Emergency Planning for Water Utilities

AWWA MANUAL M19

Fourth Edition

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Emergency Planning for Water Utility Management

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Foreword

Water utilities have a legal responsibility to provide adequate supplies of clean, safe drinking water to their customers, even when disaster strikes. The utility that is prepared will be more effective at responding to and recovering from disasters.

Preparing for disasters can be a daunting task because of the many disaster hazards and dangers that can occur. To ease this task, AWWA Manual M19 provides guidelines and procedures that can be used by utilities of any size.

This fourth edition of AWWA Manual M19, *Emergency Planning for Water Utilities,* has been updated to include information on several emergency preparedness regulations that were promulgated since the third edition.

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Chapter 1

Overview

Water utilities have a legal responsibility to provide an adequate supply of safe, high-quality drinking water to their customers. Disruptions in water quality and delivery can result from emergencies such as natural disasters, accidents, or intentional acts.

The 1974 Federal Safe Drinking Water Act (SDWA) briefly refers to “emergency circumstances” in Title XIV, Part B, Section 1413 (a):

> For purposes of this title, a State has primary enforcement responsibility for public water systems during any period for which the Administrator determines (pursuant to regulations prescribed under Subsection (b)) that such state …(5) has adopted and can implement an adequate plan for the provision for safe drinking water under emergency circumstances.

While primary enforcement agencies throughout the country can be expected to devote considerable attention to the standards addressed by the SDWA, water utilities should not wait for agencies to mandate any aspect of emergency planning. Water utilities should consider themselves responsible for providing water under emergency circumstances. Regardless of their size and location, utilities should prepare for emergencies before they occur and be able to quickly restore water service.

PLANNING FOR DISASTERS

Planning for a disaster may initially seem difficult because it essentially amounts to planning for the unpredictable. For example, despite steady progress in hurricane tracking, the exact impact time, strength, and effects of a hurricane are almost impossible to precisely predict. Other natural phenomena such as earthquakes provide even less warning. On the other hand, a great deal of knowledge has been accumulated on the impacts of natural phenomena, such as probabilities of occurrence and likely effects on infrastructure and the environment. Similarly, the effects on utility systems of human-caused hazards, such as chemical spills or accidents, also have been documented. The approach suggested in this manual is to apply this knowledge and experience to a specific water system, determine the vulnerable components of the system, and either improve the deficiency or plan an alternate strategy.

Case Study: Feel the Earth Move

A Survivor's Tale of the NW Earthquake

Before I tell you what happened on the day of the earthquake, I want to share a bit of my background prior to moving last November from Maine to the Pacific Northwest to manage operations at Seattle Public Utilities' new 120-mgd Tolt Treatment Facility.

Maine, unlike Washington, is not a hotbed of seismic activity, but I had felt small tremors there in recent years. The East Coast quakes are apparently caused by much deeper and less violent tectonic action.

I was "fortunate" enough just over a year ago to have been sitting in the treatment plant in Augusta, Maine, when a small tremor rolled through like a large, rumbling truck. It was a low-frequency, subsonic vibration of short duration that permeated everything. We barely had time to ask, "Is this an earthquake?"

Upon moving to the Puget Sound area last year, I immediately noticed the conical and pointed shapes of the mountains and how different they were from those on the East Coast. After seeing Mount St. Helens, a volcano that erupted in 1980, I thought it was fortunate that nearby Mt. Rainier hadn't suffered the same fate, considering its proximity to the seismically active Seattle metropolitan area.

Not Too Concerned

In conversations with the Tolt plant's design engineers, I learned that our facility had been designed to withstand fairly significant earthquakes. Because I had endured a couple of East Coast earthquakes that were hardly worth mentioning and because engineers are generally very safety conscious in building design, I wasn't too concerned about an earthquake at the Seattle plant.

Little did I realize how soon my blasé attitude would be tested. On Feb. 28, we were busy readying for the grand opening of our facility, which was to take place the next day. A large tent was being erected outside my office window, and some folks from our corporate offices in Houston were here to help manage the event. I had just made a cup of hot cocoa and was pulling a chair up to my desk when the first tremor hit.

My first thought was that something really heavy had fallen outside. A small crane was still on-site and perhaps it had somehow dropped onto the building (which would have made for an interesting opening-ceremony anecdote). A few seconds passed and then I felt the floor move. It was as if the plant had come alive.

Our administrative assistant, Melissa Kalouner, had arrived from downtown, and she came into my office, looking a bit confused. "What's going on?" she asked. I immediately and insistently responded, "It's an earthquake! Get under a desk now!" As fast as a shot, I retreated under my desk as the rolling continued.

I had only recently learned the "grab and hold" method of staying under a structure during an earthquake, so that if it moves, you can move with it. If an earthquake is violent enough to move a desk, it is likely violent enough to make objects fall off walls; therefore, it is important to keep the desk above you at all times as a kind of debris umbrella. I was very pleased that this maneuver came instinctively.

The floor and walls in my office are made of concrete. Yet, the 8-in.-thick walls were visibly moving, which made no sense to me. "Nothing," I thought, "can move that much concrete! Concrete doesn't bend!" It wasn't something my mind could easily comprehend. Something else I realized, as I looked out the window from where I crouched under my desk, was that the men outside erecting the tent were wobbling.

My Thoughts Raced

I considered what could be happening. My thoughts raced. "OK, so the walls are moving … will they fall in? Did the design consultants really design this place for an earthquake THIS big, or were they just trying to make me feel better? What possible good is this flimsy fiberboard desk going to do if these huge walls DO fall in?" Then I thought about the proximity of our liquid oxygen tanks to the diesel fuel for the generators, and it occurred to me that the tanks could topple and make for a really interesting morning.

The ground underneath moved in all directions, and the flexing of the plant made the same low, subsonic sounds I'd heard in previous quakes—the most unsettling sounds of massive

continued on next page

Case Study: Feel the Earth Move (continued)

concrete and steel flexing that only an earthquake can cause. Finally, the rolling and the shaking stopped. I sprang quickly from under my desk and ran into the control room to see what alarms had been triggered. I had immediate questions. Did we lose the influent pipes? Did the downstream pipes fail and cause a radical increase in effluent demand? Did the liquid oxygen tanks fall over? Oddly, nothing was in alarm.

As I reviewed the screens, I contacted SPU's Operations and Control Center to let them know we were fine, were inspecting for damage, and that they shouldn't worry—at least not right at that moment. I scrolled through screens on the supervisory control and data acquisition system, yet nothing seemed amiss. Our crew walked the premises to inspect for cracks, toppled chemicals and other objects, and plumbing leaks. After regrouping, we determined that nothing obvious had fractured or failed. Daryl Farnstrom and others at Dillingham Construction, the contractor who had built the facility, also conducted an inspection and found what appeared to be incidental damage to a footing on one of the liquid oxygen tanks. It was only cosmetic damage, however, and may not have been solely caused by the quake.

The next task was phoning our families to make sure they were unharmed and to let them know we were okay. Then we called the design engineers, our local office in Bellevue, Wash., and our corporate offices in Canada and SPU to assure them of our safety and to give them information about the earthquake and its effect on the facility. The phones were jammed, particularly cellular phones, and we wondered what might have happened had we really needed to talk to people.

Communications Critical

Often after an emergency like this, folks just want information. If you're the victim of an accident, you often need support, guidance, and assistance. If we had experienced damage, we would have been calling SPU immediately to make them aware that one third of their water supply was unavailable and that we would need priority assistance to determine how to get the facility back on line. We would have been calling our corporate offices and insurance companies and notifying standby operators of the need for additional assistance. Communications are the most critical part of an emergency.

Fortunately, our facility has a fiber-optic line to OCC, with a microwave system backup. Plus, there is a "boosted" 800-Mhz two-way radio system provided to the facility by SPU that can be used to contact downtown and emergency operators. I opted for e-mail and found that this was the easiest means to get the word out to a number of people very quickly. I have been in similar situations where it was just not possible to get in touch with someone you absolutely needed to talk to; but, e-mail often works because a person can be on the phone and read your message at the same time. We also used the Internet to get the latest news from Cable News Network. We watched video feeds to see if there would be increased demand because of main breaks or if there were widespread fires started by gas main breaks. Fortunately, there was no significant change in water flow, and within an hour or so, we were back to normal work operations.

The main thing we all learned that day was that expecting and planning for the worst make it much easier to endure a potentially disastrous event. Communications during emergencies are often not possible through normal means, and e-mail or Website postings can make this task easier by getting the word out very quickly to a large number of people.

And last, but not least, diving under your desk is not an act of cowardice (although it can be embarrassing if people see you do it). Melissa Kalouner swears that my dash to the bottom side of my desk was one of the funniest things she's seen in her lifetime.

But even though such an act can result in lighthearted jokes later, it just might save your limbs and life during an actual emergency.

Brian Tarbuck,
Source: Opflow, *May 2001.*

Water utilities cannot plan for all disasters. Sound emergency planning dictates that contingency plans be developed for only the most *probable* risks. Identifying the effects of selected disasters allows a utility to determine (1) the most vulnerable portions of its system and (2) how a likely disruption would impact service. Then, even if an improbable disaster occurs, its impacts may be similar to those of a selected disaster. For example, a New England water utility's emergency plan assumed that the treatment plant would be disabled in an earthquake and alternate sources of potable water, which could be used if the plant was out of service, were identified. The plan did not anticipate the impacts of a major treatment plant fire. When such a fire did occur, the utility was still able to implement its plan to deal with the plant shutdown; the procedures for obtaining alternate water sources were similar to those planned for an earthquake.

