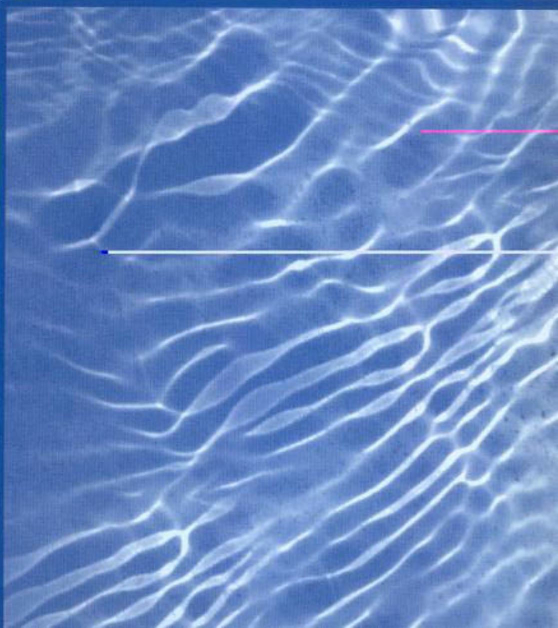
A Review of the EPA Water Security Research and Technical Support Action Plan



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A Review of the EPA Water Security Research and Technical Support Action Plan

Panel on Water System Security Research

Water Science and Technology Board

Division on Earth and Life Studies

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PANEL ON WATER SYSTEM SECURITY RESEARCH[1]

GARRET P. WESTERHOFF, *Chair,* Malcolm Pirnie, Inc., White Plains, NY
GREGORY B. BAECHER, University of Maryland, College Park
JOSEPH A. COTRUVO, Joseph Cotruvo and Associates, Washington, D.C.
GUNTHER F. CRAUN, Gunther F. Craun and Associates, Staunton, VA
CHARLES N. HAAS, Drexel University, Philadelphia
JAMES B. MCDANIEL, Los Angeles Department of Water and Power, Los Angeles
CHARLES R. O'MELIA, Johns Hopkins University, Baltimore, MD
DAVID M. OZONOFF, Boston University School of Public Health, Boston
KERRY KIRK PFLUGH, New Jersey Department of Environmental Protection, Trenton
DAVID A. RECKHOW, University of Massachusetts, Amherst
DAVID P. SPATH, California Department of Health Services, Sacramento
MARYLYNN V. YATES, University of California, Riverside

Consultant to the Panel

DAVID R. SIBURG, Kitsap Public Utility District, Poulsbo, WA

National Research Council Staff

STEPHANIE E. JOHNSON, Study Director
LAURA J. EHLERS, Senior Staff Officer
DOROTHY K. WEIR, Project Assistant

[1] The activities of the panel were overseen and supported by the NRC's Water Science and Technology Board (see Appendix B).

Preface

Water utilities have a long history of planning in preparation for emergencies, particularly natural disasters. But contingency and emergency planning has taken on a new dimension with current concern about potential threats to water system security. The range of crises that have become plausible has expanded, and utilities now are considering more robust security procedures and emergency plans than they have historically had in place. When it comes to ensuring a water system's security, few utilities, regardless of size or geographic location, can function independently. The nation's water utilities and agencies have an urgent need for the knowledge, information, and guidance related to water security, but they will need more than research and technical support if they are to effectively improve security. To achieve the highest possible level of security, utilities need to carry out emergency preparation, response, and recovery planning in conjunction with other agencies.

September 11, 2001 created awareness of our country's vulnerabilities, led to a reassessment of our homeland security measures, and ultimately instigated the production of more effective contingency plans. One manifestation of this productivity is the *Water Security Research and Technical Support Action Plan* (Action Plan), prepared by the Environmental Protection Agency (EPA) to address current water security issues. The following report was produced by the National Research Council's (NRC) Panel on Water System Security Research. The panel was organized as part of a broader NRC Review of EPA Homeland Security Efforts in the areas of water systems and safe buildings in response to an EPA request.

In order to provide timely recommendations and guidance to the EPA, the panel conducted a fast-track review of the Action Plan in two stages, with each stage resulting in the production of a short report. Overall, the panel was impressed by the EPA's dedication to the development of a comprehensive and useful plan in support of the nation's water security needs. The first stage of the panel's review determined whether the EPA Action Plan adequately identified research and technical support needs in the area of water system security. These findings are included as Part I of this publication, which was originally released in July 2003. The next stage of the panel's review examined the Action Plan in greater detail and assessed the specific research projects and their prioritization as presented in the Action Plan. These findings are included as Part II, which was originally released in October 2003. While these two reports were produced separately, they are intended to be read together and, therefore, are bound together here.

The NRC composed a panel that represents a range of scientific, technical, public policy, utility management, and social science expertise. The areas of water system management, operations, and vulnerabilities; drinking water and wastewater chemistry; drinking water and wastewater microbiology; microbial and chemical risk assessment; risk communication; and water treatment and decontamination are all included in the panel members' areas of specialization. The findings of the panel are based on their own expertise as well as discussions with the creators of the EPA Action Plan.

I would like to thank and express my appreciation to our panel members for recognizing the high priority of this effort and for dedicating their time and talents to produce this report on a fast-track schedule. I would also like to acknowledge consultant David Siburg for sharing his expertise in the area of small water systems. We were guided by the Water Science and Technology Board (WSTB) and its director Stephen Parker. Without the extraordinary help of our study director, Stephanie Johnson who set the pace, focus, and agenda for our work, maintained contact with the study sponsor, and acted as liaison to ensure compliance with NRC policies, this effort would not have been possible. Individual schedules of the panel members spread them across the globe as this report came together. Stephanie worked tirelessly to compose draft text from several separate pieces which panel members could then review, making sure that the final product represented our best thinking and advice. Ably helping Stephanie were senior staff officer Laura Ehlers, who assisted the project in a supervisory role and contributed substantially to the report's development, and Dorothy Weir, who as our project assistant was responsible for meeting logistics, research assistance, and editorial tasks.

The panel also appreciates the assistance of Jon Herrmann and Alan Hais, EPA Office of Research and Development and Hiba Shukairy and Grace Robiou, EPA Office of Water who were extremely helpful in providing information on EPA's water security research efforts to panel members and WSTB staff to assure the creation of a useful report. In addition, we also thank those who made presentations, offered their professional insights, entertained questions, and contributed to discussions during the panel meeting. These experts include Cynthia Dougherty and Janet Pawlukiewicz from the EPA Office of Water, Paul Gilman and Timothy Oppelt from the EPA Office of Research and Development, and John Vitko, Department of Homeland Security.

This report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise in accordance with the procedures approved by the NRC's Report Review Committee. The views and opinions expressed by the reviewers were assumed to be those of the individual reviewers and not their affiliated agencies. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. Parts I and II of this report were reviewed independently of one another and by separate reviewers.

We wish to thank the following individuals for their review of Part I of this report: Lewis M. Branscomb, Harvard University; Sue B. Clark, Washington State University; Yacov Y. Haimes, University of Virginia; Rebecca T. Parkin, The George Washington

University; Brian L. Ramaley, Newport News Waterworks; and David R. Siburg, Kitsap Public Utility District.

We also thank the following individuals for their review of Part II of the report: Lieutenant Colonel Patrick Bettane, Israel Defense Forces; Anne K. Camper, Montana State University; A. Russell Flegal, University of California, Santa Cruz; Peter H. Gleick, Pacific Institute for Studies in Development, Environment, and Security; Anna K. Harding, Oregon State University; Nancy G. Love, Virginia Polytechnic Institute and State University; Brian L. Ramaley, Newport News Waterworks; Deborah L. Swackhamer, University of Minnesota; John S. Young, The Hebrew University of Jerusalem.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The reviews of this report were overseen by Robert A. Frosch, Harvard University. Appointed by the National Research Council, he was responsible for making certain that an independent examination of each report was carefully carried out in accordance with the institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring panel and the institution.

Garret Westerhoff
Chair

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Part I

Overarching Issues and Research and Technical Support Needs Assessment

Executive Summary

The consequences of a terrorist attack on the nation's water supply to public health, national security, and the nation's economic services could be significant, and the sad events of September 11, 2001 have heightened concerns regarding the vulnerabilities of public water systems to deliberate attack. The Environmental Protection Agency (EPA) currently bears lead responsibilities for protecting water systems from terrorist threats, and they are currently working in partnership with federal, state, and local government agencies, water and wastewater utilities, and professional associations to ensure safe water supplies. To support their water security responsibilities, the EPA recently developed the *Water Security Research and Technical Support Action Plan* (Action Plan), which identifies critical security issues for drinking water and wastewater, outlines research and technical support needs within these issues, and presents a prioritized list of research and technical support projects to address these needs.

The National Research Council (NRC) was tasked to review the EPA *Water Security Research and Technical Support Action Plan* and provide an initial assessment according to the following questions:

- Has the Action Plan completely and accurately identified important issues and needs in the water security arena? If not, what issues and needs should be added or removed?
- Overall, what changes to the Action Plan are recommended to improve its presentation in terms of content and structure so as to more clearly convey the water security research and technical support program that is described?

This report was written by the Panel on Water System Security Research, organized under the NRC's Water Science and Technology Board. A subsequent report of the panel (see Part II) reviews the individual projects identified in the Action Plan and evaluates their prioritization and timing.

OVERARCHING ISSUES

The Action Plan contains an extensive list of drinking water and wastewater research and technical support needs and associated projects that cover many of the critical water security issues. However, the projects *will not*, in themselves, result in improved protection of the nation's drinking water and wastewater systems. Improved protection will only result when the information and knowledge obtained from the projects are integrated into funded water security plans that are implemented by collaborations of private and public organizations.

Figure ES-1 provides a suggested framework for how the individual research and technical support projects within the Action Plan should contribute to improved water security. More specifically, the Action Plan encompasses data collection and assessments, database creation, new science and research, tools and methods development, and improved communications. Information from these activities, along with play books mentioned in the Action Plan, should be woven together into a comprehensive guidance document (the Integrated Water Security Prevention and Response Guidance) that would direct a utility through available prevention strategies, information resources, communication planning, and response and recovery actions (including detection and monitoring, risk assessment, and decontamination). With the support of this guidance, each water organization can work with regional agencies to develop specific water security implementation plans based on its vulnerability assessment and any unique circumstances. The Action Plan needs to consider this broader context for improving water security.

The Action Plan is silent on the financial resources required to complete the proposed research and technical support projects and to implement the countermeasures needed to

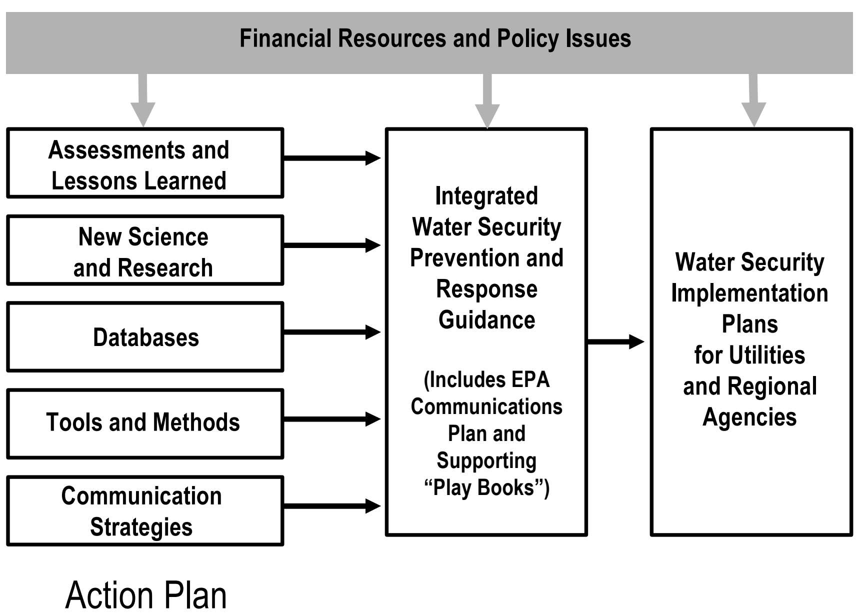

Figure ES-1. Example framework for depicting the contributions of the *Water Security Research and Technical Support Action Plan* to the broader needs for protecting the nation's water systems (including drinking water and wastewater).

improve water security. The EPA should attempt to quantify the benefits and costs accruing to the proposed research and technical support projects, and further study should be directed to better acknowledging business-enabling dual-use benefits of security enhancements. More emphasis is needed on communicating the value of water and increased water system security with the public, rate regulators, and local elected and appointed officials, because increased rate structures may be needed to create the necessary financial resources to implement such countermeasures.

The rapidity and high stakes of potential terrorist attacks on water supplies suggest that the EPA should pay particular attention to improving interagency coordination and to determining the roles, capabilities, and training of other agencies with regard to water security. The special circumstances of a purposeful attack will require that the roles and responsibilities of various relevant parties (including law enforcement, FBI, and environmental and public health authorities) be worked out in detail ahead of time. The use of field and table-top exercises is necessary to help utilities and federal, state and local agencies develop improved coordination and response and recovery strategies.

Developing an effective communication strategy that meets the needs of the broad range of stakeholders, including response organizations, water organizations and utilities, public health agencies, and the media, while addressing security concerns, should be among the highest priorities for the EPA. Criteria for classifying and distributing sensitive information should be developed that recognize the need for local and state agencies and other critical players to have access to water security information. Consideration needs to be made as to how the water security information databases will be accessed, who will be granted access, who will control and update the databases, and how the databases will be integrated with current systems. The EPA should thoroughly examine the consequences of various levels of information security and fund formal studies on the risks and benefits of widely transmitting water security data (including involvement of a wider research community). The dangers of keeping information too closely guarded may, in fact, be much greater than the dangers of informing an ill-intentioned person.

The panel recognizes the need to act quickly to address issues of water security. The EPA strategy in the Action Plan to emphasize immediate usability and first approximations is a sound one, but certain research or technological advances may only be accomplished through long-term research investments. The Action Plan should clarify which of its research activities are short-term, applied efforts and highlight long-term research needs, so that a collaboration of agencies could work to ensure that substantive, mission-oriented research questions in water security are not overlooked.

REVIEW OF RESEARCH AND TECHNICAL SUPPORT NEEDS IDENTIFIED IN THE ACTION PLAN

The drinking water research needs within the Action Plan are lengthy, detailed, and if met would go a long way toward providing information, tools, and methods necessary to help water managers respond appropriately to threats or attacks on water supply systems. Considerably less information is presented in the Action Plan regarding threats to the nation's wastewater infrastructure, which made it difficult to assess the adequacy of the proposed research needs.

The following summarizes the revisions and changes in emphasis suggested to the research and technical support needs identified in the Action Plan. These rewritten needs are discussed in detail in Chapter 3.

Protecting Physical and Cyber Infrastructure

The EPA Action Plan identifies three important needs that, with some changes in emphasis, would address most of the major research and technical support challenges related to protecting physical and cyber infrastructure. One significant gap is the need for assessments of costs and benefits associated with various countermeasures. These suggestions are included in the following rewritten needs:

- An updated identification and prioritization of physical threats to and vulnerabilities of drinking water infrastructure, taking into account the substantial information gained from the vulnerability assessments of the nation's larger water systems and on other vulnerability and consequence assessments of water systems and their cyber infrastructure, along with improved means to assess these vulnerabilities.
- A thorough understanding and documentation of the consequences of physical or cyber attacks on the drinking water supply sources and infrastructure, including the evaluation and testing of computational models and decision science.
- A suite of countermeasures to prevent, or mitigate, the effects of physical and cyber attacks on water infrastructure, including improved design of Supervisory Control and Data Acquisition (SCADA) and water systems to reduce vulnerabilities.
- Assessments of costs and benefits (direct and indirect) associated with various countermeasures; and development of programs to assist implementing organizations (including water utilities) in communicating with the public, customers, rate regulators, and local elected and appointed officials regarding the value of water, increased water system security, and increased rate structures to create the necessary financial resources to implement such countermeasures.

Contaminant Identification

Several suggestions and modifications in emphasis are suggested to improve the four research and technical support needs delineated in the Action Plan for the issue of contaminant identification. The EPA should carefully consider the scope of the tasks identified here, so that the data gathering efforts (e.g., the contaminant database and the surrogate/simulant database) focus on the highest priority and most useful information in order to conserve time and resources. Determining contaminant threat scenarios was considered a significant need that should be separated from the development of a list of water security contaminants. The following rewritten needs are suggested:

- A list of contaminants that might be used to destroy, disrupt, or disable drinking water supplies and systems. This list would be linked to relevant associated contaminant information (stored in the database mentioned below), which could be used to prioritize or group the individual contaminants, as users of the list deem appropriate.

- An assessment of threat scenarios which could result in harmful exposure of the public or utility personnel to drinking water contaminants.
- A contaminant database for consultation by approved individuals and organizations that describes critically important information on contaminants with the potential to harm drinking water supplies and systems.
- Identification of a few well-selected surrogates or simulants for use in testing and evaluating fate and transport characteristics and treatment technologies for priority contaminants.
- Methods and means to securely maintain and, when appropriate, transmit information on contaminants and threat scenarios applicable to drinking water supplies and systems.

Contaminant Monitoring and Analysis

The Action Plan includes a broad set of seven needs on the issue of contaminant monitoring and analysis; yet, depending on interpretation, there may be some gaps. Improved guidelines for sampling, careful quality assurance and quality control procedures, and geographic and liability concerns limiting effective laboratory response are some of the issues that were not adequately addressed in the Action Plan. These and other suggestions are incorporated in the following rewritten needs:

- A "play book" for sampling and analytical response to contaminant threats and attacks on water supplies and systems, including protocols for identifying "unknown" contaminants that will serve as a vital component of an overall integrated response guidance.
- Improved analytical hardware and associated field and laboratory analysis methodologies (including generic simple techniques and laboratory-based, off-line and real-time monitoring technologies) for biological, chemical, and radiological contaminants in water.
- Requirements for appropriate quality assurance and quality control (QA/QC) and sampling approaches in response to suspected biological, chemical, and radiological contamination events.
- Testing and evaluation of drinking water "Early Warning Systems" (EWSs) and EWSs from other sectors amenable to application in the water environment.
- An improved and expanded, tiered capability laboratory capacity to be fully prepared for effectively responding to threats or attacks on water.
- Training modules and evaluation exercises for analytical methodologies and monitoring systems.

Containment, Treatment, Decontamination, and Disposal

Four broad research and technical support needs were described in the Action Plan to address the issue of containment, treatment, decontamination, and disposal of contaminants in a water system. A few issues were overlooked in the identified needs of the Action Plan, such as the importance of training and input data for successful application of distribution system models to respond to water security threats and the value of current and traditional treatment technologies to address water security needs. The scope of the need to understand contaminant fate was considered excessively broad, and recommendations were made to narrow the scope so that contributions could be made within the time frame of the Action Plan. Several suggestions and changes in emphasis are noted in Chapter 3, which are summarized in the following rewritten needs:

- Improved distribution system models that can be used to more effectively protect drinking water in the event of deliberate contamination, which should consider not only technical improvements to such models, but also operator training to better use the models, the availability of information needed to run the models, and the dual-use benefits of model development.
- Improved understanding and documentation of the environmental fate of contaminants in source waters, within drinking water systems, and once they are released, focusing first on a literature review and then on either the identification of generic physical and chemical parameters that are predictive of contaminant behavior in water supply systems or on a small set of fate and transport paradigms for common threat scenarios.
- Technologies and treatment processes to achieve multiple goals, and effective disposal and/or treatment technologies for water and equipment that have been contaminated, including in-place conventional technologies, new preventive technologies, mobile technologies, and technologies that can mitigate contaminant spread through the distribution system.
- A methodology, approach, or guide for use in determining when a drinking water system is no longer contaminated and when it can be placed back into limited or unlimited service. (This need is one component, or "play book," within the overall response guidance.)

Contingency Planning and Infrastructure Interdependencies

The Action Plan outlines three research and technical support needs that with minor changes would substantially address the topic of contingency planning and infrastructure interdependencies. One overlooked technical support need is the consideration of contingencies for situations where the operating personnel for a water system might be incapacitated. The following four revised needs are suggested:

- Assessment of water supply alternatives for different types of drinking water systems in the United States (reflective of effects of size, type of supply, system design and type of distribution system), when the usual supply of water is not available.
- Testing and evaluation of improved technologies and approaches for providing supplies of water in the event of both long-term and short-term disruptions to drinking water systems. The evaluation of approaches should include customer preparedness and should assess the degree of reliability of the options.
- An improved understanding of water system interdependencies and the reliability of such interdependencies with other infrastructure sectors that are critical to national security.

- Explicit understanding of the role of failure of the "human subsystem" in water system operation, and the development of contingencies for responding to such eventualities.

Targeting Impacts on Human Health and Informing the Public about Risks

Five research and technical support needs are presented in the Action Plan to address the issues of human health impacts and risk communication. While these needs are quite comprehensive, several gaps are noted, such as the need for establishing a risk communication planning process. Overall, the assessment of current disease surveillance efforts and the discussion of frameworks for assessing and managing risks are significant weaknesses in this section. Suggestions are also presented to narrow the scope of work for some needs to the intended time frame. These suggestions are incorporated in the following rewritten needs:

- An improved understanding of contaminant exposure routes (not only direct ingestion but also dermal and inhalation exposures), and of the acute and chronic public health effects from contaminants in drinking water supplies and systems, which should focus on generic models for different large classes of agents.
- A health surveillance network to rapidly identify and help control a disease outbreak or other public health emergency associated with contaminated drinking water. This effort should be cognizant of active disease surveillance efforts already underway, the limitations of active disease surveillance, and the respective roles of the EPA and other public health agencies.
- An evaluation of the utility and validity of using non-traditional data sources (e.g., LD_{50}, Quantitative Structure Activity Relationship [QSAR]) for the derivation of acute and chronic toxicity values applied to water.
- A risk assessment/risk management framework for identifying the impact of decontamination/treatment options and the subsequent response. (This need is one component of the overall response guidance.)
- Methods and means to communicate threat risks to local communities and to respond to customers and the media in the case of an attack on drinking water systems, the success of which will depend upon the prior existence of an established relationship with communities that is the result of a detailed risk communication planning process.

Wastewater

The Action Plan presents a short overview of the extensive array of security issues facing the wastewater infrastructure. Although the human health consequences may be somewhat more indirect for threats on wastewater than in the case of drinking water systems, more thought should be given to the security of the nation's wastewater systems, and the interdependencies between drinking water and wastewater systems should be more carefully considered. Based on the panel's review of the information presented in the Action Plan, the following rewording of the needs is suggested:

- A thorough understanding and documentation of the possible threats to the nation's wastewater treatment and collection system infrastructure, including the interdependencies with drinking water systems and other critical infrastructure.
- An updated assessment of the possible health, safety and environmental risks related to potentially hazardous substances used by wastewater utilities or intentionally introduced into wastewater collection and treatment systems, or stormwater conveyance and treatment systems, including any impact on residuals management operations (sewage sludge).
- An assessment of the possible health, safety, and environmental risks related to potentially hazardous substances produced during response to security threats (e.g., decontamination materials and their byproducts) which may be discharged to sewer systems or stormwater conveyance systems.
- Improved intrusion monitoring and surveillance technologies to quickly notify wastewater utilities when these facilities or technologies are compromised by physical and cyber threats or chemical, biological, and radiological contaminants. (Note that some of this information may be transferred from knowledge gained while assessing drinking water systems.)
- Improved designs for wastewater systems to reduce vulnerability to physical threats and as a way to prevent or mitigate the effects of attacks on wastewater infrastructure.
- Enhanced prevention and response planning methods, including emergency response, contingency planning, and risk communication protocols and guidance for wastewater systems of varying types (size, geographic location, design). The potential for emergency relocation of discharge or alternative treatment should also be assessed.
- Methods and means to securely maintain and, when appropriate, transmit information on contaminants and threat scenarios applicable to wastewater systems.

Chapter 1

Introduction

The United States' water supplies are considered among the safest in the world because of unparalleled accomplishments with regard to water supply, treatment, and distribution. Over the last century, cities, states, the federal government, and private organizations have made substantial investments to provide safe and adequate supplies of water for use in homes, industry, agriculture, and more recently the environment. Advances in water treatment technologies have led to vast improvements in public health, virtually eliminating the most deadly waterborne diseases, including cholera and typhoid.

The sad events of September 11, 2001, however, have heightened concerns regarding the vulnerabilities of critical infrastructures, including the nation's water systems, to deliberate attack. There have been several documented plots against water supplies around the world: information regarding U.S. water supply systems has been found at terrorist sites overseas, and in 2002, Italian police intercepted a plan to inject cyanide into Rome's water supply system, which may have been targeted toward the U.S. Embassy (McGrory, 2002). The consequences of a terrorist attack on the water supply to public health, national security, and the nation's economic services could be significant. The country has learned from experience that it is not invulnerable to global or domestic terrorism, and efforts are currently underway to increase the security of the nation's water systems.

ROLE OF THE EPA IN HOMELAND SECURITY FOR WATER SYSTEMS

The Environmental Protection Agency (EPA) currently bears lead responsibilities for protecting water systems from attack (Office of Homeland Security, 2002), and they are working in partnership with the Department of Homeland Security, other federal, state, and local government agencies, water and wastewater utilities, and professional associations to ensure safe water supplies. The EPA's primarily role in water security is to serve as a resource by advancing water security research and technology and providing technical support for utilities and local and state agencies. The EPA held national-security-related responsibilities well before September 11, 2001, including their responsibility to "develop plans to ensure the availability of potable water after a national security incident" (Reagan, 1988). In 1995, the *United States Policy on Counterterrorism* required all federal agencies to plan for terrorist attacks and designated the EPA to provide environmental response support. In 1998, President Clinton identified water as one of the nation's critical infrastructures, and the EPA was assigned lead responsibility for protecting water from intentional attacks (Clinton, 1998).

In response to the September 11, 2001 terrorist attacks, several initiatives were introduced to strengthen water security. The EPA created the National Homeland Security Research Center within the Office of Research and Development, whose mission includes developing the scientific foundations and tools that can be used to respond to attacks on water systems. The EPA formed the Water Protection Task Force within the Office of Water to help the water sector assess their vulnerabilities, improve their security, utilize research findings and technology advancements, and respond effectively to possible terrorist attacks. In 2002, Congress passed the Public Health Security and Bioterrorism Preparedness and Response Act (Public Law No. 107-188), commonly referred to as the Bioterrorism Act, which mandated improvements in water security and created specific requirements and deadlines for both the EPA and water utilities. As part of the Bioterrorism Act, all water utilities serving over 3,300 people (representing approximately 90 percent of the population served by public water supplies) are required to complete a vulnerability assessment and prepare an emergency response plan that focuses on deliberate attacks upon water systems. The largest utilities completed these assessments in March 2003, and they are required to submit emergency response plans by September 2003. The act requires the EPA to complete an assessment of baseline threats for community water systems and to develop security guidance for water systems serving less than 3,300 people. Among its many responsibilities, the EPA was also directed to review methods by which water systems could be deliberately disrupted or rendered unsafe and review "current and future methods to prevent, detect and respond to the intentional introduction of chemical, biological or radiological contaminants into community water systems and source water for community water systems" (Bioterrorism Act, 2002). The EPA detailed its expanded security role in the *Strategic Plan for Homeland Security* (EPA, 2002).

In order to plan for meeting the EPA's water security responsibilities, the Water Protection Task Force and the National Homeland Security Research Center recently collaborated to develop the *Water Security Research and Technical Support Action Plan* (Action Plan) (EPA, 2003). This document is intended to identify critical security issues for drinking water and wastewater, outline research and technical support needs within these issues, and present a prioritized list of research and technical support projects to address these needs. The document also presents a time line for implementing the identified projects. The Action Plan was developed with input from representatives of the water industry, federal agencies, and other water stakeholders, including public health organizations and emergency response organizations. The EPA invited input at two meetings (the Water Security Partners Meeting in November 2002 and the Water Security Stakeholders Meeting in February 2003) and revised the Action Plan based on stakeholder suggestions. The Action Plan will be used to determine EPA funding priorities for water security research and technical support efforts over the next three years.

ROLE OF SCIENCE AND TECHNOLOGY IN COUNTERING TERRORISM

In many ways, scientific advancements have enabled terrorists today to use information and technology toward a catastrophic potential, but science and technology also represent tools to help prevent, protect from, and mitigate such threats. Technological advances have much to offer in new sensing, surveillance, and protection strategies, but these technologies may also bring costs that society is not willing to bear. As noted in the National Research Council (NRC) report *Making the Nation Safer* (NRC, 2002) "the role of technology can be overstated," and terrorism prevention will depend heavily upon diplomacy, international relations, intelligence gathering, and international policy. Nonetheless, a well-reasoned science and technology program will be a vital component of strategies for countering terrorism. The objectives are to develop technical means to reduce the nation's vulnerabilities and develop appropriate levels of preparedness to respond to future attacks. No amount of investment can eliminate all vulnerabilities to terrorist attacks, but effective application of current knowledge and future research advances in science and technology can reduce the likelihood of a terrorist attack and the severity of its consequences.

GENESIS OF THIS STUDY AND CHARGE TO THE PANEL

The EPA approached the National Academies[1] in the fall of 2002 seeking expert scientific advice on its homeland security efforts in the areas of water security, building decontamination, and rapid risk assessment. Subsequently, the Academies' NRC undertook a study that would assess the EPA's efforts to advance the state of knowledge related to threat detection, mitigation, and decontamination and to develop information and technologies for use in preventing and mitigating the effects of chemical and biological attacks. To carry out this study, the NRC appointed two expert panels, which will focus on the topics of water system security and building decontamination. The NRC panels will provide consultations to the EPA on a continuing basis on specific aspects of the program as requested and provide several short reports.

This report summarizes the early findings of the Panel on Water System Security Research, which is overseen by the NRC's Water Science and Technology Board. The first task for the Panel on Water System Security Research was a review of the EPA *Water Security Research and Technical Support Action Plan.* This report summarizes the findings of the first phase of this review and focuses specifically on the panel's Statement of Task questions #1 and 4, listed in bold below:

1. **Has the Action Plan completely and accurately identified important issues and needs in the water security arena? If not, what issues and needs should be added or removed?**
2. Are the needs appropriately sequenced within the issues? If not, what adjustments are warranted and why?
3. Are the projects recommended for funding in the Action Plan appropriate to meet the water security needs? Are the projects correctly prioritized and sequenced?

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[1] The National Academies consists of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The National Research Council is the advisory arm of the National Academies.

Is the timing of the projects, as identified in the Action Plan appendix, realistic? If not, what adjustments are warranted and why?

4. **Overall, what changes to the Action Plan are recommended to improve its presentation in terms of content and structure so as to more clearly convey the water security research and technical support program that is described?**

A subsequent report will address task questions #2 and 3 (see Part II); thus, individual research and technical support projects and funding priorities will not be evaluated in this first report.

The study schedule was condensed in order to provide timely advice to the EPA for identifying and prioritizing its research investments. The panel met once in May 2003 and subsequently collaborated remotely to develop this report. At the meeting, ongoing EPA homeland security efforts and the broader context for the study were discussed, and EPA personnel described the background and development process for the Action Plan. There was also discussion of the research needs identified in the Action Plan. The panel's conclusions and recommendations are based on a review of the Action Plan document, presentations and discussions from the meeting, the experience and knowledge of the authors in their fields of expertise, and the collective best professional judgment of the panel.

