

Emergency Planning for Water and Wastewater Utilities

Fifth Edition



American Water Works
Association



Documents
Document Sharing Hub

Emergency Planning for Water and Wastewater Utilities

Fifth Edition



**American Water Works
Association**



Documents

Document Sharing Hub

Manual of Water Supply Practices — M19, Fifth Edition

Emergency Planning for Water and Wastewater Utilities

Copyright © 1999, 2006, 2018 American Water Works Association

All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including scanning, recording, or any information or retrieval system. Reproduction and commercial use of this material is prohibited, except with written permission from the publisher.

Disclaimer

The authors, contributors, editors, and publisher do not assume responsibility for the validity of the content or any consequences of their use. In no event will AWWA be liable for direct, indirect, special, incidental, or consequential damages arising out of the use of information presented in this book. In particular, AWWA will not be responsible for any costs, including, but not limited to, those incurred as a result of lost revenue. In no event shall AWWA's liability exceed the amount paid for the purchase of this book.

Managing Editor: Melissa Valentine
Sr. Specialist, AWWA Manuals: Sue Bach
Cover Design: Melanie Yamamoto

Library of Congress Cataloging-in-Publication Data

Names: Gay, Stephen D., author. | Borman, Scott D., author. | American Water Works Association, issuing body.

Title: M19 emergency planning for water utilities / by Stephen D. Gay and Scott D. Borman.

Other titles: Emergency planning for water utilities | AWWA manual ; M19.

Description: Fifth edition. | Denver, CO: American Water Works Association, [2018] | Series: AWWA manual ; M19 | Includes bibliographical references.

Identifiers: LCCN 2018014152 | ISBN 9781625762795

Subjects: LCSH: Waterworks--Management. | Emergency management. | Emergency water supply.

Classification: LCC TD487 .G39 2018 | DDC 363.6/10684--dc23

LC record available at <https://lcn.loc.gov/2018014152>

Printed in the United States of America

ISBN 978-1-62576-279-5

eISBN 978-1-61300-460-9



If you are interested in using any part of this publication for training, creating a derivative work, or for any commercial use, written permission from AWWA is required. Please send your request to permissions@awwa.org.



**American Water Works
Association**

American Water Works Association
6666 West Quincy Avenue
Denver, CO 80235-3098
awwa.org

 **Documents**
Document Sharing Hub

Copyright © 2018 American Water Works Association. All Rights Reserved.

Full document details: AWWA Manual M19 2018

Contents

List of Figures, v

List of Tables, vii

Preface, ix

Acknowledgments, xi

Chapter 1	Preparedness Culture	1
	Developing an Explicit Organizational Commitment to Emergency Preparedness, 2	
	Developing the Preparedness Culture, 3	
	Supporting the Preparedness Culture with Tools and Tactics, 4	
	Evaluating the “Strength” of the Preparedness Culture, 5	
	References and Supplemental Readings, 5	
Chapter 2	Risk and Resilience Assessment	7
	What is a Risk and Resilience Assessment?, 7	
	Goals of a Risk and Resilience Assessment, 8	
	Managing a Risk and Resilience Assessment, 8	
	Conducting a Risk and Resilience Assessment, 8	
	Threat Considerations, 9	
	Acceptable Levels of Service for a System, 21	
	Conclusions, 22	
	References and Supplemental Readings, 23	
Chapter 3	Developing an Emergency Response Plan	25
	Importance of a Utility Preparedness Program, 26	
	Overview of Types of Preparedness Plans, 26	
	How to Develop an ERP, 27	
	Components of an ERP, 29	
	Incorporating the NIMS and the ICS into an ERP, 33	
	ERP Maintenance, 35	
	References and Supplemental Readings, 36	
Chapter 4	Mutual Aid and Partnerships	37
	Identify Key Partnerships, 37	
	Establish Collaborative Partnerships, 38	
	Mutual Aid, 39	
	Mutual Aid in the Water Sector, 39	
	Mutual Aid Coordination with Local and State Emergency Management, 41	
	WARN Operational Plans, 42	
	WARN Exercises, 43	
	Local WARN Incident Responses, 44	
	Conclusions, 46	
	References and Supplemental Readings, 46	

Chapter 5	Internal and External Communications	49
	General Crisis Communications Planning Guidance, 49	
	Internal Communications with Employees, 52	
	Communicating with Emergency Response Agencies and Local Government Agencies, 52	
	Communicating with Customers and the Public at Large, 53	
	Understanding the Traditional Media, 57	
	Using Social Media, 59	
	Communicating with Regulatory Agencies, 61	
	Maintaining Contact Information, 62	
	Conclusions, 62	
	References and Supplemental Readings, 63	
Chapter 6	Training and Exercises	65
	Training and Exercise Matrix, 65	
	Initial and Refresher Training, 67	
	Training Sources and Methods, 69	
	Conducting Exercises, 70	
	Documentation, 76	
	Conclusions, 76	
	References and Supplemental Readings, 76	
Chapter 7	Mitigation	77
	What is Mitigation?, 77	
	Hazard Mitigation, 78	
	FEMA Hazard Mitigation Assistance Grant Program, 80	
	Hazard Mitigation Actions for Utilities, 80	
	References and Supplemental Readings, 91	
Appendix A	Additional Resources for Emergency Preparedness and Response . . .	93
Appendix B	Emergency Response Plan Crosswalk for Plan Review Foreword Section.	95
Appendix C	Federal Policies That Support Preparedness Planning	101
	Glossary, 107	
	Acronyms, 109	
	Index, 111	
	AWWA Manuals, 117	

Figures

- 1-1 The Preparedness Culture cycle, 2
- 2-1 Risk assessment process as described in [ANSI/AWWA J100](#), 9
- 2-2 Seismic hazard map of the United States, 11
- 2-3A Landers–Big Bear earthquake fault offset, 12
- 2-3B Landers–Big Bear earthquake pipe broken in the fault offset, 12
- 2-4 Seismic forces on water storage tank, 13
- 2-5A Ground crack resulting from lateral spreading in Kobe, Japan in 1995, 14
- 2-5B Ductile-iron joint pulled apart due to lateral spreading, 14
- 2-6 Flooded K.R. Harrington Water Treatment Plant in Nashville, 17
- 2-7 Flooding at the Nashville Omohundro Water Treatment Plant, 18
- 2-8 Water utility interdependencies with other infrastructure systems, 22
- 3-1 Interconnection of various preparedness plans, 26
- 3-2 ICS diagram, 33
- 4-1 Water/Wastewater Agency Response Network program map (as of November 2015), 40
- 4-2 Water/Wastewater Agency Response Network coordination with local, state, and federal emergency management, 42
- 5-1 Communication facilitates resource requests, 61
- 5-2 Communication improves regulatory agency support of program operations, 62
- 6-1 Example of an emergency preparedness training matrix, 66
- 6-2 Example of a multiyear training and exercise plan, 68
- 6-3 Emergency preparedness training plan model, 69
- 6-4 Discussion-based and operations-based exercises, 71
- 6-5 Exercise program management, 75
- 7-1 Collapsed spring-vibration isolator supporting an emergency generator in Whittier, California, 85
- 7-2 Mitigation option for water storage tanks, 88
- 7-3 Mitigation options for pipelines at fault crossings, 89

This page intentionally blank.

Tables



- 2-1 Example disaster effects matrix, 10
- 3-1 Types of preparedness plans, 27
- 6-1 Training methods and their general parameters, 70
- C-1 Policies and legislations that support preparedness planning, 102

This page intentionally blank.

Preface

Water and wastewater utilities, hereafter referred to as the *utility*, are responsible for providing adequate supplies of safe drinking water and for reliably collecting and treating wastewater. This manual addresses best practices for the prevention, mitigation, response, and recovery of utility operations during critical incidents and is intended for use by utilities of any size. The subject of this manual is closely tied with the AWWA management standards [ANSI/AWWA G430](#), Security Practices for Operation Management; [ANSI/AWWA G440](#), Emergency Preparedness Practices; and [ANSI/AWWA J100](#), Risk and Resilience Management of Water and Wastewater Systems. This manual provides the reader with useful information and resources for satisfying the requirements set forth in the standards and related resources. Where applicable, the requirements of these standards are referenced in text box.

This fifth edition of AWWA Manual M19, *Emergency Planning for Water and Wastewater Utilities*, has been updated to align with current emergency planning best practices. Throughout the manual, the reader will find references to resources designed to support risk assessments as well as to develop mutual aid opportunities and mitigation activities.

This manual comprises the following chapters that discuss proven methodologies and best practices used by water utilities in emergency planning:

Chapter 1, Preparedness Culture, discusses how a preparedness culture increases the effectiveness of utility response to incidents as well as best practices for developing and promoting this response.

Chapter 2, Risk and Resilience Assessment, describes how water utility leaders can better understand risks to their mission and critical assets, how this assessment supports emergency planning by identifying and prioritizing utility-specific risks, and how to identify investments that can pay the greatest dividends during and after an incident.