Utilities must eliminate or minimize the adverse impacts of all emergencies. Perhaps the best way to accomplish this is through sound emergency planning. AWWA Manual M19, *Emergency Planning for Water Utilities*, presents principles, practices, and guidelines for water utility emergency planning. This manual is intended for use by all utilities regardless of size. It provides guidelines and a sufficient level of detail to complete the emergency planning process for most systems. Certain utilities may desire or require a greater level of detail than can be provided in this manual. For example, advances in earthquake science have yielded precise descriptions of the interaction between soils and structures. The higher level of analysis required to determine that interaction is unnecessary for most water systems. Utilities desiring such levels of analyses should refer to the bibliography for appropriate references

HOW TO USE THIS MANUAL

The concepts and definitions used throughout the manual to discuss emergency planning are defined below. Also included is a summary of what is discussed in each chapter of the book.

Concepts and Definitions

The following concepts and terms are used throughout this manual.

Emergency. An unforeseen or unplanned event that may degrade the quality or quantity of potable water supplies available to serve customers.

Minor emergency. A fairly routine, normal, or localized event that affects few consumers, such as a pipe break, malfunctioning valve, hydrant break, or brief power loss. Utilities plan for minor emergencies and typically have staff and materials available to correct them. If resolved quickly, minor emergencies will not become major emergencies.

Major emergency. A disaster that affects an entire or large portion of a water system, lowers the quality and quantity of the water, or places the health and safety of a community at risk. Water utilities infrequently experience major emergencies.

Natural disaster. A disaster caused by natural forces or events that create water utility emergencies. Examples include earthquakes, forest or brush fires, hurricanes, tornadoes or high winds, floods, and other severe weather conditions, such as freezing or drought.

Human-caused disaster. A disaster caused by intentional or accidental acts. Human-caused disasters may be the result of employee error, transportation accidents, employee work stoppage, vandalism, civil disorders, terrorism, biological contamination, hazardous chemical spills, equipment failures, explosions and incendiary fires, or warfare.

Hazard. A source of potential damage associated with a disaster. Examples are the high winds of a hurricane or the ground shaking of an earthquake.

Lifeline concept. The infrastructure of networks and facilities that provide essential services to citizens, businesses, and industry (Oregon Seismic Safety Policy Advisory Commission 1992). Lifelines include utilities such as water, wastewater, electric, and natural gas or other fuels. Transportation networks, communication systems, medical care facilities and equipment, fire and police facilities and equipment, and emergency operations centers can also be considered lifelines. Prompt lifeline restoration is necessary for disaster recovery.

Organization

The chapters in this manual provide a step-by-step procedure for emergency planning. Previews of each chapter follow.

Chapter 2—Hazard summary. Probabilities of disasters and their associated hazards are discussed. A utility should be able to use the information in chapter 2 to develop its own hazard summary—a matrix of the probability and magnitude of hazards.

Chapter 3—Vulnerability assessment. Once the most probable hazards that a utility may encounter have been identified, the utility should identify the system components most vulnerable to those hazards. A list of common water system components and how each one may be vulnerable to typical hazards is included in this chapter. An example of a vulnerability assessment also is presented.

Chapter 4—Mitigation actions. Actions that can be taken to decrease the vulnerability of system components are discussed. Often the proposed mitigation actions require only minimal effort, such as maintaining system plans in two different locations. Others may be more complex and expensive such as installing a second transmission line. The costs and benefits of mitigation actions are discussed.

Chapter 5—Preparedness planning. The basic principles and elements of an emergency preparedness plan are presented. Training and updating techniques are also discussed. Regulatory requirements for emergency planning, and reporting hazardous materials use, storage, spills, and releases also are included in this chapter.

Chapter 6—Emergency, response, recovery, and training. The steps to follow during an emergency that will lead to a quick recovery are presented. Recovery actions, training, and evaluation are also included. Evaluating actual emergency response actions should reveal methods to improve the emergency-preparedness plan.

REFERENCES

Oregon Seismic Safety Policy Advisory Commission. 1992. *Actions to Address Earthquake Risk in Oregon.* Report to the Governor and the Legislative Assembly for 1991–1993. Salem, Ore.

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Chapter 2

Hazard Summary

INTRODUCTION

During the late 1980s and 1990s, several major disasters occurred, causing widespread damage to local water utilities. Hurricanes Hugo in South Carolina, Andrew in Florida, Iniki in Hawaii, and Fran and Floyd in North Carolina severely disrupted water service in those areas. The 1989 Loma Prieta earthquake damaged many water systems in the San Francisco Bay area and the 1994 Northridge earthquake caused severe infrastructure damage across Southern California. In 1992, utility tunnels in Chicago flooded, shutting down the business district for several days. The series of tornadoes that struck areas of Oklahoma in May 1999 caused extensive destruction.

This chapter provides both general and specific information on natural and human-caused disasters that can create major emergencies. Each type of disaster produces hazards that can damage water system components and disrupt normal service. The hazards associated with each type of disaster are described and specific examples presented. A hazard summary table is included for water systems to use when developing an emergency response plan.

NATURAL DISASTERS AND THEIR ASSOCIATED HAZARDS

The following sections describe the most common natural disasters and their associated hazards.

Earthquakes

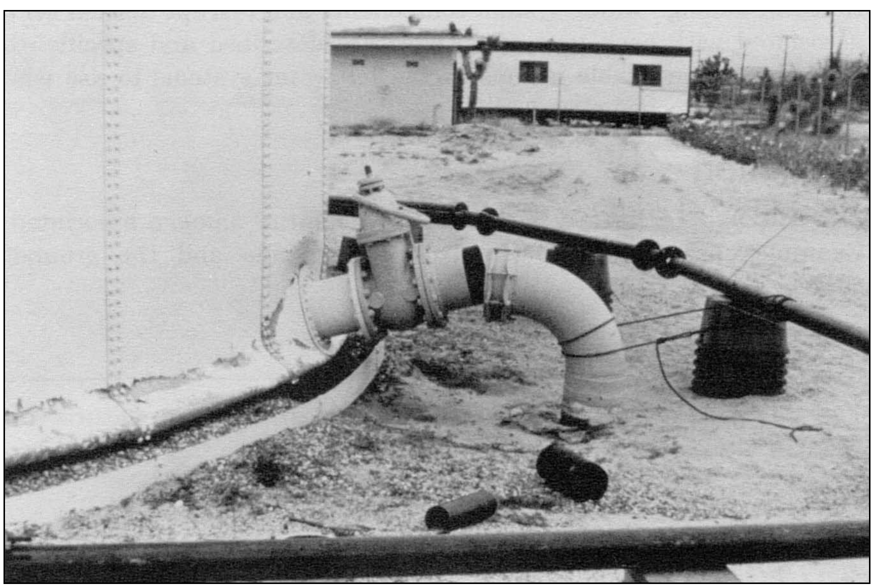
Earthquake damage can be widespread and severe. The energy released by an earthquake can be equivalent to the explosion of millions of tons of dynamite. The degree of resultant damage is related to (1) the magnitude of the earthquake, (2) the distance from the epicenter (the part of the earth's surface directly above the subsurface focus of an earthquake), (3) the soil types in the area, (4) the resulting mode of earth failure, and (5) the design and materials of structures.

The February 1971 San Fernando (Southern California) earthquake demonstrated just how destructive an earthquake can be to a water utility. A local power converter station, two dams, and outlet works were heavily damaged; two aqueducts were moderately damaged; and a partially completed water treatment plant was nearly destroyed. The earthquake also broke mains and valves, damaged pumping stations and distribution storage systems, and disrupted communications and power supplies—all of which resulted in widespread loss of water service.

In January 1994, another severe earthquake centered in Northridge, Calif., damaged aqueducts and trunk and service lines and left pumping stations without power. Approximately 100,000 people were without water service by the second day after the earthquake. Due to the loss of major treatment plants, water supplies were obtained from backup groundwater sources and imported through the Colorado River Aqueduct. The Los Angeles Department of Water and Power drew down finished water reservoirs while repairing the system.

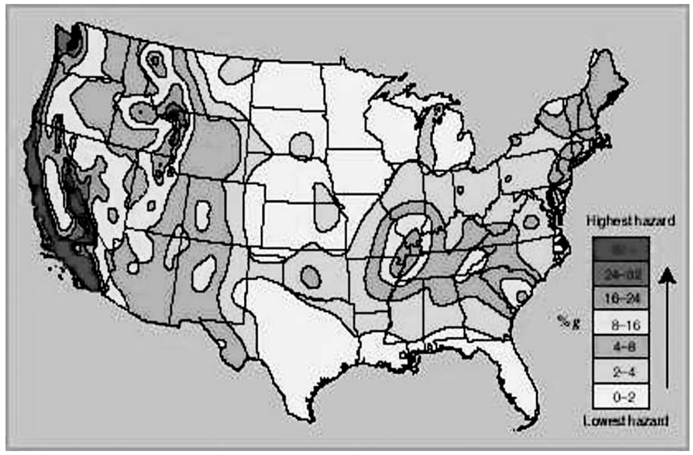
Likewise, the 1989 San Francisco Bay area Loma Prieta earthquake and the 1992 Landers/Big Bear (California) earthquake caused pipe breaks, concrete storage tank cracks, steel tank bursts, power and pump losses, and structural damage (Figure 2-1). Sixty-two people were killed in the Loma Prieta earthquake, and damage was estimated at $6 billion.

