consider a spreadsheet with 500,000 cells as required by one utility).

Additionally, the treatment of interdependencies between infrastructure systems is limited; in particular, assessments focus on physical facilities, hardware, existing policies and people. Finally, RAM-W uses a relative-risk methodology instead of an absolute-risk methodology. Other vulnerability assessment tools also have limitations. Yet with the benefit of the last two years experience, it is possible to develop more robust tools that better address this problem.

Improve tools for future use for wastewater systems: Wastewater systems are typically several years behind water supply systems in the conduct of vulnerability assessments, preparation of emergency response plans, and overall risk management. Therefore, the opportunity exists to improve the tools available based on the experience so far.

3.1.2 Tactical steps for immediate benefit (compliance-oriented policies and procedures)

Improve communications between the water sector and intelligence and law enforcement, especially at the federal level: One step required in the vulnerability assessments is to identify the suite of threats and their probability of occurrence. Threats from vandals or a disgruntled current or former employee, who has insider knowledge and perhaps access, are more common and the utility typically has some experience with these types of threats. However, utilities do not typically have experience with organized outsiders (terrorists) posing a threat. They must rely on the FBI or other agencies to provide them with credible information if they are to conduct a meaningful assessment. The quality of communication, especially with federal law enforcement agencies that would track terrorist activity, needs improvement if the utilities are to incorporate this information in the assessments.

3.1.3 Strategic steps for long-term benefit (risk management-oriented investment and operating decisions)

Institute a regular schedule of risk assessment/reduction: This should be a part of a three step risk management process with: determination of current risks through a risk assessment, production of a risk management plan to reduce risk, and implementation of the risk reduction

plan. To ensure that risk is managed as the situation evolves over time, periodic repeats of this three step process are needed.

Provide an effective mechanism for funding risk reduction that protects sensitive information about vulnerabilities from public disclosure: Security vulnerabilities create a special funding problem. In many cases, water and wastewater utilities are overseen by a public or quasi-public entity, which often requires public disclosure and discussion of any funds that are to be spent by the utility. This public disclosure of vulnerabilities is precisely what is to be avoided if the goal is to reduce risk at these utilities. Therefore, the funding mechanism to eliminate vulnerabilities may need to differ from the normal funding process.

Provide a source of funding for risk reduction: If normal funding sources are not appropriate to fund security issues, then alternative sources (e.g. grants from the federal government) should be found.

Improve communications with threat-identifying agencies: It is difficult for water sector utilities to maintain an appropriate posture toward threats without current, relevant information from threat-identifying agencies such as the FBI.

3.2 Specific Recommendations for Sector-Level Governance

Develop industry standards for risk management: Water sector officials prefer not to have additional government regulation, but would rather have guidelines and standards set through professional organizations, such as the American Water Works Association, the Association of Metropolitan Sewerage Agencies, the Water Environment Federation, and the American Society of Civil Engineers. These organizations have a long history of working with relevant government agencies and the public in designing appropriate, effective guidelines or standards of conduct and performance in the water sector. Moreover, they have been working on this issue, have made progress, will continue to do so, and should be able to provide the requisite guidance in this area.

Develop practical measures of effectiveness: Measuring effectiveness is particularly difficult in the water sector. Two examples illustrate this problem. First, with the need to limit the disclosure of information about vulnerabilities in the water sector, it is difficult to debate publicly on the effectiveness of mitigation policies (see section 3.1 for more details). Consequently, it is difficult to collect information about what vulnerabilities and risks existed, what funds were allocated to reduce these risks, and whether the actions taken actually succeeded in reducing the risks. Second, the current vulnerability assessment and risk management (VA/RM) tools require the user to select the most important threats (e.g. disgruntled employees, organized terrorists, vandals, etc.). Choosing threats dramatically influences the VA/RM by the threat selection. If the VA/RM were conducted today, assuming that terrorists are the largest problem, then certain vulnerabilities and risks will be identified, and those may be reduced through action of the utility. If two years from now, another VA/RM is conducted, and this time a disgruntled employee is identified as the key threat, then it may appear that the previous assessment highlighted the wrong vulnerabilities, and that money was spent unwisely. However, this is not necessarily the case. Therefore, it is essential that mechanisms for measuring the effectiveness of the risk management process be developed.

3.3 Specific Recommendations Addressing Dependencies

3.3.1 Intra-sectoral

Undertake the recommendations already made above in section 3.1

Develop methods and tools to address dependencies across water utilities: The National Capital Region (NCR) includes multiple water and wastewater utilities in multiple political jurisdictions. Even for those that are not physically connected, there is still an important dependency. One case of intra-sectoral dependency can be illustrated by considering the three major water suppliers in the region: Washington Suburban Sanitary Commission (WSSC) in Maryland, Fairfax Water (FW) in Virginia, and Washington Aqueduct Division (WAD) for the District of Columbia and some parts of Virginia. Suppose that one of these utilities had a much lower risk than the other two because it had funded projects to eliminate or mitigate risks. Would the NCR be more or less vulnerable? It is clear that the one utility is more secure, but if a successful attack is made against either of the other two, then several things may occur:

- People served by the attacked utility will react, and may move to areas served by the other utilities thereby increasing demands on these utilities.
- Some people served by the other utilities will ignore the fact that their utilities state they are secure, and these people may change their behavior adversely affecting their utility.
- Demands for assistance from the affected utility may arise, and if that assistance is provided, it may degrade the security of the other systems.