Chapter 2

Overarching Issues in the Review of the Water Security Research and Technical Support Action Plan

This chapter discusses overarching issues in the Action Plan and suggests improvements to strengthen the document and improve the Environmental Protection Agency's (EPA) efforts to prevent and mitigate threats on the nation's water systems. Key issues addressed include presenting an overarching framework for the Action Plan, developing an effective implementation strategy for this research, improving information sharing, clarifying the roles and responsibilities of supporting agencies, assessing the costs and benefits of water security research and technical support efforts, and clearly articulating the time frame and emphasis for the EPA's research investment strategies. Other suggestions are presented related to the structure and presentation of the document. A detailed review of the individual research needs presented in the Action Plan is found in Chapter 3.

OVERARCHING FRAMEWORK FOR RESEARCH AND TECHNICAL SUPPORT

The EPA's mission as stated is "to protect human health and safeguard the environment," and the agency has noted that it is "committed to assessing and reducing vulnerabilities and strengthening detection and response capabilities for critical infrastructures" (EPA, 2002). The Action Plan as currently developed intends to contribute to these goals by:

- identifying important water security issues for drinking water and wastewater,
- describing research and technical support needs that address these issues, and
- presenting a prioritized list of projects that are responsive to the needs (EPA, 2003).

The Action Plan also includes a description of the plan's implementation. Although the Action Plan consists of a large array of drinking water and wastewater research and technical support needs and associated projects, the projects *will not*, in themselves, result in improved protection of the nation's water and wastewater systems. Improved protection will only result when the information and knowledge obtained from the projects are integrated into funded plans that are implemented by collaborations among local, state, and federal agencies and both private and public organizations.

The Action Plan would be more effective if, early in the document, it explained how the individual pieces of the plan contribute to the greater goal of protecting the security of the nation's water systems. A diagram would be useful to illustrate how the individual research and technical support projects logically contribute to improved security and what roles water utilities or other agencies might play. Such a framework would also be helpful to illuminate unresolved questions regarding interagency coordination and financing for implementation of these security improvements. Figure 2-1 is a simplified example (note that feedback loops and review are not incorporated here) that could be further developed as the program evolves.

The five boxes on the left of Figure 2-1 represent the results of the work proposed in the Action Plan. Each of these categories can be associated with specific "needs and associated projects" identified in the Action Plan (with references to the location in the Action Plan) as follows:

- **Assessments and Lessons Learned**
  - Identification and prioritization of physical threats and vulnerabilities (*3.1.a*)
  - Assessment of national laboratory capabilities (*3.3.f*)
  - Assessment of water supply alternatives (*3.5.a*)
  - An improved understanding of water system interdependences with other infrastructure sections (*3.5.c*)

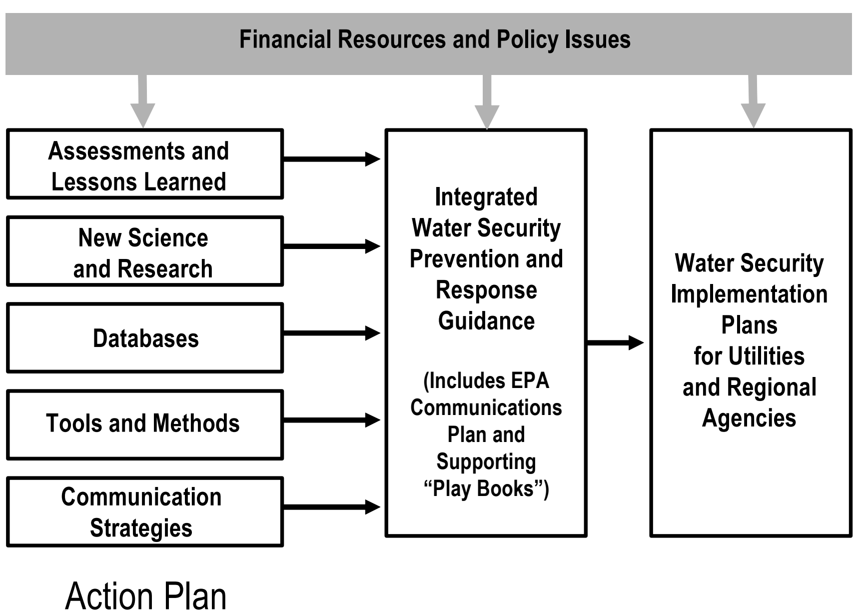

Figure 2-1. Example framework for depicting the contributions of the *Water Security Research and Technical Support Action Plan* to the broader needs for protecting the nation's water systems.

- **New Science and Research**
  - Improved methods and analysis methodologies (*3.3.b*)
  - Requirements for monitoring technologies (*3.3.c*)
  - Early warning systems (*3.3.e*)
  - Improved distribution system models (*3.4.a*)
  - Improved understanding of the environmental fate of contaminants (*3.4.b*)
  - Newer technologies and treatment processes for water and equipment that have been contaminated (*3.4.c*)
  - An improved understanding of routes of contamination and the acute and chronic public health effects from contaminated drinking water (*3.6.a*)
- **Databases**
  - Development of a list of contaminants and threat scenarios (*3.2.a*)
  - Development of a database of important information on the contaminants (*3.2.b*)
  - Development of a surrogate/simulants database (*3.2.c*)
- **Tools and Methods**
  - Countermeasures to prevent, or mitigate efforts of physical and cyber attacks (*3.1.c*)
  - A play book for analytical response (including sampling protocols, decision trees, and analytical tools) (*3.3.a*)
  - A methodology for determining when a drinking water system is contaminated and when it is clean (*3.4.d*)
  - A health surveillance network associated with contaminated drinking water (*3.6.b*)
  - A methodology for using non-traditional data for the derivation of toxicity values applied to water (*3.6.c*)
  - A risk management/risk assessment framework for identifying the impact of decontamination/treatment options and the subsequent risk assessment response (*3.6.d*)
- **Communication Strategies**
  - Means for maintaining and transmitting information (*3.2.d*)
  - Methods and means to communicate risks to local communities (*3.6.c*)

Although the research and technical support activities implemented under the Action Plan will contribute useful information and tools toward water security efforts, utilities and regional agencies need additional and integrated guidance as they prepare their own unique implementation plans. A broad "Integrated Water Security Prevention and Response Guidance" should be developed by the EPA in partnership with other water organizations. Based on existing knowledge, this guidance would serve as a generic "game plan" for prevention of, response to, and recovery from attacks on water infrastructure. This integrated guidance should eventually weave together the play books and methodologies developed in sections *3.3.a*, *3.4.d*, and *3.6.d* into a comprehensive prevention and response guidance that would direct a utility through possible prevention strategies, available information resources, and response and recovery actions (including detection and monitoring, risk assessment, and decontamination). This broad guidance should incorporate risk communication throughout, providing advice on communication planning.

Utilities and regional agencies would then need to tailor this broad guidance into specific implementation plans (Figure 2-1) that would be developed based largely on each utility's vulnerability assessment and unique circumstances (e.g., location, contingency supplies, interdependencies). The implementation plans would identify water security goals, determine strategic actions to reach the goals (e.g., priorities, cost, implementation schedules, and responsibilities), and outline utility- or agency-specific response and recovery plans, which are supported by EPA-developed play books, tools, and databases. The implementation plans would also contain individualized local communication plans that are supported by broad guidance from the EPA national water security Communication Plan and research findings and tools developed from the Action Plan. Field and table-top exercises will be critical to test regional response plans and to help utilities and agencies develop improved coordination and response strategies.

Implementation of the Action Plan, development of response guidance, and the development of water security implementation plans for utilities and regional agencies will be influenced by available financial resources and policy issues. The development and implementation of the Action Plan is driven by the Bioterrorism Act and the EPA's *Strategic Plan for Homeland Security*. Future development of prevention and response guidance could be affected by federal policy changes on information security and new government mandates for water protection. Local, regional, and organizational policy issues affect a utility's security plans on many levels, including determining public access rights to water supplies, deciding when to inform the public about threats on water safety, and negotiating increases in funding for security improvements.

The framework proposed in Figure 2-1 highlights two important and immediate water security issues for drinking water and wastewater that are missing in the Action Plan. The Action Plan does not identify the need for overarching water security guidance for prevention and response, which is needed for regional agencies and utilities to develop and implement their own prevention, response, and recovery plans. The Action Plan is also silent on the financial resources required to implement improved water security, and on the importance of communicating with the public, customers, rate regulators, and local elected and appointed officials regarding increased rate structures to create the necessary financial resources to implement countermeasures and the value of water and increased water system security. These issues will require attention from EPA managers as the Action Plan moves forward.

ACTION PLAN IMPLEMENTATION

Section 5.0 of the Action Plan, "Providing the Means to Implement the Action Plan," discusses how to conduct the research through collaborations with other organizations, but the Action Plan does not include plans for funding this research or integrating the results into effective preparedness and response plans for the nation's utilities. Additional work is needed to further develop this section. An implementation plan should be developed that would clearly articulate the roles and responsibilities of other organizations and federal agencies in respect to implementation of this research and technical support plan. Not all water security research and technical support guidance will be the responsibility of the EPA, but in order to develop effective collaborations, clear allocations of responsibilities are needed. In order to facilitate fast and effective implementation of this research plan, the Action Plan should also include a thorough and up-to-date assessment of water security research activities that are underway in other agencies or organizations (e.g., the Department of Defense and universities) as well as a summary of related ongoing EPA efforts, beyond those outlined in the Action Plan.

Section 5.0 should also include plans for communicating research findings and distributing the tools resulting from the Action Plan projects to stakeholders in a timely manner. For example, risk communication is a critical component in an overall crisis management strategy. The EPA needs to consider how to incorporate the current state of the knowledge in risk communication into its guidance to water utilities and organizations. Hopefully, this will be part of the "Communication Plan" mentioned in section 5.0 that is still in early stages of development.

Details on available funding will be needed when developing an implementation plan for the identified research and technical support projects, as availability of funding will likely determine the prioritization strategies for conducting the research. The NRC panel will review the prioritization of the water security projects detailed in the Action Plan in its subsequent report (Part II).

COMMUNICATION, INFORMATION SHARING, AND SECURITY

While the Action Plan refers to a Communication Plan that includes guidelines on communication systems and processes for properly maintaining and disseminating classified or sensitive information, the Action Plan does not define this Communication Plan or state when it will be available. Developing an effective broad communication strategy that meets the needs of the wide range of stakeholders, including response organizations, water organizations and utilities, public health agencies, and the media, while addressing security concerns, should be among the highest priorities for the EPA.

The federal government's need to restrict access to confidential information versus the need for response agencies to have such information is an issue that will impact how well the public is protected in the event of a terrorist attack. Criteria for classifying and distributing sensitive information should be developed that recognize the need for local and state agencies and other critical players to have access to information that will allow them to prepare for and respond to water security threats. The dangers of keeping information too closely guarded may, in fact, be much greater than the dangers of informing an ill-intentioned person. Even secure information distribution mechanisms may do little to prevent access from a determined saboteur, because the information will need to be distributed to such a large number of stakeholders (e.g., all water utilities). The EPA should, in consultation with other agencies, thoroughly examine the consequences of various levels of information security. Formal studies on the risks and benefits of widely transmitting water-security data could also contribute valuable support for decision makers.

Resources exist in the research community (both in academic and non-academic settings) that have much to contribute on the topic of water security, but their inputs to research or response plans are minimized at present because of heightened security concerns. Most of the research community is excluded from reviewing "sensitive" material, and mechanisms should be sought to include these communities so that the best research minds are available to address the nation's security concerns.

The Action Plan mentions the need to communicate the results "in an effective and efficient manner" (section 5.3) and suggests the need for a national clearinghouse to disseminate information on future water security technologies, although no specific mechanism is discussed. One means to communicate with water utilities is through databases, and references are made throughout the Action Plan to developing databases for one purpose or another. The Action Plan, however, does not address how the EPA will create and manage databases that are accessible to all the water stakeholders that need them. Consideration should be made as to how the databases will be accessed, who will be granted access (and with what security clearance), who will control and update the databases, and how the databases will be integrated with current systems. The WaterISAC (Information Sharing and Analysis Center) is currently the primary mechanism for secure information sharing and incident reporting. As a secure portal communication tool, the WaterISAC is versatile and can be adapted to serve the need of communicating sensitive information to a wide variety of users, such as researchers, first-responders, and public health agencies. However, the EPA will need a comprehensive strategy for relaying security information to a wider range of stakeholders than are currently served by the WaterISAC. The WaterISAC requires a fee for information access and currently limits subscription to water and wastewater utilities (http://www.waterisac.org/WaterISACFactSheet.pdf). The WaterISAC currently serves 177 drinking water and wastewater utilities, the majority of which are large utilities (Erica Michaels, Association of Metropolitan Water Agencies, personal communication, 2003).

INTERAGENCY COORDINATION, ROLES, AND RESPONSIBILITIES

The Action Plan concentrates, understandably, on matters which the EPA has traditionally handled and for which they have expertise. While there have been problems of both overlap and gaps in the activities of the EPA and other federal agencies under ordinary circumstances, the lack of urgency in most cases has allowed these issues to be addressed over an extended period of time. In the case of an emergency, however, it will be too late to discover that a critical activity that was thought to be under the control of another agency had been overlooked due to poor coordination. Although the Action Plan recognizes the importance of coordination among relevant agencies, there are assumptions made throughout the Action Plan about the activities and capabilities of other agencies that may not be correct (for example, the Action Plan overestimates the current capabilities of the Centers for Disease Control and Prevention (CDC) and health surveillance, as described in more detail in Chapter 3). Collaboration between the EPA, the CDC, and local and state health agencies will be essential to developing an effective national surveillance network. More attention needs to be paid to coordination and communication with other federal, state and local agencies, as all will be involved in the detection and control of an emergency event involving a water supply.

Clearly, coordination is a persistent problem not peculiar to water security. However, the rapidity and high stakes of the potential terrorist attacks on water supplies suggest that the EPA should pay particular attention to improving interagency coordination and to determining the roles, capabilities, and training of other agencies. The use of field and table-top exercises, where local, regional, and federal agencies collectively respond to a simulated water supply system attack, is strongly encouraged as it will reveal problems, help target resources, and allow personnel in sister agencies to meet each other and establish relationships that will be extremely valuable in case of a real emergency. All personnel who would respond to a water system attack should be involved, including water and wastewater utilities, police, public health workers, and emergency medical personnel (such as the Metropolitan Medical Response System).

The kinds of events contemplated by this Action Plan will take place in a very special context, that of a potential crime. The anthrax episode brought into sharp relief what can happen when the public is not sufficiently informed because of unclear roles and responsibilities between the Federal Bureau of Investigation (FBI) and the CDC. Thus, it is important that procedures be worked out in detail ahead of time concerning roles and responsibilities of various relevant parties, including local and national law enforcement. Legal issues related to criminal investigations, such as chain of custody, preservation of evidence, and control of information in the face of a contemplated arrest and prosecution, will need to be considered in advance because the need for information dissemination to environmental and public health authorities, communication with the public, and decontamination activities will likely present opposing demands.

IDENTIFYING COSTS AND BENEFITS OF ENHANCED SECURITY AND RESEARCH

The Action Plan as now written is silent on the question of costs accruing to the proposed research and technical support projects and water security enhancements and their associated benefits, such as reduced risk. The EPA needs to assess these costs and benefits (with assistance from its partners in water security), as utilities will face a large challenge in getting approval from governing boards or legislators for rate increases to pay for security improvements. Government agencies are also operating on limited budgets and need explanations of the products and benefits that will derive from their investments. An assessment of costs is relatively straightforward, having to do with (1) direct investments by federal, state, local, and private entities to support the program; and (2) the opportunity cost of diverting funds that might be used for facility improvements, operating enhancements, or other alternative priorities. Determining benefits is more complex and would incorporate risk analysis. The objective of the research program is to lower the probability of a catastrophic terrorist event, minimize and mitigate the consequences caused by an event, or avert the possibility of such an event all together. These benefits have to do both with the magnitude of the impact averted and with the *ex ante* probability of such an event were the research program and technical support activities not undertaken. Utilities will need assistance communicating the value of water and increased water system security to the public, rate regulators, and elected and appointed officials.

The Action Plan noted that there could be a "dual-use aspect" of some of these projects wherein multiple benefits (e.g., security and water quality) would make them more cost effective. Dual-use benefits may be obtained from the spin-off effect of technology, protocols, or other products of the research that were principally developed to avert terrorism, but which may provide other returns. There may be additional ancillary benefits with respect to improved day-to-day operations and response to more likely non-terrorism events, such as natural disasters. For example, a detailed distribution system model not only could be used to assess the movement of a contaminant after a terrorist attack but also would enable the optimization an existing system and would enhance future water system development planning. Increased cyber security could also lead to potential revenue increases by providing a secure computer network with which to conduct electronic transactions with customers (CSO magazine, 2002). Further study should be directed to better acknowledging these business-enabling benefits. Economic return on investment will be crucial if many of the countermeasures identified through the Action Plan efforts are to be implemented.

TIME LINES FOR INVESTMENTS

The Action Plan serves as the basis for making funding decisions on water security research and technical support in the coming three years. EPA staff in their presentations to the panel stressed that the Action Plan and the associated homeland security research were intended to provide products that would be timely, functional, and responsive to water security needs. Some of the products will be released before they are perfected or complete, in order to provide immediate improvements to water security and response capabilities; thus, the EPA is acknowledging that sometimes "perfect is the enemy of the good." The panel recognizes the need to act quickly to address these issues of water security and generally supports this approach. Nevertheless, the time frame of the Action Plan's emphasis should be more clearly and consistently articulated in the document. As currently written, several of the research needs and associated projects identified in the Action Plan will require continued support long after the three-year time line, which appears inconsistent with the approach identified by EPA managers.

The EPA strategy in the Action Plan to emphasize immediate usability and first approximations is a sound one, but certain research or technological advances may only be accomplished through long-term research investments. Developing a framework where research needs are organized into time frames that reflect both the priority of the activity and the time required for the effort would be helpful. For example, immediate needs (with a time frame of one year or less) could include developing tools and databases based on current research knowledge. Mid-range goals might be reached in a three-to-four year time frame, which reflects a majority of the needs in the action plan. Long-term research efforts will be required to address more complex research questions, significantly advance analytical technologies, and anticipate emerging concerns. Although the EPA has not included long-term research among its objectives for the Action Plan, long-term research needs exist in the current plan and should be identified and highlighted, so that a collaboration of agencies, perhaps including the Department of Defense, the Department of Homeland Security, and the National Science Foundation, could work to ensure that substantive, mission-oriented research questions in water security are not overlooked.

The EPA's role in homeland security will not likely diminish after this three-year effort elapses, but the Action Plan and the National Homeland Security Research Center (slated to close in three years) focus only on making near-term contributions. This approach does not acknowledge that a strong research and technical support presence will be needed to respond to new agents and threats, to maintain the water security databases and play books, and to identify continuing research and technical support needs. Although the panel supports the EPA's emphasis on short-term water security needs, the EPA should consider how a longer-term agency commitment to meeting water security needs could enhance the program's effectiveness.

STRUCTURE AND ORGANIZATION

Several changes could be made to the Action Plan to improve its presentation in terms of structure and organization. The document should clearly state the intended audience for these research and technical support products, and whether certain sizes of water and wastewater utilities were emphasized in developing this plan. Overall, removing unnecessary duplication and making each section of the plan roughly parallel in terms of detail and justification presented could tighten the document. The front matter for each section tends to be too long, and the focus for the section is confused by the presence of the "Key Research or Technical Support Questions," which are mentioned and then never referenced again. To improve the readability of the document, these questions should either be better connected to the subsequent text or deleted. Like these key research questions, other needs are mentioned early in section 3.0 (p. 15-16) as projects raised by stakeholders at the February 2003 meeting, but these needs are not explicitly developed later in the document, as promised. If these needs and projects are considered to be important, these ideas should be thoroughly incorporated into each section of the Action Plan, rather than presented in a random order at the start. Also, Appendix B does not present any new information. The dates assigned to each project should be moved to the body of the document and the appendix deleted.

Detailed project descriptions were withheld from the Action Plan due to the sensitivity of the information, but some of the project descriptions are so broad as to be easily misinterpreted. For example, the project to develop a "comprehensive database…on surrogates or simulates for priority contaminants including the relationships between the surrogate or simulant and the contaminants of interest with respect to a variety of biological, physico-chemical, and toxicological properties" (*3.2.c*, project 1) could represent a daunting and exhaustive task or could be more narrowly interpreted. More description is needed to clarify some of these broader tasks.

The scopes of the needs presented in the Action Plan tend to be widely variable, as are the projects proposed. For example, the need to improve the understanding of contaminant fate and transport (*3.4.b*) represents an entire field of study, while other needs are very narrow and specific, such as the need for training modules for analytical methodologies (*3.3.g*). The document would be easier to follow if time frames for the needs and projects were presented, and the needs were organized into immediate, mid-range, and long-term research and technical support goals.

One concern in the Action Plan is that the priorities for the research needs have not been adequately described. The Action Plan states that no prioritization was assigned to any of the identified research and technical support needs because the stakeholders considered all of the research needs high priority. However, discussions with the EPA staff and a review of Appendix C revealed that some areas of research are of higher importance (e.g. improving analytical methodologies, section 3.3, versus targeting the impacts on human health and informing the public about risks, section 3.6); these priorities are not addressed in the text. In order for the panel to assess the priorities and timing of the projects presented in the Action Plan, the underlying priorities of the research needs should be clearly articulated.

CONCLUSIONS AND RECOMMENDATIONS

- The Action Plan should present a framework that illustrates how its individual pieces contribute to the greater goal of protecting the security of the nation's water systems (e.g., Figure 2-1). The EPA should include plans for integrating the results into effective preparedness guidance and response plans for the nation's utilities and recognize the need for developing funding strategies to accomplish these goals.
- Additional work is needed to address implementation of the Action Plan. This should detail the resources needed to accomplish the research, clearly articulate the roles and responsibilities of other organizations and federal agencies, and include

plans for disseminating the tools and research findings developed from the Action Plan.

- Attention needs to be paid to coordination and communication with other federal, state, and local agencies and organizations, as all will be involved in an emergency event involving a water supply. The special circumstances of a purposeful attack will require that the roles and responsibilities of various relevant parties (including law enforcement, FBI, and environmental and public health authorities) be worked out in detail ahead of time. The use of field and table-top exercises is strongly encouraged to help utilities and agencies develop improved coordination and response strategies.
- An effective broad communication strategy should be developed that meets the needs of the wide range of stakeholders, including response organizations, water organizations and utilities, public health agencies, and the media, while addressing security concerns. Consideration should be made as to how water security information databases will be accessed, who will be granted access (and with what security clearance), who will control and update the databases, and how the databases will be integrated with current systems. Criteria for classifying and distributing sensitive information should be developed, and the impacts of distributing sensitive information (including to a wider research community) should be thoroughly examined.
- The EPA should attempt to quantify the benefits and costs accruing to the proposed research and technical support projects, and further study should be directed to better acknowledging business-enabling dual-use benefits.
- The Action Plan should clarify which of its research activities are short-term, applied efforts and highlight important long-term research needs, so that more substantive, mission-oriented research questions in water security are not overlooked.
- Several changes could be made to the Action Plan to improve its presentation in terms of structure and organization. The underlying priorities in the Action Plan should be clearly articulated.

Chapter 3

Review of Identified Water Security Research Needs

In keeping with the format used within the EPA Action Plan, this chapter discusses research issues and needs separately for drinking water and wastewater. The drinking water research needs within the Action Plan are lengthy, detailed, and if met would go a long way toward providing the overall response guidance mentioned in Chapter 2 as necessary to help water managers respond appropriately to threats or attacks on water supply systems. Considerably less information is presented in the Action Plan regarding threats to the nation's wastewater infrastructure, making it difficult to assess the adequacy of the proposed research. The significantly greater text and research focused on drinking water within the Action Plan is likely a reflection of the report's authors' expertise as well as the perception of drinking water supply systems as more vulnerable targets of a potential terrorist attack with more direct human health consequences in comparison to wastewater treatment plants.

DRINKING WATER

The research and technical support needs for preventing, preparing for, and responding to physical, cyber, and contaminant attacks on drinking water supply systems are categorized in the Action Plan under six major headings: (1) protecting physical and cyber infrastructure, (2) identifying drinking water contaminants, (3) improving analytical methodologies and monitoring systems for drinking water, (4) containing, treating, decontaminating, and disposing of contaminated water and materials, (5) planning for contingencies and addressing infrastructure interdependencies, and (6) targeting impacts on human health and informing the public about risks. A detailed evaluation for the individual research needs identified in the Action Plan is presented below, which identifies notable gaps and redundancies and suggests changes in emphasis. The application of the needs to small versus large utilities is also discussed.

Protecting Physical and Cyber Infrastructure (Action Plan Section 3.1)

Drinking water utilities (supply works, treatment plants and distribution systems) consist of physical assets, human assets, and cyber assets. The physical assets include piping, valving, reservoirs, pumps, and treatment works; human assets include operators and management personnel; cyber assets include software and hardware devoted to process control, operation of remote facilities, and accounting. The security of water utilities depends upon mitigating threats to these assets.

The EPA Action Plan delineates this work into three categories of research and technical support needs:

a) An updated identification and prioritization of physical threats to drinking water infrastructure, including an improved understanding of the vulnerability of water systems to cyber threats and improved means to assess these vulnerabilities.

b) A thorough understanding and documentation of the consequences of physical or cyber attacks on the drinking water infrastructure, including the evaluation and testing of computational models and decision science.

c) A suite of countermeasures to prevent or mitigate the effects of physical and cyber attacks on water infrastructure, including improved design of water systems to reduce vulnerabilities in the long term.

Commentary on Identified Needs

3.1.a Identification and Prioritization of Physical Threats. Identifying and prioritizing physical and cyber threats to water infrastructure represents an important first step before countermeasures can be developed. There is a substantial base of experience on physical threat identification that has been gained from the vulnerability assessments completed by larger utilities and those in progress by smaller utilities. Under American Water Works Association Research Foundation (AwwaRF) project 2909, there is to be a focus on review, prioritization, and lessons learned from these activities. Furthermore, there has been considerable effort spent at other facilities, such as in the chemical and power industries, on protection from physical and cyber threats. Need *3.1.a* should strive to incorporate knowledge gained from these efforts rather than on re-inventing such knowledge.

Another type of threat that may be worth considering is the dissemination of malicious disinformation (e.g., on the safety or reliability of a given system) via external web sites and other electronic means. Such actions have the potential for producing long-lasting impacts on the reputation of water suppliers, with potential consequences of having concerned users ultimately switching to less adequate alternate supplies.

In the assessment of resources to protect, source water catchment structures and areas (reservoirs, watersheds, artificial impoundments) and raw water conveyance structures (aqueducts, underground flow paths) should be given consideration. Other points where vulnerability may occur could include remote monitoring stations, points of chemical addition (e.g., rechlorination or fluoridation), and remote wellheads, especially those with associated disinfection facilities.

3.1.b Understanding and Documentation of the Consequences of Physical or Cyber Attacks. The vulnerability assessment efforts noted in the previous section have also resulted in the preparation of consequence analyses as part of the mandated filing.

To the degree possible, the EPA should take advantage of the efforts of AwwaRF project 2909 and similar reviews to help it in its understanding of consequences of physical or cyber attacks. In addition, the EPA should take advantage of prior threat, vulnerability, and consequence assessments in understanding potential impacts on water systems from cyber and physical threats. For example, lessons can be learned from the efforts taken for assessing cyber vulnerability in preparation for the year 2000 (Y2K) and from homeland security analyses of Supervisory Control and Data Acquisition (SCADA) system vulnerabilities and consequences for water and other utilities.

3.1.c Countermeasures to Prevent or Mitigate the Effects of Physical and Cyber Attacks. Research to reduce vulnerabilities in water systems to physical and cyber attacks is a third important need. In preventing or mitigating the effects of attacks to cyber systems, a key component is understanding the vulnerability of and consequences from malfunctioning or sabotaged SCADA systems. This understanding could be facilitated by interaction with control and software vendors and with users in other industries. The importance of this might be underscored by rewording item *3.1.c* to read "…including improved design of SCADA and water systems …." Specific attention should be placed on addressing internal threats (e.g., the disgruntled employee) and making use of existing SCADA system attack countermeasures that have been developed for other analogous institutions.

Additional Research and Technical Support Needs

In the development and assessment of countermeasures, it is important to identify both the costs and the benefits, from more obvious examples such as the benefit of risk reduction to ancillary or spin-off benefits. For example, the installation of secure Internet sites for a utility (implemented perhaps for secure process monitoring purposes) might also serve as a platform for implementation of either business-to-business or consumer e-commerce, and thereby permit an additional revenue stream (or reduction in costs of activities previously conducted non-electronically) to be realized. The suite of countermeasures that might be developed should be described by a tiered arrangement to permit selection as appropriate in a given locale (small versus large utilities, different geographic environments, etc.).

The identification of a suite of countermeasures is useful only to the degree that necessary measures can be implemented and can be paid for. A major priority should be in communicating the need for security measures with the consumer and in promoting willingness to pay for implementation of necessary countermeasures. Hence, the following additional need is suggested:

> Assessments of costs and benefits (direct and indirect) associated with various countermeasures; and development of programs to assist implementing organizations (including water utilities) in communicating with the public, customers, rate regulators, and local elected and appointed officials regarding the value of water, increased water system security, and increased rate structures to create the necessary financial resources to implement such countermeasures.

Application to Large versus Small Systems

An important difference for the Action Plan to consider is that small water systems (those serving less that 3,300 people) will not be required to conduct vulnerability assessments. This means that the EPA will have less information about the types of threats to which small systems may be subjected. This should be considered in addressing the first need and in devising appropriate and cost-effective countermeasures to reduce the vulnerabilities of small systems. Second, when recommendations are made regarding consequences or countermeasures for protecting SCADA systems, the EPA should consider the differences between the largest and more sophisticated systems and the vast majority of the systems which are quite small and may have limited or no SCADA systems and limited resources with which to secure the systems they do have. The Action Plan should focus on coming up with relatively simple-to-implement best practices (such as separating SCADA networks from data networks and installing firewalls) that can work across the broad range of water system types, rather than on the highly technical detail that would be needed for the more extensive and complicated systems.

Recommendations

In conclusion, the panel recommends the following rewritten needs:

- An updated identification and prioritization of physical threats to and vulnerabilities of drinking water infrastructure, taking into account the substantial information gained from the vulnerability assessments of the nation's larger water systems and on other vulnerability and consequence assessments of water systems and their cyber infrastructure, along with improved means to assess these vulnerabilities.
- A thorough understanding and documentation of the consequences of physical or cyber attacks on the drinking water supply sources and infrastructure, including the evaluation and testing of computational models and decision science.
- A suite of countermeasures to prevent, or mitigate, the effects of physical and cyber attacks on water infrastructure, including improved design of SCADA and water systems to reduce vulnerabilities.
- Assessments of costs and benefits (direct and indirect) associated with various countermeasures; and development of programs to assist implementing organizations (including water utilities) in communicating with the public, customers, rate regulators, and local elected and appointed officials regarding the value of water, increased water system security, and increased rate structures to create the necessary financial resources to implement such countermeasures.