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 can also present significant risk. To determine a more precise probability of an earthquake occurring and the potential magnitude, a water system should review local geological and seismological data available from such sources as the US Geological Survey, state or provincial geological agencies, and universities or employ a consultant experienced in earthquake hazard analysis.



Source: *M.J. O'Rourke.*

Figure 2-1 A 400,000-gal (1.5 million-L) steel tank was uplifted and underwent "elephant's-foot" buckling on impact during the Landers, Calif., earthquake



Source: *US Geological Survey.*

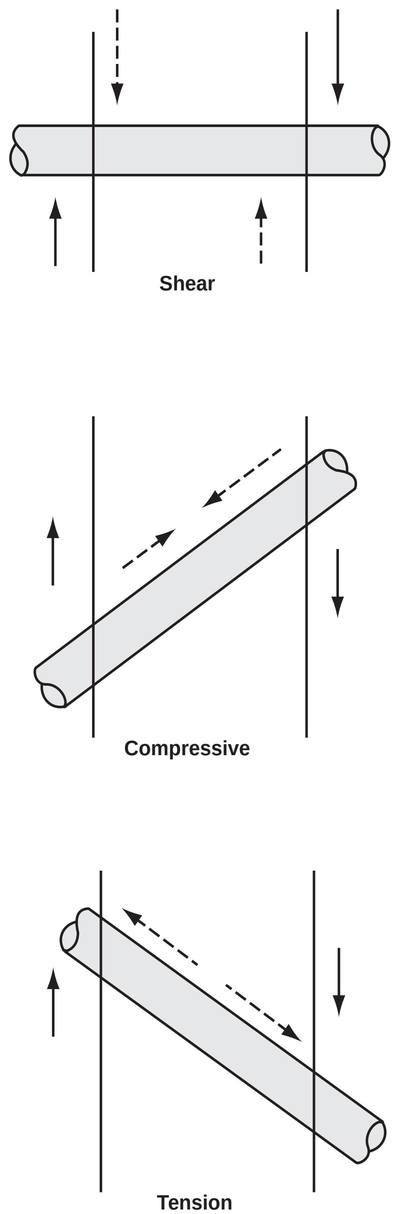
Figure 2-2 Map of relative earthquake hazards within the continental United States

Earthquakes are complex phenomena that create equally complex hazards. A great deal of research has been conducted on this subject and many references are included in the bibliography. The following summarizes some of the main earthquake hazards that can damage water system components.

Fault rupture. A fault rupture is the differential movement of two landmasses along a fault. The 1992 Landers/Big Bear earthquake created a 21-ft (7-m) offset in some areas. If a pipeline crosses a fault that ruptures, the pipeline will experience forces that can deform or split the pipe or separate sections at the joints. Figure 2-3 illustrates those forces. Known faults are identified on geological and seismic maps, and are often readily visible from aerial photographs and occasionally at ground level. Traversing faults with pipelines should be avoided if possible. If a fault crossing is required, the pipeline design should allow for fault movement.

Ground shaking. The energy created by an earthquake radiates in waves from the epicenter like ripples caused by a stone 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 water system components. For example, a pipe without flexible joints entering a concrete structure may be subject to shear failure. Another result of seismic forces is the tipping moment produced on water storage tanks, as illustrated in Figure 2-4.

Liquefaction. Pore water is the water located in the spaces between soil particles. The energy of an earthquake generates high pore-water pressure that can overcome the friction between soil particles. When pore-water pressure 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, lateral spreading, or floating of underground components. Liquefaction can also cause a loss of slope stability and produce landslides.

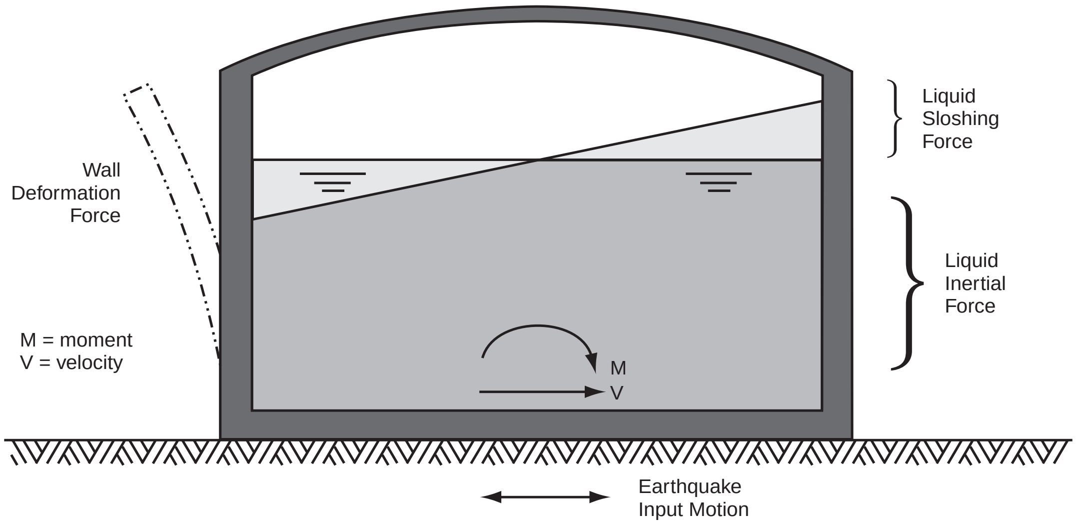


Source: *Ghassan Al-Chaar.*

Figure 2-3 Earthquake-induced forces on buried pipelines

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

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



Source: Epstein (1976).

Figure 2-4 Seismic forces on water storage tank

Tsunami and seiche. A tsunami is a tidal wave caused by an earthquake or volcanic explosion. A seiche is an oscillation of the surface of a lake, reservoir, or landlocked sea due to an earthquake. Tsunamis and seiches can also be caused by earthquake-induced landslides. The wall of water from a tsunami can greatly exceed normal high tide levels and contain tremendous energy. The tsunami produced by the 1883 Krakatau volcanic explosion was 100 ft (33 m) high and killed 36,000 people. The 1964 Alaskan earthquake tsunami destroyed coastal Alaskan communities and generated high tides as far south as La Jolla, Calif. A tsunami that hit Hilo, Hawaii, in 1960 caused damage in excess of $20 million and killed more than 80 people. In 1992 and 1993, tsunamis in Nicaragua and Indonesia caused many deaths and in 1993 a 16-ft- (5-m-) high tsunami killed more than 100 people in Japan.

A seiche can overtop dams, cause erosion of earthen dams, and result in dam failure. Seiches can also damage dam inlet and outlet structures.

Hurricanes

The costliest natural disasters in recent years have been hurricanes. Approximately 44 million people in the United States live in areas that have been hit by hurricanes. Damages in the tens of billions of dollars resulted from Hugo in South Carolina, Gloria in New York, Andrew in Florida, Iniki in Hawaii, and Fran and Floyd in North Carolina. The damage from Andrew alone was $25 billion. The main hazards associated with hurricanes are high winds, the storm surge, and flooding. Hurricane Andrew knocked down or damaged 60 percent of the power poles in its path. Though the water treatment plant in the path of Andrew remained in operation, the damage to residential and commercial structures resulted in multiple water leaks that effectively created an inoperable water distribution system (Tavano 1993).

Hurricane winds approaching 200 mph (320 km/h) have been recorded. A storm surge is a wall of water created by the extremely low atmospheric pressure in the eye of the hurricane. The surge can be higher than 20 ft (6 m) above mean sea level. Flooding is caused by the heavy rainfall from a hurricane, which can be as much as 36 in. (900 cm), such as occurred in the Corpus Christi (Texas) area during the 1967 Hurricane Beulah (Cunningham 1973).

Extreme hurricane winds coupled with high tides and the storm surge can devastate shoreline areas, and water systems can be vulnerable. Surface structures can suffer wind damage and flooding can destroy plant facilities and contaminate water supplies. Structural damage (Figure 2-5) 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.

Tornadoes

Tornadoes most commonly occur in the central United States; however, they have been reported in all 50 states. The most prevalent tornado hazard is extremely high winds. Exact speeds have not been measured because wind gauges rarely survive a tornado, but estimates range as high as 300 mph (480 km/h). While tornadoes can be tracked by radar and warnings 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. The case study on page 14 outlines one water utility's response to a tornado.

Floods

Few areas of North America can be considered completely safe from flooding. The US Army Corps of Engineers estimates that annual flood damage in the United States amounts to hundreds of millions of dollars. Flooding can be caused by heavy rainfall (Figure 2-6), snowmelt, hurricane storm surges, high tides, volcanic eruptions, or dam 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 are available at the national and regional level to take preventive measures. But floods can also occur unexpectedly as the result of a dam break, breaching of underground tunnels, or unusually severe 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 about 8 ft (2.5 m) above the 100-year flood elevation. Water service to 250,000 people was cut off for several days.

Source: *Ray Sato.*

Figure 2-5 Structural damage from Hurricane Iniki in Kauai, Hawaii

Source: D.K. Sander.