Chapter 3, Developing an Emergency Response Plan, discusses the basic principles and elements of a preparedness plan, and highlights plan development, emergency procedures, organizational use of an incident command system, and maintenance.

Chapter 4, Mutual Aid and Partnerships, discusses the value in developing partnerships between utilities and other organizations and describes in detail the Water/Wastewater Agency Response Network (WARN), which provides mutual aid and assistance.

Chapter 5, Internal and External Communications, discusses the various modes and messages of communication with stakeholders that are critical to utility emergency response.

Chapter 6, Training and Exercises, describes how utility personnel can practice preparing for and responding to incidents to build skills that will minimize losses and expedite recovery.

Chapter 7, Mitigation, describes how to increase a utility's resilience and preparedness through risk-management activities including hazard mitigation.

This page intentionally blank.

Acknowledgments

The AWWA M19 Emergency Planning for Water Utilities Manual Subcommittee, which developed this manual, had the following personnel at the time:

Stephen D. Gay, *Chair*

S. Bach, Staff Advisor, AWWA, Denver, Colo.
D.S. Borman, Benton/Washington Regional Public Works Authority, Rogers, Ark.
R. Bova, Suffolk County Water Authority, Oakdale, N.Y.
J. Cassidy, Critical Situation Management Inc., Marysville, Pa.
J. Crisologo, California Department of Public Health, Glendale, Calif.
S.A. Dennis, Alameda County Water District, Fremont, Calif.
D. Flancher, Standards Engineer Liaison, AWWA, Denver, Colo.
S.D. Gay, City of Westminster, Westminster, Colo.
M.F. Goddard, Seattle Public Utilities, Seattle, Wash.
D. Goldbloom-Helzner, US Environmental Protection Agency, Washington, D.C.
C. Grieves, Baxter & Woodman Inc., Crystal Lake, Ill.
M. Howe, Executive Director/Secretary Treasurer, Texas AWWA, Austin, Texas
J.L. Ignatowski, Ignatowski Environmental Engineering Consultant, Vienna, Va.
B. Kerr, Kerr & Associates Consulting, Victoria, B.C., Canada
H. Klein, Garden State Laboratories Inc., Hillside, N.J.
J. W. McLaughlin, Merrick & Company, Charlotte, N.C.
V. Morello, Broward County Water and Wastewater Services, Pompano Beach, Fla.
K. Morley, Manager Federal Relations, AWWA, Washington, D.C.
J.W. Moyer, AECOM, Morrisville, N.C.
S. Neumeister, Southeastern Technical Solutions, Port Saint Lucie, Fla.
K. Novick, Gradient Planning, LLC, Middletown, Conn.
J.W. Porco, Michael Baker Corporation, Pagosa Springs, Colo.
K. Raman, KUV Consultants, LLC, Phoenix, Ariz.
R.A. Riordan, City of San Ramon and CH2M, San Ramon, Calif.
L.P. Warren, Launch! Consulting, Charlottesville, Va.
J. Whitley, Bureau of Reclamation, Denver, Colo.
R. Wilson, CSC, Darien, Conn.

This manual was also reviewed and approved by the AWWA Standards Council and the Standards Committee on Emergency Preparedness Practices. The Standards Committee on Emergency Preparedness Practices had the following personnel at the time of approval:

D. Scott Borman, *Chair*

General Interest Members

T.P. Allman, Naval Facilities Engineering Command, Misawa, Japan
D.M. Apanian, USEPA Region 4, Atlanta, Ga.
J.E. Crisologo, State Water Resources Control Board, Glendale, Calif.
D.M. Flancher,* Standards Engineer Liaison, AWWA, Denver, Colo.
R. Ford,* Standards Council Liaison, CH2M, Parsippany, N.J.
K. Morley,* Manager Federal Relations, AWWA, Washington, D.C.
S.M. Neumeister, Southeastern Technical Solutions, Port Saint Lucie, Fla.
K. Novick, Gradient Planning, LLC, Middletown, Conn.
C. Sapp, CH2M, Sugar Hill, Ga.
G.G. Sturdivan, Sierra West Consultants Inc., Yucca Valley, Calif.
L.P. Warren, Launch! Consulting, Charlottesville, Va.

Producer Members

J.K. Cassidy, Critical Situation Management Inc., Marysville, Pa.
C. Herndon, Herndon Solutions Group, Las Vegas, Nev.

User Members

D.S. Borman, Benton/Washington Regional Public Works Authority, Rogers, Ark.
S.D. Gay, City of Westminster, Westminster, Colo.
M.F. Goddard, New Orleans Sewerage and Water Board, New Orleans, La.
H. Klein, Garden State Laboratories Inc., Hillside, N.J.
M.R. Nandagopal, City of Spokane, Spokane, Wash.
C. Perry, City of Hurst, Hurst, Texas
K. Schweitzer, Hicksville Water District, Hicksville, N.Y.
S. Stephens, Austin Water Utility, Austin, Texas
P. Thompson, Suffolk County Water Authority, Oakdale, N.Y.

* Nonvoting

Chapter **1**

Preparedness Culture

One mark of a utility that has the capacity to respond effectively to emergencies is a strong preparedness culture. This culture is evident when an emergency response plan (ERP) is kept current—staff are trained in their responsibilities as they relate to the plan; resources necessary to implement the ERP are supported by the budget; staff are aware of emergency preparedness activities and participate in them; an explicit organizational commitment to emergency planning is made; and a management process is in place for staff to take corrective action when necessary improvements are identified. Improvements are identified through risk assessments, plan updates, training, exercises, incident investigations, and other activities described in this manual. When a utility has a preparedness culture, the ERP “lives” as a resource that is adapted and updated whenever there are significant changes that affect the plan. Also, staff are empowered to speak up and constructively affect change that ultimately improves the utility’s level of preparedness. With this culture in place, preparedness is not a burden but an aspect of the utility that is valued and protected by staff, leadership, and other stakeholders due to its significant benefits.

Most utilities are very good at meeting their mission during normal operations, which include small and even routine process upsets. However, when upsets become nonroutine and large in scale or when emergencies arise, utilities with strong and effective preparedness cultures are better equipped to restore the critical lifeline services they provide each community. In contrast, those utilities that lack a strong preparedness culture struggle to restore services, which in some cases exacerbates the situation.

This chapter outlines and defines the concept of “culture” within an organization and presents the core components of a strong emergency preparedness culture within a utility. Organizational culture refers to a system of shared meaning that distinguishes the organization from other organizations. This shared meaning is held by organization members. A strong culture is characterized by the organization’s core values being both intensely held and widely shared (Wiener 1998). A preparedness culture, therefore, is one where being prepared for emergencies is highly valued. The core components of the preparedness culture cycle, as illustrated in Figure 1-1, include the following:



Figure 1-1 The Preparedness Culture cycle

- an explicit organizational commitment toward preparedness,
- development of the preparedness culture,
- support for the preparedness culture with tools and tactics, and
- evaluation of the “strength” of the preparedness culture.

*ANSI/AWWA G440, Sec. 4.1.1:
Explicit and visible commitment of senior leadership to preparedness. The utility shall establish an explicit, visible, and easily communicated commitment to emergency preparedness.*

The following sections provide examples of how a utility can address each component (Dwivedi).

DEVELOPING AN EXPLICIT ORGANIZATIONAL COMMITMENT TO EMERGENCY PREPAREDNESS

The utility’s general manager, public works director, or chief executive officer should demonstrate a genuine commitment to emergency preparedness. This commitment is most easily shown by participation and support for the planning effort. When senior leadership works with staff to develop and refine preparedness programs, policies, and procedures, it sends a strong message to staff, governing boards, public safety officials, and the community being served by the utility. Leading by example is a critical component of building team members’ trust, support, and commitment.

The establishment of an effective preparedness culture involves the shaping of enterprise-wide core values and promoting a “norm” of universal commitment to

emergency preparedness. The development of a culture of preparedness relies on a demonstrated commitment throughout the entire organization. Emergency preparedness should be elevated and acknowledged within the utility's core mission statement. Utility mission statements often include statements regarding the provision of "safe and reliable" drinking water and wastewater treatment. By definition, "safe and reliable" should include a component of emergency preparedness.

DEVELOPING THE PREPAREDNESS CULTURE

While the path to establishing a culture of preparedness begins with a commitment from senior leadership, it also relies heavily on the actions of key program stakeholders. Those tasked with preparing and maintaining the organization's ERP play a critical role in building and nurturing a culture of preparedness. Additionally, successful achievement of a true preparedness culture requires more than leadership's demonstration and statement of commitment. It also requires staff recognition of a genuine concern and consideration for responder safety and the safety and well-being of responders' families.