Contaminant Identification (Action Plan Section 3.2)

As the scope of available pathogens and hazardous chemicals expands so should our assessment of the threats and consequences they pose to water security. Identification of the contaminants of concern is an initial step in protecting the nation’s water supplies. Knowledge of critical contaminant properties, such as toxicity, environmental fate, and methods for mitigation, will be needed to respond effectively to threats on our water supplies.

The EPA Action Plan delineates this work into four categories of research and technical support needs:

a) A manageable, prioritized list of both contaminants and threat scenarios that might be used to destroy, disrupt, or disable drinking water supplies and systems.

b) A contaminant database for consultation by approved individuals and organizations that describes critically important information on contaminants with the potential to harm drinking water supplies and systems.

c) A surrogate/simulant database for use in testing and evaluating methods, approaches, and technologies to more effectively protect drinking water supplies and systems.

d) Methods and means to securely maintain and, when appropriate, transmit information on contaminants and threat scenarios applicable to drinking water supplies and systems.

This is a logical and comprehensive breakdown of the needs. There are no obvious gaps.

Commentary on Identified Needs

3.2.a Development of a List of Contaminants and Threat Scenarios. The development of a list of contaminants, both chemical and biological, is an important early step that will ultimately serve to guide the development of analytical techniques and treatment technologies. However, the panel struggled with the scope of this need. The word "manageable," which was not defined in the Action Plan, raised concerns that potentially relevant contaminants might be overlooked. Yet, developing a single list of all possible contaminants could be an endless task, as the list would always be incomplete and would require extensive time and effort to develop and continuously update.

One approach proposed would be to develop a list that would include only those contaminants of potential concern to water security based on a well-defined set of criteria, such as human toxicity, current and future availability, and solubility in water, among others. The EPA should work to develop this set of criteria. To expedite the formation of the water security contaminant list, existing lists (e.g., from the CDC or the EPA Office of Pollution Prevention & Toxics) could be re-visited with these criteria in mind. In addition, a mechanism needs to be built into this process ensuring that the list is regularly updated as new information becomes available. Considering that the compiled list of contaminants will guide water security activities, this list should be as complete as is practicable.

The Action Plan suggests that the list of contaminants should be prioritized. In order for this to occur, the list should also contain associated information regarding a contaminant's potential for being a threat (e.g., the well-defined set of criteria described above). This is the kind of information anticipated to be included in the database mentioned below (*3.2.b*); thus, there is significant overlap between these two needs (*3.2.a* and *3.2.b*). Prioritization is a subjective process that will depend on the weighting of various criteria and on currently available data about a contaminant (see NRC, 1999 for a more thorough treatment of contaminant prioritization). The types of information expected to be useful in prioritizing contaminants include, for example, an assessment of the contaminant's threat consequence, its current level of availability, or its resistance to residual chlorine. This information and any prioritization scheme would need to be transparent to the users of the list. The database format allows for alternate groupings or prioritization schemes based on the specific needs of treatment engineers, toxicologists, microbiologists, physical scientists, emergency response providers, etc.

An assessment of contaminant threat scenarios is necessary to improving water security because the means of introducing a contaminant into the water system can significantly affect the consequences of an attack. As more is learned about modes of attack, and as new modes of attack become available due to changes in technology, policy, or practice, the threat scenarios will change. Given the description of two separate research projects in the Action Plan (p. 21), it appears that the authors intended for there to be both a list of water security contaminants and a list of threat scenarios. Although the lists are related, this approach is advisable as threat scenarios identified may highlight appropriate and necessary countermeasures that could be implemented, which would not be specific to any particular contaminant (e.g., backflow restriction devices). Also, this approach would prevent the consideration of current threat scenarios from constraining the list of water security contaminants. This sentiment should be expressed more clearly by explicitly separating the delineation of threat scenarios from the need for creating a list of contaminants.

3.2.b Development of a Database on the Critical Contaminants. As the list of contaminants is assembled, the most relevant physical, chemical, biological, and toxicological data should be included in a supplementary database. The nature of the data to be included in this database should be established based on perceived needs from potential end users, which would include emergency response personnel, public health department personnel, toxicologists, planners, treatment engineers/scientists, etc. Based on the anticipated uses of the supplementary database, the relevant contaminant properties should be identified. This task of identifying appropriate categories of information to be contained in this database would likely be the first project for such an activity. It should be noted that some of the parameters needed for the database will be contaminant specific. For example, a parameter critical for understanding viruses in water supply systems may have no bearing on the behavior of other pathogens.

Filling in every gap within the database of critical contaminants and relevant parameters may not be necessary or worthwhile. Rather, research should be initiated to fill the most important gaps in the contaminant properties lists. This might include combing the literature for contaminant-specific information, and it should also embrace theoretical, semi-empirical, and expert judgment as needed. One way to organize the research and data gathering needs associated with the database is to determine early on which contaminant properties are most useful for particular classes of contaminants. In many cases, estimates or educated guesses might be used in place of well-established contaminant-specific data in order to address near-term risk management needs, although the sources and the reliability of the data should be noted.

3.2.c Development of a Surrogate/Simulant Database. Simulants or surrogates are intended to be similar in some specific way to individual contaminants or a group of target contaminants, but they are less toxic and therefore less hazardous to work with than the contaminants of concern. The nature of the similarity between target and simulant would necessarily depend on the type of investigation for which it will be used (e.g., size and charge would be key parameters if removal by membrane filtration is the focus). An ideal simulant would be non-toxic and easily measured using an analytical method applicable to the contaminant of concern, but this may not be possible in many cases. Studies on treatment, decontamination, transport, and environmental fate of contaminants could benefit from a few well-selected simulant compounds or microorganisms. Developing a complete and comprehensive database of surrogates and simulants would not likely be a wise use of resources. One of the end products of this work would be a set of guidelines or an operational handbook describing how surrogates or simulants should be used. Consideration should be given to selection of the simulant, handling, analysis, and data interpretation.

3.2.d Means for Maintaining and Transmitting Information on the Above. Once compiled, the information that is the subject of research needs *3.2.a* through *3.2.c* should be continually updated and made available to those for whom it was intended. As discussed in detail in Chapter 2, information security will play an important role in carrying out the Action Plan. A plan for providing essential information to response agencies, while restricting access to classified information should also be developed.

Application to Large versus Small Systems

The identification of contaminant lists and compilation of data are centralized activities that do not have any specific bearing on utility size. However, the nature and relative importance of certain threat scenarios may be highly dependent on utility size. Data handling and transfer may also be different for large utilities versus small ones.

Recommendations

In conclusion, the panel recommends the following rewritten needs:

- A list of contaminants that might be used to destroy, disrupt, or disable drinking water supplies and systems. This list would be linked to relevant associated contaminant information (stored in the database mentioned below), which could be used to prioritize or group the individual contaminants, as users of the list deem appropriate.
- An assessment of threat scenarios which could result in harmful exposure of the public or utility personnel to drinking water contaminants.
- A contaminant database for consultation by approved individuals and organizations that describes critically important information on contaminants with the potential to harm drinking water supplies and systems.
- Identification of a few well-selected surrogates or simulants for use in testing and evaluating fate and transport characteristics and treatment technologies for priority contaminants.
- Methods and means to securely maintain and, when appropriate, transmit information on contaminants and threat scenarios applicable to drinking water supplies and systems.

Contaminant Monitoring and Analysis (Action Plan Section 3.3)

Reliable detection of contaminants is essential to protecting consumers against chemical and biological attacks on water supplies. As the scope of available pathogens and toxic chemicals expands, so must our abilities expand to detect their presence. Early detection of an intrusion will be one defense against widespread exposure. Aside from the more obvious need to define the extent of contamination, advise the public of the contamination, and, if necessary, take actions to avoid exposure, detection methods and associated protocols are needed for purposes of assessing performance of treatment and decontamination efforts.

The EPA Action Plan delineates this work into seven research and technical support needs:

a) A "play book" for analytical response to contaminant threats and attacks on water supplies and systems, including protocols for identifying "unknown" contaminants.

b) Improved analytical hardware and analysis methodologies for biological, chemical, and radiological contaminants in water.

c) Requirements for monitoring technologies used in responding to biological, chemical, and radiological contamination events.

d) Testing and evaluation of monitoring technologies, including standard operating procedures, for biological, chemical, and radiological contaminants and threats.

e) Testing and evaluation of drinking water "Early Warning Systems" (EWSs), and EWSs from other sectors amenable to application in the water environment.

f) An improved and expanded laboratory capacity and capability (as necessary) to be fully prepared in responding to threats or attacks on water.

g) Training modules and evaluation exercises for analytical methodologies and monitoring systems.

This set of needs is quite comprehensive, yet depending on interpretation, there may be some important gaps. There may also be some reasons for combining portions of these.

Commentary on Identified Needs

3.3.a "Play Book" for Analytical Response. The analytical "play book" includes decision trees as well as analytical methodologies and end points and is therefore much more than a toolbox. An ideal play book for analytical response would combine tools (e.g., formal analytical methods and early warning system detection methods) and provide clear direction to those trying to identify or clarify a known or perceived threat. This play book would also include protocols for sampling and identifying unknown contaminants. The play book would also consider special sampling needs and the analytical environment. Early investigations at sites where high toxicity levels are deemed possible might require the use of small mobile "Hazmat"-type labs. Once the nature of the contamination is better understood, subsequent analysis would likely take place in state or federal laboratories.

The analytical play book should serve as one component of a larger integrated response guidance, which needs to be created to enable other appropriate parallel actions (e.g., communication, remediation, risk assessment, emergency response). Other components of this response guidance are discussed in sections *3.4.d* and *3.6.d*. The integrated prevention and response plan should invoke appropriate action from within the analytical play book when a disease outbreak of unknown origin is detected. In other words, the play book should include protocols for water quality sampling to determine whether drinking water is a potential vector of a disease outbreak.

3.3.b Improved Hardware and Analysis Methodologies. The need for new methods and analytical hardware is obvious when one considers that even the most abbreviated of contaminant lists is populated with numerous chemicals or microorganisms for which there are no properly validated methods. In some cases there may never have even been an attempt to detect the contaminant in a water matrix. The problem of analyzing for a contaminant threat of unknown origin is so challenging that general screening methods may have to be developed and used in lieu of or in addition to the traditional well-validated specific method.

3.3.c Requirements for Monitoring Technologies. This sub-category is not clearly described in the EPA document, and the project list does not seem to logically follow from the preceding text. This confusion limited a thorough review of this need. Nevertheless, the development of quality assurance methods and other analytical features within need *3.3.c* is a logical extension of need *3.3.b*. New analytical methodologies will need to be accompanied by adequate protocols for sampling, analytical performance, and quality assurance, as described in the Action Plan. The document also highlights considerations that should be given to safety, sample transport, and integration with other activities—issues which may also be addressed by the analytical play book.

There are some rather unique quality assurance and quality control (QA/QC), sampling, and detection issues that characterize this sub-category that were overlooked in the discussion of this need in the Action Plan. Analytical quality assurance probably takes on greater importance when considering contaminants that can cause widespread illness and/or panic. For this reason, standard QA/QC procedures need to be carefully examined in light of the high stakes involved. Rates of false positives and false negatives should be clearly understood and results should be interpreted accordingly.

Research should also explicitly address some aspects of sampling protocols and some of the unique challenges faced when monitoring treatment efficiency. Sampling may be especially problematic for hazardous contaminants because of concerns over the health of the technician and possible spreading of the contaminant by opening closed systems (e.g., unwanted exposure from opening hydrants). Protocols need to be developed to match the level of care during sampling with the likelihood of risk.

Sampling guidelines are needed that address issues of spatial and temporal sampling requirements for particular types of events. Toxic contaminants may be relatively insoluble or in a particulate or micellized form. Any of these can lead to non-homogeneous distributions of contaminants. Elevated concentrations may exist at interfaces (e.g., air:water, pipe:water) or imbedded in solid phases (e.g., biofilms, scale formations, aquifer materials). Methods for sampling such heterogeneous systems need to be considered. Refined sampling methodology may be needed for detecting pathogens in complex field settings.

The Action Plan notes in section 3.4 that point-of-use/point-of-entry (POU/POE) devices already in place may trap some contaminants, thereby serving as remote sampling devices during a contamination event. The analyses of POU/POE devices would be almost experimental in nature and produce only qualitative results because of the many unknowns and uncontrolled variables (e.g., volume of flow during the event, length of time in use, variability of the types of adsorber, and competition with other adsorbates from the water). In order to obtain valid historical water contamination data, a proactive network of metered surveillance water sampling units with defined characteristics, such as flow through units with activated carbon collectors or microbial sampling devices, would be required. Such a surveillance network would be costly to establish and would require a regular schedule of collection, replacement, and analysis.

The monitoring of treatment efficiency presents some other unique challenges. This is especially problematic when residuals streams (e.g., backwash water, settled sludge) need to be examined for assessing hazards or formulating mass balances. For example, microbial contaminants may be especially difficult to detect against the high background of particulate matter.

3.3.d Testing and Evaluation of Monitoring Technologies. Although very important, this particular sub-category does not merit separate treatment within the Action Plan. For the purposes of this discussion, monitoring is assumed to refer to analysis of contaminants or surrogates in the field, possibly using flow-through devices. Work on monitoring (and sensing) technologies is taking place in many different fields for many different purposes. There have been startling advancements in the sensitivity and selectivity of micro devices for field deployment. However, the distinction between classical laboratory methods and field monitors may be an artificial one. In particular, detection of chemical contaminants includes a spectrum of techniques, many of which can be used with both laboratory and field methods. The two often employ identical methodology and even similar hardware. There may be cases where field sampling requires additional concentration techniques that would not be required in standard laboratory protocols, and monitoring technologies will need to be thoroughly tested under field conditions, but these issues can be addressed in the above needs. For this reason it seems unnecessary to separate needs *3.3.b* and *3.3.d*.

3.3.e Early Warning Systems. Early warning systems are valuable components in the overall analytical effort. They may be the only means by which a utility is alerted to potential problems, prior to widespread illness. In some cases, existing and commonly used technologies may be employed as early warning systems. Examples include online sensors for turbidity, UV absorbance, pressure, conductivity, and chlorine residual. However, while the appropriate technology may be available, other factors such as signal processing capabilities and sufficient baseline data may need additional attention. These factors should be considered in the Action Plan.

The EPA may want to include the use of dedicated water sampling devices as part of an overall water quality monitoring plan where the devices could function as a non-specific early warning system. Other monitoring systems could also be considered, such as a flow-through biomonitoring system using selected fish species (e.g., medaka, flat head minnows, or trout) whose behavior and physical state could quickly reflect the presence of a toxic material in the water. Maintaining such a system is complicated and costly, requiring fixed facilities with technical staff and active management. In addition, decision logic would need to be developed to determine the interpretation and follow-up that would be needed in the event that a physiological reaction was noted in the fish.

There is also a spectrum of new technologies that are applicable to early warning systems, some of which come from other fields of study. Some of these technologies are compound specific, whereas others are used to measure bulk or surrogate parameters.

3.3.f Assessment of National Laboratory Capability. The ability of the nation's analytical laboratories to respond to a toxic attack will depend on the nature and scope of the attack. Most of the potential toxic chemical and biological agents are not routinely measured by water testing laboratories. While methods and equipment may be developed to measure these agents, there will be little incentive for commercial laboratories to acquire these capabilities unless routine monitoring is needed. Nevertheless, the most common emergency scenario is one of a sudden need for fast and reliable analysis of non-standard analytes. Strategies need to be developed that will ensure the ready availability of such analytical services. These strategies should include a tiered capability analytical structure, matching the most sophisticated analytical needs to the laboratories that are best equipped to handle them. Commercial laboratories will have to resolve liability issues prior to taking a role in analytical response and will need analytical methods that will minimize risks to workers. Liability issues may require that government laboratories play a leading role in analytical readiness, or that commercial labs be compensated in new and creative ways for providing analytical services for high risk or likely threat contaminants.

Analytical readiness also requires that the nation's laboratories be able to effectively respond to threats. Thus, capacity and need should be geographically well matched. It is of little advantage if advanced laboratory capabilities exist in California, when an attack occurs in Florida that requires rapid turn-around. Mobile analysis units might be evaluated relative to regionally distributed laboratories for their ability to meet local laboratory needs (in terms of timeliness, reliability, and capacity) following a terrorist threat.

3.3.g Training. Training of personnel for routine monitoring as well as event sampling and analysis of biological and chemical hazards in water should necessarily follow the development of key analytical protocols and the analytical play book. The EPA has appropriately recognized this by including the need for training modules and evaluation exercises in the Action Plan. Adequate training of personnel from water utilities and local and state agencies is essential to early detection and to effective water terrorism response. To promote collaboration and effective response, public health officials should also be involved in this training.

Application to Large versus Small Systems

In general, small utilities, whether they are community or non-community water systems, will not have in-house capabilities to monitor or measure specific priority contaminants. However, they may be able to monitor for some indicators that could serve as early warning systems (e.g., monitoring chlorine residual). Other more sophisticated early warning systems will probably be too expensive or complicated for small systems to easily employ.

Once there is credible evidence for a toxic attack, the analytical play book would probably require that state agencies become involved and that state personnel and laboratory facilities would become available, such that utility size may not affect the path taken. On the other hand, some of the early stages in the play book could be tailored to utility size based on differing analytical and diagnostic capabilities.

Recommendations

In conclusion, the panel recommends the following rewritten needs:

- A "play book" for sampling and analytical response to contaminant threats and attacks on water supplies and systems, including protocols for identifying "unknown" contaminants, that will serve as a vital component of an overall integrated guidance plan.
- Improved analytical hardware and associated field and laboratory analysis methodologies (including generic simple techniques and laboratory-based, off-line, and real-time monitoring technologies) for biological, chemical, and radiological contaminants in water.
- Requirements for appropriate QA/QC and sampling approaches in response to suspected biological, chemical, and radiological contamination events.

- Testing and evaluation of drinking water "Early Warning Systems" (EWSs), and EWSs from other sectors amenable to application in the water environment.
- An improved and expanded tiered capability laboratory capacity to be fully prepared for effectively responding to threats or attacks on water.
- Training modules and evaluation exercises for analytical methodologies and monitoring systems.

Containment, Treatment, Decontamination, and Disposal (Action Plan Section 3.4)

One of the most important stages in dealing with a contamination or threat event will be the actions taken to contain and treat contaminated water. Depending on where a contaminant is introduced, this may involve mitigation within a drinking water treatment plant, within the distribution system, or at points downstream. Any materials, including water, that cannot be successfully treated to meet water quality or other standards will have to be disposed of properly. In addition, the physical infrastructure of water systems may require decontamination before it can be safely reused.

The EPA Action Plan delineates this work into four categories of research and technical support needs:

a) Improved distribution system models that can be used to more effectively protect drinking water in the event of deliberate contamination.

b) Improved understanding and documentation of the environmental fate of contaminants in source waters, within drinking water systems, and once they are released.

c) Newer technologies and treatment processes to achieve multiple goals, and effective disposal and/or treatment techniques and technologies for water and equipment that have been contaminated.

d) A methodology, approach, or guide for use in determining when a drinking water system is contaminated and when it is clean and can be used.

Commentary on Identified Needs

3.4.a Improved Distribution System Models. Distribution system hydraulic models can help delineate deliberate or accidental contamination that may be introduced into source waters or at points in the water distribution system. Hydraulic models can be used to identify affected areas within the water system, contaminant concentration, the influence of decay and dilution, and the duration of the exposure, providing information that can be used to determine which areas may need to be isolated, closed, sampled, or cleaned and when these areas can be returned to use. Further development and resolution of distribution system hydraulic models are clear research needs. In general, the Action Plan adequately describes the need for improved models and identifies research issues and requirements for their implementation. However, several issues should be more clearly addressed.

Hydraulic models have many applications in addition to their use as part of water security efforts. The multiple benefits that may be obtained from the research activities should be better described.

The EPA should conduct an inventory or survey of water systems to determine (1) how many utilities have developed and calibrated models, (2) which models are being used, and (3) the availability of information to develop models. The Action Plan should discuss the likely difficulties associated with the development, calibration, and implementation of the models. Training needs should be described, since water utility operators will need to be able to use the models on short notice and under adverse conditions. For example, such training could be made part of the Operator Continuing Education Program that all states are now required to have. Training and implementation needs should devolve from information gained from the water system vulnerability assessments.

Hydraulic models can be developed for all types and sizes of water systems including large, complex systems that have multiple wells or surface water sources, storage facilities, and treatment sites. Nevertheless, calibration of the models for each utility's unique conditions can be time consuming and expensive and may be beyond the financial and technical capabilities of many medium- and small-sized systems, even though small systems may be structurally simpler than larger systems. The EPA should describe the need for hierarchical models for various sizes and types of water systems. The models for small systems may be less complex, and the EPA should determine the applicability of developing a less complicated model that may be used by many smaller systems. It may be possible to develop a model with relatively few parameters that can, in conjunction with information from continuous pressure monitors and flow meters, provide useful information when small systems are contaminated.

The models should consider both decay or die-off rates of water contaminants and the possible adsorption or attachment of the contaminants to the interior surfaces of pipes and storage reservoirs. In addition, the current models are limited to the consideration of a contamination event of relatively short duration (5 minutes or less). Continuous introduction of a contamination over a longer period of time should be modeled as well.

The Action Plan notes that existing models can be overlaid with geographic information system (GIS) and public health data and recommends the development of an interface module to allow overlapping of health data, consumer complaints, GIS, and SCADA data with current hydraulic models for data collection and manipulation in close to real time. Before developing such a module, the intended use of the information and limitations should be considered and any associated research or implementation needs should be described in conjunction with the surveillance activities described in section *3.6.b*. In addition, the limitations of the information garnered from this application should be made available to water system managers. Coding the location of health outcome information for routine display on a water distribution system map is not likely to be feasible in the near future, and its effectiveness in warning of potential waterborne exposures seems questionable. However, it might be useful to develop an interface module for mapping cases as they occur during an investigation of an outbreak or contamination event. This type of mapping could assist officials in identifying and isolating a general area of contamination.

Finally, it should be noted that the Action Plan discusses the use of POU devices for sampling purposes in conjunction with distribution system models. The panel's review of this application is discussed in the previous section.

3.4.b Improved Understanding of the Environmental Fate of Contaminants. A better understanding of contaminant fate and transport in various source waters (including both surface water and groundwater) and within water systems is clearly integral to determining how pollutants that are intentionally added to such systems might behave. Nonetheless, this need is stated in such broad terms that it is impossible to define logical starting points for attempting such research, which should necessarily be cognizant of the very large body of work that has occurred on this topic over the last 30 years. Thus, the need should be restated in a way that is more approachable from the standpoint of understanding possible threats to water supply systems.

The complexity of the need is illustrated by considering the amount of work involved in better understanding the fate and transport of every individual contaminant of concern. Given limited resources, it may be desirable to instead have as the goal the identification of generic physical and chemical parameters (e.g., K_{ow}, K_d, other partition coefficients, half-lives) that are predictive of contaminant behavior in water supply systems. A second approach would be to develop a set of fate and transport paradigms for a small number of common threat scenarios (which might be defined in response to the need stated in section *3.2.b*). This is consistent with the notion in section 3.2 of developing a short list of possible threat scenarios that explicitly consider certain exposure routes. Finally, a literature review is necessary as a precursor to engaging in research on this topic in order to document where the field of contaminant fate and transport has been and is going.

3.4.c Newer Technologies and Treatment Processes for Water and Equipment That Have Been Contaminated. Although the Action Plan highlights a number of treatment processes to address water security needs, the Action Plan could better articulate the important treatment issues by structuring the discussion according to the following four general approaches:

- What kind of treatment can be expected from in place conventional technologies?
- What kind of new technologies could be added in a preventive or quickly reactive mode?
- How can mobile technologies be brought in?
- How can mitigation of distribution system contamination occur (with POU devices, turning off part of the distribution system, flushing, and others)?

Traditional centralized whole or partial system mitigation, depending upon the type of contamination, has successfully included:

- boosting chlorination levels
- improving central treatment performance
- adding powdered activated carbon at the plant or in the distribution system (experimentally)
- isolating portions of the distribution system
- flushing mains and service lines
- bringing in mobile treatment systems (e.g., Reverse Osmosis Water Purification Unit)
- others

These traditional techniques are likely to be more feasible than newer, more complex techniques (e.g., post-contamination POU/POE), and they can be implemented rapidly in most cases. Readily accessible information is needed on techniques that are particularly effective for decontaminating distribution systems and treatment facilities after they have become contaminated with various types of agents. Both here and with the other contamination circumstances, linkage of the finite types of contamination scenarios based upon physical and chemical properties, to the relatively short list of mitigation approaches should be made. This approach would be more efficient than creating long lists of potential contaminants and attempting to develop specific mitigation data on each one. And again, this is consistent with the notion in section 3.2 of developing a short list of possible threat scenarios that explicitly consider certain exposure routes.

The Action Plan suggests a possible role for POU or POE devices for mitigation of some types of contamination. POU (single tap) and POE (whole house) water treatment devices cover a broad range of chemical and microbiological removal capabilities. Although many POU/POE devices undoubtedly have capacity to remove the more exotic terrorism agents, to date they have not been tested against those agents (although programs are underway to develop expanded test protocols and assess several units). For their application as a mitigation or protection against high risk contaminants, the units may need to be more ruggedly designed, undergo more rigorous QA/QC in manufacture, and be proven in tests against the actual agents or suitable surrogates.

The presence of appropriate POU or POE devices prior to a contamination event may provide some serendipitous benefit in removing the agent. For example, the incidence of cryptosporidiosis was reported to be lower among people in Milwaukee who had certain treatment devices in place during the *Cryptosporidium* outbreak in 1993. On the other hand, the devices could also increase exposure if the accumulated contaminant leached into the water at a later time. Consideration should be given to exploring the possible role for POE treatment as a preemptive approach for certain essential and high risk facilities such as police and fire stations and medical care facilities. In hospitals, POE technologies might also provide immediate ancillary benefits by providing protection from routine water quality variability.

Using POU or POE devices for post contamination mitigation is problematic, although this approach might be appropriate during persistent distribution system contamination that cannot be rapidly removed by conventional treatment. However, the logistics of implementing a decentralized POU/POE system would be formidable, both in terms of installation time and expense, especially in a large community.

3.4.d A Methodology for Determining When a Drinking Water System Is Contaminated and When It Is Clean. This need is an amalgam of several broad objectives. The main goal appears to be to develop a research plan that would provide the means for the EPA to say with confidence when a water system or supply is no longer contaminated and when it can be again used for limited or unlimited beneficial purposes, including as a source of drinking water. This need represents an additional play book, like that mentioned in section *3.3.a* for monitoring and in *3.6.d*, which identifies the need for a risk assessment/risk management framework for identifying the impact of decontamination and treatment options and the subsequent risk assessment response. As discussed in Chapter 2, these play books should be combined into a comprehensive response guidance document.

Application to Large versus Small Systems

For two of the needs above, there are substantive differences that may accrue between small and large water supply systems. In particular, the development of adequate hydraulic models of distribution systems becomes much more complex as the size of the system increases, although larger systems may have greater financial and personnel resources for conducting this activity. Second, with respect to the treatment of purposefully contaminated water, larger water supplies are likely to have more treatment options available compared to smaller water systems, and thus may be less vulnerable to certain threat scenarios.

Recommendations

In conclusion, the panel recommends the following rewritten needs:

- Improved distribution system models that can be used to more effectively protect drinking water in the event of deliberate contamination, which should consider not only technical improvements to such models, but also operator training to better use the models, the availability of information needed to run the models, and the dual-use benefits of model development.
- Improved understanding and documentation of the environmental fate of contaminants in source waters, within drinking water systems, and once they are released, focusing first on a literature review and then on either the identification of generic physical and chemical parameters that are predictive of contaminant behavior in water supply systems or on a small set of fate and transport paradigms for common threat scenarios.
- Technologies and treatment processes to achieve multiple goals, and effective disposal and/or treatment technologies for water and equipment that have been contaminated, including in-place conventional technologies, new preventive technologies, mobile technologies, and technologies that can mitigate contaminant spread through the distribution system.
- A methodology, approach, or guide for use in determining when a drinking water system is no longer contaminated and when it can be placed back into limited or unlimited service. (This need is one component of the overall response guidance, which is also expressed in Chapter 2 and sections *3.3.a* and *3.6.d*, and would be best expressed in combination with those needs.)

Contingency Planning and Infrastructure Interdependencies (Action Plan Section 3.5)

Water systems will need to develop contingency plans for providing a sufficient quantity of adequate quality water to their service area in the event that deliberate malfeasance (or "natural" hazards) causing service disruption occurs. Water systems, particularly (but not only) larger ones, are increasingly relying on automation, and they depend on the reliable functioning of other systems (e.g., electric, telecommunications). Thus, contingency planning should consider the potential for disruption to occur not only within a water supply system but also to one or more of these necessary auxiliary systems.

The EPA Action Plan delineates this work into three categories of research and technical support needs:

a) Assessment of water supply alternatives for different-sized drinking water systems at different geographical locations in the United States when the usual supply of water is not available.

b) Testing and evaluation of improved technologies and approaches for providing supplies of water in the event of both long-term and short-term disruptions to drinking water systems.

c) An improved understanding of water system interdependencies with other infrastructure sectors that are critical to national security.

Commentary on Identified Needs

3.5.a Assessment of Water Supply Alternatives. The Action Plan stresses the importance of contingency planning for a range of system types, but this research need should be expanded to acknowledge that size and geographic location are not the only factors that account for diversity in water systems. Other factors, which may influence the nature of the required contingency plan or infrastructure interdependence, include:

- type of source water (e.g., lake, river, groundwater, etc.)
- existence of multiple sources of supply
- use of water purchased from a wholesaler
- interconnections with neighboring water systems
- system design (looped distribution, ability to blend supplies in distribution, treatment type)
- pressure source (predominantly gravity systems versus predominantly pumped systems)

The degree to which contingency planning can and should rely on consumer preparedness should be addressed. Is it realistic to rely on POU treatment or on consumer stockpiling of potable water (for how long; with what degree of compliance can be anticipated)? Such consumer preparedness can only be carried out with the assistance of a well-developed communication plan for response prior to and during an emergency. This communication plan should be developed upfront and should be known in advance by the potential recipients of information to minimize misinformation during an incident.

It should be noted that other benefits could arise from planning for contingencies resulting from terrorist actions or threats. These include improved preparedness for natural hazards (e.g., earthquakes, floods, tornadoes) or accidents (e.g., crashes, chemical tank failures). Indeed, the ancillary benefits that may arise from preparing for contingencies from terrorist actions or threats may make the implementation of such preparations more economically justifiable to ratepayers, regulators, and other stakeholders.

3.5.b Testing and Evaluation of Improved Technologies and Approaches for Providing Supplies of Water. Previous sections of this report (*3.3.c* and *3.4.c*) have discussed POU devices and how they might be utilized both for sampling and treatment purposes during a contamination event. That discussion is relevant here as well. In addition, identification and enumeration of technologies for providing emergency potable water supply would also be valuable, probably in the form of a database. To what degree, for example, are military resources available to handle the task of water supply during large-scale interruption? The appropriate alternative strategies for a given location will be site-specific but should be enumerated in such a database.