Figure 2-6 Flooding in Washington State

Forest or Brush Fires and Firestorms

A forest or brush fire can damage watersheds and water system structures and strain water supplies if used for fire fighting. Forest and brush fires can occur anywhere, but particularly in areas affected by dry weather or drought. Firestorms in urban or suburban areas, such as the one in Oakland, Calif., in 1991 and those throughout the western United States during the summer of 2000, are likely to increase in frequency owing to widespread development into formerly non-urban areas.

Volcanic Eruptions

The Pacific Northwest, Alaska, Hawaii, and central Mexico are areas particularly prone to volcanic eruptions. The most dramatic recent example of a volcanic eruption occurred at Mount St. Helens (Washington) in 1980. More than 80 people died and damage was widespread. The predictability of volcanic eruptions has become more refined in recent years, although volcanoes can erupt without warning. Residents near Mount St. Helens were given several days warning that an eruption was imminent.

The hazards from eruptions include explosive winds, fire, falling rock, lava flow, floods due to mud and snowmelt, and ash. These hazards can damage structures and equipment, foul water supplies, choke intake structures, and contaminate watersheds.

Other Severe Weather

Severe weather such as extreme heat or cold, heavy snows or ice storms, high winds, and lightning can have both short- and long-term impacts on a water system. Deep snows can prevent water utility personnel from reaching their stations. Snow also can cover the locations of valves and other components. Lightning can cause power failures or damage electronic equipment. Extreme cold can freeze valves, pipes, and storage structures. Extreme heat can produce drought and deplete water supplies. High winds can damage structures and often cause power outages. The probabilities

Case Study: Manson, Iowa, Responds to Tornado

Consider these problems: service and line breaks, a loss of system pressure, more than 100 yd^3 (76 m^3) of debris strewn over the cover of the ground storage reservoir, and suspected backsiphonage. No water supplier would want to be faced with these problems, yet the town Manson, Iowa, struck by a tornado on June 29, 1979, had to deal with these dilemmas.

Some of the damaged or destroyed facilities held stocks of pesticides; damaged pesticide containers were scattered throughout the city. The tornado downed electrical transformers, and it was feared that coolant leaking from the transformers could be seeping into the water supply, adding the possible threat of polychlorinated biphenyl (PCB) contamination to an already critical situation. Further investigation revealed that the transformer coolant was a highly refined petroleum product rather than the suspected PCB. Tests also showed that no organic pesticide contamination was present.

Membrane-filter tests did show, however, that the water was contaminated with bacteria. Because the water supply had no disinfection treatment, system personnel had to devise a way to introduce chlorine into the system. The first chlorination effort involved dissolving 200 lb (91 kg) of 70 percent available chlorine granules to form a saturated solution in 30-gal (113-L) garbage cans and emptying them manually into the reservoir. This proved to be a difficult and slow process.

The final solution to the chlorination dilemma was characteristic of the ingenuity and resourcefulness that often result from critical situations. The water supplier called on the city fire department for a 500-gal (1,900-L) pumper unit to be used as a makeshift chlorinator. Initially, one half of a barrel (50 lb [23 kg]) of chlorine granules was added to the pumper and mixed by on-board agitation. Because the National Guard was supplying the town with an emergency potable water supply and requested that residents curtail their water usage, a longer contact time was allowed for the high-strength chlorine solution being drawn into the distribution system. An additional 600 lb (273 kg) of chlorine granules were subsequently introduced into the system with the aid of the pumper. Complete potable water service was restored to the residents within one week of the tornado. In order to prevent a future emergency makeshift operation, a hypochlorinator was installed July 2, 1979.

Source: Journal AWWA*, April 1980.*

of extreme weather hazards are area-specific. Local weather bureaus can help determine the probabilities of such events.

Waterborne Diseases

Organisms such as *Giardia* and *Cryptosporidium* can contaminate an entire water supply and cause waterborne diseases. The 1993 Milwaukee, Wis., cryptosporidiosis outbreak affected more than 350,000 people. Utilities can usually learn from state or provincial health departments which biological agents are most likely to affect them. (See also AWWA Manual M48, *Waterborne Pathogens*.)

HUMAN-CAUSED DISASTERS AND THEIR ASSOCIATED HAZARDS

The following sections describe the most common human-caused disasters and the hazards associated with those disasters.

Hazardous Material Releases

The Occupational Safety and Health Administration (OSHA) defines a hazardous material as, "any chemical which is a physical hazard or a health hazard." We can expand this definition to state that any chemical that can harm humans directly or contaminate air or water should be considered hazardous. OSHA publishes a list of hazardous, toxic, and reactive materials in the *Code of Federal Regulations* (29 *CFR* 1910.1000). Some hazardous materials, such as chlorine, are used directly in water treatment systems; others may not be used by utilities but have the potential to be introduced into the system through other means, such as transportation accidents.

Spills can originate from pipelines, ships, airplanes, motor vehicles, railroads, or 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 water intake to a city water supply.

Spills may consist of liquid, solid, or gaseous materials. They can occur at any time and can result in injury, loss of life, damage to property, 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 management measures must attempt to prevent spilled materials from reaching the water system or minimize the spread of contamination throughout the system. Damage to the water system and its users caused by a spill can be very expensive, not only in terms of cleanup costs but in replacement of system components and potential lawsuits.

Structure Fires

A fire at a pump station or a treatment plant can seriously reduce a utility's ability to deliver water and destroy many critical components such as computer control systems. Fires may also destroy administrative buildings (including the equipment and records inside) and storage and maintenance structures. A large fire involving many structures or a wide area of a city can deplete water supplies through firefighting efforts.

Construction or Transportation Accidents

Accidents during construction can damage water system components, both aboveground and underground. All forms of transportation should be considered in emergency planning, including road, rail, water, and air. Such accidents may also disrupt traffic and block access to system components. Transportation accidents most likely will damage aboveground components.

Nuclear Power Plant Accidents or Nuclear Explosions

On April 26, 1986, the Chernobyl Atomic Power Plant in Ukraine exploded, emitting radionuclides (such as cesium-137 and strontium-90) into the air. Initially, the prevailing winds carried the radiation away from the city of Kiev, but when the winds changed direction four days later, the radiation drifted toward the city and its 2.7 million inhabitants. Kiev's primary water supply, the Dnieper River and reservoir, was contaminated (Tsarik 1993).

The Chernobyl accident was the most serious incident on record involving a nuclear power plant and is an unrealistic scenario in the United States as there are no comparable reactor designs in this country. However, radioactive contamination could also result from a less explosive type of accident such as a release of radioactive steam, water, or air from a plant or other nuclear facility. A detonation of a nuclear warhead could also cause widespread contamination.

The probability of a major radiation release from a nuclear power plant or warhead detonation is remote. However, utilities located near a nuclear plant or other facility, or even at some distance (Kiev is 62 mi [100 km] from Chernobyl), should consider radiation contamination in an emergency plan.

Vandalism, Riots, Strikes, and Terrorism

Vandals can damage plants, pumping stations, dams, water towers, hydrants, and administrative offices. Civil unrest can be directed at water systems, placing utility personnel at risk. Water supplies can be contaminated or intentionally depleted. Strikes by water utility or other workers can result in work stoppage or slowdowns, but may also result in vandalism, sabotage, interference of supply deliveries, or picket line disturbances. Finally, terrorist threats to all critical infrastructure systems, including water supplies, should be considered a potential hazard, as demonstrated by the devastating attacks of Sept. 11, 2001.

HAZARD SUMMARY

A hazard summary lists the disasters that can affect a water system and the potential magnitude of the hazards associated with those disasters. Figure 2-7 is a sample hazard summary form. The form can be expanded or condensed to meet individual system needs.

The "estimated probability" column includes the average occurrence interval of each disaster appropriate to a particular system (for example, once every 100 years). The estimated probability could also be more generally rated as low, medium, or high. By listing all disaster possibilities and rating their probabilities of occurrence, it is possible to establish emergency planning priorities.

The "estimated magnitude" column includes the potential severity of the hazard using such measurements as Richter scale magnitude, wind speed, or flood elevation.

Type of Hazard	Estimated Probability	Estimated Magnitude	Comments
Earthquake	1 in 60 years	7.0 (Richter scale)	
Fault rupture	Medium	2 ft	Meridian fault
Ground shaking	High		
Liquefaction	Medium–low	Vertical and horizontal accelerations	Fill areas
Densification	Medium		Fill areas
Landslide	Medium–high		In slopes of 30 percent
Tsunami and seiche	None		
Hurricane	None		
Wind			
Storm surge			

(continued on next page)

Figure 2-7 Hazard summary for a hypothetical water system

Type of Hazard	Estimated Probability	Estimated Magnitude	Comments
Flooding			
Tornadoes	Low		
Floods	Low–medium	100-year flood to elevation = 1,020 ft	At treatment plant
Forest or brush fires	High		Dry creek watershed
Volcanic eruptions	1 in 300 years	150 miles away	Mount Nueces
Other severe weather			
Snow or ice	None		
Extreme heat	High	100-year drought	Reservoirs depleted
Wind	Medium	60–80 mph	Usually in winter
Lightning	Low		
Other			
Waterborne diseases	Low		Cryptosporidiosis
Hazardous-material release			
Chlorine	Medium–high	1-ton containers	Earthquake damage
Other spill	Medium	Tanker car	Dry creek reservoir
Structure fires	Low		
Construction accidents	Medium	Line damage	In older area of system
Transportation accidents			
Road	Low		
Rail	Medium		Rail yard near warehouse
Water	Low		
Air	Low		
Nuclear power plant accidents	Low	Contamination	Lake West reservoir
Nuclear bomb explosions	Low		
Vandalism, terrorism	Medium		Storage tanks
Riots	Low		
Strikes	Low		

Figure 2-7 Hazard summary for a hypothetical water system (continued)

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Chapter 3

Vulnerability Assessment

INTRODUCTION

After a utility completes its hazard summary, the effects of those hazards on system components and on water quality and quantity should be determined. Although each water system is unique, it can be described and analyzed in terms of its components and expected level of service. All aspects of an individual water system must be understood in relation to specific disaster hazards before drafting a vulnerability assessment and the resultant emergency operational plans. The case study on page 20, which describes the seismic improvements made by Tacoma Public Utilities, illustrates the importance of a vulnerability assessment.