Examples of actions aimed at demonstrating and reinforcing a clear commitment to the emergency planning effort and development of a culture of preparedness include the following:

- inclusion of a statement that conveys a commitment to emergency preparedness in the organization's mission statement;
- direct participation and a verbal statement of support and agency commitment at preparedness planning meetings;
- attendance and direct participation with all staff during emergency preparedness response plan training and response exercises;
- promotion of printed materials and posted commitments of emergency preparedness throughout the organization;
- institution of a recognition award program for staff who demonstrate actions aimed at personal and family preparedness;
- promotion and attendance at annual all-staff events/workshops centered around promoting emergency preparedness and recognizing those staff who have shown an outstanding effort to embrace the culture of preparedness;
- adoption of awareness programs that are directed at employees and the general public; and
- adoption of some level of funding in the operating budget that is dedicated to supporting preparedness activities such as training and/or awards programs.

*ANSI/AWWA G440, Sec. 4.2.1:
Promote emergency preparedness awareness. The utility shall promote a culture whereby management and personnel/employees understand and contribute to enhanced utility preparedness.*

One of the most important elements in supporting and maintaining a strong preparedness culture is communication. People need to actively be reminded of the risks, purpose, and objectives of being prepared and their role in the overall plan. These messages can be delivered in many ways, including the following:

- regular emergency drills and exercises (e.g., tabletop exercises);
- annual employee preparedness fairs held onsite at the utility where the efforts to be prepared are recognized by top management and where employees can purchase discounted personal emergency preparedness supplies for themselves and their families; and

- recognition among staff for participation in emergency response activities or for actions that demonstrate they are better prepared for disaster. These include giving away t-shirts or coffee mugs that indicate the event response or preparedness actions taken.

Additional information on preparedness training and exercises can be found in Chapter 6.

Other efforts to communicate the need to prepare can be passive and done on an ongoing basis. The messaging of preparedness should be “branded” around the utility and within regular communications to staff. This can be accomplished in the following ways:

- Posting the utility’s statement of commitment to emergency preparedness (included in the mission statement) in and around both public access and employee-only areas at the utility. The more people are exposed to the official message of preparedness, the more it becomes a “norm” within the culture.
- Discussing emergency preparedness during staff meetings.
- Maintaining updated and current emergency-preparedness-themed bulletin boards around the utility.
- Single-line messages of preparedness in common areas of the utility (e.g., lunchroom, meeting rooms).
- Including a standard statement that relates the need to be prepared at the bottom or within the signature line of all e-mail messages from management to staff.

ANSI/AWWA G440, Sec. 4.3.1:
Identify employees responsible for emergency preparedness. The utility shall identify employees responsible for establishing and maintaining a level of emergency preparedness correlated with known or perceived risks. These employees shall also become an integral part of the overall security program.

SUPPORTING THE PREPAREDNESS CULTURE WITH TOOLS AND TACTICS

When updating an ERP, consider how the plan might support the preparedness culture. It is very important to focus the plan directly on the staff who need to be prepared. This can be done using the results of the risk assessment (see Chapter 2) to guide ERP updates on all hazards and the most vulnerable critical assets and by including policies and procedures that will make an impact in incident outcomes. Some questions to ask when updating an ERP include the following:

- Does this update support the utility’s commitment to emergency preparedness?
- Does this update provide the staff with information that they will need during an emergency?
- Is this update supportive of actual conditions that exist during an emergency (e.g., recognition of the need to secure the safety of family before responding)?

The planning process should be open and transparent. Regular solicitation of comments on plan updates should be supported with scheduled meetings. It should be communicated that staff review and participation are necessary for an effective plan and are therefore

ANSI/AWWA G440, Sec. 4.2.2:
Sustain focus on preparedness. The utility shall sustain focus on preparedness by maintaining it as a high priority.

ANSI/AWWA G440, Sec. 4.3.2:
Establish emergency preparedness expectations. The utility shall identify and disseminate emergency preparedness expectations for staff and periodically review employee performance and proficiencies.

expected. This supports the preparedness culture with a sense of plan ownership that extends throughout the utility. This culture may be further enhanced with the following activities:

- Leverage staff meetings to inform employees of the importance of emergency preparedness at the utility.
- Keep staff updated on milestones in emergency preparedness. One example is an emergency preparedness bulletin board, and another is inclusion of emergency preparedness as an agenda item for routine meetings.
- Manage preparedness activities through a committee or stakeholder review team composed of representatives from each aspect or department of the utility, including staff members who are most critical to emergency preparedness and response activities.
- Use small teams to manage specific preparedness activities to accomplish a specific goal such as planning for a functional exercise or updating a risk assessment.

EVALUATING THE “STRENGTH” OF THE PREPAREDNESS CULTURE

Ongoing evaluation to measure progress and set new goals will maintain a strong preparedness culture. Remember that even the very best written ERP will fail unless it remains current and is understood in purpose and process by all who are expected to participate in preparedness and response activities. Keeping the plan current requires keeping the preparedness culture strong. Ongoing evaluations typically occur whenever a risk assessment or ERP is updated, training and exercise results are reviewed, and responses to real incidents are investigated. Each evaluation in a utility’s preparedness program should be documented and include the evaluation results and recommendations for improvement. Within an active culture of preparedness, recommendations for improvement are inevitable due to the shared goal of an emergency preparedness program.

At least once per year, an objective person or group should evaluate the emergency preparedness program. The questions posed should be direct and aimed at the emergency planning effort’s core elements that have a direct impact on the culture. Standard questions may include the following:

- With the emergency preparedness efforts undertaken, do you feel you understand the organization’s need to be able to respond effectively?
- Do you feel as though you have been given the correct amount of information to respond effectively during an emergency?
- How can the organization better support your need to personally prepare for emergencies (e.g., family preparedness)?
- What would you like to see done to improve the utility’s overall preparedness?

The information gained from regular evaluations of the emergency planning effort and the related strength of the culture should provide a guide for adopting new ideas. It is important to acknowledge those who bring forward new ideas to strengthen the plan, as is using every opportunity to recognize and boost stakeholder participation. The preparedness culture of the organization will reap the benefit.

REFERENCES AND SUPPLEMENTAL READINGS

[ANSI/AWWA G440-17](#). Emergency Preparedness Practices. Denver, CO: AWWA.

Wiener, Y. 1998. Forms of Value Systems: A Focus on Organizational Effectiveness and Cultural Change and Maintenance. *Academy of Management Review*, 13:4:534–535.

This page intentionally blank.

Chapter 2

Risk and Resilience Assessment

Utilities are critical to the protection of public health and the environment, ensuring the economic vitality and public confidence in the communities they serve. It is therefore a utility's goal to be prepared for natural, intentional, and technological threats that could adversely impact operations and service deliveries.

This chapter describes how utility leaders can better understand risks to their mission and critical assets by performing a risk and resilience assessment, how this assessment supports emergency planning by identifying and prioritizing utility-specific risks, and how to identify investments that can pay the greatest dividends during and after an incident.

WHAT IS A RISK AND RESILIENCE ASSESSMENT?

A risk and resilience assessment is a process designed to identify hazards and their relative probabilities of occurrence, to identify assets at risk, and to quantify the potential impact of the hazards on those assets at risk. A risk and resilience assessment answers questions such as the following:

- What are the worst reasonable threats that could impact utility operations?
- What makes the utility vulnerable to various threats?
- What is the best way to allocate limited resources and strengthen the utility against the impact of an identified risk?
- How might a supply chain disruption impact utility operation?
- What interdependencies exist that, if lost, could disrupt service delivery (e.g., electrical power)?

- What new risks might a utility face with system expansion or development near utility assets?
- How will geographically relevant natural hazards affect utility operations?

GOALS OF A RISK AND RESILIENCE ASSESSMENT

The primary goals of a risk and resilience assessment are to become more aware of the risks to which a utility is exposed and to identify options that can mitigate undesirable consequences. Utilities provide essential lifeline services to their communities. Therefore, it is imperative that utility investments are made to ensure day-to-day continuity of service during times of crisis. Identifying risk and potential mitigation strategies before an event occurs is a vital step that results in huge dividends during times of crisis.

The goal of a risk and resilience assessment is to better enable a utility to do the following:

- understand threats, consequences, and vulnerabilities that may negatively impact operations;
- inform efficient resource allocations to maximize risk mitigation and improve resiliency; and
- inform and update the emergency response plan (ERP) to enhance its effectiveness during an incident.

MANAGING A RISK AND RESILIENCE ASSESSMENT

In coordination with experts from within the utility as well as those outside the utility (e.g., local emergency management professionals, law enforcement, consultants), a utility should form a committee to conduct and/or guide the risk and resilience assessment. This committee should include those with expertise on the system(s) being assessed, the history of emergencies and near misses that affected the utility, and each part of the utility organization. One person, assigned to lead this committee, should be responsible for ensuring adequate representation from utility staff and, as needed, outside participation in the risk and resilience assessment. Also, this person should ensure that the risk and resilience assessment is documented and make recommendations to fund key risk mitigation measures that are identified as a result of conducting the assessment.