3.5.c An Improved Understanding of Water System Interdependencies with Other Infrastructure Sectors. This need should be expanded to include an understanding of the *reliability* of systems upon which continued functioning of the water system depends (e.g., electric power, road transportation, telecommunications), and an assessment of the weakest links among the systems that are required for continued functioning. For large utilities, a fault tree analysis for the most critical components or processes might be conducted, and in this manner such dependencies could be detected. It might be a more efficient use of resources to "harden" aspects of other infrastructure so as to promote reliability of a particular water system component (e.g., electric power utility substation), rather than to harden an aspect of the water utility itself. It should be noted that preparation for the Y2K changeover proved to be a valuable source of lessons regarding interdependencies, and this knowledge should be captured in responding to the challenge of terrorism.

A potential contingency response by utilities to system vulnerability is disaggregation or decentralization of supply and/or treatment systems. The Action Plan should consider to what degree this is beneficial or undesirable from a preparedness viewpoint (e.g., is there an optimum level of disaggregation or a maximum safe level of aggregation?).

Additional Research and Technical Support Needs

Missing from this section is a discussion of a key element to successful operation of most water systems—the human factor. The Action Plan should consider under what circumstances the operation of a water treatment plant (or supply system) could be adversely impacted by the incapacitation of the operating personnel and whether there are potential contingencies or mitigations for such occurrences. The Action Plan should also consider potential back-up support that might exist for this failure pathway (e.g., importing personnel from neighboring utilities, or military and civilian emergency response personnel). It should be noted that a failure of "human subsystems" that could impact a water system could occur as a result of a direct attack via a non-water route, for example via a massive community bioterrorism incident in which a substantial fraction of operating personnel were affected.

Application to Large versus Small Systems

Contingency planning is highly dependent upon the size, location, and type of water supply system to be protected. In general, smaller systems may be less dependent upon automated control technologies, and therefore less vulnerable to cyber threats. Small systems may or may not be able to readily arrange for alternative sources of supply or redundant connections from other necessary infrastructure systems (especially for small systems in sparsely populated regions). These considerations indicate that the overall response guidance needs to consider diverse strategies depending upon the threat encountered as well as the nature of the system.

Recommendations

In conclusion, the panel suggests the following rewording of the identified needs:

- Assessment of water supply alternatives for different types of drinking water systems in the United States (reflective of effects of size, type of supply, system design, and type of distribution system), when the usual supply of water is not available.
- Testing and evaluation of improved technologies and approaches for providing supplies of water in the event of both long-term and short-term disruptions to drinking water systems. The evaluation of approaches should include customer preparedness and should assess degree of reliability of the options.
- An improved understanding of water system interdependencies and the reliability of such interdependencies with other infrastructure sectors that are critical to national security.
- Explicit understanding of the role of failure of the "human subsystem" in water system operation, and the development of contingencies for responding to such eventualities.

Targeting Impacts on Human Health and Informing the Public about Risks (Action Plan Section 3.6)

Because human health protection is one of the ultimate endpoints of the EPA's water security efforts, research into better understanding the human response to contamination or threat scenarios is critical. This includes not only human physical response to different classes of waterborne contaminants and ways to measure that response, but also the social and psychological response to contamination events and how best to communicate relevant threat information to all stakeholders.

The EPA Action Plan delineates this work into five categories of research and technical support needs:

a) An improved understanding of contaminant exposure routes, and the acute and chronic public health effects from contaminants in drinking water supplies and systems.

b) A health surveillance network to help public health officials and water utility operators rapidly identify and control a disease outbreak or other public health emergency associated with contaminated drinking water.

c) A methodology or procedure for using non-traditional data sources (e.g., LD_{50}, Quantitative Structure Activity Relationship [QSAR]) for the derivation of acute and chronic toxicity values applied to water.

d) A risk management/risk assessment framework for identifying the impact of decontamination/treatment options and the subsequent risk assessment response.

e) Methods and means to communicate risks to local communities with respect to threats and to respond to customers and the media in the case of an attack on drinking water systems.

Commentary on Identified Needs

3.6.a An Improved Understanding of Contaminant Exposure Routes and the Acute and Chronic Public Health Effects from Contaminants in Drinking Water. The large scope of this need makes it unusable as an objective in an Action Plan. Taken literally it describes a decades-long research agenda that has already been in progress for many years. It includes yet another database with no clear idea of how this product will be used, articulated with other databases and systems, and maintained over time. An EPA strategy that emphasizes immediate usability and first approximations is a sound one. This need, therefore, should be interpreted in that light and be stated more modestly and specifically.

Generic categories corresponding to the three routes of exposure (inhalation, ingestion, dermal) could be developed to provide generic models for different large classes of agents that would provide some initial, albeit crude, guidance in a relatively short span of time, and the details could be continually filled in as additional information becomes available (e.g., regarding sensitive subpopulations such as children, the elderly, and immunocompromised individuals). This is consistent with the notion in section 3.2 of developing a short list of possible threat scenarios that consider explicitly certain exposure routes.

3.6.b A Health Surveillance Network Associated with Contaminated Drinking Water. In describing this need, the EPA makes assumptions about the activities and capabilities of the CDC and other Department of Health and Human Services (DHHS) agencies that need to be corrected. The Action Plan states that "if the [water] contaminant causes a 'notifiable disease,' it will be picked up by existing health surveillance systems," and thereby presumes that most notifiable diseases (e.g., giardiasis and cryptosporidiosis) are typically reported and in a timely fashion. Indeed, the percentage of reportable diseases reported by even the largest and most sophisticated active disease surveillance systems is surprisingly low (for an example from New York City see NRC, 2000, Chapter 6). The Action Plan also incorrectly notes that a national surveillance system for potentially waterborne diseases is well underway. The Action Plan should contain an accurate evaluation and description of current surveillance and other related activities in the public health sector, and the EPA should define its role and research agenda in this regard. The EPA may not be the lead agency for public health surveillance but should be an active participant in understanding and establishing effective surveillance for waterborne agents, since it is the lead agency for water security.

The primary goal(s) of the waterborne surveillance system should be stated. Is the primary goal to detect a possible terrorist attack, or detect outbreaks of accidental contamination, or both? If the goal is to detect a terrorist attack, then surveillance may focus on very different agents and illnesses. The Action Plan should describe the overall needs of a surveillance program and how waterborne surveillance would fit into a larger surveillance program. The plan should also address the investigative response (e.g., who will take the lead for initiating action, and how will the investigative teams coordinate their activities?) in addition to describing research activities. Finally, the needs for training and coordination of local health department employees and medical personal in the development of an effective water surveillance program should be acknowledged.

Public health surveillance is important to help detect possible outbreaks or epidemics. The surveillance activities should be sensitive enough to detect increased risks early enough for the initiation of timely investigations, mitigation actions, and efforts to prevent the spread of illness. Surveillance activities can be designed to monitor various outcomes such as selected diseases (e.g., cases reported by clinicians), symptoms (e.g., complaints to nurse practitioners), events (e.g., sale of anti-diarrheal medicines), and/or laboratory analyses (e.g., positive stool specimens for *Cryptosporidium*). If the incidence of any of the outcomes is increased, officials must then assess the risk and take appropriate actions. Information will be required about the possible routes of exposure (ingestion, inhalation, dermal), modes of transmission (indoors and outdoor airborne, foodborne, waterborne, person-to-person, direct contact), type and source of contamination, and water supply treatment or isolation options. Thus, surveillance activities will need to include a well-thought-out plan not only how best to monitor outcomes of interest but also how to coordinate the response of a team of investigators (epidemiologists, physicians, microbiologists, chemists, and engineers) if water is the suspected mode of transmission. There is a substantial communication component to this need on many levels (e.g., among the investigators, with the public), especially for intentional contamination events that are investigated in the context of a potential crime.

In recent years, several active disease surveillance systems have been initiated at the local and state level for the improved detection of both foodborne and waterborne outbreaks. An evaluation of these systems should be included among the research needs. The effectiveness of monitoring various alternative outcomes (e.g., complaints, symptoms, drug sales, sentential populations) should also be evaluated.

Finally, water quality monitoring and analysis should be used in conjunction with active disease surveillance data to help confirm or deny the role of water as a route of transmission during an event. This suggests better linking this research need with the monitoring activities discussed in section 3.3.

3.6.c A Methodology for Using Non-traditional Data for the Derivation of Toxicity Values Applied to Water. This need would be applicable in cases where new contaminants are noted for which there are few or no available toxicological data. The EPA already has substantial in-house resources and expertise in predictive toxicology, especially in the New Chemicals Program within the Office of Pollution Prevention and Toxics (OPPT). The Office of Ground Water and Drinking Water/Office of Science and Technology also has a functioning Health Advisory Program for non-regulated contaminants that includes short-term exposure scenarios. It would be logical and probably most efficient for the EPA to make use of those resources rather than contracting externally. The Food and Drug Administration is also engaged in some similar work, and the Department of Defense (DOD) has efforts in these areas. Collaborations between the active organizations for a concerted effort would appear to be highly desirable and most efficient.

Use of single point toxicity estimates such as LD_{50} values and structure/activity relationships to project acute toxicity values for human populations is a difficult concept and one that would require significant validation before carrying much weight in a decision process. Work is underway and some models do exist (e.g., MCASE, TOPCAT, DEREK3, PALLAS). The DOD's Armed Forces Medical Intelligence Center recently held a conference on prediction of acute toxicity that concluded that acute toxicity endpoint QSARs are less well developed than QSARs for chronic toxicity endpoints (William Waugh, EPA OPPT, personal communication, 2003).

QSAR methodologies have been developed for many longer-term toxicology endpoints, such as cancer and reproduction and neurotoxicity, and these are used routinely by the OPPT New Chemicals Program. Commercially available systems also exist. QSAR or other predictive systems for ecological endpoints also exist (e.g., ECOSAR and Aquatox), and these would be relevant for assessing the potential consequences of discharges of contaminated wastewater. Predictive airborne contaminant assessment work related to terrorism is also underway in the OPPT (e.g., Acute Exposure Guideline Levels). This would also have applicability in the water context for aerosol exposures in the home and in water and wastewater treatment plants.

Predictive tools applied to microbial contaminants have not developed as far as it has for chemical toxicology. The concept of Virulence Factor Activity Relationships (VFARs) has been suggested as appropriate for some pathogens. However, the state of the art and the scientific complexities involved place this in the long-term basic research realm. The far-reaching implications of this potential tool in public health and medicine are such that it would be best addressed by a research agency such as NIH rather than the EPA.

3.6.d Frameworks for Assessing and Managing Risks.[1] The centrality of risk assessment and risk management to an overall response for water security stands in stark

[1] The NRC's *Risk Assessment in the Federal Government: Managing the Process* (1983) distinguishes risk management and risk assessment, and this view is reflected in the Action Plan. Therefore, the distinction is maintained here.

contrast to its brief treatment in Action Plan. Indeed, the need statement suggests that risk assessment follows risk management, which is counter to prevailing uses of both terms (see NRC, 1983 for detailed descriptions). As envisioned by the panel, this particular need should stress the importance of integrating risk assessment and risk management into decision making during all stages from threat assessment to event response. Although the Action Plan recognizes that on-scene decision makers will require the support of a risk assessment/risk management protocol and it emphasizes the utility of table-top exercises, no information is provided on possible frameworks for use during contamination events or threat scenarios. This need requires considerably more thought from the EPA authors, and it should be put in the appropriate context, since it represents another component of the overall response guidance mentioned in Chapter 2, section *3.3.a*, and section *3.4.d*.

3.6.e Methods and Means to Communicate Risks to Local Communities. Prior to the development of methods and means to communicate risks to communities, there should be an established relationship in place with these communities. This relationship is the result of a detailed risk communication planning process that identifies not only the people with whom risks must be communicated, but also the appropriate methods and tools that can and should be used in diverse scenarios. Thus, risk communication cannot be viewed as the last step in the management of water system security but should be incorporated throughout. No one method or means will be appropriate for all places or times. Knowing what tool to use, and when, and how can only be determined through communication planning and research. For example, standard public health notices (e.g. "boil water" or "do not use," as mentioned in section *3.4.d* of the Action Plan) may not be effective in all or even a majority of cases (O'Donnell, et al., 2000).

Risk communication can be defined as a process to develop two-way communication between various parties that addresses the needs and concerns of all affected parties (NRC, 1989). Risk communication is an essential component in the overall risk management scheme. It should not be considered a separate piece of the model to be utilized and developed after the other steps, but something that should be factored into each step of the risk management model. Additionally, risk communication is not limited to the thoughtful development of tools to assist in the communication process. It is a methodology or strategic planning process to establish contact up-front with various constituent groups within and outside of an agency, facility or community. This process takes into account how communities see risk and requires earning trust and credibility and explaining risk.

There are seven important steps in risk communication planning: 1) issue identification and clarification; 2) setting the goal for the communication; 3) profiling or understanding the nature of the issue or event and the parties that will be affected; 4) identifying and assessing audience need and concerns; 5) message development; 6) method development; and 7) plan implementation and evaluation (Pflugh et al., 1992). In order for a plan to be successful, it must be in place prior to an event with all potentially affected parties informed in advance of what will be communicated and what they will be asked to do to protect themselves.

Information developed in advance and in consultation with the potentially affected parties will yield the response required and desired by the communicator should a national security situation arise. Having a plan in place, using tools developed through the risk communication planning process, and knowing how people will respond to risk information will help in the distribution of information to the appropriate people as needed. Releasing appropriate information in a timely fashion can build trust and may moderate the public response in the event of an actual attack or a hoax.

Application to Large versus Small Systems

For at least one research need in this section, there are considerations that should be taken into account for small versus large water supply systems. Resources for local health surveillance may be very limited for small water systems, and some surveillance methods may not be as effective for small systems. Thus, the evaluation of an active disease surveillance system should include an assessment of its effectiveness and financial feasibility for systems of various sizes.

Recommendations

In conclusion, the panel recommends the following rewritten needs:

- An improved understanding of contaminant exposure routes (not only direct ingestion but also dermal and inhalation exposures), and of the acute and chronic public health effects from contaminants in drinking water supplies and systems, which should focus on generic models for different large classes of agents.
- A health surveillance network to rapidly identify and help control a disease outbreak or other public health emergency associated with contaminated drinking water. This effort should be cognizant of active disease surveillance efforts already underway, the limitations of active disease surveillance, and the respective roles of the EPA and other public health agencies.
- An evaluation of the utility and validity of using non-traditional data sources (e.g., LD_{50}, QSAR) for the derivation of acute and chronic toxicity values applied to water.
- A risk assessment/risk management framework for identifying the impact of decontamination/treatment options and the subsequent response. (This need is one component of the overall response guidance, which is also expressed in Chapter 2 and sections *3.3.a* and *3.4.d*, and would be best expressed in combination with those needs.)
- Methods and means to communicate threat risks to local communities and to respond to customers and the media in the case of an attack on drinking water systems, the success of which will depend upon the prior existence of an established relationship with communities that is the result of a detailed risk communication planning process.

WASTEWATER

In areas of dense population, the carriage and appropriate treatment and disposal of human waste via the wastewater system provides an essential service to the maintenance of public health and sanitation. Wastewater collection and treatment systems are also control points for water quality protection. There are many health-related issues when considering the security of the nation's wastewater plants, because many surface water supplies of drinking water contain treated wastewater. The purposeful impairment of wastewater treatment facilities could notably affect drinking water quality downstream. In addition, there are other beneficial uses of surface water resources that can be adversely affected by disturbances in the wastewater system, including aquatic ecosystems and contact recreation.

The wastewater collection system, by design, serves as an access point to numerous structures in a region. Hence this system is not only physically vulnerable to terrorist activities, but it also presents a potential conduit for malicious use to damage structures that may be serviced by the system. Thus, it is appropriate that consideration be given to the security of the nation's wastewater systems, although the human health consequences may be somewhat more indirect than in the case of drinking water systems.

Wastewater Infrastructure (Action Plan Section 4.0)

The EPA Action Plan delineates this work into six categories of research and technical support needs:

a) A thorough understanding and documentation of the possible threats to the nation's wastewater treatment and collection system infrastructure, including the interdependencies with drinking water systems and other critical infrastructure.

b) An updated assessment of the possible health and safety risks related to potentially hazardous substances used by wastewater utilities or intentionally introduced into wastewater collection and treatment systems, including any impacts on residuals management operations (sewage sludge).

c) Improved intrusion monitoring and surveillance technologies to quickly notify wastewater utilities when these technologies are compromised by physical and cyber threats or chemical, biological, and radiological contaminants.

d) Improved designs for wastewater systems to reduce vulnerability to physical threats and as a way to prevent or mitigate the effects of attacks on wastewater infrastructure.

e) Enhanced prevention and response planning methods, including emergency response, contingency planning, and risk communication protocols and guidance for systems of varying sizes.

f) Methods and means to securely maintain and, when appropriate, transmit information on contaminants and threat scenarios applicable to wastewater systems.

Commentary on Identified Needs

In general the panel is concerned that the level of detail in this section of the Action Plan is much less than the level of detail that exists in section 3.0. Broad threats to wastewater systems include contaminant impact on facility performance, effects on receiving water quality and associated damage to environmental targets such as aquatic ecosystems, physical damage to collection systems or treatment facilities, and use of the sewer system as a means to get undetected access to sensitive locations. In addition, impacts on stormwater and collection systems (either separate or combined) should be considered. Within the Action Plan, more thorough and thoughtful analyses are needed to consider the security needs of wastewater infrastructure.

Certain distinct features differentiate wastewater systems from drinking water systems. First, wastewater system disruption is physically simple in that it is possible to introduce materials to a sewer on a surreptitious basis from almost anywhere (an intrinsic design feature of such systems). Second, it is impossible to turn off a wastewater collection system, which could make mitigation of a contamination event very difficult.

The Action Plan should address the broad spectrum of threats to wastewater systems and a various facility types. The interdependencies between drinking water and wastewater systems should be considered. For example, contaminated drinking water can serve as an input to the wastewater system *and* contaminated wastewater may adversely impact downstream sources of drinking water.

Emergency responders would benefit from an examination of the possibility and availability of emergency points of relocation of an effluent discharge or the availability and utility of emergency treatment systems to continue to protect vulnerable water resources. Emergency relocation or treatment may be especially useful where wastewater discharge is a major contributor to groundwater recharge or where it impacts a nearby surface water intake for drinking water supplies.

The degree to which deliberately introduced contaminants pass through a wastewater treatment plant and either into the effluent or the sludge needs to be reviewed. The potential impact of residuals from cleanup of a terrorist event needs to be judged (e.g., could wash waters sent to a sewer damage routine plant operation or pose a major additional load?). Occupational risks to wastewater collection system and treatment plant operators from these materials need to be assessed, along with recommendations for personal protective gear when contamination is suspected.

Recommendations

The security of the nation's wastewater infrastructure needs additional effort within the Action Plan, similar to that undertaken for drinking water systems, including input from various stakeholder groups. Based on the information presented in the Action Plan, the following rewording of needs is suggested:

- A thorough understanding and documentation of the possible threats to the nation’s wastewater treatment and collection system infrastructure, including the interdependencies with drinking water systems and other critical infrastructure.
- An updated assessment of the possible health, safety and environmental risks related to potentially hazardous substances used by wastewater utilities or intentionally introduced into wastewater collection and treatment systems, or stormwater conveyance and treatment systems, including any impact on residuals management operations (sewage sludge).
- An assessment of the possible health, safety, and environmental risks related to potentially hazardous substances produced during response to security threats (e.g., decontamination materials and their byproducts) which may be discharged to sewer systems or stormwater conveyance systems.
- Improved intrusion monitoring and surveillance technologies to quickly notify wastewater utilities when these facilities or technologies are compromised by physical and cyber threats or chemical, biological, and radiological contaminants. (Note that some of this information may be transferred from knowledge gained while assessing drinking water systems.)

- Improved designs for wastewater systems to reduce vulnerability to physical threats and as a way to prevent or mitigate the effects of attacks on wastewater infrastructure.
- Enhanced prevention and response planning methods, including emergency response, contingency planning, and risk communication protocols and guidance for wastewater systems of varying types (size, geographic location, design). The potential for emergency relocation of discharge or alternative treatment should also be assessed.
- Methods and means to securely maintain and, when appropriate, transmit information on contaminants and threat scenarios applicable to wastewater systems.

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Part II

Project Evaluation

Executive Summary

In the United States there is a new heightened concern regarding the vulnerabilities of critical infrastructures, including the public water systems, to a deliberate terrorist attack, and the potential consequences. The U.S. Environmental Protection Agency (EPA) holds lead responsibility for protecting the nation's water systems and is currently working with other federal, state, and local government agencies, water and wastewater utilities, and professional associations to improve water security. To support these responsibilities, the EPA developed the *Water Security Research and Technical Support Action Plan* (Action Plan), which identifies security issues for drinking water and wastewater, outlines research and technical support needs within these issues, and presents a prioritized list of projects to address these needs.

The National Research Council (NRC) was tasked to review the Action Plan. The NRC's Water Science and Technology Board organized the Panel on Water System Security Research to undertake this project. This report focuses specifically on the panel's Statement of Task questions #2 and #3, listed in bold below:

1. Has the Action Plan completely and accurately identified important issues and needs in the water security arena? If not, what issues and needs should be added or removed?
2. **Are the needs appropriately sequenced within the issues? If not, what adjustments are warranted and why?**
3. **Are the projects recommended for funding in the Action Plan appropriate to meet the water security needs? Are the projects correctly prioritized and sequenced? Is the timing of the projects, as identified in the Action Plan appendix, realistic? If not, what adjustments are warranted and why?**

4. Overall, what changes to the Action Plan are recommended to improve its presentation in terms of content and structure so as to more clearly convey the water security research and technical support program that is described?

A review of the water security issues and needs presented in the Action Plan (tasks #1 and #4) was provided in the panel's first report (See Part I).

ORGANIZING PRINICIPLES FOR WATER SECURITY

Prioritization is needed for the EPA to meet urgent needs for water security while simultaneously preserving a longer-term research strategy and remaining mindful of the agency's other essential tasks that contribute to public health and security. The basic organizing principles of the EPA water security research and technical support agenda should be to emphasize a continuing increase in the effectiveness and efficiency of our response and recovery capacity while identifying cost-effective preventive or mitigative countermeasures based on an understanding of the nature and likelihood of potential threats. Accordingly, the information needed to respond to a water system security event should be gathered and made available to those who might need it at every step—not just the final step. The ability to respond will be a process of successive approximations that will improve as information and methods improve. Key tasks that have relatively quick and immediate value should be given higher priority over longer-term projects that, while worthwhile, compete for human and financial resources.

In support of these organizing principles for water security, the EPA should:

- **Develop and implement a specific management plan within the agency** for the water security effort that includes adequate continuing resources and effective, stable leadership.
- **Mine existing data** for pertinent information and assemble it in an accessible and immediately useable form.
- **Develop effective information transfer and two-way communication** at the first stage of project planning.
- **Prepare research and technical support results for broad dissemination at the project level.**
- **Develop continually evolving guidance and integrated response protocols** for utilities and responders in case of a water security emergency.
- **Determine the value of water security measures**.
- **Consider the funding constraints of the end users** in the development and prioritization of the research and technical support efforts**.**

REVIEW OF PROJECTS IDENTIFIED IN THE ACTION PLAN

The Action Plan identifies a lengthy and substantive list of research and technical support projects that, if completed, would support and advance water-security related prevention, mitigation, response, and recovery activities (see Boxes 3-1 through 3-8 for complete project listings). In the panel's first report (see Part I), the general drinking water and wastewater security needs were evaluated. Chapter 3 of this report presents an evaluation of the research and technical support projects identified in the Action Plan to meet those water security needs. Because further development of wastewater research priorities is underway at the EPA, this review focuses primarily on the projects to support drinking water security needs, with some evaluation of wastewater projects currently underway. The following summarizes the recommended changes in emphasis, prioritization, and timing suggested for the research and technical support projects identified in the Action Plan as well as additional proposed projects. A chart highlighting suggested revisions to the project time lines (including additional recommended projects) is provided in Appendix A.

Drinking Water

The projects identified to support the protection of physical and cyber infrastructure are appropriate to address the needs identified in the Action Plan (section 3.1), but some revisions are suggested. Overall, the projects identified to support consequence analysis (*3.1.b*) need additional refinement to clarify their contribution to the current state of knowledge. Refinement of the vulnerability assessment methodologies (*3.1.a.4*) should be compressed and postponed until the end of the Action Plan life span so that information resulting from other projects can be incorporated in this analysis. Additional projects are proposed in support of a fourth need recommended in the panel's first report (see Part I) to assess the costs and benefits of countermeasures. These additional projects are of high priority and should be initiated as soon as possible and sequenced appropriately with the identification of countermeasures.

The prioritization and sequencing of the research projects to meet the needs for contaminant identification (Action Plan section 3.2) are all considered appropriate, but recommendations are made to strengthen the projects and focus the EPA on activities that will provide useful results in a timely manner. In the development of the contaminant database (*3.2.b*), the EPA should identify the most relevant criteria to be included in the database and focus initial data gathering on the highest priority information needed for response efforts. Where feasible, similar contaminants could be grouped into categories, thereby minimizing the time and effort required to produce a useful database. Information for the database should first be sought from existing sources, and the EPA will need to coordinate with other agencies to fill the remaining critical information gaps in a longer-term research effort. The scope of the simulant database should be narrowed to better address the potential applications for this effort, and guidance should be developed on the appropriate use of simulants. The EPA should also consider additional methods to improve accessibility of its databases and carefully evaluate current restrictions on information access.

Although the prioritization of the contaminant monitoring and analysis projects (Action Plan section 3.3) is reasonable to meet the needs, recommendations are offered to improve the projects, and several additional projects are suggested. The analytical response protocol is an essential task in the Action Plan that should be integrated with other proposed response protocols and carefully coordinated with related projects. More emphasis should be given to quality assurance/quality control measures in the projects concerning methods development, considering the potential impact of false positives and false negatives. Related monitoring projects should be closely coordinated with the Early Warning System projects so that monitoring technologies can be evaluated in that context. A project should be developed to explicitly address sampling protocols for water security threat scenarios, and additional research is needed to examine the spatial and temporal sampling requirements for water security events. Issues of liability and geographic distribution of laboratories also need to be addressed. It is clear that some of the projects (e.g., *3.3.b.1* and *3.3.b.5*) will not be completed within the three-year time frame of the Action Plan and may require large financial resources to conduct as described.

Many of the projects proposed to address the needs of containment, treatment, decontamination, and disposal (Action Plan section 3.4) are central to building an improved recovery capacity. The two sets of response protocols (*3.4.b.1* and *3.4.d.1*) represent high priority projects and should begin as soon as possible. Early versions of the protocols may require estimates to fill information gaps, but the refinement of response protocols should be considered a continuous effort that proceeds through successive improvements. Coordination with the other response protocols identified in the Action Plan and the many other projects which provide the data that inform the protocols will be essential. The development of a treatment technology document database (project *3.4.c.8*) should be advanced in time to provide treatment guidance as quickly as possible. Two additional projects are also recommended to support the need for improved distribution system models: the EPA should conduct a survey of the use of hydraulic models at water utilities, and additional long-term research is needed to further enhance the capabilities of distribution system models. Several recommendations are provided to focus the projects on more reasonable near-term goals and to clarify longer-term research objectives.

The research projects to meet the drinking water security needs regarding contingency planning and infrastructure interdependencies (Action Plan section 3.5) are appropriate in their prioritization, timing, and sequencing. Recommendations are offered to improve the projects, and one additional project is suggested. A review of the appropriate role and responsibility of customers in preparing for water system emergencies should be included in the contingency analyses. An analysis of recently developed water supply technologies should include an assessment of the reliability of the technologies, and the information should be made available as soon as is feasible. The projects to assess the interdependencies with other infrastructure should utilize lessons learned from various case studies before evaluating potential contingency responses, and the benefits and risks of disaggregation or decentralization should also be considered. In support of the additional research need recommended in the panel's first report (see Part I), the Action Plan should develop a project to evaluate impacts from failure of the "human subsystem" and whether there are potential contingencies for such occurrences.

Several recommendations are made to enhance or expand on the projects identified to improve the understanding of contamination-related health effects, develop or refine a risk management framework, and enhance risk communication (Action Plan section 3.6). The project to generate an operating procedure for risk assessment and risk management for water security is essential to decision making and should be accelerated and coordinated with other response protocols in the Action Plan (*3.3.a.1-2, 3.4.b.1, 3.4.d.1)*. Analyses of acute and chronic health effects and quantitative assessments of potential exposure should build on existing knowledge in order to provide initial and timely guidance to utilities and responders. A review of predictive methodologies to assess toxicology values in absence of experimental data should be accelerated to illuminate gaps where additional method development work is needed and to clearly define the limitations of these methods. In the area of risk communication, EPA should emphasize research that reviews and refines existing communication strategies and explores how tools can be used more effectively, instead of only emphasizing tool development. A two-phased effort is recommended to support the needs of water security: first, focusing on selecting and refining a risk communication strategy, and second, addressing the development, testing, and distribution of communication tools. Recommendations are provided to assist the EPA in planning and implementing an active disease surveillance network.

Wastewater

Protecting the wastewater systems against attack and precluding the system from being used as an instrument of attack upon other critical infrastructure are both important and deserve attention. Yet, the threats potentially posed by an attack on the wastewater system are different in important ways from those posed by an attack on the drinking water system, and treatment plant disruptions represent less direct risks to human health than drinking water system contamination. Because EPA is currently working with stakeholders to revise project plans for wastewater security, the panel focused its review on those projects identified in the Action Plan (section 4.0) that are currently ongoing or slated to begin in 2003. Generally, these projects are appropriate to meet the most pressing needs for wastewater, focusing primarily on threat assessment, determination of countermeasures, and access control. However, the project to assess technologies for identifying physical threats and contaminant introduction should be delayed until vulnerability assessments and threat assessments have been conducted for wastewater infrastructure, so that the importance of contaminant detection for wastewater security can be evaluated relative to other proposed wastewater projects. Several additional topics are suggested where further research is needed, including management and disposal of contaminated waste and sludge and the adequacy of plant worker protection to prevent harm during potential water security attacks.

Implementation

Implementation of the Action Plan involves communicating and disseminating results, continually assessing ongoing work and emerging needs in the area of water security, building and sustaining collaborative relationships with other water security researchers and organizations, determining and articulating the roles and responsibilities of other organizations and federal agencies conducting the work identified in the Action Plan, and identifying and securing the funding necessary to support the identified projects. Overall, the projects identified in the draft Implementation Plan will make valuable contributions to the implementation effort, with the following suggested improvements.

Effective and broad collaboration with other water security experts is essential to the success of the Action Plan. The distribution system consortium should be expanded beyond “several federal agencies and AwwaRF” to include expert researchers, consultants, utilities, and national laboratories. Several projects involve verification of emerging water-security technologies; these should be selected using cost-benefit analyses. For projects *5.2.a.2-3*, Environmental Technology Verification funds should be awarded selectively to technologies that are broadly applicable to classes of chemicals/microbes or that are specific to high-risk, likely threat agents. The subsidization should be provided for essential devices that would not otherwise be tested because they have very limited commercial potential.