PERFORMING A VULNERABILITY ASSESSMENT

A vulnerability assessment is essentially a four-step procedure:

1. Identify and describe the separate components of the water supply total system.
2. Estimate the potential effects of probable disaster hazards (determined in chapter 2) on each component of the system.
3. Establish performance goals and acceptable levels of service for the system.
4. If the system fails to operate at desired levels under potential disaster conditions, identify key or critical system components responsible for the condition.

Definitions

Water system. The facilities and equipment constructed and operated to supply drinking water for residential or commercial uses. A water system generally consists of the following subsystems: source, transmission, treatment, storage, and distribution. In turn, each subsystem contains critical components (e.g., power,

Case Study: Seismic Improvements Minimized Earthquake Damage

Investments in seismic improvements helped Tacoma Public Utilities survive the recent earthquake with minimal damage to both its water and power utilities. Tacoma Water—which serves 87,000 customers in Tacoma, University Place, and parts of Pierce and South King counties—has spent about $1.3 million on adding seismic protection at its facilities since 1995. Tacoma Power has spent $1.93 million on its facilities.

Mark Crisson, director of Tacoma Public Utilities, said he was "convinced that the seismic improvements made during the past few years minimized damage in this occurrence and will greatly assist in preventing catastrophic damage in a future larger quake. The only damage we experienced was a break in an old, cast-iron water main and some cosmetic damage to a few of our buildings."

Tacoma Water took several steps to strengthen its facilities to withstand the stresses of an earthquake:

- The utility conducted a seismic vulnerability assessment on water supply facilities and the building that houses the Tacoma Public Utilities administrative complex.
- Retrofits were done on a number of facilities to provide more seismic protection—the Water Distribution Building; the McMillin Reservoir chlorination building; the Fletcher Heights, Bismark, and North End standpipes; and storage tanks in University Place.
- Portable standby power was purchased for critical facilities.
- Seismic equipment was installed at the Portland Avenue and McMillin reservoirs to automatically close valves during an earthquake in order to prevent uncontrolled releases of water. The quake on February 28 was not strong enough to actuate the controls.

Source: Journal AWWA*, June 2001*

personnel, materials and supplies, equipment, structures, transportation, gas and liquid fuels, and communications) that must be examined when developing an emergency plan.

Total system. A concept that incorporates a whole system, such as a water supply system, including the interrelationship or interdependency of various other lifelines. For example, a water utility constitutes a system, but the "total system" incorporates the water facilities, water users, maintenance facilities, administration, and other lifelines, such as communications, transportation, gas and liquid fuels, and electrical power.

Component. A discrete part of a system that is capable of operating independently but is designed, constructed, and operated as an integral part of the total system. Examples of individual water system components are wells, booster stations, or reservoirs.

Step 1: Identify Major System Components

Key elements of the total system should be listed and described as components under the following general headings: (1) administration and operations, (2) source water, (3) transmission system, (4) treatment facilities, (5) storage, (6) distribution system, (7) electric power, (8) transportation, and (9) communications.

Of course, each water system is unique; when identifying major components, a utility should include components that may not have been referenced or place those mentioned in a more appropriate category. The following is a suggested list of major components:

Administration and operations

- Personnel
- Facilities and equipment (buildings and computers)

- Records (accounting, customer lists, and system maps)
- Emergency plan

Source water

- Watersheds and surface water sources
- Reservoirs and dams
- Groundwater sources
- Wells and galleries

Transmission system

- Intake structures
- Aqueducts
- Pump stations
- Pipelines, valves, and other appurtenances

Treatment facilities

- Facility structures (buildings, basins, and tanks)
- Controls (manual and computer)
- Equipment (feeder, pumps, and piping)
- Chemicals

Storage

- Tanks
- Valves
- Piping

Distribution system

- Pipelines, valves, and other appurtenances
- Pump or pressure-reducing stations
- Materials (extra pipe, valves, hydrants, etc.)

Electric power

- Substations
- Transmission lines
- Transformers
- Standby generators

Transportation

- Vehicles (including construction equipment)
- Maintenance facilities
- Supplies, spare parts, and fuel
- Roadway infrastructure

Communications

- Telephone
- Radio
- Telemetry
- Mass media outlets (such as newspaper, radio, and television)

The vulnerability assessment will be simplified if system components are described with as much detail as possible. System maps or geographic information system (GIS) files can assist with the process and should be included with the list. For widely dispersed components, such as the distribution system, a general description accompanied by a detailed map is adequate. Typical items included in a general description are pressure zones, location of pressure-relief valves, pipe sizes, pipe material and ages, typical distance between hydrants, and major valve locations.

A larger utility may have to divide its system into regions to perform an assessment with an adequate level of detail. The system-wide assessment should then include the combined regional analyses. The example vulnerability assessment at the end of this chapter will elaborate on this step.

Step 2: Determine the Effects of Probable Disaster Hazards on System Components

Disaster hazards can degrade the quality and/or quantity of potable water supplies. Each hazard has unique impacts on different components of the utility, and damage to one part of the system may or may not affect other parts of the utility. For example, a tornado would probably not rupture underground pipes but could destroy power sources necessary for continuous operation of the water system. A dam break and loss of reservoir water might not destroy pumping stations or disrupt the communications system but without a source of water the system could not continue to operate. A case study which describes the damage from Hurricane Hugo, is provided on page 23 (Buehrer 1989).

Disaster hazard-effects summary. The following sections summarize disaster hazard effects on system components.

Personnel shortages. The most critical water system component is trained operations personnel. Any disaster could potentially cause a shortage of employees through evacuation, death or injury, or because of personal situations. For example, during Hurricane Andrew, the homes of 268 Miami–Dade Water and Sewer Authority employees (15 percent of total staff) were destroyed or severely damaged. Despite the critical nature of their jobs, employees' first responsibility must be the safety and well-being of themselves and their families.

Along with hurricanes, earthquakes can produce widespread damage that can injure employees or prevent them from reaching their jobs. Similarly, a chlorine leak could disable all of a plant's operators. Depending on the disaster, all of a small utility's employees could conceivably be unavailable for work.

In addition to direct impacts on employees, a disaster may prevent employees from reporting to work because of damage to the transportation system. Roads can be blocked by fallen trees, downed power lines, collapsed structures, or loss of road surface. In the wake of Hurricane Andrew, large numbers of nails on the road produced an epidemic of flat tires. Compounding transportation woes, gasoline was also in short supply.

Communication systems are highly vulnerable and often disrupted during many disasters. Employees cannot contact their supervisors for work assignments and

Case Study: Charleston Utility Weathers Hugo's Devastation

"We were ready for it—as ready as we could have been—but you can't imagine the magnitude of the disaster here."

That was Steve Kinard's assessment of Hurricane Hugo's devastation and the readiness of the Charleston Commission of Public Works when the storm thrashed the South Carolina seaboard.

Kinard, commission manager, estimated utility damages may total $1 million: "I don't know what the final number will be. We're still counting."

Hugo hit Thursday night, September 21—30 years and 2 days since the last major hurricane, Gracie, pelted the Charleston coast.

John Cook, director of engineering for the commission, said, "We anticipated a power outage, but we didn't anticipate such ferocious winds. The winds stirred up the sedimentation basins so badly that filters in the treatment plant were severely clogged." The stoppage cut off the water supply at about 2 a.m. Friday, September 22, except for gravity-fed supplies. Utility personnel began cleaning filters, and water was restored to some areas by 11 a.m.

Service was then hampered by a tremendous drop in pressure caused by system interruptions when trees were uprooted and debris went flying. "There were broken service lines everywhere, damage to hydrants, and main breaks," Cook said. "A major 40-in. (1,000-mm) main had the end of it blown off."

Sprinkler systems released streams of water in buildings damaged by trees and debris. Demand on the system surged, and pressure dropped below operable levels. There were at least 1,500 service-line and main breaks.

Repair crews worked feverishly to fix breaks and turn off flows to renegade sprinklers. Cook said expedient repairs and a backflow-prevention system, which has been in place for about 10 years, enabled the utility to restore water service to most areas by Friday evening.

The utility's customer service department worked 24 hours a day for a week. Repair crews walked all the water lines in the streets and checked meters and readings of lines beneath rivers and in marshes for leaks and breaks.

The state Department of Health and Environmental Control issued a boil-water order Friday morning, triggered by the drop in pressure. Sampling began throughout the 450-mi^2 (1,200-km^2) system, but no contamination was found. The state rescinded the order by 5 p.m. Monday.

Inundated with repair orders, the utility also began receiving complaints about the water's taste and odor. The cause was finally traced to Hugo's devastation of South Carolina's forests.