CONDUCTING A RISK AND RESILIENCE ASSESSMENT

The Bioterrorism Act of 2002 (42 USC 300i-2) required drinking water utilities to conduct a vulnerability assessment (now commonly referred to as a *risk assessment*). While a similar federal mandate was not placed on wastewater systems, many have performed risk assessments since it is recognized as a best practice. It is recommended that risk assessments be reviewed and updated no less than every five years per [ANSI/AWWA G430](#), Security Practices for Operation and Management. It is also recommended that the assessment be based on the methodology in [ANSI/AWWA J100](#), Risk and Resilience Management of Water and Wastewater Systems. [ANSI/AWWA J100](#), which is suitable and scalable for use by utilities of any size or type, follows a seven-step process, as shown in Figure 2-1.

A risk and resilience assessment should cover all critical assets including people, equipment, systems, materials and supplies, records, and other resources critical to the utility's mission. The assessment should prioritize threats, assets, and vulnerabilities as a function of consequences and what could be lost, including life, property, consumer



Figure 2-1 Risk assessment process as described in [ANSI/AWWA J100](#)

confidence, and continuity of service to priority users and others. With this information, utility managers can develop an action plan that can be followed to mitigate risks and update their ERP. For more information on risk and resilience mitigation strategies, see Chapter 7.

An assessment should also include mission-essential functions to support the development of a business continuity plan (see Chapter 3 for more information). Each time an assessment is revised and updated, useful information is gathered about the risks to the utility, how to mitigate those risks, and how to improve preparedness.

THREAT CONSIDERATIONS

When conducting a risk assessment, the first step is to identify relevant threats and hazards. Information on natural, human-caused, and technological hazards is presented in subsequent sections of this chapter. It is helpful to review this information before conducting a risk assessment.

The impact of various threats and hazards on utility operation are listed in Table 2-1 and should be used to inform the assessment. [ANSI/AWWA J100](#) includes a set of reference threats that a utility is required to consider as part of the assessment. Only threats that are relevant to the utility's location are retained for further analysis based on a worst reasonable case approach. For example, hurricanes are very unlikely to impact North Dakota, so that threat, while considered, is set aside from further analysis. Alternatively, earthquakes are a viable threat on the West Coast and are retained for further analysis. Based on the moment magnitude scale, a utility might only consider the impact of earthquakes with a maximum selected/design magnitude based on the assumption that anything larger is beyond any reasonably affordable design.

[ANSI/AWWA J100](#) reference threats include natural hazards (e.g., earthquakes, hurricanes, tornadoes, wildfires, ice storms), dependency and proximity threats (e.g., to the power supply, transportation, supply chain), offsite threats (e.g., at industrial sites, source water or underground tanks, at a gas station), and malevolent threats (e.g., intentional contamination, cybersecurity threat, direct physical attack).

Table 2-1 Example disaster effects matrix

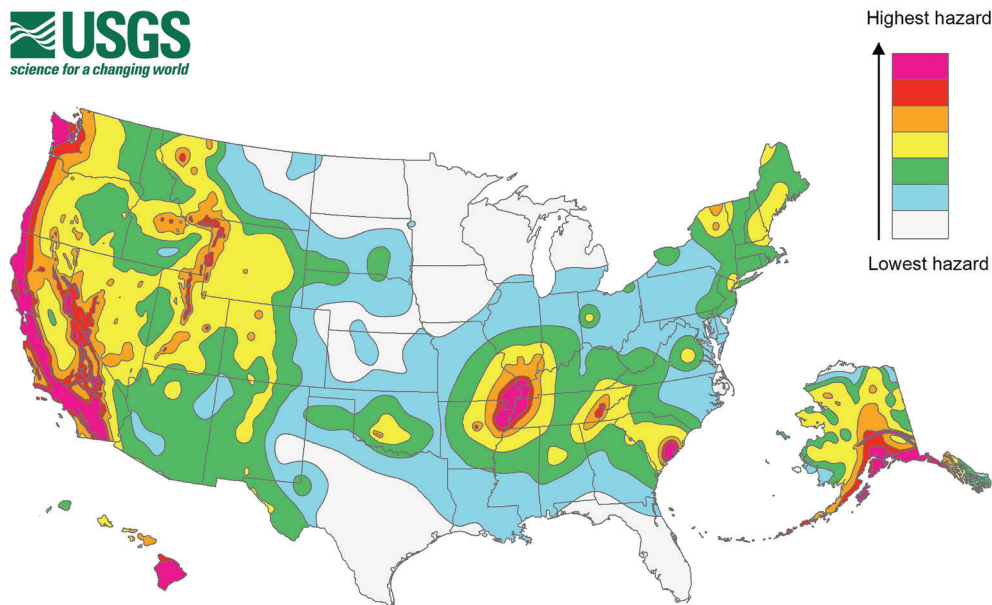
System components—likely damage, loss, or shortage due to hazards	Earthquakes	Hurricanes	Tornadoes	Floods	Forest or Brush Fires	Volcanic Eruptions	Other Severe Weather	Waterborne Disease	Hazardous Material	Structure Fire	Construction Accidents	Transportation Accidents	Nuclear Event	Vandal, Riots, Strikes
Administration/ operations Personnel Facilities/equipment Records	♦ ♦ ♦	♦ ♦ ♦	♦ ♦ ♦	♦ ♦ ♦	♦ ♦ ♦	♦ ♦ ♦	♦ ♦ ♦	♦ ♦ ♦	♦ ♦ ♦	♦ ♦ ♦	♦ ♦ ♦	♦ ♦ ♦	♦ ♦ ♦	♦ ♦ ♦
Source water Watersheds/surface sources Reservoirs and dams Groundwater sources Wells and galleries	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦
Transmission Intake structures Aqueducts Pump stations Pipelines, valves	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦
Treatment Facility structures Controls Equipment Chemicals	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦
Storage Tanks Valves Piping	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦
Distribution Pipelines, valves Pump or pressure-regulating valve stations Materials	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦
Electric power Substations Transmission lines Transformers Standby generators	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦
Transportation Vehicles Maintenance facilities Supplies Roadway infrastructure	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦
Communications Telephone Two-way radio Telemetry	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦	♦ ♦ ♦ ♦

Natural Hazards

Natural disasters during the first decades of the 21st century were among the most severe in American history in terms of both deaths and damage. In fact, in 2011, more than \$12 billion in damage and the deaths of more than 1,000 people were attributed to weather-related disasters. Many of these disasters had profound disruptive effects on utilities. In 2005, Hurricane Katrina struck the Gulf Coast, causing major aboveground damage to systems in many cities, especially New Orleans. In May 2011, more than 180 tornadoes struck the Midwest, including a devastating F5 tornado that destroyed Joplin, Missouri. The record drought in Texas and the lower Midwest significantly stressed water supplies. Although it did not happen in the United States, the 2011 Tohoku earthquake in Japan and resulting tsunami remind us of the fragility of infrastructure and the critical interdependencies among utilities.

Earthquakes. Earthquake damage can be widespread and severe. The energy released by an earthquake can be equivalent to the explosion of millions of tons of dynamite. The degree of resultant damage is related to the earthquake's magnitude, the distance from the epicenter (i.e., the part of the earth's surface directly above the subsurface focus of an earthquake), the soil types in the area, the resulting mode of earth failure, and the design and materials of structures.

From a practical standpoint, earthquake risk for areas of North America has been defined with relatively high precision using geological and historical information. Figure 2-2 illustrates seismic damage risk in the United States. While it is apparent that portions of the Pacific Coast have the highest risk, other areas are at significant risk. To determine a more precise probability of an earthquake occurring and the potential magnitude, utilities should review local geological and seismological data available from such sources as the US Geological Survey, state and provincial geological agencies, and universities, or the utility can employ a consultant experienced in earthquake hazard analysis.



Source: US Geological Survey Seismic Hazard Mapping Project.

Figure 2-2 Seismic hazard map of the United States

Fault rupture. A fault rupture is the differential movement of two land masses along a fault. The 1992 Landers–Big Bear (California) earthquake created a 21-ft (7-m) offset in some areas (Figures 2-3A and 2-3B). If a pipeline lies across a fault that ruptures, it will be exposed to forces that can deform or split the pipe or even separate pipe sections at the joints.

Known faults are identified on geological and seismic maps and are often readily visible from light detection and ranging mapping, aerial photographs, and occasionally



Source: Photo by Michael O'Rourke. Person in picture, LeVal Lund.

Figure 2-3A Landers–Big Bear earthquake fault offset



Source: Photo by Michael O'Rourke.

Figure 2-3B Landers–Big Bear earthquake pipe broken in the fault offset

at ground level. If a fault crossing is required, the pipeline design should allow for fault movement. In northern California, the San Francisco Public Utilities District has implemented sophisticated pipeline designs for crossing the Calaveras and Hayward faults.

Ground shaking. The energy created by an earthquake radiates in waves from the epicenter like ripples that appear after a stone is thrown into a pond. The propagating waves cause the ground to shake. The closer to the epicenter, the more violent and vertical the ground shaking; conversely, the farther from the epicenter, the less severe and more rolling the ground shaking. Soil types also affect the intensity of ground shaking. Released energy produces both vertical and horizontal accelerations that can damage utility system components. For example, a pipe without flexible joints that enters a concrete structure may be subject to shear failure due to the differential dynamic response between the buried pipe and the structure. Another result of seismic forces is the rotational moment produced at the base of water storage tanks that results from internal hydrodynamic forces, as illustrated in Figure 2-4.