Developing an effective broad communication strategy that meets the needs of the wide range of stakeholders, including response organizations, water organizations and utilities, public health agencies, and the media, while addressing security concerns, should be among the highest priorities for the EPA. The projects identified in the draft implementation plan are appropriately prioritized, although some additional components and separate projects are suggested to strengthen the communication efforts. The project on how to get the right information to the right people at the right time should be among the highest priority efforts of the entire Action Plan. Several additional projects are suggested, including an analysis of the consequences of various levels of information security, an assessment of the benefits and limitations of existing methods of dissemination (e.g., web pages, the Water Information Sharing and Analysis Center), and research on means to utilize pertinent information from the community.

Chapter 1

Introduction

Our nation has learned that it is not invulnerable to global or domestic terrorism, and recent events have heightened concern regarding the vulnerabilities of critical infrastructures, including the public water systems, to deliberate attack. The consequences of an attack on water systems could be substantial, and even a small-scale attack could lead to widespread panic and a loss of confidence in the water system. Efforts are underway at many water and wastewater utilities to reduce the vulnerabilities of the nation's water systems and develop appropriate levels of preparedness to respond to future attacks. The U.S. Environmental Protection Agency (EPA) holds lead responsibility for protecting the nation's water systems (Office of Homeland Security, 2002) and is currently working with other federal, state, and local government agencies, water and wastewater utilities, and professional associations to improve water security.

To support its water security responsibilities, the EPA in a joint activity of the Water Protection Task Force and the National Homeland Security Research Center recently developed the *Water Security Research and Technical Support Action Plan* (Action Plan) (EPA, 2003a). The Action Plan identifies security issues for drinking water and wastewater, which make up the major sections of the document (Sections 3.1-3.6, 4.0, and 5.0). The Action Plan also outlines research and technical support *needs* within these issues, and presents a prioritized list of projects to address these needs (See boxes 3-1 to 3-8 for listings of the needs and projects identified in the Action Plan). The research and technical support projects identified in the Action Plan are intended to provide products that will be timely, functional, and responsive to water security needs. The document presents a schedule for implementing the identified projects and will be used to determine EPA funding priorities for water security research and technical support efforts over the next three years. A subsequent draft the *Water Security Research and Technical Support Implementation Plan* (Implementation Plan) (EPA, 2003b) provides additional descriptions of the projects identified in the Action Plan, and it presents minor revisions to the scheduling of the projects.

GENESIS OF THIS STUDY AND CHARGE TO THE PANEL

The EPA approached the National Academies[1] in the fall of 2002 seeking expert scientific advice on its homeland security efforts. Subsequently, the Academies' National Research Council (NRC) undertook a study that would assess the EPA's efforts to advance the state of knowledge related to threat detection, mitigation, and decontamination and to develop information and technologies for use in preventing and mitigating the effects of chemical and biological attacks. To carry out this study, the NRC has appointed two expert panels, focusing on the topics of water system security and building decontamination. The NRC panels will provide consultations to the EPA on a continuing basis on specific aspects of the program as requested and produce several short reports.

This report summarizes the findings of the Panel on Water System Security Research, which is overseen by the NRC's Water Science and Technology Board. The panel was asked to review the EPA Action Plan, and this report summarizes the conclusions of the second phase of this review, focusing specifically on the panel's Statement of Task questions #2 and #3, listed in bold below:

1. Has the Action Plan completely and accurately identified important issues and needs in the water security arena? If not, what issues and needs should be added or removed?
2. **Are the needs appropriately sequenced within the issues? If not, what adjustments are warranted and why?**
3. **Are the projects recommended for funding in the Action Plan appropriate to meet the water security needs? Are the projects correctly prioritized and sequenced? Is the timing of the projects, as identified in the Action Plan appendix, realistic? If not, what adjustments are warranted and why?**
4. Overall, what changes to the Action Plan are recommended to improve its presentation in terms of content and structure so as to more clearly convey the water security research and technical support program that is described?

The panel's first report (see Part I) addressed task questions #1 and #4, providing an overarching review of the Action Plan and the research and technical support needs. Several additional water security needs were identified, and modifications or changes in emphasis were suggested. Part I recommended increased attention to interagency coordination and encouraged reconsideration of current restrictions on secure information dissemination. It further suggested that EPA incorporate the results of their research activities into integrated water security guidance for water and wastewater utilities. The report also highlighted some of the unique characteristics of small utilities that the EPA should consider when planning its water security effort. This second short report provides a more detailed review of the projects identified in the Action Plan and their prioritization and scheduling. Chapter 2 provides general organizing principles for prioritizing activities in the area of water security. Chapter 3 contains a focused review of the specific projects identified in the Action Plan, and it suggests modifications and

[1] The National Academies consists of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The National Research Council is the advisory arm of the National Academies.

additional projects to strengthen the water security research and technical support program.

Chapter 2

Organizing Principles for Water Security

The *Water Security Research and Technical Support Action Plan* (Action Plan) includes a broad suite of research and technical support topics that address many issues of pressing importance for preventing and managing serious attacks on the nation's water systems. Given the urgency and short time frame under which the Environmental Protection Agency (EPA) has been working on water security issues, the panel commends the agency for the speed and diligence of its efforts. Nevertheless, the development of the EPA's water security plans has reached a critical juncture, as implementation is just getting underway. The EPA will need to prioritize its efforts to meet urgent needs while simultaneously preserving a longer-term research and technical support strategy for water security and remaining mindful of the agency's other essential tasks that contribute to the public health and security.

Given the time and resource constraints on the water security program, it is clear that some kind of overarching prioritization is needed. It will be impossible to harden water infrastructure to the extent needed to eliminate all vulnerabilities, and the expense of many preventive actions and technologies may be high relative to the risk reduction generated. Moreover, if an event were to happen tomorrow, water systems, local and state health departments, and emergency response agencies would have to respond on the basis of whatever information was available. Thus, the basic organizing principles of the EPA water security research and technical support agenda should be to emphasize a continuing increase in the effectiveness and efficiency of our response and recovery capacity while identifying cost-effective preventive or mitigative countermeasures. Central to this objective is the development of a continually evolving integrated prevention and response guidance for utilities and responders, as recommended in the panel's first report (see Part I), which would weave together protocols, databases, training, and methodologies developed in the Action Plan effort.

The Action Plan recognizes that information is an essential component of effective response and recovery programs, but there should be additional emphasis on making this information immediately useful. The information needed to respond to a water security event should be gathered and made available to those who might need it at every step—

not just the final step. The ability to respond and recover will be a process of successive approximations that will improve as information and methods improve. The Action Plan should be implemented with this iterative process in mind.

The implications of the above are that key tasks that have relatively quick and immediate value should be given higher priority over longer-term projects that, while worthwhile, compete for human and financial resources. An example of a short-term, immediately valuable project is the harvesting of peer-reviewed and non-peer-reviewed scientific and technical literature (e.g., unclassified military documents) for pertinent information and the assembling of that information in a database that allows unimpeded access and use by any personnel who might need it (e.g., rapid response teams from the EPA, Centers for Disease Control and Prevention [CDC], or local and state public health personnel). Within this project, the most useful and relevant information should be made available as soon as possible. For most chemical or biological agents, the most important information pertains to an agent's removal or inactivation by water treatment processes already in use. In some cases, responders may only need to know whether a specific agent (e.g., a virus) is more or less resistant than the agents for which current water treatment technologies are already designed. Other valuable information includes potential health impacts, relevant routes of exposure, decay rates for chemicals, and survival time for microorganisms. Where feasible, similar contaminants can be lumped into categories to hasten the production of usable information. An example of a longer-term activity that should proceed on a less urgent schedule is the development of a master contaminant database with comprehensive, experimentally determined information on each contaminant.

In keeping with this strategy, the EPA should identify a minimum required data set for response and remediation at present and then gradually work to improve the levels of knowledge. A potential danger of the Action Plan, as it is currently expressed, is that some areas could generate information that is too detailed for our present state of response capabilities while other projects that could produce more general but useful results, such as risk communication strategies and information dissemination, lag behind. The EPA should strive to keep the production of useful water security projects "in phase" with current response capabilities, so that responders can be as effective as possible at any given point in time.

The following bullets constitute organizing principles for water security recommended by the panel.

Overall goal:
To improve the security of the nation's water systems.

Strategy:
Develop a practical program of water security research and technical support, emphasizing a continuing increase in the effectiveness and efficiency of our response and recovery capacity while identifying cost-effective countermeasures based on an understanding of the nature and likelihood of potential threats.

Suggested strategic actions:

- **Develop and implement a specific management plan within EPA** for the realization of the Action Plan that includes adequate continuing financial and human resources and effective, stable leadership to monitor and coordinate the many projects and project managers. Action Plan project managers need to be continually aware of related activities both within and outside EPA in order to minimize duplication of effort and allow integration and updating of protocols as new data are generated. If projects suffer from frequent change of leadership, coordination will be impaired, harming the essential integrating functions of many of the Action Plan's projects. A process and schedule for reviewing the overall water security effort, evaluating its progress and impact, and reassessing its priorities should also be created and implemented.

- **Mine existing data** for pertinent information and assemble it in an accessible and immediately useable form. Information should be harvested from the literature (both peer reviewed and non-peer reviewed) and through collaboration with knowledgeable personnel, utilizing existing experience in this field among other agencies and experts (e.g., Department of Defense, CDC).

- **Develop effective information transfer and two-way communication** at the first stage of research project planning. Results that are not accessible, are too complex, are misunderstood, or do not utilize pertinent information from the community are not useful to achieve the overall goals. Communication plans should carefully assess who needs to use the information, so that the research and technical support products can be directed to the appropriate target audiences for maximum effectiveness.

- **Prepare research and technical support results for broad dissemination at the project level.** By requiring researchers and technical support staff to produce results in an immediately usable form, the EPA could make information available at the earliest possible time. For example, project staff doing literature searches for existing data should be responsible for providing their findings in a format that is compatible with relevant existing databases.

- **Develop continually evolving guidance and integrated response protocols** for utilities and responders in case of a water security emergency. An overarching comprehensive guidance is needed that would weave together the protocols and methodologies developed in the Action Plan and direct a utility through possible prevention strategies, available information resources, and response and recovery actions. The overarching guidance and the individual protocols (or play books) that support it should be made available as soon as possible and continually revised as new information becomes available.

- **Determine the value of water security measures**. Cost-benefit data, where feasible, are needed to help water utility mangers assess the value of specific water security measures relative to the estimated costs and risk reduction. The EPA should state its position on the value of improving water security to guide and support utility managers, who must communicate this information to the public and elected and appointed officials in order to obtain financial resources to implement security improvements.

- **Consider the needs and funding constraints of the end users** in the development and prioritization of the research and technical support plans**.** Products that are not affordable to the target users (e.g., utilities, state and local agencies) are not useful to achieving water security goals.

Chapter 3

Review of Projects Identified in the Action Plan

The *Water Security Research and Technical Support Action Plan* (Action Plan) identifies a lengthy and substantive list of research and technical support projects that, if completed, would support and advance water-security-related prevention, mitigation, response, and recovery activities. The subsequent draft *Water Security Research and Technical Support Implementation Plan* (Implementation Plan) (EPA, 2003b) provides additional information on near-term projects related to drinking water and the Action Plan's implementation. Consistent with a recommendation in the panel's first report (see Part I), the Environmental Protection Agency (EPA) is currently working in cooperation with the Water Environment Research Foundation (WERF) and other stakeholders to more carefully consider wastewater security needs, holding a stakeholder meeting in August 2003. Because this activity is anticipated to lead to many revisions in the wastewater section of the Action Plan, this report focuses primarily on the projects to support drinking-water security needs, with some evaluation of wastewater projects currently underway and suggestions on an overall strategy for addressing wastewater priorities.

In the panel's first report (see Part I) the general drinking water and wastewater security needs were evaluated. This chapter presents an evaluation of the research and technical support projects identified in the Action Plan to support those water security needs. The water security needs and supporting projects from the Action Plan are included, for reference, in boxes throughout the chapter (Boxes 3-1 to 3-8). Although the needs (in bold) were not prioritized in the Action Plan and were merely sequenced in a logical order, the projects listed under each water security need were arranged in priority order. Despite the many revisions and several additional needs suggested by the panel in its first report, for simplicity and ease of comparison with the first report, this chapter is organized according to the numbering scheme originally presented in the Action Plan. Changes suggested in Part I are noted where relevant.

As stated in Chapter 2, the basic organizing principles of the EPA water security research and technical support agenda should emphasize a continuing increase in the effectiveness and efficiency of our response and recovery capacity while identifying cost-effective countermeasures based on an understanding of the nature and likelihood of potential threats. The projects presented in the Action Plan are reviewed in that context within this chapter. The Action Plan presents a total of 123 projects, and, except where noted in the discussions below, the projects are appropriate for the high intensity, short time-frame effort envisioned by the EPA. Consistent with the recommendations in Chapter 2, many of the projects emphasize technical support and focus on short-term, data mining efforts. To streamline this review, the panel focused its comments on specific aspects of project content, scope, prioritization, timing, and sequencing for certain projects only. Projects that were considered appropriate are not discussed at length; thus, the amount of discussion on individual projects should not be viewed as a reflection of the panel's priorities.

DRINKING WATER

The research and technical support projects for preventing, preparing for, and responding to physical, cyber, and contaminant attacks on drinking water supply systems are categorized in the Action Plan in six major sections: (1) protecting physical and cyber infrastructure, (2) identifying drinking water contaminants, (3) improving analytical methodologies and monitoring systems for drinking water, (4) containing, treating, decontaminating, and disposing of contaminated water and materials, (5) planning for contingencies and addressing infrastructure interdependencies, and (6) targeting impacts on human health and informing the public about risks. The projects are discussed in detail below, and a chart highlighting suggested revisions to the time lines (including additional recommended projects) is provided in Appendix A.

Protecting Physical and Cyber Infrastructure (Action Plan Section 3.1)

The projects described within this need involve identifying physical threats to water systems, understanding the consequences of physical attacks on those systems, and identifying countermeasures to such attacks. These are core activities that establish the character and level of threat, and collect and disseminate information for cognizant officials at water utilities.

Project Evaluation

The suite of projects described appears to adequately address the needs identified in the original Action Plan (see Box 3-1), although some suggestions are provided to improve the projects. In addition to these, a new 'need' was suggested in the panel's first report (see Part I) that involved assessing costs and benefits of various countermeasures, including immediate ancillary benefits, and communicating the value of water and increased water securities to the public. Several projects should be developed to address this new need, for which suggestions are outlined below.

3.1.a Identification and Prioritization of Physical Threats. The projects concerning an updated identification and prioritization of threats are clearly important, and the Action Plan recognizes this in the timing of these projects. The project to identify likely physical and cyber threat scenarios (project *3.1.a.1*) based on input from threat analysts and the intelligence community is already underway. This project should also recognize dissemination of malicious disinformation as a potential vulnerability, as recommended in the panel's first report (see Part I). The project to examine lessons learned by utilities in assessing their vulnerabilities (project *3.1.a.2*) is also already underway through the American Water Works Association Research Foundation (AwwaRF), even though its outcomes may be of greater value farther in the future than at present. Developing lessons learned takes time; outcomes have to be evaluated before they become lessons, and organizations may be reluctant to share negative outcomes. The project should also include lessons learned from other infrastructure sectors (e.g., electric power utilities, the chemical industry).

Two projects are proposed to evaluate and refine the vulnerability assessment (VA) methodologies for drinking water utilities (projects *3.1.a.3* and *3.1.a.4*). The evaluation of the basic VA methodology (e.g., Risk Assessment Methodology for Water or RAM-W) is generic to all utility applications and clearly valuable. Nevertheless, these projects appear of lower importance than projects *3.1.a.1* or *3.1.a.2* because projects *3.1.a.3* and *3.1.a.4* focus primarily on refining existing methodologies rather than on the overall need of identifying physical and cyber threats. If financial resources are limited, they could be postponed. Refinement of the vulnerability assessment process should already be part of a good comprehensive planning process. In any event, it would make sense to perform the *3.1.a.4* project toward the end of the Action Plan life span so that information resulting from other projects can be incorporated into this analysis. Project *3.1.a.4* may not need to start as early as is currently scheduled, and it may require less time than the proposed 16-month time line.

3.1.b Understanding and Documentation of the Consequences of Physical or Cyber Attacks. The emphasis under this need for "thorough understanding and documentation of consequences of physical or cyber attacks" seems to be on cascading consequences in infrastructure networks, not on traditional distribution system models, although the nature of the proposed models was not described in the draft Implementation Plan. While such cascading effects are critical to network performance, it must be remembered that utilities deal with outages and natural hazards in the normal course of their business, including cascading effects. Operators understand the behavior of their own distribution networks, and most large utilities already use simulation models of their distribution networks. As a result, project *3.1.b.1* should not be given as high a priority as the *3.1.a* projects. Overall, the projects should be refined so that their contributions to current understanding are clearer, and these projects should take advantage of consequence assessments prepared for other infrastructure sectors.

3.1.c Countermeasures to Prevent or Mitigate the Effects of Physical and Cyber Attacks. The *3.1.c* projects concerning "a suite of countermeasures," which largely have to do with technical information collection and dissemination, are all important and reasonable to meet the identified need and should proceed as described. All water utilities will benefit from this information, but small and midsized utilities will particularly appreciate the findings from these projects, especially if the projects lead to guidelines for prevention and mitigation.

The project to prepare voluntary design standards (*3.1.c.1*) refers to pulling together recommendations for construction, hardening, and other aspects of utility security operations, so that facility designs can benefit from security experiences of the past. This project should emphasize the development of a "best practices" manual. Three years appears to be too long for the effort described.

The project to develop standards for minimum security protection of Supervisory Control and Data Acquisition (SCADA) systems (*3.1.c.2*) should be informed by parallel work in other industries such as chemicals and energy and by federal initiatives such as the National Institute for Standards and Technology's (NIST) Common Criteria, which includes a SCADA system security standard.

Additional Research and Technical Support Needs

In the panel's first report (see Part I), a fourth need was added to section 3.1, for which appropriate projects should be developed. This fourth need statement reads:

> Assessment of costs and benefits (direct and indirect) associated with various countermeasures; and development of a program to assist implementing organizations (including water utilities) in communicating with the public, customers, rate regulators, and local elected and appointed officials regarding the value of water, increased water systems security, and increased rate structures to create the necessary financial resources to implement such countermeasures.

Costs and benefits can only be meaningfully evaluated in the context of specific threat scenarios; thus, this project will need to be closely integrated with projects *3.1.a.1* and *3.2.a.2*. Cost and benefit information will help utility managers, customers, and elected and appointed officials assess the value of specific countermeasures (e.g., hardening facilities or contaminant detection technologies) and recognize the need to finance appropriate security measures, including effective response and recovery programs. Financing will be crucial if actions are to be implemented by water utilities to improve their systems security. Water utility resources are already under severe financial restraint, particularly small systems, which have limited financial resources. Typical projects responsive to this fourth need are:

1. Assessment of costs and benefits associated with various security countermeasures, including dual-use benefits. This should include the EPA taking a public position on the value of improved water system security.
2. Research on various rate structures that utilities are using or might be able to use, to finance the costs associated with improved water system security.
3. Development of a manual or other communication vehicle that water utilities can use to assist in increasing the awareness of the public, customers, rate regulators, and elected and appointed officials regarding the value of water, increased water security, and the increased rate structure necessary to create the financial resources for implementing improved water security measures.

These projects should be given high priority and initiated soon, since it will take time to put in place rate structures that will generate required financial resources. Projects #2 and #3 should be initiated immediately, and project #1 should be conducted concurrently with projects *3.1.c.1-4*, which will identify countermeasures for drinking-water protection.

Summary

The projects identified to support the protection of physical and cyber infrastructure are appropriate to address the needs identified in the Action Plan, but some revisions are suggested. Overall, the projects identified to support consequence analysis (*3.1.b*) need additional refinement to clarify their contribution to the current state of knowledge and project *3.1.b.1* should follow the higher priority projects such as *3.1.a*. Refinement of the vulnerability assessment methodologies (*3.1.a.4*) should be compressed and postponed until the end of the Action Plan life span so that information resulting from other projects can be incorporated in this analysis. Additional projects were proposed in support of a fourth need to assess the costs and benefits of countermeasures. These additional projects are of high priority and should be initiated as soon as possible and sequenced appropriately with the identification of countermeasures.

BOX 3-1
Protecting Physical and Cyber Infrastructure (Section 3.1)

The following lists the research and technical support needs and associated projects for protecting physical and cyber infrastructure as identified in the Action Plan (EPA, 2003a). The associated project scheduling reflects updates from the subsequent draft Implementation Plan (EPA, 2003b). The numbering scheme is consistent with that used in the Action Plan. Some modifications and additions to these needs were suggested in the panel's first report (see Part I).

3.1.a. An updated identification and prioritization of physical threats to drinking water infrastructure, including an improved understanding of the vulnerability of water systems to cyber threats and improved means to assess these vulnerabilities.

1. Identification of physical and cyber threat scenarios facing the drinking water sector, including a comparison of their impacts. (1/03-9/03)
2. Examination of lessons learned by drinking water utilities in assessing their vulnerabilities and in implementing countermeasures. (6/03-7/04)
3. Evaluation of vulnerability assessment methodologies currently used by water utilities. (3/04-2/05)
4. Refinement of the methodology for community water system vulnerability assessments, including evaluation of distribution systems. (8/04-12/05)

3.1.b. A thorough understanding and documentation of the consequences of physical or cyber attacks on the drinking water infrastructure, including the evaluation and testing of computational models and decision science.

1. Evaluation and demonstration of computational models and decision science models to address the consequences of physical and cyber attacks on water infrastructure, with particular emphasis on the distribution system and distribution system end points. (10/03-7/04)
2. Assessment of the consequences of physical and cyber attacks with an emphasis on the cascading consequences of such attacks on overall water system integrity. (1/04-12/04)
3. Assessment of the consequences of pressurized water loss on other critical infrastructure sectors and the community served by a drinking water system. (1/04-12/04)
4. Compilation of technical information and tools for enhanced consequence analysis of physical and cyber threats to drinking water systems. (6/04-9/05)

3.1.c. A suite of countermeasures to prevent, or mitigate the effects of, physical and cyber attacks on water infrastructure, including improved design of water systems to reduce vulnerabilities in the long term.

1. Working with standards setting organizations, preparation of voluntary design standards and recommendations for new construction, reconstruction, and retrofitting with a focus on security in combination with operations. (1/04-12/06)
2. Standards for minimum security protection of SCADA and other computer systems. (3/04-12/06)
3. Identification of physical countermeasures that could be used by a drinking water utility to minimize threats or mitigate the consequences of terrorist attacks, including disaster response and recovery plans (e.g., shut down methods, reconstruction). (3/04-12/05)
4. Assessment of existing security measures for the storage and transport of hazardous materials at water utilities and ways to improve security. (3/04-12/05)

Contaminant Identification (Section 3.2)

As the scope of available pathogens and hazardous chemicals expands, so should our assessment of the threats and consequences they pose to water security. Knowledge of critical contaminant properties, such as toxicity, environmental fate, and methods for mitigation, will be needed to respond effectively to attacks on the country's water supplies. The projects identified in the Action Plan are intended to address this need.

Project Evaluation

Overall, the projects that are proposed to identify the contaminants of concern and the relevant threat scenarios (see Box 3-2) are appropriate to meet the needs outlined in the Action Plan. The concerns discussed below relate to the project approach and the time and resources available to complete some of the projects. Suggestions are offered to streamline certain projects.

3.2.a Development of a List of Contaminants and Threat Scenarios. The project to develop and prioritize contaminant threat scenarios (*3.2.a.2*) will contribute valuable information to several other projects in the Action Plan (e.g., developing sampling strategies, *3.3.c*; evaluating treatment processes, *3.4.c*) and therefore merits early scheduling. In developing the list of threat scenarios, it is recommended that, where possible, the threat scenarios be designed to handle categories of contaminants, rather than designed for individual contaminants. This should streamline development of the list and should simplify the development of responses to the threat scenarios. The development of the list should take into consideration the point of entry to the system (e.g., reservoir, treatment plant, distribution system, or wellhead) as well as the amount of material that would be needed for the different types of contaminants to pose a threat.

The list of priority contaminants that may pose a threat to water utilities (project *3.2.a.1*) should be linked to a well-defined set of relevant criteria (e.g., treatability, solubility, human toxicity), which would be stored in the database mentioned below (need *3.2.b*). The development of this set of criteria is not a trivial effort. These data could be used to group or prioritize the individual contaminants as users of the list deem appropriate, although this prioritization process will be complex (see Part I for further discussion of prioritization). Developing this set of criteria and establishing an initial prioritization scheme based on these criteria will be essential components of project *3.2.a.1*. The project related to developing an improved understanding of the role of biologically produced toxins as drinking water contaminants (project *3.2.a.3*) is deserving of a substantial effort because this is an area in which a great deal is unknown.

3.2.b Development of a Database on the Critical Contaminants. In developing the contaminant database (project *3.2.b.1*), the EPA should initially focus on the minimum amount of information that would be needed to guide response activities. Essential information necessary for determining an appropriate response may vary according to the contaminant or contaminant group (e.g., treatability via chlorination is important information to have for types of microorganisms). Grouping the contaminants by type, where feasible, is suggested (1) to simplify the database, (2) to reduce the number of data gaps to be filled, and (3) to provide a means for including data on a larger number of relevant contaminants. Nevertheless, the benefits of grouping the contaminants may ultimately depend on the number of contaminants to be included in the database, and grouping would lead to greater uncertainty about the characteristics of agents within the contaminant groups.

As the database is developed and additional contaminant properties are considered for inclusion in the database, it will be important to keep in mind how the end users of the information will ultimately use the data. Building a comprehensive contaminant database for the sake of completeness will not be a wise use of resources. For simplicity, this project should be merged with project *3.4.c.8*, which develops a treatment technology database for contaminants in drinking water.

Critical information for the database should be sought first from existing sources, including peer-reviewed and non-peer reviewed literature and even best professional judgment where no data exist. Useful resources may include recent publications from the U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM, 2003a,b).

In designing research projects to fill the most important information gaps (project *3.2.b.3*), efforts should be made to coordinate with on-going research projects, such as those being conducted for contaminants on the Candidate Contaminant List. The time frame (approximately 18 months) and resources identified for this project appear to be insufficient to achieve its stated goal. Millions of dollars have been spent in dozens of research laboratories on characterizing contaminants during the last several years; it is unrealistic to expect that all of the identified gaps can be filled in with the available resources within the specified time frame. The draft implementation plan recognizes that this effort will need to be directed toward the most critical information gaps and projects that will be most likely to yield results. The EPA will also need to coordinate their efforts with other agencies currently funding research on specific contaminants to address this research need.

The lower prioritization of project *3.2.b.4*, which calls for a survey of background concentrations of priority contaminants in source or treated waters, seems appropriate. Considering the limited time and resources, this "survey" is assumed to represent a literature search rather than the collection of new water quality data. Analysis of existing data is most likely to shed light on only the well-known environmental contaminants (e.g., pesticides, some pharmaceuticals). It is unlikely that a substantial number of priority contaminants will have been measured with the necessary frequency, sensitivity, and accuracy to permit a meaningful assessment of background levels. The EPA should not invest in more exhaustive data collection at this time because adequate characterization of background concentrations for a broad suite of contaminants would require enormous resources (INFORM, Inc., 1995). With anticipated future advances in sampling devices and a better understanding of contaminant threat scenarios, a project to sample background concentrations of priority contaminants could be developed later. This would represent a long-term research goal that would need to be coordinated with related contaminant monitoring projects in sections 3.3 and 3.4.

3.2.c Development of a Surrogate/Simulant Database. The terminology used here merits additional explanation in the Action Plan, because the terms "simulant" and "surrogate" may have different meanings in various fields. "Simulant" is commonly used to describe non-pathogenic or non-toxic agents that can be used in experiments to study the behavior of similar agents (NRC, 2003b, Layne et al, 2001), and it is assumed that "surrogate" is used similarly here. Nevertheless, the term "surrogate" may add confusion, because the term is also used to describe alternate measures of risk or occurrence in actual samples in lieu of the target chemical or species (NRC, 1996).

The language used in the Action Plan ("a comprehensive database… on surrogates or simulates for priority contaminants"—project *3.2.c.1*) suggests an activity which is likely beyond the means of the program given its time frame and other priorities, and thus would not be a wise use of resources. Simulants may have limited applicability because there can be significant inherent variability in the response of seemingly similar agents. However, some field research might benefit from the use of a comparable non-pathogenic organism to assess the possible response of a pathogenic organism (e.g., use of *Bacillus cereus* spores vs. those from *Bacillus anthracis*). One end product should be a set of guidelines or an operational handbook describing how simulants should be used, including selection of the simulant, handling, analysis and data interpretation.

3.2.d Means for Maintaining and Transmitting Information on the Above. The EPA has proposed a number of communication mechanisms for water security (EPA, 2003c), and work is ongoing to refine its information sharing strategy. The EPA should consider additional methods to improve the accessibility of its databases. For a large database, this may include developing several interface windows, which are appropriately designed for different types of end users. Large utilities may be able to dedicate staff to become trained in using the proposed databases, but it will not be feasible for many of the mid-sized and smaller utilities to do so. Therefore, it may be more efficient to have designated individuals at the state or regional level to serve as resources to those utilities that do not have the in-house expertise. The system could be modeled after poison-control hotlines, where individuals are highly trained to lead the caller through the response steps, based on the characteristics of the event.

When making decisions about the classification of and access to information, consideration must be given to the costs and benefits of widely releasing the water security information. Overly restricting access to this information may unnecessarily impede efforts to prepare for and respond to an attack as well as result in the loss of valuable input from those who could provide improvements to the information. Ultimately, the criteria used to decide who shall or shall not have access to the information should be made available to the public. Essential water-security information should also be made available to the appropriate users at no cost.

Summary

Overall, the prioritization and sequencing of the projects to meet the needs are all considered appropriate, but recommendations are made to strengthen the projects and focus the EPA on activities that will provide useful results in a timely manner. In the development of the contaminant database, the EPA should identify the most relevant criteria to be included and focus initial data gathering on the highest priority information needed for response efforts. Where feasible, similar contaminants could be grouped into categories, thereby minimizing the time and effort required to produce a useful database. Information for the database should first be sought from existing sources, and the EPA will need to coordinate with other agencies to fill the remaining critical information gaps in a longer-term research effort. The scope of a simulant database should be narrowed to better address the potential applications for this effort, and guidance should be developed on the appropriate use of simulants. The EPA should also consider additional methods to improve the accessibility of its databases and carefully evaluate current restrictions on information access.

BOX 3-2
Identifying Drinking Water Contaminants (Section 3.2)

The following lists the research and technical support needs and associated projects for contaminant identification as described in the Action Plan (EPA, 2003a). The associated project scheduling reflects updates from the subsequent draft Implementation Plan (EPA, 2003b). The numbering scheme is consistent with that used in the Action Plan. Some modifications and additions to these needs were suggested in the panel's first report (see Part I).