The storm ravaged 60 to 80 percent of the pine trees. Phenols from the felled trees in the Charleston utility's watershed contaminated the groundwater, which flowed into the drainage basin and the treatment plant. Although the water was safe to drink, the contamination caused an objectionable odor and taste. Kinard recalled, "The smell was the talk of the town for several days."

Cook said the initial tests showed about 50–100 mg/L of phenols coming into the plant. "We tried several methods for removing the phenols, but we didn't find anything that did a good job. Toward the end of the week our jar tests revealed the phenols diminished to 30 mg/L. We concluded it was best to let the problem rectify itself, which it did."

Prior to the storm the objective of the commission's hurricane disaster-preparedness plan was to provide uninterrupted service. "We anticipated power outages and installed diesel-driven pumps and generators. We got fuel supplies and additional treatment chemicals, and set up a communications network," Kinard said.

A crew of about 200 staffed the treatment plant, customer service, and repair center. Food, cots, first-aid kits, chain saws, and other supplies were stockpiled at the plant.

The utility evacuated its downtown offices because of hurricane advisories and surge waves predicted in the storm's aftermath. Surge waves peaked at 12 ft (4 m), enough to wreak havoc on the utility's building and much of downtown.

Kinard described the magnitude of the disaster: "It's the worst. You can't imagine the destruction. Every house in Charleston (a city of 1.5 million) has some kind of damage."

Source: Buehrer 1989

supervisors cannot contact employees to determine their status. Thus, the simple lack of communications can cause employee shortages.

Contamination of water supplies. Disaster hazards can contaminate both raw and finished water supplies. In the broadest sense, contamination can be considered the addition at any point (watershed area, groundwater, surface reservoir, storage tank, or distribution system) of any material in concentrations that may produce a nuisance or harmful effects on the consumer or the system.

When rain falls on the watershed, some of the water will flow overland to the collection point; another portion of the rainfall will pond or soak into the ground. The sheet flow will pick up sediment and other substances, organic or inorganic, toxic or nontoxic. Excessive quantities of sediment entering a reservoir because of a watershed fire, flood, or landslide is contamination and may cause undue strain on treatment plant facilities. Many western US water utilities faced this vexing problem during widespread wildfires that occurred over spring and summer 2000.

The addition of toxic chemicals to a storage tank or reservoir also is considered contamination. Detecting such materials may require the use of special monitoring equipment and may result in the need to isolate a portion of the system. One of the most likely sources of contamination is an accidental spill of gasoline, oil, chemicals, or other hazardous materials. Debris or chemicals can also be scattered by high winds and contaminate water supplies. Finally, contamination can occur when treatment chemicals are added to the system in incorrect amounts.

Many disaster hazards cause numerous pipe breaks, which in turn reduce system pressure. Contamination can enter the distribution system through the breaks or through backflow. Likewise, wells can become contaminated if the sanitary seal or casing is broken.

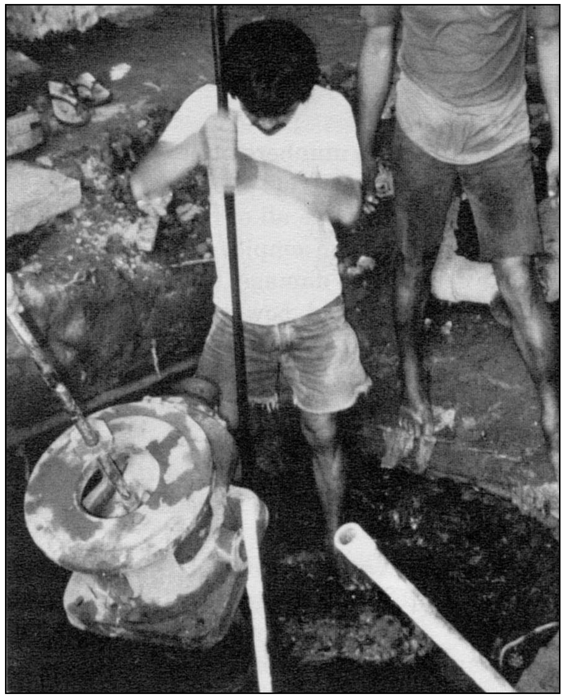
Contamination of air. Disaster hazards can also contaminate the air. A chlorine release is one of the most severe hazards and can be deadly. Air can be contaminated by other hazardous material releases including radioactive particles. The immediate effects of acute air contamination on water systems are personnel injuries and inaccessibility to system components. However, surface water sources can also be impacted by air contaminants.

Well and pump damage. Wells are among the many components susceptible to damage from earthquakes. Well casings can be bent by lateral spreading due to liquefaction (Figure 3-1), making pumps inoperable. Ground shaking can cause sanding problems, particularly in older wells with slotted casings. Connecting pipes can break due to relative movements. Pump or motor castings can shatter from shaking.

Flooding can produce similar problems such as bent casings, mud in casings, and damaged pumps or piping. Wells can be contaminated by sewage flowing from broken sewer lines or septic tanks.

Pipeline breaks and appurtenance damage. Pipeline breaks deplete supplies and lower system pressure. Widespread pipeline breaks are typical of earthquake damage. Earthquake hazard effects include failure due to

- Bending
- Shear
- Tension
- Compression
- Collapsed-structure impacts



Source: *D.B. Ballantyne.*

Figure 3-1 Well casing bent by lateral spreading during an earthquake in Daugpan, Philippines

Pipeline joints are particularly vulnerable because they are typically weaker than pipe. Appurtenances such as valves are vulnerable to the same hazards as pipe. Valves can become inoperable when bent.

Other hazards that can cause widespread breaks include severe freezing temperatures, structure damage due to hurricanes or tornadoes, uncontrolled water hammer, or pipes weakened by corrosion. Breaks in large transmission lines are particularly harmful to systems. Piping in structures is at risk when connections are rigid and differential settlement occurs (Figure 3-2).

Structure damage. Water system structures that are vulnerable to disaster hazards include dams, intake facilities, treatment plants, pump stations, administrative offices, storage tanks, vehicle storage buildings, and material warehouses. Hazards from earthquakes, floods, hurricanes, fires, transportation accidents, and intentional acts are particularly likely to damage structures. Both dams and storage tanks are highly vulnerable to earthquake hazards. Dam failures have been caused by liquefaction, internal soil piping, and overtopping. Storage tanks may suffer the following types of damage in earthquakes:

All tanks

- Foundation and soil failure
- Roof damage from sloshing
- Connecting pipe damage

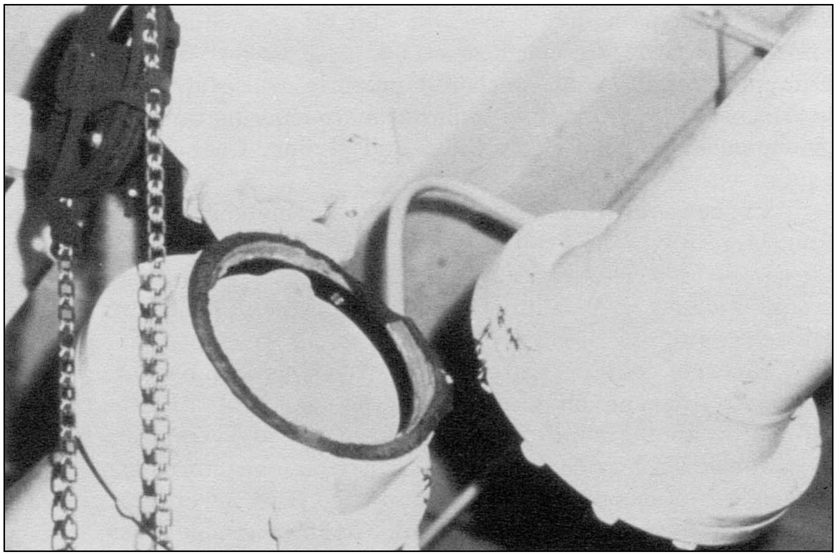


Figure 3-2 Broken pipeline in Olive View Hospital after 1971 San Fernando, Calif., earthquake

Wire-wrapped concrete tanks (prestressed or post-tensioned)

- Failure of corroded wire wrapping
- Wall/foundation separation (particularly in pre-1970s tanks)

Steel standpipes and ground storage tanks

- Sliding
- Elephant's-foot buckling
- Splitting bottom or wall seam

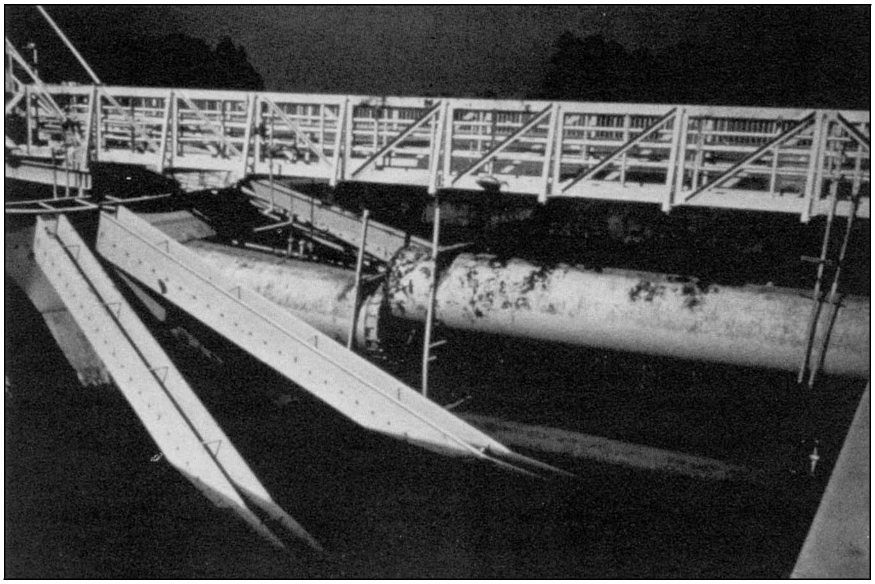
Elevated tanks

- Collapse of supports

Nonreinforced masonry and steel-frame buildings that have had structural members removed or weakened are particularly vulnerable to earthquake hazards. For earthquake, hurricane, and flooding hazards, proper roof–wall and wall–foundation connections are critical to structure survivability. Note that fires can cause reinforcement failure.