Liquefaction. The energy of an earthquake generates high pore-water pressure that can overcome the friction between soil particles. When the pressure of the water located in the spaces between soil particles, or pore water, exceeds particle friction forces, particularly in loose sands with high water content, the soil will become a soil–water slurry with significantly reduced shear strength. The result can be foundation bearing failure, differential settlement, and lateral spreading or floating of underground components. Figure 2-5A shows a ground crack caused by lateral spreading and Figure 2-5B shows the resulting pipe joint separation. Liquefaction can also cause a loss of slope stability and produce landslides.

Densification and consolidation. Earthquake-induced ground shaking can cause soil to become denser. The process is similar to using a vibratory roller to compact fill or to shake loose sand in a tray to make it more compact. Ground subsidence can occur as the soil densifies. In Valdivia, Chile, subsidence due to densification during a 1960 earthquake amounted to more than 3 ft (1 m) (Lambe and Whitman 1969).

Landslides. Landslides occur when slopes lose shear strength because of a disturbance such as ground shaking. Most damage caused by the 1964 Alaskan earthquake resulted from landslides. Landslides can cause earthen dams to fail and can also impact source

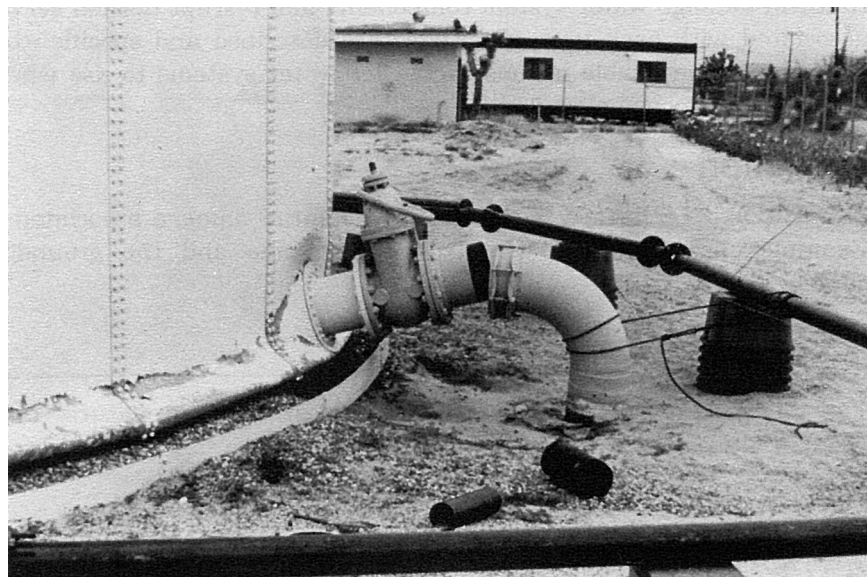


Figure 2-4 Seismic forces on water storage tank



Source: Photo by Don Ballantyne.

Figure 2-5A Ground crack resulting from lateral spreading in Kobe, Japan in 1995



Source: Photo by Don Ballantyne.

Figure 2-5B Ductile-iron joint pulled apart due to lateral spreading

water if large amounts of debris enter a reservoir. Landslide hazard maps have been developed for some earthquake-prone areas.

Tsunamis and seiches. A tsunami is a series of ocean waves generated by sudden displacements in the sea floor, landslides, or volcanic activity. In the deep ocean, a tsunami wave may be only a few inches high. A tsunami wave may come ashore gently or may increase in height to become a fast-moving wall of turbulent water several meters high. Earthquakes, volcanic eruptions, and other underwater explosions, landslides, sudden glacier activity, meteorite impact, and other disturbances above or below water have the

potential to generate a tsunami. Tsunamis cause damage in two ways: the smashing force of a wall of water travelling at high speed and the destructive power of a large volume of water draining off the land and carrying everything with it, even if the wave did not look large. The wall of water from a tsunami can greatly exceed normal high-tide levels.

A seiche is an oscillation of the surface of a lake, reservoir, or landlocked sea due to an earthquake. A seiche can overtop dams, erode earthen dams, and result in dam failure. Seiches can also damage dam inlet and outlet structures.

Wind hazards. High winds are known to cause damage on a massive scale and often contribute to other hazards such as flooding, erosion, wildfires, structural damage, and contamination. There are many types of wind hazards including tornadoes, hurricanes and other cyclones, and straight-line wind events. These conditions can also impact the utility crew's ability to operate safely in the field.

Tornadoes. Tornadoes most commonly occur in the central United States; however, they have been reported in all 50 states. The most common prevalent tornado hazard is extremely high winds. Exact speeds have not been measured because wind gauges rarely survive a tornado, but estimates are as high as 300 mph (480 km/h). While tornadoes can be tracked by radar and warnings can be issued, the actual spawning of a tornado can occur with little or no warning. Because of this, tornadoes can be deadly. Structural damage from tornadoes can be extensive as aboveground facilities are rarely designed to withstand tornado-force winds.

Hurricanes. The costliest natural disasters in the United States in recent years have been hurricanes. Approximately 44 million people in the United States live in areas that have been hit by hurricanes. The main hazards associated with hurricanes are high winds, storm surge along shorelines, and flooding. Surface structures can suffer wind damage, and flooding can destroy plant facilities and contaminate water supplies. Structural damage and the roots of trees toppled in a hurricane can break pipelines and result in tremendous flow demands due to numerous leaks. Power outages are also widespread. Damages in the tens of billions of dollars is not uncommon.

The 2017 hurricane season ranks among the most intense and the most expensive in history. Most of the damage was caused by 3 of 17 named storms, namely, Harvey, Irma, and Maria. From Harvey's historic flooding of Texas to Irma's pounding of the Florida Keys and Maria's devastation in Puerto Rico, early estimates indicate the United States suffered more than \$200 billion with 207 fatalities from the deadly trio.

The damage caused by Harvey was not as much from the Category 4 winds, but rather from a slow-moving storm that dumped an estimated 51 in. or 27 trillion gallons of rain over Texas and Louisiana in a six-day period. Florida Department of Environmental Protection reported 85 percent of drinking water and wastewater facilities were impacted by Irma, causing an estimated 500 boil-water notices and approximately 600 sewer system overflows. Federal Emergency Management Agency (FEMA) reports that progress is slow, but four months after Maria made landfall, water services are getting back on track.

In contrast, Hurricane Katrina in 2005 inflicted nearly \$125 billion (2005 USD) in damage with over 1,800 deaths. Hurricane Katrina remains the single most catastrophic natural disaster in US history and is tied with Hurricane Harvey as the costliest hurricane in US history. Damage in New Orleans was exacerbated by flooding from failed levees, which inundated 80 percent of the city. There was major damage to numerous Louisiana utilities, where 23 percent of the drinking water facilities were inoperable soon after the hurricane struck. About 3 percent of the drinking water facilities in Mississippi were out of service. Wastewater facilities in Louisiana bore the brunt of damage, with 29 percent becoming inoperable. Damage to utilities from this storm was estimated at more than \$2 billion.

Case Study

Effects from Hurricane Katrina: New Orleans Sewerage and Water Board

The effects from Hurricane Katrina in New Orleans have been long-lasting. As the center of Hurricane Katrina passed southeast of New Orleans on August 29, 2005, winds downtown were in the category 3 range, with frequent intense gusts and tidal surge. Hurricane-force winds were experienced throughout the city, although the most severe portion of Hurricane Katrina missed the city. The hurricane made final landfall in eastern St. Tammany Parish. The western eye wall passed directly over St. Tammany Parish as a category 3 hurricane on August 29, 2005. The storm surge in the region was as high as 16 ft (4.9 m). In New Orleans, the storm surge caused more than 50 breaches in drainage canal levees and in navigational canal levees, and precipitated the worst engineering disaster in US history. By August 31, 2005, 80 percent of New Orleans was flooded, with some parts under 15 ft (4.6 m) of water. Most of the city's levees, designed and built by the US Army Corps of Engineers (USACE), broke. These breaches were responsible for most of the flooding, according to a June 2007 report by the American Society of Civil Engineers.

The New Orleans Sewerage and Water Board (NOSWB) had fulfilled its primary duty of protecting the city from the effects of a massive tropical storm system. However, it was soon evident that water was rising throughout the East Bank of the city, although there was no appreciable flooding suffered to this point from the hurricane itself. The source of the water was numerous breaches in the flood-protection levee system in the 17th Street Canal, London Avenue Canal, and the Inner Harbor Navigation Canal, which apparently were unable to withstand the water levels, which exceeded design criteria, and simply folded in against the weight of the water. NOSWB suffered massive losses in water, sewage, and drainage facilities, equipment, supplies, fleet vehicle, and heavy equipment. The result of the flooding on the East Bank of the city was loss of virtually all pumping equipment contained within seven major drainage stations and serious flooding damage to six other drainage stations, plus loss of most of the sewage lift and pumping stations, including the entire East Bank Sewage Treatment Plant. Of even greater impact was flooding of the power house and boiler room and the complete loss of a 25-Hz generating plant; this had never occurred in the history of the board.