3.2.a. A manageable, prioritized list of both contaminants and threat scenarios that might be used to destroy, disrupt, or disable drinking water supplies and systems.

1. Preparation of a prioritized list of contaminants (and contaminant classes), which includes a ranking approach that allows for dynamic changes to various parameters in order to routinely generate robust prioritization of contaminants based on emerging data or concerns. (10/02-3/04)
2. Identification and prioritization of contaminant threat scenarios facing the drinking water sector. (1/03-9/03)
3. Development of an improved understanding of the role of biologically produced toxins as drinking water contaminants. (10/03-1/05)

3.2.b. A contaminant database for consultation by approved individuals and organizations that describes critically important information on contaminants with the potential to harm drinking water supplies and systems.

1. Development of a comprehensive database of contaminants, specific to water threats, for use by individuals or organizations responding to a water contamination event. (1/03-ongoing)
2. Development of guidance on training approved individuals and organizations in the effective use of the database. (10/03-6/04)
3. Development of an improved understanding of the biological, physico-chemical, and/or toxicological properties of contaminants, based on gaps in the database developed under Project 1. (10/03-3/05)
4. Survey of information about background levels of priority contaminants known or suspected to occur in source or treated drinking waters. (3/04-12/05)

3.2.c. A surrogate/simulant database for use in testing and evaluating methods, approaches, and technologies to more effectively protect drinking water supplies and systems.

1. Development of a comprehensive database (possibly as a component of the contaminant database) on surrogates or simulants for priority contaminants including the relationships between the surrogate or simulant and the contaminants of interest with respect to a variety of biological, physico-chemical and toxicological properties. (1/04-9/04)
2. Development of guidance and training material for approved individuals and organizations to effectively use the database. (6/04-2/05)

3.2.d. Methods and means to securely maintain, and when appropriate, transmit information on contaminants and threat scenarios applicable to drinking water supplies and systems.

1. Evaluation of existing methods and means of information sharing on contaminants to ensure appropriate access to individuals and organizations based on their need for this information. (10/03-9/05)
2. Development of a framework for evaluating the sensitivity of information and for addressing individual and organizational needs identified in Project 1. (10/03-9/05)

Contaminant Monitoring and Analysis (Section 3.3)

Reliable detection of contaminants is an important component of effective response to chemical and biological attacks on water supplies. As the scope of available pathogens and toxic chemicals expands, so must our abilities to detect their presence. Early detection of an intrusion will be one defense to minimize widespread exposure. Aside from obvious needs to define the extent of contamination, advise the public of the contamination, and, if necessary, take actions to avoid exposure, detection methods and associated protocols are essential for assessing performance of treatment and decontamination efforts.

Project Evaluation

The research projects identified in the Action Plan were evaluated to assess whether they could meet current water security needs related to contaminant identification. In general, the proposed research projects are appropriate, although there are some concerns related to individual projects that are described below. The panel's first report (Part I) recommended several revisions to the research and technical support needs, but for simplicity, the needs and projects as presented in the Action Plan (and their associated numbering scheme; see Box 3-3) are used to organize the project-specific discussion below.

3.3.a "Play Book" for Analytical Response. According to the draft Implementation Plan, the preparation of a draft analytical response plan for addressing threats to drinking water from chemical contaminants, including unknowns (projects *3.3.a.1* and *3.3.a.2*), was scheduled to occur over a six-month period. Additional time may be needed to develop a complete and thorough analytical response module and to incorporate information that develops out of project *3.2.a.1,* the identification of priority contaminants. As recommended in Part I, a play book may also need to be tailored to address the capabilities of small systems. The other projects identified to meet this need (projects *3.3.a.3-6*) appear to be appropriate and logically sequenced.

The development of response protocols (or modules, such as *3.3.a.1*) is an essential task but needs to be integrated with the other proposed drinking water response protocols (*3.3.a.2, 3.4.b.1, 3.4.d.1, 3.6.d.3*) and coordinated with all the other parts of the Action Plan that provide the data to inform the protocols. Project managers responsible for the development of response protocols will need to communicate frequently and effectively with staff from salient portions of the entire research agenda to allow integration and updating as new data are generated. There must also be communication from those involved with the protocol development to those running other projects, indicating where important gaps are appearing as the protocols are examined, tested, and used by utilities and agencies. Therefore, adequate and continuing resources and effective, stable project management are especially important for this project to support the essential integrating function of the response guidance.

3.3.b Improved Hardware and Analysis Methodologies. Concentration techniques (project *3.3.b.1*) are essential to the sampling and analysis of biological components, and the development of concentration techniques should be closely coordinated with projects on associated detection methodologies (*3.3.b.3* and *3.3.b.5*). The resources committed to developing these concentration techniques for priority biological contaminants, however, may be insufficient to enable the EPA to achieve its goals. It is also likely that this effort will require a longer period than the two years currently allotted. For example, the efforts to develop methods for a single contaminant, *Cryptosporidium*, for the purposes of the Information Collection Rule lasted for more than a year, involved several research laboratories, and cost more than a million dollars. It may be more efficient to focus on groups of contaminants in this project, rather than on individual contaminants.

Project *3.3.b.4*, as described in the draft Implementation Plan, involves the compilation of a list of existing protocols for microbiological contaminants. The length of time allotted to this project (15 months) may be excessive, since the project simply represents a thorough literature review. It should be noted that the Action Plan describes *3.3.b.4* as a different project—the development of data quality objectives and other analysis goals—which should be added to the Implementation Plan under *3.3.c*.

The sequencing of projects *3.3.b.5* and *3.3.b.6*, which use the information obtained in projects *3.3.b.1* through *3.3.b.4*, is appropriate and logical. Specifically with respect to project *3.3.b.5*, which involves the development and application of new analytical hardware and analytical methodologies for biological, chemical, and radiological contaminants, it is doubtful that this can be accomplished within the 2.5-year time frame allotted and with the available resources. A great deal of effort has been expended in this area by the Defense Advanced Research Projects Agency (DARPA) and others during the past several years, involving hundreds of researchers and at least $100 million. It is unreasonable to expect that the existing gaps can be filled in such a short time period with less than $1 million, as suggested in the draft Implementation Plan, although the EPA could make a valuable contribution by assessing recent and ongoing technological developments in contaminant analysis and identifying gaps and long-term research needs.

3.3.c Requirements for Monitoring Technologies. According to the projects *3.3.c.1* and *3.3.c.2*, as described in the draft Implementation Plan, EPA plans to ask the water industry for their preferences in monitoring instruments and equipment, but this seems to have the wrong focus. Instead, the EPA should define a series of performance specifications for monitoring instruments and equipment. These specifications can then be used by the manufacturers when developing products to meet the monitoring needs of the industry. The EPA should not have the primary responsibility for surveying the industry about their preferences in monitoring instruments and equipment, but the agency could play a pivotal role in this process by bringing the water industry and manufacturers together to discuss this issue.

There are some unique quality assurance and quality control (QA/QC), sampling, and detection issues related to monitoring technologies that were noted in the panel's first report (see Part I). Analytical quality assurance takes on special importance when considering contaminants that can cause widespread illness or panic. There are a few projects in the Action Plan that address some aspects of QA/QC (e.g., projects *3.3.b.4*, and *3.3.d.2*), but QA/QC considerations should be an explicit component of all projects concerned with methods development and testing. For example, QA/QC measures need to be explicitly included in the development of standard operating procedures for evaluating monitoring techniques that will be done in project *3.3.d.2*. Rates of false positives and false negatives should be clearly understood for all relevant monitoring technologies. It should be noted that at least one component of project *3.3.f.5* (development of performance criteria for methods and infrastructure to assure the adequacy of training of field and laboratory personnel) is also a QA/QC project.

The following projects should also be added to address gaps identified in the panel's first report. First, a project should be developed to explicitly address sampling protocols for water security threat scenarios. Sampling may be especially problematic for hazardous contaminants because of concerns over the health of the technician and possible spreading of the contaminant by opening closed systems (e.g., unwanted exposure from opening hydrants). Protocols need to be developed to match the level of care required during sampling with the likelihood of risk. Second, a research project is needed to examine the spatial and temporal sampling requirements for particular types of events and for sampling contaminants in heterogeneous systems (e.g., in biofilms, associated with particulate matter, or at interfaces). Refined sampling methodology may be needed for detecting pathogens in complex field settings. The results from this project should be incorporated into the above sampling protocol.

3.3.d Testing and Evaluation of Monitoring Technologies. Part I noted that the work to test and evaluate monitoring technologies used in the field (*3.3.d*) could be combined with the work on improving analytical hardware and analysis methodologies (*3.3.b*) because the distinction between the technologies is somewhat artificial. Nevertheless, for consistency, the projects listed under *3.3.d* in the Action Plan have been reviewed here. Testing and evaluation of existing water monitoring technologies (such as turbidimeters and pH meters) for their ability to respond to changes in water quality under various contamination scenarios (project *3.3.d.1*) is highly relevant to the development of Early Warning Systems (EWS) (projects *3.3e.1-4*). It could be more efficient, however, to begin this study by collecting existing information on the analytical sensitivity of technologies, including data from the U.S. Army's Joint Service Agent Water Monitor project, before investing in bench-scale studies. This contaminant-specific information on monitoring sensitivity could ultimately feed back into the contaminant database in *3.2.a.2*. Project *3.3.d.4* involves the testing and evaluation of bio-sentinels for monitoring changes in water quality. While this may be a useful tool for assessing changes in source water quality and in the quality of treated water at the plant or in source waters, the project should consider the maintenance requirements for using bio-sentinels at multiple locations across a large distribution system.

3.3.e Early Warning Systems. As previously mentioned, there is some overlap between the Early Warning System (EWS) projects and projects *3.3.d.1* and *3.3.d.4*, but no information was provided in the draft Implementation Plan to elaborate on the *3.3.e* projects. However, upon discussion with EPA personnel, it appears that projects *3.3.e.1-4* are focused on the processing of information from sensors and sensor arrays so that a decision can be reached—on an ongoing basis—as to whether or not a potential adverse event has occurred. This is an interesting and important set of problems that involves the fusion of information from different sensors located at different positions and/or sampling at different times, requiring carefully crafted decision logic. This work should consider information from other fields of research on signal detection and data fusion.

The potential impact of false positives should be carefully reviewed in assessing how such Early Warning Systems could or should be implemented. It is critical to define at the outset what false positive rate and false negative rate would be acceptable, considering that false alarms will erode public confidence and burden responders. If the false positive rate is too high, there is a chance that responding personnel would tend, over time, to disregard the signals. Even if the false positive rate is very low, if many samples are taken in the face of very few expected "real" events, a large proportion of the positive signals would be false alarms. Projects *3.3.e.1-4* should be closely coordinated with monitoring projects *3.3.d.1* and *3.3.d.4* and project *3.4.a.5*, which investigates the impact of noise levels in real time monitors on data collection and use, so that monitoring technologies can be evaluated considering the data accuracy needed to support an early decision framework.

3.3.f Assessment of National Laboratory Capacity. All of the projects proposed to meet this need generally appear to be appropriate, as well as logically sequenced. Project *3.3.f.1*, which will assess the analytical laboratory capacity, should also consider liability issues, including worker safety and the impact of obtaining false positive and false negative results. Therefore, as a part of project *3.3.f.1*, the EPA should perform an assessment of analytical laboratories that handle other types of samples where liability is an issue (e.g., Superfund sites, forensics laboratories). Another consideration is the geographic distribution of the laboratory capacity. Project *3.3.f.1* should also assess the desirability of having mobile laboratories that could respond to contamination events at remote locations and their potential availability.

As field monitoring capabilities expand, the need for laboratory analytical capacity may change; therefore, it will be important that project *3.3.f.1* be coordinated with monitoring technology assessment projects under *3.3.b* and *3.3.d*. Information obtained through projects *3.3.f.1* and *3.3.f.2* will need to be incorporated into improved contaminant analysis protocols and updates of the analytical response play book (projects *3.3.a.5* and *3.3.a.6*).

3.3.g Training. The development of training modules and evaluation exercises for the analytical methodologies and monitoring systems is a critical component of the Action Plan, and the projects described under this need are appropriate, although it should be noted that projects *3.3.g.2* and *3.3.g.3* are identical.

Summary

Overall, the prioritization and sequencing of the projects to meet the needs are reasonable, although recommendations are offered to improve the projects, and several additional projects are suggested. The analytical response protocol is an essential core task in the Action Plan that should be integrated with other proposed response protocols and carefully coordinated with related projects. More emphasis should be given to QA/QC measures in the projects concerning methods development, considering the potential impact of false positives and false negatives. Related monitoring projects should be closely coordinated with the Early Warning System projects so that monitoring technologies can be evaluated in that context. A project should be developed to explicitly address sampling protocols for water security threat scenarios, and additional research is needed to examine the spatial and temporal sampling requirements for water security events. Issues of liability and geographic distribution of laboratories also need to be addressed. As stated above, it is clear that some of the projects (e.g., *3.3.b.1* and *3.3.b.5*) will not be completed within the three-year time frame of the Action Plan and may require extensive resources to conduct as described.

BOX 3-3
Improving Analytical Methodologies and Monitoring Systems for Drinking Water (Section 3.3)

The following lists the research and technical support needs and associated projects for contaminant monitoring and analysis identified in the Action Plan (EPA, 2003a). The associated project scheduling reflects updates from the subsequent draft Implementation Plan (EPA, 2003b). The numbering scheme is consistent with that used in the Action Plan. Some modifications to these needs were suggested in the panel's first report (see Part I).

3.3.a. A "play book" for analytical response to contaminant threats and attacks on water supplies and systems, including protocols for identifying "unknown" contaminants.

1. Preparation of a draft analytical response "play book" (which includes decision trees, fully tested protocols, and methodical approaches) for use in addressing drinking water contamination threats and attacks. (2/03-9/03)
2. Development of a protocol for the analysis of "unknowns" that is specific to drinking water supplies and systems. (5/03-9/03)
3. Laboratory testing and validation of the analytical response protocol using a round-robin approach with a variety of laboratories that would be expected to provide support in a threat or attack situation. (10/03-3/04)
4. End-user testing and validation of the analytical response protocol and identification of ways that it could be improved. (1/04-6/04)
5. Development of an improved protocol for the analysis of "unknowns" taking into account lessons learned from Projects 3 and 4, and real-world experiences in responding to "unknowns in drinking water." (6/04-12/04)
6. Continuously update the analytical response "play book" based on results from the above projects and the projects in Needs b and c, below (6/04-12/05)

3.3.b. Improved analytical hardware and analysis methodologies for biological, chemical, and radiological contaminants in water.

1. Development of concentration techniques and technology for priority biological contaminants in water. (10/02-9/04)
2. Adaptation of the NEMI methods database to include water security contaminant analytical hardware and analysis methodologies. (12/02-6/04)
3. Survey, analysis, and compilation of existing analytical hardware and analysis methodologies for their applicability to water security analytical needs. (10/03-9/04)
4. Development of a comprehensive understanding and definition of analysis goals, such as data quality objectives, for water contamination events. (10/03-12/04)
5. Based on gaps revealed in Project 3, development and application of new analytical hardware and analysis methodologies for biological, chemical, and radiological contaminants in water. (6/04-12/06)
6. Incorporation of analytical hardware and analysis methodologies from the above projects into the NEMI methods database and the analytical response "play book. (12/04-12/06)

3.3.c. Requirements for monitoring technologies used in responding to biological, chemical, and radiological contamination events.

1. Analysis of water utility and response organization preferences or standards for technology design and operation. (11/03-5/04)
2. Identification of desired monitoring system characteristics and associated rationale for monitoring technologies used for contaminated water systems. (11/03-5/04)
3. Implementation of a systematic approach for advancing desired characteristics and parameters through a collaborative effort with technology users and providers. (4/04-3/05)

4. Incorporation of lessons learned from the above Projects into the analytical response "play book." (1/05-12/05)

3.3.d. Testing and evaluation of monitoring technologies, including standard operating procedures, for biological, chemical, and radiological contaminants and threats.

1. Testing and evaluation of currently-used water monitoring technologies for their ability to meaningfully respond to changes in drinking water quality. (11/03-12/05)
2. Preparation of a set of preliminary standard operating procedures for evaluating monitoring technologies, including the adequacy, accuracy, and usability of the set of preliminary standard operating procedure in a variety of response situations. (11/03-8/04)
3. Testing and evaluation of detectors used in sectors other than the water sector and in various applications for their utility for drinking water monitoring and detection. (11/03-12/05)
4. Testing and evaluation of bio-sensors and biological monitors in responding to changes in drinking water quality. (11/03-12/05)
5. Preparation of a set of revised standard operating procedures for evaluating monitoring technologies for use by utility operators, emergency and remedial responders, public health officials, and laboratory personnel. (7/04-1/05)
6. Preparation of a handbook on currently available and emerging water security monitoring technologies that is periodically updated. (1/05-12/05)

3.3.e. Testing and evaluation of drinking water "Early Warning Systems" (EWSs), and EWSs from other sectors amenable to application in the water environment.

1. A survey and improved understanding of EWSs that could be employed in protecting water supplies and systems. (11/03-5/04)
2. Pilot-scale testing and evaluation of EWSs that could be used by water utilities to give an early warning of a contaminant threat or contamination event. (2/04-11/04)
3. Field-scale testing and evaluation of EWSs that could be used by water utilities to give an early warning of a contaminant threat or contamination event. (6/04-5/05)
4. Preparation of a handbook on the application of EWSs for drinking water supply and system protection. (5/05-2/06)

3.3.f. An improved and expanded laboratory capacity and capability (as necessary) to be fully prepared in responding to threats or attacks on water.

1. Assessment and characterization of existing laboratory capacity and capability for drinking water sample analysis in emergency situations, and development of a database. (10/02-8/03)
2. Determination of which laboratories are currently able, or potentially able, to run the analytical protocol developed for Section 3.3, need "a," and determine the most effective way to structure a network to assist drinking water utilities in an emergency. (5/03-8/03)
3. Conduct a gap analysis for resources (e.g., personnel and equipment), training, and methods, and develop a report to list short-, medium-, and long-term recommendations to address these gaps. (6/03-8/03)
4. In concert with other parts of EPA and other federal organizations, integration of laboratories able to support emergency water analyses into an existing national network or establishment of an appropriate mechanism to meet these needs. (7/03-6/04)
5. Development of an outreach and communication plan for facilitating inter-laboratory coordination and information exchange for water security. Development of performance criteria for methods and infrastructure to assure the adequacy of training of field and laboratory personnel. (7/03-6/04)

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BOX 3-3
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3.3.g. Training modules and evaluation exercises for analytical methodologies and monitoring systems.

1. Compilation and development of training exercises and simulation modules designed to ensure the preparedness of analytical laboratories to respond to drinking water contamination events. (1/04-12/04)
2. Development of training exercises and simulation modules for water utility personnel, emergency response personnel, and public health officials on the use of monitoring and detection technologies for timely response to potential threats or actual contamination events. (1/04-9/05)
3. Development of training exercises and simulation modules for water utility personnel, emergency response personnel, and public health officials on the use of monitoring systems for mitigation of potential threats or actual contamination events. (1/04-9/05) *[note that projects 2 and 3 are identical]*

Containment, Treatment, Decontamination, and Disposal (Section 3.4)

One of the most important stages in dealing with a contamination event will be the actions taken to contain and treat contaminated water. Depending on where a contaminant is introduced, this may involve response actions within a drinking water treatment plant, within the distribution system, or at points downstream. Any materials, including water, that cannot be successfully treated to meet water quality or other standards will have to be disposed of properly. In addition, the physical infrastructure of water systems may require decontamination before it can be safely reused.

Project Evaluation

The Action Plan presents a series of research and technical support projects (see Box 3-4) intended to support a response to a drinking water contamination event. The panel generally supports these projects, but provides suggestions for some expansion and reprioritization below. The projects are sequenced appropriately except where noted.

3.4.a Improved Distribution System Models. The projects identified here can improve the application of hydraulic models for water security events. In general, the nine listed projects are appropriate with a few exceptions noted below. Project *3.4.a.3* (the use of distribution system models to determine strategic locations for backflow prevention devices) is important because backflow prevention can help protect consumers from both accidental and intentional contamination events. This project should be accelerated so that it is conducted concurrently with projects *3.4.a.1* and *3.4.a.2*. The value of these models for non-security-related system management applications should also be considered, such as for identifying weak points in their systems, because it is unlikely that models will be financially feasible in small systems unless they are developed to fulfill multiple operating purposes.

An analysis tool for using distribution system models in small systems (project *3.4.a.7*) may be important, but without a more detailed description, it is difficult to evaluate this project. This project should focus on evaluating the usefulness of a simplified model for small systems. Some systems may be so small that a model is not necessary, and other small systems may be too difficult to model without extensive efforts. Models may also not be as relevant for attacks that occur closer to consumers.

There may be some value to modeling water flow after the water meter at large industrial, residential, or commercial sites that have extensive water piping (project *3.4.a.8*); however, the complexity and site-specific applicability of this project suggests that its lower priority in the Action Plan is appropriate.

Coding health data and consumer complaints for routine display on a water system distribution system map as they occur (one of several goals for project *3.4.a.2*) is a huge task and may represent a longer-term goal than the current time frame of the Action Plan. In addition, the effectiveness of linking routine health monitoring to water systems for early warning of potential waterborne exposures seems questionable considering the low disease reporting rates and incubation times relative to the transport time of a contaminant in the distribution system (see NRC, 2000). Nevertheless, developing a Geographic Information System (GIS) interface module for mapping cases of illness onto a map of the water supply system would be a valuable contribution in the near term to assist investigators in determining the cause of an outbreak after it has occurred.

Project *3.4.a.5* will investigate real-time monitors and the impact of data noise on their use. This project should be closely linked and appropriately sequenced with related work on Early Warning Systems described in projects *3.3.d.1* and *3.3.e.1-4*. Although no details are provided on this project, it should in the near term examine currently available basic parameter measurement techniques (e.g., water pressure, particulates, indicator microbes, chlorine residual), while considering more specific contaminant detection techniques as longer-range research objectives. Basic monitoring technologies can be used to identify extraordinary occurrences, signaling a breach in the system that merits further investigation. Once the contaminant threat scenarios have been developed and the list of priority contaminants established (projects *3.2.a.1-2*), the costs and benefits of specific contaminant detection technologies can be better evaluated. A program to develop and test specific detection technologies for the priority contaminants would likely require resources that far exceed the current estimated costs of the Action Plan effort.

Two additional projects are recommended to support the need for improved distribution system models. First, the EPA should conduct an inventory or survey of water systems to determine (1) how many utilities have developed and calibrated hydraulic models, (2) which models are being used, and (3) the availability of information to develop models. The survey should also ask about the likely difficulties associated with the development and implementation of the models and training needs. This is a priority project, since it will inform other EPA efforts related to the development and application of distribution system models. A second project, which may represent a longer-term research effort, should focus on refining distribution system models to consider decay or die-off rates of water contaminants, the possible adsorption or attachment of the contaminants to the interior surfaces of pipes and storage reservoirs, and the continuous introduction of a contamination over a longer period of time.

3.4.b Improved Understanding of the Environmental Fate of Contaminants. The development of treatment protocols (or standard operating procedures) to employ if a contaminant is introduced into a drinking water system (project *3.4.b.1*) is a high priority project whose prompt start is warranted, as the provision of immediately usable information to utilities and response organizations should be the primary goal of the Action Plan. It may be logical and efficient to organize and develop these protocols by categories of contaminants rather than by single substances since there is a limited range of responses available to a water system. Initially the project could marshal existing documentation from many sources (including the military and other agency literature) and make it available for immediate use. There will naturally be many gaps that will have to be filled by best professional judgment or assumptions. In time, many of these gaps will be filled in or narrowed by more rigorous scientific investigation. Thus, the project should not be viewed as a single effort to produce a specific document or set of documents, but as a continuous effort that proceeds through successive improvements. The response procedures should be tested and disseminated to all essential players. Ease of use, ready access, and training should be key elements.

Environmental fate data will be necessary to guide long-term response and remediation efforts after a water security contamination event. Nonetheless, the panel's first report (see Part I) recommended a more focused effort for examining the environmental fate of contaminants in drinking water, including a literature review as a precursor to any additional research, and the description of project *3.4.b.2* in the draft Implementation Plan is consistent with this recommendation. Improved understanding of the effects of biofilms on contaminant fate in distribution systems (*3.4.b.3*) represents a long-term research objective that is not likely to be accomplished within the time frame of the Action Plan.

3.4.c Newer Technologies and Treatment Processes for Water and Equipment That Have Been Contaminated. The nine projects to address the need for contaminant treatment after a water system has been contaminated should be viewed as support for the development of response protocols for water security (projects *3.4.b.1* and *3.4.d.1*), and as such, the content of these projects are appropriate. Considering the narrow time frame of the Action Plan and the need for immediate applicability of the results, most of the water security treatment projects appropriately emphasize an evaluation of existing treatment technologies. In the review of applicable technologies, various approaches should be considered, including in-place conventional treatment, new technologies that could be added in a quickly reactive mode, mobile technologies, and decontamination methods for treating the distribution system. In addition to assessing treatment technologies needed after a contamination event has occurred, the review should also note those technologies which could be used for prophylactic water treatment. The development of a treatment technology document database (project *3.4.c.8*) should be advanced in time and conducted concurrently with project *3.4.c.1*, to provide treatment guidance as quickly as possible.

3.4.d A Methodology for Determining When a Drinking Water System Is Contaminated and When It Is Clean. As with project *3.4.b.1*, the project to develop protocols to guide response and recovery actions is at the heart of the Action Plan's overall objective. In order to provide immediate and applicable guidance to utilities and response organizations, the project should begin as soon as possible (simultaneously with the parallel response protocol development project, *3.4.b.1*) instead of almost a year later. Like the other protocols proposed, this will be an exercise in successive approximations and should not be delayed until all pieces are in place. This is a continuous process, which will require periodic updates to the protocols. As with all of the protocol development projects, this effort will need stable management, effective two-way communication with all the other projects, and adequate and continuing resources.

Summary

Many of the projects proposed to address the needs of containment, treatment, decontamination, and disposal are central to building an improved recovery capacity.

The two sets of response protocols (*3.4.b.1* and *3.4.d.1*) represent high priority projects and should begin as soon as possible. Early versions of the protocols may require estimates to fill information gaps, but the refinement of response protocols should be considered a continuous effort that proceeds through successive improvements. Coordination with the other response protocols identified in the Action Plan and the many other projects which provide the data that inform the protocols will be essential. The development of a treatment technology document database (project *3.4.c.8*) should be advanced in time to provide treatment guidance as quickly as possible. Two additional projects are recommended to support the need for improved distribution system models: the EPA should conduct a survey of the use of hydraulic models at water utilities, and additional long-term research is needed to further enhance the capabilities of distribution system models. Several recommendations are provided to focus the projects on more reasonable near-term goals and to clarify longer-term research objectives.

BOX 3-4
Containing, Treating, Decontaminating, and
Disposing of Contaminated Water and Materials (Section 3.4)

The following lists the research and technical support needs and associated projects for containment, treatment, decontamination, and disposal identified in the Action Plan (EPA, 2003a). The associated project scheduling reflects updates from the subsequent draft Implementation Plan (EPA, 2003b). The numbering scheme is consistent with that used in the Action Plan. Modifications to these needs were suggested in the panel's first report (see Part I).

3.4.a. Improved distribution system models that could be used to more effectively protect drinking water in the event of deliberate contamination.

1. A systematic analysis of the capabilities of EPANET, Pipeline Net, Modflow, and other readily available hydraulic models. (10/02-9/05)
2. Development of an interface module to allow overlapping of health data, consumer complaints, GIS, and SCADA data into current hydraulic models for data collection and manipulation in as real time as possible. (9/03-5/05)
3. Use of models to determine strategic locations for the installation of backflow prevention devices within a distribution system (e.g., isolate flows from subdivisions or sections of a municipality). (1/04-12/04)
4. Development of a decision tree for water utilities to use in determining what background information needs to be collected as a baseline to assist them in using information from distribution system models. (1/04-5/05)
5. Investigation of various "real time" monitors in a distribution system to determine the impact of instrument noise levels on reported data collection and use. (6/04-5/05)
6. An investigation to determine how distribution system models could be used to identify potential weak points (e.g., critical valves, pumps, mains) in a distribution system, particularly where large populations could be impacted. (6/04-7/05)
7. Creation of an analysis tool for using distribution system models in small systems. (1/04-12/05)
8. Development of an analysis tool or module for using distribution system models post-endpoint in distribution systems (after the water meter). (6/04-6/05)
9. Investigation of contaminants in pipe loops to determine if theoretical flow patterns can be reproduced in pipe loop situations. (1/05-7/06)

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BOX 3-4
Continued

3.4.b. Improved understanding and documentation of the environmental fate of contaminants in source waters, within drinking water systems, and once they are released.

1. Development of guidance/protocols for specific actions to take if a contaminant is introduced into a drinking water system, including cleanup of a system once contaminated. (8/03-2/05)
2. An assessment of the environmental fate of biological, chemical, and radiological contaminants in source waters, drinking water treatment plants, and the distribution system. (10/03-9/04)
3. An investigation to determine what contaminants may attached themselves to pipe walls or to biofilms, and how best to remove those contaminants from those surfaces. (1/04-12/04)

3.4.c. Newer technologies and treatment processes to achieve multiple goals, and effective disposal and/or treatment techniques and technologies for water and equipment that have been contaminated.

1. Review of the literature on contaminants most likely to be used in contaminating drinking water supplies and systems, including military documentation that may not be available in the open literature, for their treatability information. (7/03-2/04)
2. Preparation of a systematic method for evaluating treatment technology efficacy for contaminants most likely to be used in contaminating water supplies or systems. (10/03-9/05)
3. Execution of bench-scale studies to determine disinfection capabilities of typical water treatment disinfection technologies for most likely biological contaminants. (2/02-12/05)
4. Execution of bench-scale studies to determine removal capabilities for typical water treatment technologies for the most likely biological, chemical, and radiological contaminants (and the impact of various water quality parameters such as pH, turbidity, or temperature). (6/03-7/05)
5. Identification of POU/POE capabilities for treating or capturing the most likely contaminants and disposal procedures for such devices should they become contaminated. (11/03-10/04)
6. Identification and documentation of chemical contaminants that may create hazardous byproducts when exposed to drinking water disinfectants. (1/04-12/04)
7. Development of treatment technology capabilities for the ultimate disposal of contaminated water. (6/04-5/05)
8. Development of treatment technology documents and database for contaminants in drinking water. (6/04-9/05)
9. Development of guidance for the discharge of the water used for cleaning that may be contaminated. (in collaboration with wastewater expertise). (9/04-8/05)

3.4.d. A methodology, approach, or guide for use in determining when a drinking water system is contaminated and when it is clean and can be used.

1. Development of protocols and guidance to address water usage concerns, water cleanup actions, and criteria to determine when a system is safe to use. (6/04-9/05)

Contingency Planning and Infrastructure Interdependencies (Section 3.5)

As part of an emergency response program, water systems need contingency plans for providing a sufficient quantity of water to their service area in the event that deliberate malfeasance or natural hazards occur. Water systems are increasingly relying on automation, which depends on the reliable functioning of other systems (e.g., electric, telecommunications). Thus, contingency planning should consider the potential for disruption to occur, not only within a water supply system, but also to one or more of these necessary auxiliary systems. The projects identified in the Action Plan are intended to address this need.