Equipment and material damage or loss. Water system equipment such as computers, tools, vehicles, and laboratory equipment can be destroyed, damaged, lost, or become inaccessible due to many disaster hazards. Materials such as chemicals, pipe, valves, and hydrants can also be damaged or lost due to other disaster hazards. Equipment that is not anchored properly will slide or fall in earthquakes and hurricanes. Chlorine tanks and containers, which can be damaged by toppling, rolling, and sliding, are also vulnerable to hazards.

Process tank or basin damage. Submerged elements and baffles can break from extreme hydraulic loading due to sloshing in earthquakes (Figures 3-3 and 3-4). Cast-in-place concrete tanks are susceptible to structural failure due to sloshing, ground shaking, soil failure, and structure flotation. High winds may also damage tank roofs (Figure 3-5).



Source: *D.B. Ballantyne.*

Figure 3-3 Flocculator/clarifier center mechanism damaged from sloshing water in Loma Prieta earthquake (Rinconada Water Treatment Plant, San Jose, Calif.)

Source: *D.B. Ballantyne*

Figure 3-4 Damaged clarifier plates after earthquake in Limon, Costa Rica

Source: Ray Sato.

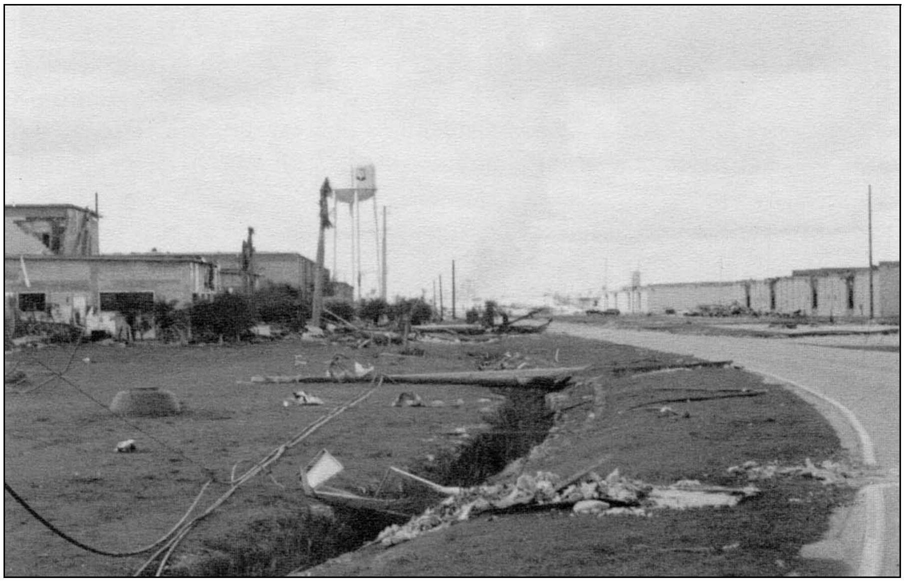
Figure 3-5 Tank damage in Hurricane Iniki, Kauai, Hawaii

Electric power outage. Many system components, such as pumps and computers, depend on electrical power to operate. Electrical power components, especially aboveground lines (Figure 3-6) and transformers (Figure 3-7), are particularly vulnerable to hurricanes, earthquakes, tornadoes, and floods. Voltage and phase fluctuations may damage motors. Downed power lines can create access problems.

Communications disruption. Communication failures fall into two categories: failure of automatic signal equipment and associated telemetry and failure of communications that link people, such as telephones and two-way radio. Mass media—television, radio, and newspapers—are also important communication channels, particularly for informing the public about a disaster. The communication system is particularly vulnerable to hurricanes, earthquakes, floods, and tornadoes. Disruption can be caused by physical damage or system overload (this includes cellular telephones as well). Usually, a telephone system fails before other communication systems, but there have been cases where radio communication failed but telephones remained operable. Communication systems usually depend on electric power to function and can be affected by power outages. Cable wire for telemetry systems will break in earthquake and other disaster hazards. During the 1989 Loma Prieta earthquake, cellular-to-cellular communication posed only a small problem (some cell sites lost power); however, communication between cellular and land-based systems was disrupted due to system overload.

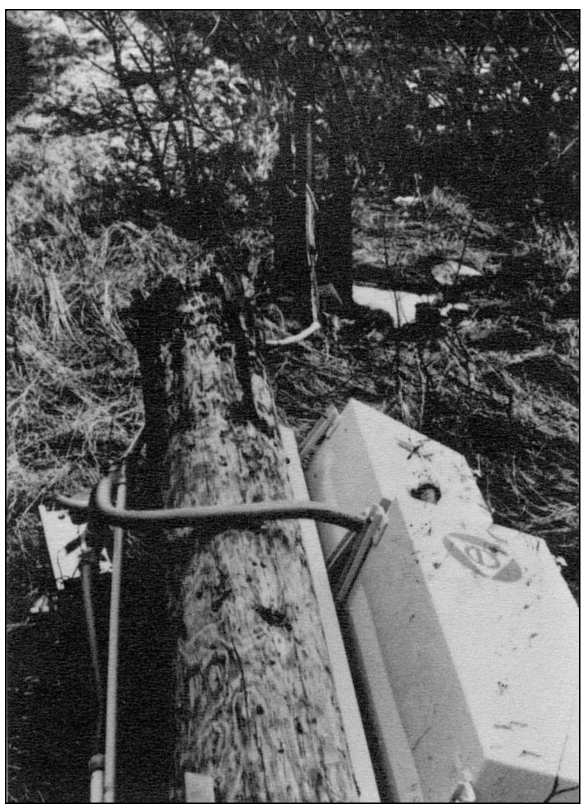
Real-time flow, pressure, and water quality sensors are essential in the recognition and remediation of emergency situations. For a complete discussion of sensors and telemetry, refer to *Instrumentation and Computer Integration of Water Utility Operations* (AWWARF and JWWA 1993) or AWWA Manual M2, *Instrumentation and Control.* Sensor information is also presented in chapter 4 of this manual.

Transportation failure. Transportation system failure can be expected during natural disasters due to washed-out roads (Figure 3-8), damaged or destroyed bridges, collapsed overpasses, or similar situations. Personnel, equipment, and material could be isolated after floods, hurricanes, or earthquakes. Vehicles can be damaged and fuel supplies lowered. During work stoppages or riots, access to water utility facilities may be curtailed or blocked.



Source: *Ghasson Al-Chaar.*

Figure 3-6 Downed power lines at Homestead Air Force Base, Fla., after Hurricane Andrew



Source: *Ray Sato.*

Figure 3-7 Downed pole-mounted transformer in Hurricane Iniki, Kauai, Hawaii

Source: D.K. Sander.

Figure 3-8 Road washed out in flooding in Washington State

Disaster hazard effects on system components. To complete step 2 of the vulnerability assessment, the effects of disaster hazards are evaluated for each component of the total system. This can be accomplished using a form for each type of disaster or a matrix of the hazard summary and effects on components. An example is shown in Figure 3-9.

Step 3: Establish Performance Goals and Acceptable Levels of Service for the System

A water system is considered a lifeline because water is essential to the safety and health of the population it serves. A utility should develop specific goals and acceptable levels of service under disaster and recovery conditions. The following are specific goals to consider.

Goals. *Life safety.* A water system's primary goal should be to preserve the health and safety of its personnel while providing sufficient quantities of safe, clean water to the public. Meeting this goal should be considered a continuous function of the system—before, during, and after a disaster. Examples of life-threatening or injury-causing conditions are

- Failure of distribution system
- Failure of dams
- Distribution of contaminated water
- Release of hazardous materials, especially chlorine
- Collapse of structures such as water towers

Fire suppression. Most fire suppression activities depend on the potable water distribution system. During disasters, particularly earthquakes, there may be an onslaught of fires that could severely tax the system. Water for fire suppression should be made available as soon as possible after a disaster.