The first step in recovery of the city was to restore the power plant and water purification to operating conditions. As a result of the flooding that followed the hurricane, the utility's 61-MW generating capacity had been reduced to 6 MW by loss of three generators. The water plant and support services were placed back on line using a single 6-MW generator after the Herculean effort of a handful of employees and on-the-spot invention of a workable method referred to as "black startup."

Restoration began in earnest on Saturday, September 3, when the handful of NOSWB engineering, maintenance, and operating personnel were joined by the General Electric Disaster Management Team. One result of this partnership was the installation of a new switchgear for the number 3 generator in one week as opposed to the standard 26 weeks. To facilitate restoration, two temporary workforce housing units were set up by General Electric, one in LaPlace to house and feed up to 200 journeyman craftsmen and one to house homeless board employees and the General Electric emergency management teams. Among the improvements installed after Hurricane Katrina was a \$3.5 million, 15-MW generator installed on the grounds of the Carrollton Water Purification Plant, which will give the board more reliable power for drainage and water operations in the event of a commercial power failure. This was funded 100 percent by USACE. NOSWB crews repaired more than 80,000 water main breaks, house service leaks, broken water meters, and fire hydrant leaks. Full repair of all damage done to the system will take another 15 years; this includes waterline replacement and sewer line replacement, along with associated road repairs. To date, the Federal Emergency Management Agency (FEMA) has allocated nearly \$500 million in public assistance funds. In addition, USACE is providing \$204 million for restoration. Finally, FEMA has also provided \$161 million in hazard mitigation planning grant funds for flood-proofing improvements.

Source: Bob Moeinian, PE, Retired Chief of Operations, New Orleans Sewerage and Water Board.

Floods. Few areas can be considered completely safe from flooding. The USACE estimates that annual flood damage in the United States amounts to hundreds of millions of dollars, with some events causing damage in billions.

Flooding can be caused by heavy rainfall, snowmelt, hurricane storm surges, high tides, volcanic eruptions, and dam or levee breaks. A flood can contaminate water supplies, inundate transmission and treatment facilities and pumping stations, scatter and ruin stockpiled equipment, and disrupt power, transportation, and communications. Floods from precipitation are relatively easy to predict and mitigate, provided sufficient funds can be obtained to take preventive measures. However, floods can also occur unexpectedly as a result of a dam break, breaching of underground tunnels, or unusually heavy rainfall. For example, the Des Moines, Iowa, water treatment plant was flooded and taken out of service during the summer of 1993 when the Raccoon River overflowed its banks. Flood elevations at the Des Moines plant were approximately 8 ft above the 100-year flood elevation. Water service to 250,000 people was cut off for several days.

More recently, flooding of the Cumberland River in May 2010 left many of the Nashville, Tennessee, utilities severely damaged. Government officials considered this event to be a 1,000-year flood event. Two-day rain totals in some areas were more than 19 in. (0.5 m). One of two water treatment plants and both wastewater treatment plants in the Nashville Metro Water Services system were out of service.

Case Study

Nashville Flooding

Metro Water Services (MWS) is a water, wastewater, and storm water utility. Nashville's water supply comes from the Cumberland River and is treated at two water treatment plants: R.L. Lawrence (Omohundro) and K.R. Harrington, each with a rated capacity of 90 mgd. More than 2,900 miles of pressurized water mains, 41 reservoirs, and 57 water-pumping stations provide water to more than 177,000 customers. The average daily treatment is approximately 100 mgd.

On May 1 and May 2, 2010, middle and western Tennessee experienced record (one in 500–1,000 years) flooding when rains totaling 13–18 in. (0.3–0.45 m) fell over a widespread area. Damages exceeded \$2 billion in the metropolitan Nashville and Davidson County (metro Nashville) area alone. The heaviest rain occurred in the uncontrolled basins of the Cumberland River, resulting in extensive, devastating flash flooding as well as unprecedented flooding along the Cumberland River and its tributaries. There were 11 fatalities in Nashville directly attributed to this event, and more than 10,000 homes were impacted by flood waters. Also, 160 MWS staff members (21 percent) were personally affected by the flood, reducing the available work force during the emergency.

On Saturday, May 1, 2010, the K.R. Harrington Water Treatment Plant was flooded as the river rose to a record 51.86 ft (15.8 m), approximately 30 percent above flood stage at this location (Figure 2-6). As the facility began to flood, the staff planned and conducted a controlled shutdown to protect the infrastructure.



Figure 2-6 Flooded K.R. Harrington Water Treatment Plant in Nashville



Source: Sonia Allman, Nashville Public Information Officer.

Figure 2-7 Flooding at the Nashville Omohundro Water Treatment Plant

Additionally, modeling predicted the Omohundro Water Treatment Plant flooding to be 52 ft (15.8 m) (Figure 2-7). The projected elevation of the Cumberland River was 52.5 ft (16.0 m), which would result in loss of the remaining water treatment plant in Nashville. Sandbagging and pumping water from within the pumping station protected the Omohundro plant from the flood waters, which peaked at 51.86 ft on May 3, 2010. Fortunately, MWS was able to maintain water quality throughout the flood event and continued to meet all state and federal regulations and guidelines.

When the K.R. Harrington plant was taken off line, the utility asked customers to conserve water. Unfortunately, the original reaction was to hoard water, as customers began filling bathtubs, buckets, and other containers because they feared complete loss of water service. As finished water storage reservoir levels dropped to dangerously low levels, the utility again asked customers to conserve water. The Tennessee Department of Environment and Conservation issued a mandatory water conservation order for Davidson and Williamson counties on May 4, 2010. This assisted MWS in providing ample, safe water supply to customers with only one water treatment plant in operation. The order was lifted on June 1, 2010.

The utility's customers responded admirably. Water conservation became "cool" and expected; those who wasted water were publicly criticized on social media (e.g., Facebook). Lamar Advertising provided free billboard ads regarding water conservation; church bulletins and business signs promoted conservation; and neighborhood groups had contests to see who could take the shortest shower and/or come up with the best water conservation idea. Even the Restaurant Association jumped on board; many local restaurants began using paper plates and utensils in addition to only serving water when requested.

Once the floodwaters receded, the risk of waterborne illnesses remained until municipal and home water systems could be fully disinfected. Most infections came from drinking water contaminated with fecal matter. Further, flooding can cause fuels to mix with floodwaters, which makes the sterilization of drinking water more difficult as it becomes harder to boil.

Following are the lessons learned from these events and advice for future event preparedness:

- Understand what other agencies and entities have in place and work closely with them before, during, and after an event.
- Prepare and deliver effective messages to local officials and customers to help curb water demand and make it possible to maintain supplies even while a plant is out of service (even customers reinforced the need to conserve via Facebook).
- Have workable piping interconnections (and relationships) with neighboring utilities for backup emergency water supply.
- Work closely with staff and contractors to monitor and address any potential main breaks during a plant outage to minimize water loss and intrusion potential.

- Ensure that emergency plans include getting key staff on site, even if by boat.
- Appreciate utility staff who will work tirelessly due to “ownership” and pride in operations, and make sure staff take time to rest and care for themselves.

Wild fires. Forest and brush fires can damage watersheds and water system structures and strain water supplies if used for firefighting. Forest and brush fires can occur anywhere, particularly in areas affected by dry weather or drought. Firestorms in urban and suburban areas are likely to increase in frequency because of widespread development into formerly nonurban forested areas, termed the “wildland–urban interface.” Wildfires scorch soils and create ash and debris that can clog rivers and reservoirs, increasing the cost of water treatment for years to come. When trees and underbrush are destroyed, there is less groundcover to absorb rainfall and prevent soil erosion. Storms flush silt and other debris from the fires into rivers, reservoirs, and ultimately into municipal water treatment facilities, adversely impacting the treatment process. This condition has been experienced repeatedly as a result of forest fires throughout the West.

Dependency and Proximity Hazards

Dependency hazards are the risks that result from supply chain disruptions. The supply chain in a utility is the network of interconnected businesses that are involved in moving the water from its source to the customer’s tap. Examples of dependency hazards include the following:

- disruption of services provided by other utilities (e.g., electric power, gas, communication),
- disruption of services provided by key suppliers (e.g., chemicals, fuel, parts and fittings, contractors),
- inability or unwillingness of key employees to come to work,
- inability of key customers to accept production, and
- systems that send water into the facility or transport it out become inoperable.

Proximity hazards cause collateral damages to a water utility when incidents occur close to the utility’s assets. Damage can be caused by humans, natural events, and accidents. It is important that the water utility identify all high-risk operations and businesses within its service area and in the region and understand how their failure can impact water service.

An example of this type of threat is a hazardous material release such as the one experienced on the Elk River in Charleston, West Virginia, in January 2014. Spills originate from pipelines, ships, airplanes, motor vehicles, railroad cars, and fixed containers. For example, in 1981, a crop-dusting plane carrying the herbicide 2,4-D crashed into a central California river not far from the intake for a city water supply. Liquid, solid, and gaseous materials can be spilled, and spills can occur at any time and result in injury, loss of life, property damage, and considerable costs to restore normal water utility activity.