Project Evaluation

The suite of projects described appears to adequately address the needs identified in the original Action Plan (see Box 3-5). However, the panel recommended in Part I that an additional need be added to section 3.5 to assess the consequences of and response to issues of operator incapacity in the event of a critical emergency. One or more projects should be developed to address this need, for which suggestions are outlined below.

3.5.a Assessment of Water Supply Alternatives. The assessment of alternative water supplies is an essential step for emergency response and preparedness. Nevertheless, many factors that differentiate water systems other than size and geography, including sources of water, interconnections, and system design among others (see Part I for further discussion) should be considered. The development of case studies for contingency planning (project *3.5.a.1*) could appropriately be combined or sequenced with the assessment of redundancy approaches (project *3.5.a.3*). Customer preparedness should be included in the contingency analyses or a new project should be developed to review the appropriate role and responsibility of customers in preparing for water system emergencies. The project on systematic analysis of optimal water supply sources using a GIS-based approach (project *3.5.a.4*) was not clearly described; thus, it was difficult to evaluate. Each water utility is unique, and analyses of alternate water sources are typically already covered by emergency response and/or VA plans. The prioritization of the projects generally seems appropriate.

3.5.b Testing and Evaluation of Improved Technologies and Approaches for Providing Supplies of Water. Few details were provided on the projects to evaluate approaches for long- and short-term emergency water supplies (*3.5.b.1-2*). Some overlap exists between these projects and project *3.5.a.2*, although the Action Plan places an emphasis on evaluating novel technologies to meet this need. The development of "innovative" technologies would be unrealistic in the time frame of the Action Plan and more appropriate for a long-term research agenda. However, an analysis of recently developed technologies would be appropriate and should include an assessment of the reliability and capacity of the technologies, since the ability to supply alternative water may not be indefinite. The work conducted for project *3.4.c.5* to assess Point of Use/Point of Entry (POU/POE) device capabilities is also relevant here. The information gained from these projects should be made available to water utilities and emergency responders as soon as is feasible, perhaps in a widely accessible database.

3.5.c An Improved Understanding of Water System Interdependencies with Other Infrastructure Sectors. The scope of the project identified to address water system interdependencies with other infrastructure should be expanded to include an understanding of the *reliability* of systems upon which continued functioning of the water system depends (e.g., electric power, road transportation, telecommunications, etc.). The project should assess the weakest links among the systems that are needed to support continued functioning, utilizing lessons learned from various case studies (e.g., Y2K, the August 2003 blackout), before evaluating potential contingency responses. The benefits and risks of disaggregation or decentralization should also be considered. This project may also benefit from information gained in project *3.1.b.2*, which will explore cascading consequences of attacks on water supply systems.

Additional Research and Technical Support Needs

In its July 2003 report (Part I), the panel added a fourth need to section 3.5 to reflect a missing element that should be considered, for which appropriate projects should be developed. This need statement reads:

> Explicit understanding of the role of failure of the "human subsystem" in water system operation, and development of contingencies for responding to such eventualities.

The Action Plan should include a project to consider under what circumstances the operation of a water treatment plant or supply system could be adversely impacted by the incapacitation of the plant operators or supporting personnel, and whether there are potential contingencies or mitigations for such occurrences. It should be noted that a failure of "human subsystems" that could impact a water system could occur as a result of a direct attack via a non-water route, for example via a massive community bioterrorism incident.

Summary

Overall, the panel felt that the prioritization, timing, and sequencing of the research projects to meet the needs are appropriate. Recommendations are offered to improve the projects, and one additional project is suggested. A review of the appropriate role and responsibility of customers in preparing for water system emergencies should be included in the contingency analyses. An analysis of recently developed water supply technologies should include an assessment of the reliability of the technologies, and the information should be made available as soon as is feasible. The projects to assess the interdependencies with infrastructure should utilize lessons learned from various case studies before evaluating potential contingency responses, and the benefits and risks of disaggregation or decentralization should also be considered. In support of the additional research need recommended in Part I, the Action Plan should develop a project to evaluate impacts from failure of the "human subsystem" and whether there are potential contingencies for such occurrences.

BOX 3-5
Planning for Contingencies and
Addressing Infrastructure Interdependencies (Section 3.5)

The following lists the research and technical support needs and associated projects for contingency planning and infrastructure interdependencies identified in the Action Plan (EPA, 2003a). The associated project scheduling reflects updates from the subsequent draft Implementation Plan (EPA, 2003b). The numbering scheme is consistent with that used in the Action Plan. Some modifications and additions to these needs were suggested in the panel's first report (see Part I).

3.5.a. Assessment of water supply alternatives for different-sized drinking water systems at different geographical locations in the United States when the usual supply of water is not available.

1. Development of case studies under varying situations (e.g., community water system size, geographical location) that provide a spectrum of contingency planning situations and responses (e.g., water sharing), including one specifically focused on the National Capital area. (8/03-9/04)
2. Assessment of truck-mounted and otherwise portable treatment facilities that are designed for use in crises to areas where drinking water quality is not dependable. (8/03-9/04)
3. Assessment of redundancy approaches that can be used by small, medium and large systems to assure continuity in water supplies. (8/03-9/04)
4. Systematic analysis of optimal water supply sources and alternatives linked to likely threat scenarios using a GIS-based approach. (2/04-9/05)
5. Development of a compendium of options for providing alternative supplies of drinking water in various situations (e.g., system size and location, extent of need). (2/04-9/05)

3.5.b. Testing and evaluation of improved technologies and approaches for providing supplies of water in the event of both long-term and short-term disruptions to drinking water systems.

1. Assessment of innovative technologies that specifically enable or enhance the short-term delivery of drinking water to impacted customers, as well as those that enable long-term delivery in event of a systemic collapse of water supplies or systems. (1/04-12/05)
2. Testing and evaluation of the most promising innovative technologies with an analysis of the positive features and those areas needing improvement prior to full-scale deployment in the field. (1/04-12/05)

3.5.c. An improved understanding of water system interdependencies with other infrastructure sectors that are critical to national security.

1. Identification and analysis of interdependencies between critical infrastructures that affect water systems in order to maintain operations and develop mitigation strategies. (8/03-3/05)

Targeting Impacts on Human Health and Informing the Public about Risks (Section 3.6)

Because human health protection is one of the ultimate endpoints of the EPA's water security efforts, research into better understanding the human response to contamination or threat scenarios is critical. This includes not only human physical response to different classes of waterborne contaminants and ways to measure that response, but also the social and psychological response to contamination events and how to best communicate relevant threat information to all stakeholders.

Project Evaluation

The Action Plan presents a series of research and technical projects (see Box 3-6) intended to support an assessment of impacts on human health from a drinking water contamination event. The panel generally supports these projects, but provides suggestions for improving the projects and presents several additional projects below. The projects are sequenced appropriately except where noted.

3.6.a An Improved Understanding of Contaminant Exposure Routes and the Acute and Chronic Public Health Effects from Contaminants in Drinking Water. The compilation of acute, short-term, and chronic non-cancer health effect information into a database of the priority contaminants (project *3.6.a.1*) should build upon existing information from such agencies as the CDC and the Department of Defense (DOD). Acute toxicity data would be needed for the early phase of response to an attack on water supplies. Chronic health effect data are important to the recovery phase when determining whether or not low levels of residual exposures over weeks or months pose any significant risks. Cancer information could easily be included and would be useful information for assessing the risks of longer-term exposures and for reassuring the public. Several models exist to support quantitative predictions/estimates of the extent of the exposure from various routes (e.g., showering, bathing, cooking) for substances based upon their physical and chemical properties (project *3.6.a.2*). Nevertheless, models to estimate acute exposure from waterborne routes are less well developed than the equivalent information for chronic exposures. Information on secondary transmission of pathogens should be gathered from agencies such as the CDC or the Department of Homeland Security for this exposure assessment. Early analyses should be conducted on broad classes of agents, where possible, to quickly provide initial guidance, and additional details could be continually filled in over time. The results of these estimations will be important to support selection of the appropriate response and recovery actions and determinations of when systems may be returned to limited or unrestricted service. The database (project *3.6.a.3*) of the information developed in projects *3.6.a.1-2* would be a valuable tool both for water security concerns and for responding to the reports of drinking water contamination that occasionally occur. This information should be made widely available in a user-friendly format to utilities, public health agencies, and responders.

A fast-paced review of existing methods to evaluate the toxicity or infectivity of contaminants for which little toxicological data exists (project *3.6.a.4*) is an important activity, which should be initiated immediately and closely coordinated with the activities in *3.6.c*. This review should enable tested methodologies to be applied immediately to filling in the data gaps for priority contaminants, and it should illuminate the gaps where additional method development work is needed. The review should also clearly present the limitations of these methods.

3.6.b A Health Surveillance Network Associated with Contaminated Drinking Water. A single project is proposed (*3.6.b.1*) that recognizes the importance of having significant EPA participation as well as collaboration with the CDC and other federal agencies in developing procedures for detecting an outbreak and investigating the possible role of water. The project is appropriate and of high priority. The following recommendations are made to assist the EPA in planning this project and implementing a surveillance network (see also Part I).

In developing procedures for effective surveillance and investigation, it will be important to collaborate with state and local agencies as well as other federal partners. The identified project should describe the overall needs of a surveillance program, how waterborne disease surveillance would fit into a larger surveillance program, and the investigative response (e.g., who will take the lead for initiating action). Surveillance activities should include procedures for monitoring outcomes of interest and coordinating the response of a team of investigators (epidemiologists, physicians, microbiologists, chemists, and engineers) if water is the suspected mode of transmission. In order to confirm or deny the role of water as a route of transmission during an event, water quality sampling and analysis will need to be paired with active disease surveillance data. The effectiveness of current active disease surveillance systems at the local and state level should be clearly understood, and public health surveillance during recent inadvertent drinking water contamination events should be examined for lessons learned. There is also an important communication component to this need (*3.6.b*) on many levels (e.g., among the investigators, with the public).

3.6.c A Methodology for Using Non-traditional Data Sources for the Derivation of Toxicity Values Applied to Water. Methodology for estimating toxicity values using Quantitative Structure Activity Relationships (QSAR) (project *3.6.c.2*) already exists for several health endpoints, and expertise exists in EPA to both apply existing methodology and to develop new methodologies that might be desirable. These predictive systems are far from perfect, but several methodologies are capable of providing useful information in the absence of specific experimental data. Applying LD_{50} data for risk assessment (project *3.6.c.1*) presents more difficulties, and EPA should defer to other agencies (e.g., the U.S. Army) that are already exploring this methodology, assuming that an appropriate collaboration can be established.

3.6.d Frameworks for Assessing and Managing Risks. As noted in the panel's first report (Part I), risk assessment and risk management should be integrated into decision making during all stages of a water security event, from threat assessment to event response. The projects identified in the Action Plan should support this objective. However, considering the time constraints of the Action Plan, the *3.6.d* projects should represent a focused and applied effort that builds upon the existing knowledge base in risk assessment and risk management (e.g., NRC, 1983; PCC, 1997; ILSI, 2000). Ultimately, the projects should generate an operating procedure for risk assessment and risk management that is designed to apply specifically to the water security context. This would naturally begin with a review of current approaches, but because many of these approaches are conceptually similar, such a review should not take long. All three projects identified here are essentially part of the same project, and they should be combined and completed within one year, as they are high priority components of a water security response protocol, along with the protocols or "play books" developed in *3.3.a.1-2* and *3.4.d.1*.

3.6.e Methods and Means to Communicate Risks to Local Communities. The panel's first report (Part I) noted that "developing an effective broad communication strategy that meets the needs of a wide range of stakeholders, including response organizations, water organizations and utilities, public health agencies, and the media, should be among the highest priorities for the EPA." The Action Plan recognizes the importance of risk communication within the risk analysis framework. However, the project to develop a framework for risk assessment and risk communication (*3.6.e.1*) as described in the draft Implementation Plan emphasizes developing tools. Communication tools provide mechanisms for water managers to communicate with stakeholders about a variety of issues, but they should not precede a thoughtful communication strategy or minimize active two-way communication. Thus, EPA should prioritize research that reviews and refines existing communication strategies and explores how tools can be used more effectively, instead of only emphasizing tool development. Tools without a process to support them will not provide the return on the investment that EPA is making, nor will they help water mangers communicate effectively. Projects *3.6.e.1-4* should focus on identifying the appropriate risk communication planning process that will help water managers not only select tools but also identify stakeholders, assess stakeholder needs, and determine how stakeholders communicate within their network. These projects should be conducted in two phases.

The first phase of the project focuses on the selection and refinement of a risk communication strategy for water security and consists of several steps. Many risk communication resources exist that should first be consulted and evaluated (see for example NRC, 2003a; USHHS, 2002; EPA, 2002; EPA, 2003d; USFDA, 2002; ATSDR, 2001; Hance et al., 1988; Pflugh et al., 1992). Information sharing strategies also have to be considered, such as when to release information, who are the audiences, and how to explain risk. If existing risk communication strategies do not meet the needs of water security, the project could then tailor existing strategies as necessary. Once a strategy is selected or adapted, it should be field-tested using an emergency simulation to determine its effectiveness should a real emergency arise. It is not anticipated that Phase One should take more than 18 months to complete.

The second phase (projects *3.6.e.2-4*) of the research should focus on developing, testing, and distributing communication tools. Such tools might include written materials (e.g., pamphlets, websites), an on-line database of water-related information, or a water information hotline. Phase Two should only be initiated after careful testing and evaluation of the communication planning strategy has been completed, because the planning strategy will provide the basis for identifying and developing the tools proposed in Phase Two. Tools should be developed with different scenarios in mind based on several case examples, and field testing will be critical in order to determine the behavioral response to a risk message. The tools should then be distributed through existing networks being used by water managers.

Additional communication research is warranted relative to risk and the public's response to risk messages in a water terrorism event. The following research topics should be considered as additions to the projects identified in the Action Plan:

- Analyze when to release information versus when to withhold it due to security concerns.
- Conduct a case study analysis of risk communication strategies and tools for past disaster events.

- Develop a national training program on water-related risk communication planning and implementation for water managers.
- Analyze factors that build trust, reduce fear, and prevent panic to improve overall communication strategies.
- Analyze methods to counter and reduce the possibility of misinformation or false information being distributed to the public and key stakeholders.

A thorough assessment of the risks and benefits of widely releasing water security information is critical to the development of a risk communication strategy, and the decision of when to release or withhold information may influence the subsequent selection of communication tools (see also the comments on section 5.2). This project should be conducted as soon as possible. The case study analysis should be conducted concurrent to the selection and refinement of risk communication strategies (Phase One, as proposed above) to incorporate lessons learned from prior emergency events. The training program is a high priority effort, but it should be sequenced to incorporate the knowledge developed in projects *3.6.e.1-4*. The final two proposed projects are also important to the refinement of risk communication strategies and tools, but information from these projects can be incorporated to improve the communication strategies and tools over time.

Summary

The projects identified to improve the understanding of contamination-related health effects, develop or refine a risk management framework, and enhance risk communication are essential for water security preparedness and response, and several recommendations are made to enhance or expand on the projects proposed. The project to generate an operating procedure for risk assessment and risk management for water security is essential to decision making and should be accelerated and coordinated with other response protocols in the Action Plan. Analyses of acute and chronic health effects and quantitative assessments of potential exposure should build on existing knowledge in order to provide guidance to utilities and responders as quickly as possible. A review of predictive methodologies to assess toxicology values in absence of experimental data should be accelerated to illuminate gaps where additional method development work is needed and to clearly define the limitations of these methods. In the area of risk communication, EPA should emphasize research that reviews and refines existing communication strategies and explores how tools can be used more effectively, instead of only emphasizing tool development. A two-phased effort is recommended to support the needs of water security: first, selecting and refining a risk communication strategy, and second, developing, testing, and distributing communication tools. Several additional research projects are recommended that could improve risk communication activities. Recommendations are also provided to assist the EPA in planning and implementing an active disease surveillance network.

BOX 3-6
Targeting Impacts on Human Health and
Informing the Public about Risks (Section 3.6)

The following lists the research and technical support needs and associated projects for targeting impacts on human health and informing the public about risks identified in the Action Plan (EPA, 2003a). The associated project scheduling reflects updates from the subsequent draft Implementation Plan (EPA, 2003b). The numbering scheme is consistent with that used in the Action Plan. Some modifications to these needs were suggested in the panel's first report (see Part I).

3.6.a. An improved understanding of contaminant exposure routes, and the acute and chronic public health effects from contaminants in drinking water supplies and systems.

1. Compilation of a comprehensive, readily-modified database on the acute, short-term, and chronic non-cancer health effects associated with the priority contaminants. (11/03-6/04)
2. Evaluation of all possible routes by which people might be exposed to contaminated water and conduct of an analysis as to the likelihood of the viability of these routes for exposure. (11/03-10/04)
3. Creation of an easily updated and secure information portal on exposure routes and public health effects associated with various threat scenarios to water supplies and treated water. (6/04-5/05)
4. Critical review and assessment of various methods or models (e.g., Quantitative Structure Activity Relationships), as well as other available information and scientific judgments regarding the toxicity or infectivity of the priority contaminants to estimate reference and infective doses. (6/04-5/05)

3.6.b. A health surveillance network to help public health officials and water utility operators rapidly identify and control a disease outbreak or other public health emergency associated with contaminated drinking water.

1. Collaboration with the Centers for Disease Control and Prevention in the development of a health surveillance network to rapidly detect and control a disease outbreak by more effectively linking public health and water system information and data. (12/03-6/05)

3.6.c. A methodology or procedure for using non-traditional data sources (e.g., LD_{50}, QSAR) for the derivation of acute and chronic toxicity values applied to water.

WASTEWATER

The wastewater section of the Action Plan is not as developed as the drinking water section; therefore, the panel's comments in its first report (see Part I) were correspondingly less detailed. The threats potentially posed by an attack on the wastewater system are different in important ways from those posed by an attack on the drinking water system. Protecting the wastewater systems against attack and precluding the wastewater system from being used as an instrument for attacking other critical infrastructure are both important and deserve attention.

Wastewater Infrastructure (Section 4.0)

Two general aspects need to be considered for protecting wastewater systems: (1) risks from physical damage, and (2) risks to public health and environmental quality via treatment plant disruption. Unlike much of the water supply infrastructure, wastewater

1. Development of a methodology for extrapolating from a LD_{50} data to derive toxicity values for priority contaminants that are threats to drinking water supplies and systems. (8/03-9/05)
2. Development of a methodology for using QSAR to estimate toxicity values for the priority chemical contaminants that are threats to drinking water supplies and systems. (8/03-9/05)

3.6.d. A risk management/risk assessment framework for identifying the impact of decontamination/treatment options and the subsequent risk assessment response.

1. Analysis of current approaches to and procedures for integrating risk assessment and risk management decision making in order to quickly respond to threats and attacks with information for on-scene decision makers from threat notification through threat response. (10/03-9/04)
2. Testing and refinement of approaches and procedures through the application of simulations, table top exercises, and information applications that involve risk assessment and risk management integration. (1/04-12/04)
3. Development of a test protocol for use by risk assessors and risk managers in addressing threats and attacks on drinking water supplies and systems as part of improved consequence management. (1/04-12/04)

3.6.e. Methods and means to communicate risks to local communities with respect to threats and to respond to customers and the media in the case of an attack on drinking water systems.

1. Creation or adaptation of a Risk Assessment/Risk Communication Framework that can be used to respond to threats or attacks on drinking water systems. (8/03-8/05)
2. Preparation of information, materials, and models prior to an actual threat or event that facilitate early response to customers facing concerns about their drinking water. (12/03-11/04)
3. Development and stocking of a repository where prepared information and materials can be maintained and retrieved for use, when and if the need arises, in response to a threat or attack on drinking water supplies and systems. (12/03-3/05)
4. Development of access-controlled methods and means of information sharing on risk assessment/risk management methodologies to ensure appropriate access to individuals and organizations based on their needs. (12/03-3/05)

collection systems can provide easy access to many physical structures, serving as a potential conduit for malicious use; thus, physical damage by means of wastewater collection systems may represent the greatest risk to people and infrastructure. Wastewater treatment plants may also be disrupted by physical or some types of contaminant attacks, resulting in reduced treatment performance. One consequence would be the direct discharge of untreated or marginally treated sewage to receiving waters until the plant can be reinstated, affecting downstream drinking water quality and aquatic ecosystems. Because treatment plant disruptions have occasionally occurred, there are techniques and practices already available to deal with temporary outages and they represent less direct risks to human health than drinking water system contamination. Storage of hazardous materials, such as chlorine gas, and disposal of contaminated wastes and sludges represent additional security concerns specific to wastewater systems. There are also some similarities between drinking water and wastewater security needs, and research and technical projects should be carefully planned so as not to duplicate ongoing work.

Project Evaluation

EPA is currently collaborating with the Water Environment Research Foundation for additional input and will soon present revised plans for research and technical support in the area of wastewater infrastructure. Because the projects proposed in the Action Plan are likely to undergo substantial revision in this process, the panel focused its review on those projects which are currently ongoing or slated to begin in 2003 (*4.a.1-4; 4.b.1; 4.c.1-2; 4.e.1*; see Box 3-7) . Generally, these early projects are appropriate to meet the most pressing needs for wastewater, focusing primarily on threat assessment, determination of countermeasures, and access control. However, project *4.c.2* (to assess technologies to identify physical threats and contaminant introduction) should be delayed until vulnerability assessments and threat assessments have been conducted for wastewater infrastructure, so that the importance of contaminant detection for wastewater security can be evaluated relative to other proposed projects. The project that evaluates the linkages and interdependencies between drinking water and wastewater systems (*4.a.4*) may provide important insight that will help EPA managers evaluate the relative priority of additional wastewater security research. The significance of wastewater contamination or sewage discharges on drinking water quality will depend upon stream flow conditions, distance, time of travel, dilution, and the characteristics of the particular agent—all of which can be modeled. The Ohio River Monitoring and Notification Network is an example of an existing system designed to detect sewage and chemical spills in the river and provide rapid warnings to downstream water systems. EPA may wish to examine examples of these types of networks to assess their capabilities and applicability with regard to terrorism incidents. With regard to hazardous materials used in wastewater plants (*4.b*), the wastewater industry could benefit from the knowledge and experience of other industries (e.g., the paper and chemical industries) that are facing similar security concerns.

The remaining projects were not reviewed since more detailed wastewater security discussions and further project development are ongoing at EPA.

Additional Projects

Management and disposal of contaminated waste and sludges (including materials generated in the course of a cleanup or response action) is an area where additional research and technical support projects may be needed. There is considerable experience with managing wastes from hazardous waste sites that may provide sufficient background. As a first order of business, existing procedures should be assembled and examined for adequacy in the context of a municipal waste contamination incident.

The adequacy of plant worker protection to prevent harm during potential water security attacks should also be considered. However, since sewage is routinely laden with pathogens and chemicals, current practices may be sufficiently protective.

BOX 3-7
Protecting Wastewater Treatment and Collection Infrastructure (Section 4.0)

The following lists the research and technical support needs and associated projects for protecting wastewater treatment and collection infrastructure identified in the Action Plan (EPA, 2003a). Some later projects were not reviewed in this report (italicized below) because of ongoing refinement of the wastewater security program by the EPA. The associated project scheduling reflects updates from the subsequent draft Implementation Plan (EPA, 2003b). The numbering scheme is consistent with that used in the Action Plan. Modifications to these needs were suggested in the panel's first report (see Part I).

4.a. A thorough understanding and documentation of the possible threats to the nation's wastewater treatment and collection system infrastructure, including the interdependencies with drinking water systems and other critical infrastructure.

1. Identification and prioritization of potential physical, cyber, and contaminant (e.g., biological, chemical, radiological) threats and threat scenarios for the nation's wastewater treatment and collection infrastructure. (1/03-6/03)
2. Assessment of countermeasures or system redundancies that could be employed for the most likely threats and threat scenarios. (10/03-6/04)
3. Evaluation of "unattended operations" and how they can best be protected from physical, cyber, and contaminant threats and attacks. (10/03-6/04)
4. Improved understanding and assessment of the critical linkages and interdependencies between drinking water and wastewater systems, and how these linkages directly impact human health and safety as well as the operation and performance of the wastewater system. (10/03-9/04)
5. *Identification and analysis of interdependencies between critical infrastructure that affect, or are affected by, impacted wastewater systems to maintain operations and to promote the development of prevention, mitigation, and response technologies. (6/04-12/05)*

4.b. An updated assessment of the possible health and safety risks related to potentially hazardous substances used by wastewater utilities or intentionally introduced into wastewater collection and treatment systems, including any impacts on residual management operations (sewage sludge).

1. Preparation of a "Baseline Threat Document" for wastewater systems that is analogous to the drinking water baseline threat document. (12/03-7/04)
2. *Screening level risk assessment of biological, chemical, and radiological contaminants that could be used as contaminant threats in wastewater treatment plants and collection systems. (2/04-9/04)*
3. *Comparative assessment (including associated risks) of alternatives to conventional disinfection that uses chlorine, including the byproducts that may result. (3/04-12/05)*
4. *Evaluation of wastewater treatment technologies that either currently or through enhancement can more effectively remove contaminants introduced into or received by wastewater collection systems. (3/04-2/05)*
5. *Evaluation of impacts on sewage sludge and other residuals associated with wastewater treatment when impacted by intentionally introduced biological, chemical, or radiological contaminants. (3/04-5/05)*

Continued on next page

BOX 3-7
Continued

4.c. Improved intrusion monitoring and surveillance technologies to quickly notify wastewater utilities when these technologies are compromised by physical and cyber threats or chemical, biological, and radiological contaminants.

1. Development and assessment of information on current practices and methods for the control of inappropriate access to wastewater collection systems (including combined systems and stormwater systems). (9/03-8/04)
2. Assessment of existing and new technologies and systems (i.e., commercially available) for use in identifying physical threats and contaminant introduction into wastewater collection and treatment systems. (11/03-10/04)
3. *Testing, evaluation, and verification of intrusion monitoring and surveillance technologies and systems, as well as their ability to provide timely notification of physical attacks or contamination events on the wastewater collection and treatment systems. (10/04-9/05)*
4. *Assessment of currently applied wastewater/stormwater/combined sewer overflow models for simulating the movement of dangerous/hazardous materials in wastewater collection systems. (10/04-3/05)*
5. *Assessment and dissemination of information on technologies and methods for developing a continuous monitoring system for wastewater/stormwater collection systems for dangerous levels of explosive and toxic gases. (10/04-3/05)*
6. *A thorough identification and analysis of potential threats to computerized and automated controls associated with wastewater collection and treatment systems, and the means to protect them from cyber attacks. (12/04-6/06)*

4.d. Improved designs for wastewater systems to reduce vulnerability to physical threats and as a way to prevent or mitigate the effects of attacks on wastewater infrastructure.

1. *Working with standards setting organizations, preparation of voluntary design standards and recommendations for new construction, reconstruction, and retrofitting with a focus on security in combination with improved operations. (1/04-12/06)*

4.e. Enhanced prevention and response planning methods, including emergency response, contingency planning, and risk communication protocols and guidance for systems of varying sizes.

1. Development of response protocol “play books” for use by all key participants for development of their own “game plans” in responding to wastewater collection and treatment system threats or attacks. (12/03-7/04)
2. *Preparation of a wastewater system table top exercise to guide, and accompanying case studies resource document to encourage, interaction among wastewater system organizations and to provide them with insight and experience in role playing threat scenarios. (2/04-1/05)*
3. *Improvement of risk communication tools (with the public, individuals, and organizations) for those personnel and organizations responsible for protecting wastewater collection and treatment systems and/or responding to threats or attacks. (2/04-12/05)*

4.f. Methods and means to securely maintain, and when appropriate, transmit information on contaminants and threat scenarios applicable to wastewater systems.

1. *Evaluation of existing methods and means of information sharing on wastewater contaminants to ensure appropriate access to individuals and organizations based on their need for this information. (3/04-12/05)*
2. *Development of a framework for evaluating sensitivity of information, related to wastewater systems, and address needs identified in the first project. (3/04-12/05)*

IMPLEMENTATION

Effective implementation of the Action Plan is an essential component for improving water system security through enhanced research and technical support. Communication and dissemination of the results of the Action Plan are among the most important aspects of implementation. Implementation also involves continually assessing ongoing work and emerging needs in the area of water security, building and sustaining collaborative relationships with other water security researchers and organizations, determining and articulating the roles and responsibilities of other organizations and federal agencies in conducting the work identified in the Action Plan, and identifying and securing the necessary funding to support the identified projects. An effective implementation plan would also include a process and schedule for reviewing the water security effort as it progresses, evaluating its impact, and reassessing its priorities.

Providing the Means to Implement the Action Plan (Section 5.0)

Eight projects have been identified in the draft Implementation Plan (EPA, 2003b), expanding on the ideas presented in the Action Plan (see Box 3-8). Overall, the projects that are proposed make valuable contributions to the implementation effort. However, some projects or aspects of projects may be missing, as discussed in more detail below.

Project Evaluation

5.1.a Collaborative Research and Technical Support. As noted in NRC (2003a), building collaborative relationships with a broad array of knowledgeable researchers and agency representatives to share existing knowledge, identify research and technical support gaps, target resources to projects that can generate the most benefit, and minimize duplication of effort is essential to the success of the Action Plan and should be a high priority for the EPA. The formation of the Distribution System Research Consortium is an important first step toward improving coordination and collaboration among researchers in the water security arena. Currently, the consortium includes representatives from the military (e.g., Edgewood Chemical Biological Center, the U.S. Army Corps of Engineers), AwwaRF, and several federal agencies (e.g., CDC, U.S. Geological Survey, EPA). However, as currently comprised, the group represents only a portion of the broad spectrum of those with expertise in this area. The group should be expanded to include researchers, consultants, utilities, and national laboratories with expertise in this area, as originally identified in the Action Plan. The EPA should also continue to strengthen partnerships with organizations that have focused on deliberate attacks on water systems for several years, such as the U.S. Army and international experts. EPA managers have noted that developing research consortia is a new, experimental effort, which may be expanded into other fields once the success of this first project is evaluated. Additional topics and research fields that might also benefit from improved collaboration in order to share findings and minimize duplicative research include incident assessment/risk analysis; mitigation, treatment, and response; and contaminant detection.

5.2.a Technology Advancement. Several projects were identified that involve verification of emerging water-security technologies. The cost for the Environmental Technology Verification (ETV) projects ($8.1 million) would consume over 30 percent of the total estimated budget for the Action Plan (EPA, 2003b). Undoubtedly, there are benefits to advancing key technologies and providing a structured verification process that will assist utilities in evaluating the water security technologies available. However, considering the enormous resources required, these technologies should be selected using cost-benefit analyses. The verification process should focus on those technologies that provide the greatest potential benefits considering the relative risks and factors affecting their ultimate use, such as cost to utilities. For projects *5.2.a.2-3*, ETV funds should be awarded selectively to technologies that are broadly applicable to classes of chemicals/microbes or that are specific to high-risk, likely threat agents. The subsidization should be provided for essential devices that would not otherwise be tested because they have very limited commercial potential.