In all cases, confidence in all water supplies will decline, perhaps significantly. Therefore, it is important not only for each utility to manage its risk, but also for the risk of the collection of water utilities to be considered and managed to achieve balanced preparedness.

3.3.2 Inter-sectoral

Improve tools to address inter-sectoral dependencies better: As mentioned in 3.1, one of the significant limitations of all the existing tools is the treatment of inter-sectoral dependencies. This is an especially difficult problem because the effort required to consider these is large and information is often unavailable or difficult to collect by the water sector utility.

Institute regular cross-sector tabletop exercises: Many of the utilities in the National Capital Region have participated in tabletop exercises in the past. These exercises may be useful in identifying interdependencies and starting the process to deal with them.

3.3.3 Regional

Develop methods and tools to address dependencies across water utilities: This recommendation has already been included in section 3.3.1.

Institute regular cross-sector tabletop exercises: This recommendation has already been included in section 3.3.2.

3.4 Measuring Effectiveness

Measuring effectiveness of risk management in the water sector is difficult. A key recommendation in section 3.3.1 addresses this problem, and more details are provided in section 2.4.

3.5 *Managing Continuous Improvement*

Managing continuous improvement is directly related to development of a security analysis process, and development of measures of effectiveness. This process includes a three step continuous cycle: risk assessment, risk reduction plan, and implementation of the risk reduction plan. The implementation of the risk reduction plan is then followed by the risk assessment and the cycle continues, although it is not intended that the three steps are completely sequential and that the next step must wait for completion of the preceding step. Already mentioned in section 3.1.1, but important to reiterate, is that regular scheduling of the first step in the cycle be considered every two or three years.

4. Conclusions

The water sector is clearly a critical infrastructure. In fact, it is one of the few critical infrastructures whose service providers have already met federal requirements to conduct a thorough vulnerability assessment and subsequently to develop an emergency response plan. Although this requirement was imposed only on water supply utilities, many wastewater utilities completed both steps as well.

A variety of tools to support the vulnerability assessment in the water sector were developed and used. These tools range from highly sophisticated to relatively simple, and from appropriate for large systems (> 50,000 people) to appropriate for small ones (< 10,000 people). These tools typically focus on the water sector and each has limitations.

To date, the experience of incorporating terrorist threats to the water sector has been remarkably good. Vulnerability assessments that include terrorist threats were completed by water supply utilities and are either completed, underway, or under consideration by wastewater utilities. Importantly, vulnerabilities were identified and funds allocated to reduce these risks. The professional organizations associated with the water sector are actively engaged in incorporating this threat into standard practice. Despite this good news, significant short-term and long-term challenges exist.

4.1 *Challenges*

The challenges faced by the water sector with regard to vulnerability assessments and risk management are numerous and driven by three factors: the nature of water systems, the setting of the NCR, and the need for information security. A number of recommendations were made in section 3. These represent the challenges for the future. In summary, they are:

- Improve risk management tools for future use by water supply and wastewater systems.
- Improve communication between the water sector and threat-identifying, law enforcement agencies.
- Institute a regular schedule of risk assessments/reduction as part of an overall risk management plan.
- Provide an effective mechanism for funding risk reduction that protects sensitive information about vulnerabilities from public disclosure.
- Develop industry standards for risk management.
- Develop practical measures of effectiveness in reducing risk.
- Develop methods and tools to address dependencies across water utilities within the NCR.
- Improve tools to address inter-sectoral dependencies better.

- Institute regular cross-sector tabletop exercises.

4.2 *Future Work*

The recommendations call for significant efforts by individual water utilities; professional organizations focused on the water sector; local, state and federal government; universities; and consultants. Only through coordinated action by all these groups can real progress be made in meeting the challenges outlined above.

Appendix A: Methodology for data gathering and analysis

Three steps comprise the data gathering exercise.

1. A literature review of previous work on risk management and the water sector was conducted. Refer to bibliography in Appendix B.
2. Discussions with various experts in the National Capital Region were held. These experts were from various utilities, relevant professional trade associations, and government agencies. The discussions were in a variety of forums. Some were held at the offices of the experts. In some cases, a group of experts met together in a workshop setting. Others participated in a semester-long course at George Mason on Water and Wastewater System Security.
3. A review of general and sector-specific vulnerability assessment tools and processes was conducted.

Discussions with water sector experts from the National Capital Region focused on the following points:

- What has been the experience with vulnerability assessments in the water infrastructure system within the NCR?
- Have they been conducted? If so, what methodology?
- Were they useful? How were they useful?
- What were the problems associated with the VAs? Why?

What should be done to improve vulnerability assessments now and in the future?