Perhaps the most serious impact of a hazardous material spill on a water utility is contamination of surface water and/or groundwater supplies. Emergency response measures should be taken to prevent spilled materials from reaching the water system or to minimize the spread of contamination throughout the system. Damage to the water system and negative effects on its users can be very expensive, not only in terms of cleanup costs but in replacement of system components and disruption to the community.

Malevolent Threats

Malevolent threats are deliberate acts carried out by person(s) with the intention of causing harm to others and of causing physical destruction. Such acts can be carried out by an

insider (e.g., utility employee), outsider (e.g., vandals, criminals, and terrorists), or by collusion between the two. [ANSI/AWWA J100](#) provides suggestions on how to deal with specific malevolent threat scenarios, including attacks with explosives (e.g., in the air, on land, and in the water), various sizes of attack (e.g., small, medium, large, and extra-large), and attacks not involving explosives (e.g., contamination, theft, and cyberattacks).

Malevolent acts include the following:

- *Contamination:* An adversary gains access to and adds potentially toxic chemical, biological, radiological, or pathogenic contaminants to a treatment process, distribution system, storage tank, or treatment chemicals with the intent to contaminate the finished drinking water.
- *Sabotage:* An adversary damages, disables, or destroys equipment and process control systems, causing harm to a utility and its customers. Sabotage can be caused by physical means or through cyberattack.
- *Theft or diversion:* An adversary steals or diverts information, dangerous substances, valuable resources, or similar materials to compromise the safety and reliability of a drinking water system. Theft and diversion can be caused by physical means or through cyberattack.
- *Direct attack:* An adversary makes a direct attack on a critical utility facility using a boat, plane, or automotive vehicle as a weapon or with an assault team comprising one or more assailants. The perpetrators of such malevolent acts are typically well-trained terrorist groups with significant resources and capabilities.

Cybersecurity. Department of Homeland Security and intelligence communities agree that cybersecurity is a top concern, particularly as it applies to critical infrastructure sectors including water. Federal officials underscore that the nation faces significant risks of cyber intrusion/cyberattack on process control systems that stem from vulnerabilities in enterprise/business systems and/or process control systems. Vulnerabilities can be focused on employee records (enterprise system), customer records (enterprise system), and utility records and processes that include financial assets (enterprise system) and operations (process control system/supervisory control and data acquisition).

Multiple high-profile cyberattacks on large companies (e.g., Home Depot, Target, Sony, JP Morgan, Yahoo) have served to reinforce the reality that cyber vulnerabilities can impact critical infrastructure systems. As a result, federal actions regarding cybersecurity do have implications for the water sector.

Executive Order 13636, Improving Critical Infrastructure Cybersecurity, directed the National Institute of Standards and Technology (NIST) to work with stakeholders to develop a voluntary cybersecurity framework for reducing cyber risks. AWWA's guidance document, *Process Control System Security Guidance for the Water Sector*, was developed to provide utility managers with an overview of 12 core practice areas that support a consistent and repeatable recommended course of action to reduce vulnerabilities of cyberattacks. A Use-Case Tool was prepared to support voluntary use of the guidance in alignment with the NIST Cybersecurity Framework. The Use-Case Tool generates a prioritized list of recommended controls based on how a utility may apply various process control technologies. For more information, see the AWWA website.

Case Study

Stuxnet, The First Cyber Threat Able to Reprogram Industrial Control Systems

In July 2010, malicious software code that targets industrial control systems, such as the supervisory control and data acquisition systems used at utilities to control the flow and treatment of water and wastewater, was discovered. This code, dubbed Stuxnet, exploits Windows vulnerabilities and

infects its intended target with a malicious computer worm. It is the first known work to target and can reprogram industrial control systems. Stuxnet is highly complex and implements state-of-the-art techniques and capabilities to infect a system, prevent detection, exfiltrate data, and inhibit analysis of the malicious code if it is detected. Given the emergency of this and other new breeds of cyber threats, it is essential that utilities develop and maintain cybersecurity programs to protect their control systems.

Source: Edwards (2010)

Case Study

Hacker Holds Water Utility Hostage

Two reports from small systems in Missouri indicate that the utility computer systems and password-restricted files had been hacked and held hostage until a ransom was paid by the system. Payment was to be in bitcoin; in both cases, it was approximately \$500. In both instances, the systems “thought” they were doing adequate backup; however, flaws were discovered in their procedures. In both cases, information technology experts advised the systems to either deem their files as “lost” or unrecoverable or to pay the ransom because the cost of attempting to circumvent the event would cost more than the ransom. Small systems with little computer expertise offer “low hanging fruit” to hackers.

Case Study

Impact of the 2003 Northeast Power Outage on Water Supply

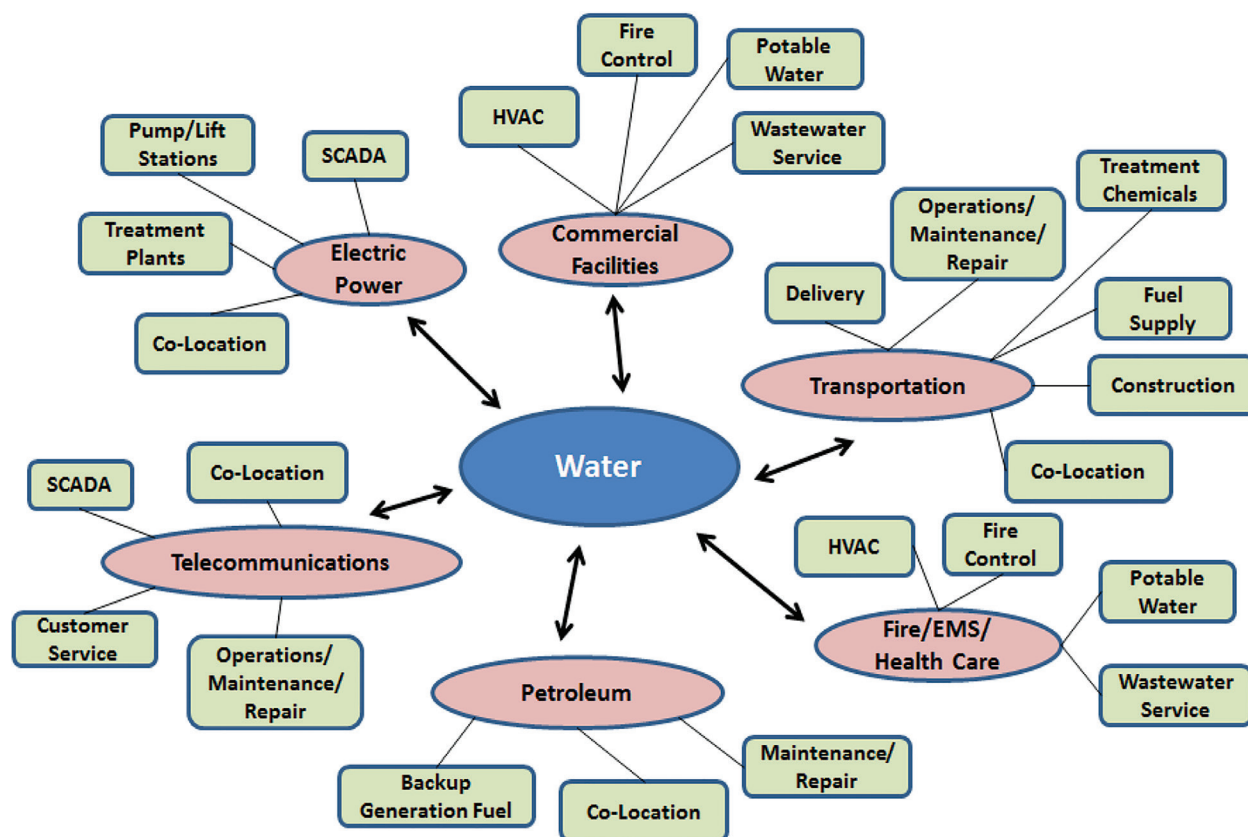
On August 14, 2003, a series of equipment and alarm faults caused a cascade of failures throughout southeastern Canada and eight northeastern states. All told, 50 million people lost power for up to two days in the biggest blackout in North American history. The event contributed to at least 11 deaths and cost an estimated \$6 billion. The lack of power significantly affected the water sector in the affected area. Many water systems lost water pressure, which resulted in potential contamination and response actions to protect the public. For example, 4 million customers in eight counties surrounding the Detroit area were under a boil-water advisory until August 18, four days after the initial outage. In Macomb, Michigan, town officials ordered all 2,300 restaurants closed until they were decontaminated after the advisory was lifted. Cleveland also lost water pressure and instituted a boil-water advisory. Many wastewater systems spilled sewage into waterways. A dependency hazard in the water sector was strikingly revealed by this event. Experts indicate that although significant steps to improve the US power grid have been taken, currently there is no way to guarantee the extinction of large blackouts. The frequency of large-scale blackouts remains relatively high.