5.3.a Information Sharing. Developing an effective broad communication strategy that meets the needs of the wide range of stakeholders, including response organizations, water organizations and utilities, public health agencies, and the media, while addressing security concerns, should be among the highest priorities for the EPA. Results that cannot be communicated, are not accessible, or are poorly conveyed so that they are misunderstood are not useful. The EPA is currently struggling with many of these issues, and a plan for water security research communication is under development.

The projects identified in the draft Implementation Plan are appropriately prioritized, although some additional components and separate projects are suggested to strengthen the effort. The project to develop example practices (*5.3.a.1*) is important, as it will guide future communications efforts within EPA. Overall, the number and complexity of databases should be minimized to improve the accessibility of the data to the target users, and there are several cases where databases could be combined (e.g., the databases of treatment technologies, *3.4.c.8*, and the critical properties for priority contaminants, *3.2.b.1*). As noted with regard to section 3.2, in order to broaden the accessibility of the information and because the database training requirements may be extensive and unnecessary for all utilities, multiple communication strategies should be considered. Small utilities should be given the option to call EPA (or designated state agencies) directly and allow staff to search the databases on their behalf to answer immediate questions.

A second project (*5.3.a.2*) addresses how to get the right information to the right people at the right time, and this project should be among the highest priority efforts of the entire Action Plan. In this project, EPA will need to identify who might use and need the information being produced from the Action Plan and how will it be used, in order to effectively target dissemination methods and products to the appropriate audience. The draft concept paper on Water Security Information Sharing Strategy (EPA, 2003c) makes a good initial assessment of this, recognizing the wide array of potential information users and products. Several important issues, however, were not adequately addressed and the following projects are recommended to fill in these gaps:

- Conduct an analysis of the consequences of various levels of information security, including studies on the risks and benefits of widely transmitting water security data. This study should incorporate case study analyses of similar events, such as the anthrax attacks in 2001. (This project could be combined with the project proposed in *3.6.e.*)
- Assess the benefits and limitations of existing methods of dissemination (e.g., web pages, the Water Information Sharing and Analysis Center), including the cost burden to the government and those who need the information, so that managers can decide whether existing dissemination mechanisms are appropriate

to the agency's communication needs. (This project should be coordinated with projects in *3.2.d* and *3.6.e* and database development projects, such as *3.2.b*, *3.2.c*, and *3.4.c.8*.)

- Investigate means to utilize pertinent information from the community and incorporate improved two-way communication into the EPA communication strategy.

BOX 3-8
Providing the Means to Implement the Action Plan (Section 5.0)

The following lists the research and technical support needs and associated projects with scheduling to support implementation as presented in the draft Implementation Plan (EPA, 2003b). The numbering scheme is consistent with that used in the draft Implementation Plan.

5.1.a. Collaborative Research and Technical Support

1. Support to the Distribution Systems Research Consortium. (9/03-8/05)

5.2.a. Technology Advancement

1. ETV water security technology testing – Program outreach and support. (8/02-3/06)
2. ETV water security technology testing – detection technologies (11/02-3/06)
3. ETV water security technology testing – Point of use water treatment. (11/02-3/06)
4. Verification testing of wastewater and residuals treatment systems in support of homeland water security issues. (8/02-7/05)
5. Support for Technology Advancement at the less-than-commercial- ready stage of advancement/development. (1/04-12/05)

5.3.a. Information Sharing

1. Example practices in water security – Targeted products from the water security at the National Homeland Security Research Center. (5/03-4/06)
2. Information sharing support for the National homeland Security Research Center – Meeting water security stakeholder needs over the long term. (8/03-7/06)

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Appendix A

Original and Suggested Time Lines for EPA Research Projects

The following tables illustrate the original project time lines as set forth in the EPA draft Implementation Plan (EPA, 2003b) and suggested scheduling revisions proposed by the panel. These revisions summarize the ideas related to project scheduling that are presented in the body of the report and are intended to provide general guidance to EPA water security program managers. The original schedules are displayed as black bars, and revisions for certain projects are shown in the table as gray bars. This appendix does not capture other proposed changes for the projects (e.g., emphasis, approach, or improved linkages with other projects) that are described in Chapter 3 of Part I.

The project titles have been abbreviated and organized below under the research and technical support needs as written in the EPA Water Security Research and Technical Support Action Plan. New research and technical support needs and projects that have been suggested by the panel in Parts I and II are included in the table, denoted by the word "PROPOSED." The time lines for projects shown in italics (see section 4.0) were not reviewed.

Legend:

(black bar)	Original EPA scheduling as proposed in the draft Implementation Plan (EPA, 2003b)
(gray bar)	Suggested adjustment to project scheduling
- - - - - - - -	Time period during which continued updates and revision are necessary as new information becomes available, although the effort may be less intense

	2002				2003				2004				2005				2006			
	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4
3.1.a. Identification and prioritization of physical and cyber threats																				
3.1.a.1. Identification of physical and cyber threats scenarios																				
3.1.a.2. Lessons learned via vulnerability assessments																				
3.1.a.3. Evaluation of vulnerability assessment methodologies																				
3.1.a.4. Refining of methodologies for vulnerability assessments																				
3.1.b. Understanding the consequences of physical or cyber attacks on drinking water infrastructure																				
3.1.b.1. Evaluation of models to address consequences of phys/cyber attacks on infrastructure																				
3.1.b.2. Assessment of consequences of phys./cyber attacks on water system integrity																				
3.1.b.3. Assessment of consequences of pressurized water loss on other infrastructure sectors																				
3.1.b.4. Compilation of technical info. and tools for enhanced consequence analysis																				
3.1.c. Countermeasures to prevent or mitigate physical and cyber attacks on water infrastructure																				
3.1.c.1. Preparation of voluntary design standards																				
3.1.c.2. Protection standards for SCADA and other computer systems																				
3.1.c.3. Identification of phys. countermeasures to minimize threats and consequences of attacks																				
3.1.c.4. Assessment of security measures for storage and transport of hazardous materials																				
New PROPOSED Need: Assessing costs and benefits of preventative countermeasures																				
PROPOSED: Assessment of costs and benefits associated with various security countermeasures																				
PROPOSED: Research on rate structures to finance improved water system security																				
PROPOSED: Develop a manual on the value of water, inc. water security, and rate structures																				

	2002				2003				2004				2005				2006			
	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4
3.2.a. Development of a list of contaminants and threat scenarios																				
3.2.a.1. Preparation of a prioritized list of contaminants (and contam. classes)																				
3.2.a.2. Identification and prioritization of contaminant threat scenarios																				
3.2.a.3. Improved understanding of biologically produced toxins as contaminants																				
3.2.b. Development of a database on critical contaminants.																				
3.2.b.1. Development of a database of contaminants																				
3.2.b.2. Development of guidance on the use of this system																				
3.2.b.3. Improved understanding of contaminant properties based on gaps in database																				
3.2.b.4. Information survey about contaminant background levels in drinking water																				
3.2.c. Development of a surrogate/simulant database																				
3.2.c.1. Development of a surrogate/simulant database for priority contaminants																				
3.2.c.2. Development of guidance on the use of this database																				
3.2.d. Means for maintaining and transmitting information on contaminants and threat scenarios																				
3.2.d.1. Evaluation of existing methods/means for info. sharing on contaminants																				
3.2.d.2. Development of framework to evaluate the sensitivity of information																				

	2002	2003	2004	2005	2006
3.3.a. A "play book" for analytical response					
3.3.a.1. Preparation of a draft analytical response module for drinking water contaminant threats					
3.3.a.2. Development of a protocol to analyze "unknowns"					
3.3.a.3. Lab testing and validation of analytical protocol using round robin approach					
3.3.a.4. End-user testing and validation of analytical response protocol					
3.3.a.5. Development of improved protocol based on lessons learned in projects 3-4					
3.3.a.6. Update the analytical response "play book"					
3.3.b. Improved analytical hardware and analysis methodologies					
3.3.b.1. Development of concentration techniques for priority biological contaminants					
3.3.b.2. Adaptation of NEMI database for water security					
3.3.b.3. Analysis and compilation of existing analyt. hardware and methods for water security					
3.3.b.4. Understanding and definition of analysis goals, such as data quality objectives					
3.3.b.4 (Impl.Plan). Development of list of existing protocols for microbiological contaminants					
3.3.b.5. Development and application of new analyt. hardware and methods for contaminants					
3.3.b.6. Updating the NEMI database and "play book" based on the above projects					
3.3.c. Requirements for monitoring technologies					
3.3.c.1. Analysis of water utility and org. standards for technology design and operation					
3.3.c.2. Identification of desired monitoring technology characteristics for water contaminants					
3.3.c.3. Implementation of approach for advancing desired tech. characteristics via collaboration					
3.3.c.4. Incorporation of lessons learned in above projects into analytical response "play book"					
PROPOSED: Develop sampling protocols for water sec. threat scenarios, incl. worker safety					
PROPOSED: Examine spatial/temporal sampling requirements and incorporate into protocols					
3.3.d. Testing and evaluation of monitoring technologies					
3.3.d.1. Evaluation of existing monitoring technologies for response to changes in water quality					
3.3.d.2. Preparation of preliminary SOPs for evaluating monitoring technologies					

	2002				2003				2004				2005				2006			
	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4
3.3.d. Testing and evaluation of monitoring technologies (cont.)																				
3.3.d.3. Evaluation of detectors from non-water sectors for their utility for water monitoring																				
3.3.d.4. Evaluation of bio-sensors and bio-monitors for response to changes in water quality																				
3.3.d.5. Preparation of revised SOPs for evaluating monitoring technologies																				
3.3.d.6. Preparation of handbook on current/ emerging water security monitoring technologies																				
3.3.e. Early warning systems																				
3.3.e.1. Survey of EWSs that could be used in protecting water																				
3.3.e.2. Pilot testing of EWSs for early warning of contamination event																				
3.3.e.3. Field testing of EWSs for early warning of contamination event																				
3.3.e.4. Preparation of handbook on applications of EWSs for water security																				
3.3.f. Assessment of national laboratory capacity																				
3.3.f.1. Assessment of existing lab analytical capacity/capability and development of database																				
3.3.f.2. Determine labs able to run protocol from 3.3.a; structure a network for utilities																				
3.3.f.3. Conduct a gap analysis for resources, training, methods																				
3.3.f.4. Integrate labs into a nat'l network or other mechanisms to meet water emerg. needs																				
3.3.f.5. Development of a plan for inter-lab coordination and information exchange																				
3.3.g. Training																				
3.3.g.1. Training exercises to ensure prepared-ness of analytical labs for contam.events																				
3.3.g.2. Training exercises for field personnel on use of detection technologies for response																				
3.3.g.3. Training exercises for field personnel on use of monitoring systems for mitigation																				

	2002				2003				2004				2005				2006			
	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4
3.4.a. Improved distribution system models																				
3.4.a.1. Analysis of EPANET, Pipeline Net, Modflow, and other hydraulic models																				
3.4.a.2. Develop module for merging health data, GIS, and SCADA data with hydraulic models																				
3.4.a.3. Use models to determine strategic locations of backflow prevention devices																				
3.4.a.4. Decision tree for utilities for use in determining background info. needs																				
3.4.a.5. Investigation of "real time" monitors and impact of instrument noise																				
3.4.a.6. Determine how distr. sys. models could be used to identify weak points in the system																				
3.4.a.7. Creation of analysis tool for using distribution system models in small systems																				
3.4.a.8. Development of analysis tool for using distribution system models post-endpoint																				
3.4.a.9. Investigation of contaminants in pipe loops																				
PROPOSED: Conduct an inventory of water systems to assess hydraulic models																				
PROPOSED: Refine distribution system models to consider decay rates of water contaminants																				
3.4.b. Understanding the fate of contaminants once they are released																				
3.4.b.1. Develop a protocol for actions if a contaminant is introduced in drinking water																				
3.4.b.2. Assessment of the environmental fate of water contaminants																				
3.4.b.3. Investigation of contaminant attachment to biofilms or pipe walls																				
3.4.c. Treatment processes for water and equipment that have been contaminated																				
3.4.c.1. Review of literature for treatability information for most likely contaminants																				
3.4.c.2. Prepare a method for evaluating treatment tech. efficacy for likely contaminants																				
3.4.c.3. Bench-scale studies on disinfection capabilities of typical treatment technologies																				
3.4.c.4. Bench-scale studies on removal capabilities of typical treatment technologies																				
3.4.c.5. Identification of POU/POE contaminant treatment capabilities and disposal procedures																				
3.4.c.6. Identify contaminants that may create hazardous byproducts due to disinfectants																				
3.4.c.7. Develop treatment technology capabilities for disposal of contaminated water																				
3.4.c.8. Develop contaminant treatment technology documents and database																				
3.4.c.9. Develop guidance for the discharge of cleaning water that may be contaminated																				
3.4.d. A guide for determining when a system is contaminated and when it can be used																				
3.4.d.1. Develop protocols to address water usage concerns (when a system is safe to use)																				

	2002				2003				2004				2005				2006			
	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4
3.5.a. Assessment of water supply alternatives																				
3.5.a.1. Case studies that provide spectrum of contingency planning situations																				
3.5.a.2. Assessment of truck-mounted and portable water treatment facilities																				
3.5.a.3. Assessment of redundancy approaches to assure continuity in water supplies																				
3.5.a.4. Analysis of optimal water supply sources using a GIS-based approach																				
3.5.a.5. Develop a compendium of options for providing alternate water supplies																				
3.5.b. Evaluation of approaches for providing water in the event of both long-term and short-term disruptions																				
3.5.b.1. Assessment of technologies for short and long-term water delivery																				
3.5.b.2. Evaluation of the most promising water supply technologies																				
3.5.c. An improved understanding of water system interdependencies with other infrastructure																				
3.5.c.1. Identification and analysis of critical infrastructures interdependencies that affect water																				
New PROPOSED Need: Failure of the "human subsystem" in system operations and development of contingencies																				
PROPOSED: Determine circumstances where systems impacted by incapacitated personnel																				

	2002	2003	2004	2005	2006
	Qtr1 Qtr2 Qtr3 Qtr4	Qtr1 Qtr2 Qtr3 Qtr4	Qtr1 Qtr2 Qtr3 Qtr4	Qtr1 Qtr2 Qtr3 Qtr4	Qtr1 Qtr2 Qtr3 Qtr4
3.6.a. An improved understanding of exposure routes and contaminant health effects					
3.6.a.1. Compilation of database on non-cancer health effects associated w/ contaminants					
3.6.a.2. Evaluation of contaminant exposure routes and the likelihood of viability					
3.6.a.3. Creation of info. portal on exposure routes and health effects for water threats					
3.6.a.4. Review of models to estimate doses regarding contaminant toxicity or infectivity					
3.6.b. A health surveillance network associated with contaminated drinking water					
3.6.b.1. Collaboration w/ CDC in developing a health surveillance network assoc. with water					
3.6.c. Methodology for using non-traditional data sources deriving acute and chronic toxicity values applied to water					
3.6.c.1. Develop methodology for extrapolating LD_{50} data to derive toxicity for priority contam.					
3.6.c.2. Develop methodology for using QSAR to estimate toxicity for priority contam.					
3.6.d. Frameworks for assessing and managing risk					
3.6.d.1. Analysis of current approaches for risk assessment/management to respond to attacks					
3.6.d.2. Testing risk assessment/mgmt approaches via simulations and table top exercises					
3.6.d.3. Develop protocol for risk assessors/ managers in addressing attacks on water supplies					
3.6.e. Methods and means to communicate risk					
3.6.e.1. Creation or adaptation of a Risk Assessment/Risk Communication Framework					
3.6.e.2. Preparation of materials that facilitate early response to customers					
3.6.e.3. Development of a repository of information and materials for response to attack					
3.6.e.4. Development of methods for info. sharing on risk assessment/mgmt methodologies					
PROPOSED: Analyze when to release info. vs. when to withhold it due to security concerns					
PROPOSED: Conduct case study analysis of risk comm. strategies for past disaster events					
PROPOSED: Develop natl. training program on risk comm. planning for water managers					
PROPOSED: Analyze factors that build trust, reduce fear, and prevent panic to improve comm.					
PROPOSED: Analyze methods to reduce misinformation being dist. to public and stakeholders					

	2002				2003				2004				2005				2006			
	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4
4.0.a. Documentation of wastewater threats including interdependencies																				
4.0.a.1. Identification of potential threats for wastewater infrastructure																				
4.0.a.2. Assessment of countermeasures or system redundancies																				
4.0.a.3. Evaluation of "unattended operations" and how they can be protected																				
4.0.a.4. Assessment of linkages between drinking water and wastewater systems																				
4.0.a.5. Analysis of interdependencies between critical infrastructures related to ww																				
PROPOSED: Examine worker safety and protection during water security attacks																				
4.0.b. Risks related to hazardous substances used by wastewater utilities																				
4.0.b.1. Preparation of a "Baseline Threat Document" for wastewater systems																				
4.0.b.2. Screening level risk assessment of contaminant threats to wastewater systems																				
4.0.b.3. Comparative assessment of alternatives to disinfection that uses chlorine																				
4.0.b.4. Evaluate ww treatment technologies that can more effectively remove contaminants																				
4.0.b.5. Evaluate contaminant impacts on sewage sludge and other residuals																				
4.0.c. Intrusion monitoring and surveillance technologies																				
4.0.c.1. Assess methods for controlling inappropriate access to wastewater systems																				
4.0.c.2. Assess techn. for identifying physical threats and contam. introduction into ww sys																				
4.0.c.3. Evaluation of intrusion monitoring and surveillance technologies for wastewater systems																				
4.0.c.4. Assessment of models for simulating movement of hazardous materials in ww systems																				
4.0.c.5. Assessment of technologies for continuous monitoring for explosive/ toxic gases																				
4.0.c.6. Identification of cyber threats to controls of ww systems and means to protect them																				
4.0.d. Improved designs for wastewater systems																				
4.0.d.1. Preparation of design standards and recommendations for construction for security																				
4.0.e. Enhanced prevention and response planning methods																				
4.0.e.1. Development of "play books" for wastewater security response																				
4.0.e.2. Preparation of wastewater table top exercises for threat scenarios																				
4.0.e.3. Improvement of risk communication tools for those responsible for ww systems																				
PROPOSED: Examine procedures for managing cont. waste based on ww threat scenarios																				
4.0.f. Methods to maintain and transmit contaminant and threat information																				
4.0.f.1. Evaluation of information sharing methods on wastewater contaminants																				
4.0.f.2. Develop a framework for evaluating wastewater information sensitivity																				

	2002				2003				2004				2005				2006			
	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4
5.1a. Collaborative research and technical support																				
5.1.a.1. Support to the Distribution Systems Research Consortium																				
5.2.a. Technology advancement																				
5.2.a.1. ETV water security technology testing: program outreach and support																				
5.2.a.2. ETV water security technology testing: detection technologies																				
5.2.a.3. ETV water security technology testing: point of use water treatment																				
5.2.a.4. Testing of wastewater and residuals treatment systems in support of security issues																				
5.2.a.5. Support for Technology Advancement at the less-than-commercial-ready stage																				
5.3.a. Information sharing																				
5.3.a.1. Example practices in water security--targeted products from the NHSRC																				
5.3.a.2. Information sharing support for NHSRC																				
PROPOSED: Analysis of the consequences of various levels of information security																				
PROPOSED: Assess the benefits and limitations of existing methods of dissemination																				
PROPOSED: Investigate ways to improve two-way communication.																				

Appendix B

WATER SCIENCE AND TECHNOLOGY BOARD

RICHARD G. LUTHY, *Chair,* Stanford University, Stanford, California
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JAMES CROOK, Water Reuse Consultant, Norwell, Massachusetts
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ELLEN A. DE GUZMAN, Research Associate
PATRICIA JONES KERSHAW, Study/Research Associate
ANITA A. HALL, Administrative Assistant
JON Q. SANDERS, Senior Project Assistant
DOROTHY K. WEIR, Project Assistant

Appendix C

Biographical Sketches for the Panel on Water System Security Research and NRC Staff

Garret P. Westerhoff, *Chair*, is Senior Vice President and Director, Malcolm Pirnie, Inc. From 1999 to 2002 he served as Chairman and Chief Executive Officer for Malcolm Pirnie. He has 45 years of experience in the areas of water resources planning, water and wastewater treatment systems, and consulting for water utilities. Early in his career he pioneered innovative technologies such as high-rate and direct filtration and led the design of the nation's first major installation of granular activated carbon treatment to remove organics from drinking water. He previously was Technical Director for Drinking Water Projects at Malcolm Pirnie and has worked with numerous large municipal clients, including Metropolitan Water District of Southern California and the City of New York, on the design and study of water supply, treatment, and distribution facilities. He has focused his recent efforts on improving the performance and efficiency of water utilities. Mr. Westerhoff is a member of the National Academy of Engineering. He received his B.S. in civil engineering and his M.S. in sanitary engineering from the New Jersey Institute of Technology.

Gregory B. Baecher is professor of Civil and Environmental Engineering at the University of Maryland. Dr. Baecher served on the faculty of the civil engineering department at the Massachusetts Institute of Technology from 1976 to 1988, and he served as the CEO and founder of ConSolve Incorporated, Lexington, Massachusetts, from 1988 to 1995. His fields of expertise include risk analysis, water resources engineering, and statistical methods. He serves on the Water Science and Technology Board and the Board on Infrastructure and the Constructed Environment. He also recently served on the NRC committee on Science and Technology for Countering Terrorism: Panel on Energy, Facilities, Cities, and Fixed Infrastructure. Dr. Baecher received his B.S. degree in civil engineering from the University of California-Berkeley and his M.S. and his Ph.D. degrees in civil engineering from the Massachusetts Institute of Technology.

Joseph A. Cotruvo is principal of Joseph Cotruvo and Associates, an environmental and public health consulting firm. His work focuses on the area of water quality and safety, technologies for small water systems, risk assessment for environmental contaminants, and point-of-use water treatment technology. He previously was Vice President of Environmental Health Sciences for NSF International and head of the WHO/NSF Collaborating Centre for Drinking Water Safety and Treatment. From 1973 to 1996 he worked at the U.S. Environmental Protection Agency and was responsible for the development of the National Drinking Water Quality Standards and Guidelines for organic and inorganic chemicals, microbials, and radionuclides. He also directed the EPA's Health and Environmental Review Division and the Chemical Screening and Risk Assessment Division. Dr. Cotruvo received his B.S. degree in chemistry from the University of Toledo and his Ph.D. in physical organic chemistry from Ohio State University.

Gunther F. Craun is president of Gunther F. Craun & Associates, Global Consulting for Environmental Health. He has nearly 30 years of experience in assessing the health effects of microbial drinking water contaminants. From 1965 until 1991, he was a commissioned officer in the U.S. Public Health Service. From 1971 until 1991, he was assigned to the Environmental Protection Agency's drinking water program and research and development office. He held positions as coordinator of environmental epidemiology for the Health Effects Research Laboratory and assistant to the director of the Drinking Water Research Division. He has authored or co-authored several books in the drinking water field, including *Microbial Pathogens and Disinfection By-products in Drinking Water: Health Effects and Management of Risks*, *Providing Safe Drinking Water in Small Systems*, and *Methods for the Investigation and Prevention of Waterborne Disease Outbreaks*. Mr. Craun served on the NRC Committee on Small Water Supply Systems. He holds a B.S. in civil engineering and an M.S. in sanitary engineering from Virginia Polytechnic Institute and an M.P.H. and S.M. in epidemiology from Harvard University.

Charles N. Haas is the Betz Professor of Environmental Engineering at Drexel University. He was formerly a professor and acting chair in the Department of Environmental Engineering at the Illinois Institute of Technology. His areas of research involve microbial and chemical risk assessment, chemical fate and transport, hazardous waste processing and disposal practices, industrial wastewater treatment, and water and wastewater disinfection processes. He is currently conducting research to evaluate the analytical capabilities for monitoring intentional contamination of drinking water. He has co-authored fourteen books or major works on water and wastewater treatment and/or microbial risk assessment. He has served on five NRC committees, including the Committee for Indicators of Waterborne Pathogens and the Committee to Review the New York City Watershed Management Strategy. Dr. Haas received a B.S. in biology and an M.S. in environmental engineering from the Illinois Institute of Technology and a Ph.D. in environmental engineering from the University of Illinois.

James B. McDaniel is deputy assistant general manager and director of water quality and operations for Los Angeles Department of Water and Power (LADWP). He is responsible for the quality and regulatory compliance of drinking water served to 3.8 million residents of the city of Los Angeles, and he oversees all treatment and storage facilities for the utility. He has over 20 years of experience in water utility operations and management and is now specifically responsible for strategic planning and water security at LADWP. Mr. McDaniel provided oversight of the preparation of the vulnerability assessment for LADWP and designed the utility's post-9/11 increases in security. He also participated in the development of the Water Sector Information Sharing and Analysis Center (ISAC) to facilitate secure information sharing among water and wastewater utilities. Mr. McDaniel received his B.S. in civil engineering from the University of California at Irvine.

Charles R. O'Melia is the Abel Wolman Professor of Environmental Engineering in the Department of Geography and Environmental Engineering at The Johns Hopkins University. His professional experience includes positions at Hazen & Sawyer Engineers, University of Michigan, Georgia Institute of Technology, Harvard University, and the University of North Carolina, Chapel Hill. His research interests are in aquatic chemistry, environmental fate and transport, predictive modeling of natural systems, and the theory of water and wastewater treatment. He is a member of the National Academy of Engineering and past member of the Water Science and Technology Board and the Board on Environmental Studies and Toxicology. He has served on numerous NRC committees, including the Committee on Research Opportunities and Priorities for EPA, the Committee on Wastewater Management for Coastal Urban Areas, and the Committee on Water-Treatment Chemicals, and he was chair of the Committee to Review the New York City Watershed Management Strategy. He received a B.C.E. from Manhattan College and an M.S.E. and Ph.D. in sanitary engineering from the University of Michigan.

David M. Ozonoff is a professor in the Department of Environmental Health in Boston University's School of Public Health. He is also a professor in the Department of Sociomedical Sciences and Community Medicine at Boston University School of Medicine. His research centers on epidemiological studies of populations exposed to toxic agents, new approaches to investigate small exposed populations, and the effects of exposure misclassification in environmental epidemiology. He is the editor-in-chief of the online journal Environmental Health and director of the Program on Public Health Preparedness at Boston University. He is also a member of the Massachusetts Bioterrorism Preparedness and Response Program, and he served on the NRC Committee on Drinking Water Contaminants. Dr. Ozonoff received his B.S. in mathematics from the University of Wisconsin, his M.D. from Cornell University, and his M.P.H. from The Johns Hopkins School of Public Health.

Kerry Kirk Pflugh is manager of the Office of Outreach and Education in the Division of Watershed Management at the New Jersey Department of Environmental Protection. Previously, she was chief of the Raritan Bureau in the Division of Watershed Management. From 1987 to 2001 she was a research scientist in the Risk Communication Unit, Division of Science and Research, NJDEP. Ms. Pflugh's area of expertise has been strategic communication planning focusing on citizen participation in environmental management decision making. Her research projects include studies of the perception of risk related to fish consumption advisories in the Latino community, sociodemographic indicators as a response to risk information, and citizen knowledge of remediation techniques for lead in drinking water and radium in groundwater. She holds a B.A. in environmental communication from Cook College-Rutgers University and an M.S. degree in agricultural journalism from the University of Wisconsin at Madison.

David A. Reckhow is professor of civil and environmental engineering at the University of Massachusetts, Amherst. He also serves as the director of the University of Massachusetts Environmental Institute and interim director of the Massachusetts Water Resources Research Center. His research interests include water and wastewater treatment, physical-chemical processes, water chemistry, and water quality modeling, with special emphasis on disinfection byproducts, the use of ozone for water purification, and new techniques for water quality monitoring. He is a board member of the American Water Works Association Research Foundation. Dr. Reckhow received his B.S. in civil engineering from Tufts University, his M.S. in civil engineering from Stanford University, and his Ph.D. in environmental engineering from the University of North Carolina.

David P. Spath is chief of the Division of Drinking Water and Environmental Management at the California Department of Health Services, where he has worked since 1972. He is currently responsible for overseeing California's Public Water System Regulatory Program, its Medical Waste Regulatory Program, and the state's Nuclear Emergency Response Program. He is chair of the National Drinking Water Advisory Council and also serves on the California Recycled Water Task Force. He is past president of the Association of State Drinking Water Administrators and served on a steering committee for the EPA's environmental technology verification program related to small water systems. Dr. Spath received his B.S. in civil engineering from Tufts University, and his M.S. and Ph.D. in civil and environmental engineering from the University of Cincinnati.

Marylynn V. Yates is professor of environmental microbiology in the Department of Environmental Sciences and associate executive vice chancellor at the University of California, Riverside. Dr. Yates conducts research in the area of water and wastewater microbiology. Her current research focuses on contamination of water by human pathogenic microorganisms, especially through use of reclaimed water and biosolids; developing and improving methods to detect microorganisms in environmental samples; persistence of pathogenic microorganisms in the environment; and efficacy of water, wastewater, and biosolids treatment processes to inactivate pathogenic microorganisms. Dr. Yates has also served on the WSTB Committee on Indicators for Waterborne Pathogens and the Committee on Groundwater Recharge. She received a B.S. in nursing from the University of Wisconsin at Madison, an M.S. in chemistry from the New Mexico Institute of Mining and Technology, and a Ph.D. in microbiology and immunology from the University of Arizona.

CONSULTANT

David R. Siburg is General Manager of the Kitsap Public Utility District, in Poulsbo, WA, which owns and operates 54 water systems that serve populations ranging from 18 (6 connections) to 14,000 (4500 connections) people, and provides contract service to 106 other small systems. He provides management guidance nationally and internationally for small water system issues and combined utility functions. He currently serves as chair of the American Water Works Association Small Systems Division. He also served on the NRC Committee on Small Water Supply Systems. Mr. Siburg has a Master of Planning degree from the University of Minnesota.

STAFF

Stephanie E. Johnson is a project officer with the Water Science and Technology Board. Since joining the NRC in 2002, she has served as study director for three committees, including the Panel to Review the Critical Ecosystem Studies Initiative and the Committee to Review the Desalination and Water Purification Technology Roadmap. She received her B.A. from Vanderbilt University in chemistry and geology, and her M.S. and Ph.D. in environmental sciences from the University of Virginia on the subject of pesticide transport and microbial bioavailability in soils. Her research interests include contaminant transport, aqueous geochemistry, and hydrogeology.

Laura J. Ehlers is a senior staff officer for the Water Science and Technology Board of the National Research Council. Since joining the NRC in 1997, she has served as study director for nine committees, including the Committee to Review the New York City Watershed Management Strategy, the Committee on Riparian Zone Functioning and Strategies for Management, and the Committee on Assessing the TMDL Approach to Water Quality Management. She received her B.S. from the California Institute of Technology, majoring in biology and engineering and applied science. She earned both an M.S.E. and a Ph.D. in environmental engineering at the Johns Hopkins University.

Dorothy K. Weir is a project assistant with the Water Science and Technology Board. She received a BS in Biology from Rhodes College in Tennessee. Ms. Weir is involved with the project *Water Quality Improvement for the Pittsburgh Region: A Model in Systematic Management of Wastewater with Multiple Political Jurisdictions*. She joined the National Research Council in 2003.