- Institutional/people issues
- Physical system issues
- Information issues
- Short-term concerns versus long term concerns
- Limited scope versus the world
- Intra-dependencies (i.e. dependencies within the water sector)
- Interdependencies: What are the important interdependencies? How long can you operate with a failure/loss of one of your inputs (e.g. chemicals delivered by truck)? How important is each input; can these be ranked or scored? What are your outputs and who are your customers; how important is each of these and can you rank or score them?
- Static assessment versus dynamic, continuous assessment
- Funding for improved security
- Communications with other infrastructures
- Dealing with the rest of the world during a crisis

What is needed to facilitate these improvements?

- What should you—the water infrastructure—be doing to improve security, and what can be done to ensure that these same issues are raised by other water infrastructure providers?
- What should others outside the water infrastructure—other infrastructure providers, educational institutions, regulatory agencies, funding agencies, etc.—be doing to improve the security of the water sector? What can be done to ensure that these actions are considered or taken?

Leading discussions for this research project:

- Professor Gregory B. Baecher, University of Maryland
- Professor Thomas J. Grizzard, Jr., Virginia Tech
- Professor Mark H. Houck, George Mason University
- Mr. Wayne S. Williams, Jr., George Mason University

Some of the organizations represented in these discussions include:

- Fairfax Water serves 1.6 M Virginians and is by far the largest water supplier in northern Virginia.
- Washington Aqueduct Division (WAD) of the US Army Corps of Engineers wholesales treated water to the District of Columbia Water and Sewer Authority.
- District of Columbia Water and Sewer Authority (DCWASA) is the water retailer and wastewater utility for the District.
- Metropolitan Washington Council of Governments (WashCOG) is instrumental in working for and with the various governmental jurisdictions in the greater metropolitan area. They have a lengthy history of working on environmental and water resources issues directly related to water and wastewater.
- County of Fairfax, Wastewater Treatment Division is responsible for the collection, treatment and disposal of wastewater in Fairfax County, Virginia.
- Washington Suburban Sanitary Commission (WSSC) is the water and wastewater utility for Prince Georges and Montgomery Counties in Maryland.
- American Water Works Association (AWWA) has been the lead professional association active in developing the vulnerability assessment tool most commonly used by water supply utilities.
- City of Manassas, Water and Sewer Department is responsible for water and wastewater for the City of Manassas.
- Loudoun County Sanitation Authority is responsible for the wastewater system in Loudoun County, Virginia.
- Prince William County Service Authority is responsible for providing a comprehensive county-wide water and sewer system.
- Alexandria Sanitation Authority is responsible for the wastewater system that serves the City of Alexandria and parts of Fairfax County, Virginia.

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Appendix C: Appreciation

Many individuals contributed to this project by participation in discussions with project staff, or participation in the course on water and wastewater system security at George Mason University in Spring 2005. The generous and dedicated individuals listed below deserve special thanks for their assistance. However, this report is the sole work of its authors, and any errors, omissions, or opinions rest solely with them.

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Laurel Shultzaberger, Engineer II—Environmental Management System Coordinator, Fairfax County Wastewater

Lloyd Stowe, Director of Operations, Washington Aqueduct

Richard C. Thoesen, Deputy General Manager, Loudoun County Sanitation Authority

Appendix D: Endnotes

¹ Service Area for Washington Metropolitan Region Water Suppliers and Distributors, Metropolitan Washington Council of Governments, http://www.mwcog.org/environment/water/watersupply/supply_map.asp, 2004.

² Metropolitan Water Region Water Supply Agencies, Metropolitan Washington Council of Governments, <http://www.mwcog.org/environment/water/watersupply/suppliers.asp>, 2004.

³ Water Distributors, Metropolitan Washington Council of Governments, <http://www.mwcog.org/environment/water/watersupply/distributors.asp>, 2004

⁴ “The Clinton Administration’s Policy on Critical Infrastructure Protection: Presidential Decision Directive 63”, White Paper, May 22, 1998.

⁵ The 13 nationally recognized critical infrastructure sectors are: agriculture, banking and finance, chemicals and hazardous materials, defense industrial base, emergency services, energy, food, government, information technology and telecommunications, postal and shipping, public health and healthcare, transportation, and drinking water and water treatment systems.

⁶ Security Self-Assessment Guide for Small Water Systems, Association of State Drinking Water Administrators and National Rural Water Association, http://www.doh.wa.gov/ehp/dw/Security/Security_Vulnerability.pdf, May, 2002.

⁷ Security and Emergency Management System (SEMS) Software Program, National Rural Water Association, <http://www.vulnerabilityassessment.org/>, November, 2003.

⁸ Security Self-Assessment Guide for Small Wastewater Systems, Northeast Rural Water Association and National Rural Water Association, http://www.neruralwater.org/downloads/NeRWA_Wastewater_Vulnerability_AssessmentB.pdf, February, 2004.

⁹ NEWWA ASSET Vulnerability Assessment Tool for Small Systems, New England Water Works Association, http://www.newwa.org/asset_software/index.php, 2005.

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