Source: Minkel (2008)

ACCEPTABLE LEVELS OF SERVICE FOR A SYSTEM

An important step in risk assessment is to understand the consequences if a threat or hazard materializes. To support this task, a utility should develop specific goals and acceptable levels of service under disaster and recovery conditions. An example goal for a utility is to provide quality water while protecting public health, safety, and the environment, including the preservation of watersheds. Meeting this goal should be a continuous process before, during, and after a disaster.

When considering water system service priorities, an obvious approach is to examine the interdependencies that exist with other critical infrastructure and key resource sectors. Figure 2-8 illustrates some of the dependencies that exist between water and other sectors.



EMS: emergency, management system, HVAC: heating, ventilating, and air conditioning, SCADA: supervisory control and data acquisition

Source: Morley (2012)

Figure 2-8 Water utility interdependencies with other infrastructure systems

Establishing Acceptable Levels of Service

Utility requirements during disasters can be estimated based on user needs and the system's capabilities. For planning purposes, a utility should work with local emergency management directors, local hospitals and health care centers, business organizations and large employers, and other priority users to learn more about their service needs. This type of planning is as vital to a utility as the work to strengthen resiliency and mitigate risk.

CONCLUSIONS

This chapter provides information on hazards and threats, why updating risk assessments is an important activity that enhances a utility's resilience, how often risk assessments should be updated, the standard methodology for initiating or updating a risk assessment, and case studies that show how water utilities have been impacted by natural hazards, human-caused threats, and technological threats. No utility is immune to the sudden and/or disruptive incidents known as "emergencies" that occur from time to time over the life of a utility. However, by understanding how utilities might be impacted by these events through the risk assessment process, managers are in a better place to address whatever the future may bring.

REFERENCES AND SUPPLEMENTAL READINGS

- AWWA. 2011. [M60](#), *Drought Preparedness and Response*. Denver, CO: AWWA.
- AWWA. 2010. [ANSI/AWWA J100-10](#). *Risk Analysis and Management for Critical Asset Protection (RAMCAP) Standard for Risk and Resilience Management of Water and Wastewater Systems*. Denver, CO: AWWA.
- AWWA. 1989. [M32](#), *Distribution Network Analysis*. Denver, CO: AWWA.
- AWWA. 1983. [M2](#), *Automation and Instrumentation*. Denver, CO: AWWA.
- AWWA. *Cybersecurity Guidance & Tool*. www.awwa.org/cybersecurity.
- AWWA. *Process Control System Security Guidance for the Water Sector*. www.awwa.org/Portals/0/files/legreg/documents/AWWACybersecurityguide.pdf.
- Buehrer, J. 1989. Charleston Utility Weathers Hugo's Devastation. *AWWA MainStream*, 33:11:1.
- Edwards, D. 2010. Robust ICSs Critical for Guarding Against Cyber Threats. *Journal AWWA*, 102:11:30–33.
- Greenemeier, L. 2011. Half-Life and Death: Radioactive Drinking Water Scare in Japan Subsides, but Questions Remain. www.scientificamerican.com/article/fukushima-water-fallout/.
- Kennedy/Jenks Consultants Engineers and Scientists. 1993. *Guide Document Earthquake Vulnerability of Water Systems. Prepared for US Geological Survey*. Washington, D.C.: USGS.
- Lambe, T.W. and Whitman, R.V. 1969. *Soil Mechanics*. New York, N.Y.: Wiley.
- Minkel, J.R. 2008. *The 2003 Northeast Blackout—Five Years Later*. www.scientificamerican.com/article/2003-blackout-five-years-later/.
- Morley, K.M. 2012. *Aging Infrastructure: Water Sector Perspective*. Presented at the 2012 Critical Infrastructure Protection Advisory Committee Plenary, Washington, D.C.
- Morley, K.M. 2010. Advancing the Culture of Security and Preparedness in the Water Sector. *Journal AWWA*, 102:6:34–37.
- Moyer, J.; Dakin, R.; Newman, R.; Groves, D. 2009. The Case for Cyber Security in the Water Sector. *Journal AWWA*, 101:12:30–32.
- Tokyo Electric Power Company, Inc. 2012. Fukushima Nuclear Accident Analysis Report (Summary). June 20, 2012.
- US Department of Homeland Security and USEPA (US Environmental Protection Agency). 2007. *Water: Critical Infrastructure and Key Resources Sector-Specific Plan as Input to the National Infrastructure Protection Plan*, May 2007.
- USEPA. 2016. *Drought Response and Recovery Guide for Water Utilities*. www.epa.gov/waterutilityresponse/drought-response-and-recovery-guide-water-utilities.

This page intentionally blank.

Chapter 3

Developing an Emergency Response Plan

This chapter focuses on development of an emergency response plan (ERP), which is useful in organizing a utility to prepare for, respond to, and recover from an emergency incident. The ERP provides guidance for utility staff during emergencies. This chapter provides proven methods and national standards used to develop and maintain an ERP. This plan establishes a proven management structure, the incident command system (ICS), as the foundation for managing response activities. It also provides utility staff with well-defined response procedures that are intended to restore and/or maintain service delivery during times of crisis. The ERP is designed to address probable system failures. In all response activities, whether foreseen or unforeseen, safety, good judgment, and common sense must take precedence.

Utility resiliency can be best achieved when an ERP is part of an overarching program that includes risk assessment, business continuity planning, training, and exercises. In this chapter, preparedness plan types and components are described, with more detail provided for the ERP. A case study from a utility that has activated their plan during their response to incidents is also included. An example ERP framework with brief descriptions of each section is provided in the following.

*ANSI/AWWA G440, Sec. 4.5.1:
The utility shall develop and document preparedness plans in a format conducive with their operations. Preparedness plans must include an Emergency Response Plan and may also include other supplemental plans such as a Resource Typing Plan, Crisis Communications Plan, Disaster Recovery Plan, Mutual Aid and Assistance Plan, and/or a Business Continuity/Continuity of Operations Plan.*

By the end of this chapter, the reader should be able to:

- use the results of their risk and resilience assessment to build a comprehensive ERP that fits the utility's needs;
- understand the value of developing and updating an ERP from operational, fiscal, legal, and legislative perspectives;
- develop or revise an ERP for a utility using the framework in Appendix A; and
- choose the components of an ERP that are appropriate for use at a utility.

IMPORTANCE OF A UTILITY PREPAREDNESS PROGRAM

Preparedness planning and exercises can make even a major emergency more manageable and can expedite recovery efforts. However, plan development and exercises require that a utility invest fiscal and human capital. The return on this investment is realized through the organization's resiliency.

OVERVIEW OF TYPES OF PREPAREDNESS PLANS

Many utilities have several types of preparedness plans, and using the plans together can be challenging without an understanding of how they fit together. Figure 3-1 shows how numerous plans can be combined. Table 3-1 describes the types of plans described in Figure 3-1.



Figure 3-1 Interconnection of various preparedness plans

Table 3-1 Types of preparedness plans

Type of Plan	Included Documents
Hazard mitigation	Vulnerability assessment/risk analysis Business impact analysis Impact assessment Hazard identification Risk mitigation plan
Standard operating procedures or guidelines to support mission-essential functions	Documentation policy Timekeeping procedures Safety and security plan
Preparedness	Facility response plan Hazard-specific (e.g., hurricane, flood) preparedness plan Spill prevention control and countermeasure
Response	Emergency response plan Emergency operations plan Fire evacuation plan Incident management plan Crisis communications plan Point of dispensing plan Hazard-specific (e.g., flood, tornado, bomb threat, water quality emergency) response plan
Recovery plans	Continuity of operations plan Laboratory continuity of operations plan Pandemic plan Information technology disaster recovery plan

A business continuity plan (BCP), sometimes referred to as a *continuity of operations plan* (COOP), helps a utility to continue essential operations throughout any event that disrupts business. The BCP is designed to keep the utility's "heart beating" while the ERP is designed to "stop the bleeding" after disaster strikes. For more information on business continuity planning, refer to the Water Research Foundation (2013).

Note that a disaster recovery plan, or "drip plan," is typically the name of the information technology (IT) recovery plan. A utility's IT recovery plan can be a component of the BCP.

HOW TO DEVELOP AN ERP

After the events of September 11, 2001, all US utilities that serve more than 3,300 people were required, through the Bioterrorism Act of 2002, to conduct a hazard and vulnerability assessment and to develop an ERP. [ANSI/AWWA G440](#), Emergency Preparedness Practices, was developed as a reference standard for utilities to comply with the act. The following basic principles should be recognized when developing an ERP, which should reference existing resources, be concise and logical, and be coordinated with other partner agencies.

Steps to Developing an ERP

Utility staff should follow the steps described below when developing a useful ERP.

1. *Establish a team to develop and review the ERP.* The team members will be based on the utility's size and complexity. Team members are subject matter experts in utility management, emergency management, water and wastewater treatment