System Components—Likely damage, loss, or shortage due to hazards	Earthquakes	Hurricanes	Tornados	Floods	Forest or Brush Fires	Volcanic Eruptions	Other Severe Weather	Waterborne Disease	Hazardous Material	Structure Fire	Construction Accidents	Transportation Accidents	Nuclear	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 PRV stations	■	■	■	■	■	■	■			■	■	■		■
Materials	■	■		■	■					■				■
Electric power														
Substations	■	■	■	■	■		■			■	■	■	■	■
Transmission lines	■	■	■	■	■		■			■	■	■		■
Transformers	■	■	■	■	■	■	■			■	■	■		■
Standby generators				■						■				■
Transportation														
Vehicles		■	■	■	■		■				■	■		
Maintenance facilities	■	■	■	■	■		■			■		■		■
Supplies		■		■	■					■				■
Roadway infrastructure	■			■		■	■				■	■		■
Communications														
Telephone	■	■	■	■	■		■			■	■	■		■
Two-way radio														■
Telemetry	■		■	■	■	■								■

Figure 3-9 Disaster effects matrix

Public health needs. Water is essential to life and health. However, some needs are more immediate than others. The following list details several public health needs and an allowable time span to be without potable water (note that times are guidelines only and depend on the magnitude of the disaster).

- Hospitals—continuous need
- Emergency shelters—immediate need
- Kidney dialysis—24 hours
- Personal hygiene, waste disposal—72 hours

Commercial and business uses. Many businesses depend directly on water for their operations, but nearly all business cannot function adequately without potable water for drinking, waste disposal, and cooling water for air conditioning and other process systems. Also, many commercial structures are protected with fire suppression systems that require an adequate supply of water.

Service priorities. Priority demand can be defined as the minimum quantity needed for health and safety. Establishing priorities for service is an important part of completing this step of the vulnerability analysis.

Most medical facilities need continuous service; contact them to determine approximate daily needs or estimate their needs from utility records. Other priorities should be police and fire departments and the emergency operations center. For medical facilities and other priority customers, utilities should maintain a record of a contact person or persons, their phone numbers, reasons for needing priority service, approximate daily needs, and an alternative water source if one is available. A sample form to record service priorities is found in chapter 5 (Figure 5-8). Priorities need to be periodically reviewed and updated.

Water requirements. Water requirements during disasters can be assumed or estimated only in terms of the nature and magnitude of the disaster, user needs, and the capabilities of the system itself. Although only approximate, a plot of the anticipated water demand under a specified set of circumstances could be developed. Figure 3-10 illustrates the normal fluctuation of water demand against time before a disaster, then shows the demand following a major earthquake. In this hypothetical case, it is assumed that a number of water lines and mains are broken, significant fire fighting is under way, and the reservoir supplies are being depleted rapidly. Assuming further that workers were unable to valve off broken mains and that the firefighting requirement continued, reservoirs would likely be emptied and the water supply system would not be able to supply the amount of water required to continue fire fighting under such emergency conditions. The priority need is also shown on the curve of Figure 3-10.

From a water supply viewpoint, the amount of available water has been sharply reduced and the system is unable to meet the requirements of the community (the supply is deficient). The demand for water would have to be met by importing water from other sources, such as tank trucks or by fire-pumper relay. Under the worst-case scenario, demand simply could not be met. Eventually, restoration of capability within the water utility would permit the production of adequate water supplies and, as the community recovered, this capability would continue to match the community's demand. This process could take considerable time.

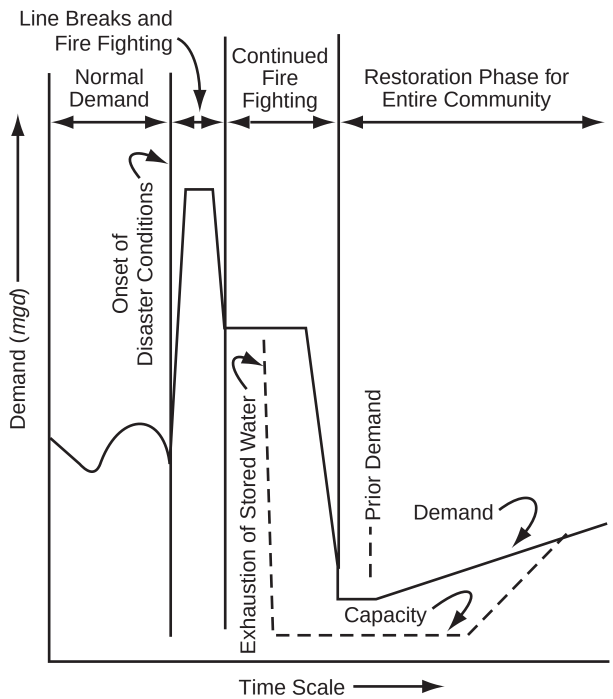


Figure 3-10 Water demand under normal and emergency conditions

Step 4: Identify Critical Components

With the first three steps complete, a utility has identified the most probable disaster-hazards effects on major components and has established service priorities and performance goals. Identifying the critical components of the system or its subcomponents (for example, a run of older cast-iron main could be considered a subcomponent of the distribution system) is the final step in the vulnerability analysis.

Critical components are those *most* vulnerable to failure or partial failure because of a disaster hazard. Failure of a critical component will reduce the system's ability to meet minimum health and safety performance goals. The best way to approach this step is to select a particular disaster scenario and then focus on those components whose failure would render the entire system inoperative—these are the most vulnerable components.

Repeated application of this process (e.g., assuming various disasters, constructing anticipated demand curves, determining measures required to meet minimum health and safety demands, and identifying critical components) eventually will isolate the most critical components in the entire water system. Predisaster protective measures should then focus on these components.

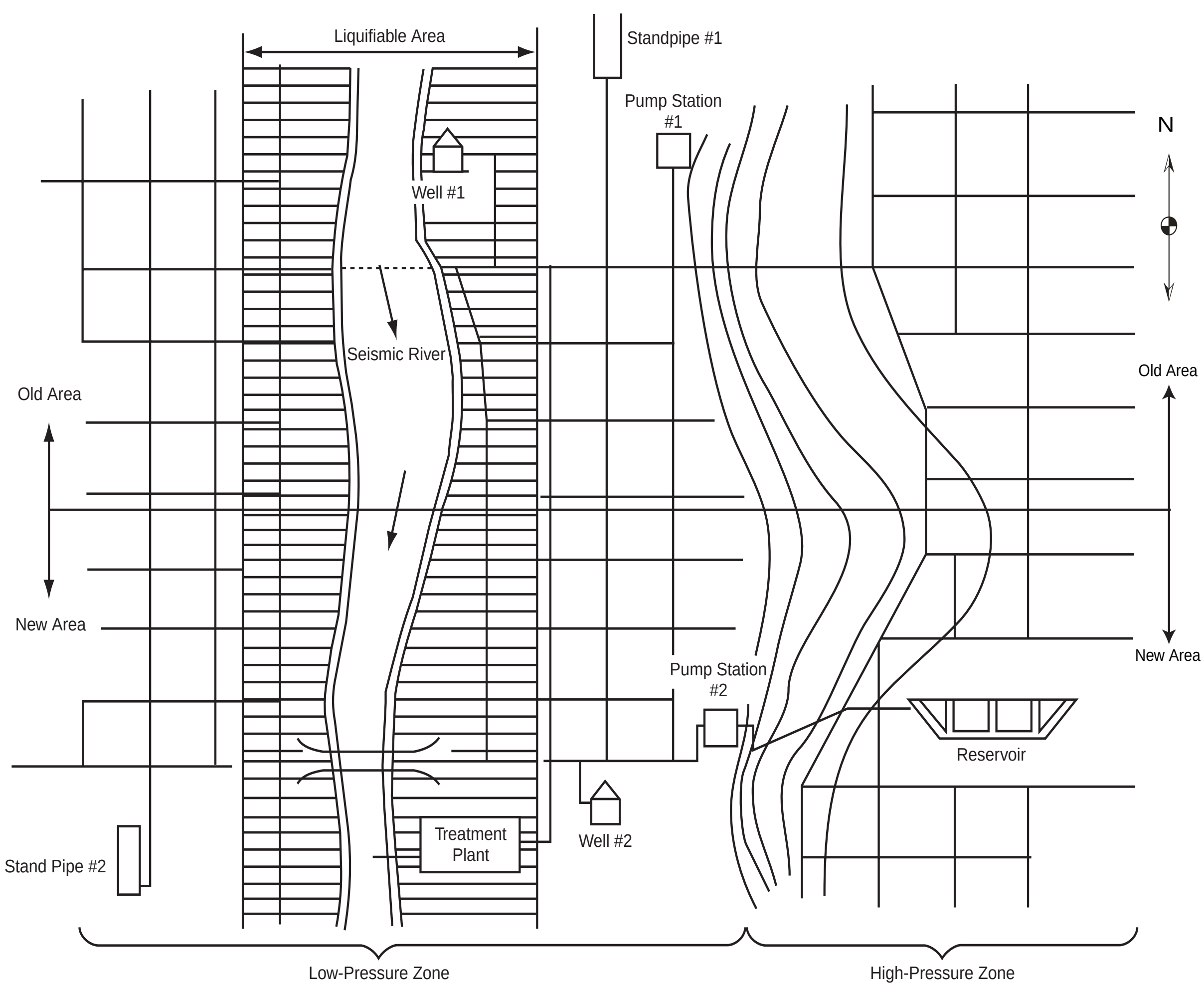
A computer model of the distribution system can be used to simulate disaster conditions. For example, the model can demonstrate the effects on water supply if a treatment plant or storage tank is off-line. Refer to AWWA Manual M32, *Distribution Network Analysis,* for more information on system models.

Example

The following is a brief example of a water system vulnerability analysis in an earthquake-prone region. Figure 3-11 is a schematic of a hypothetical system—Seismic City. This example was developed by the American Society of Civil Engineers Technical Council on Lifeline Earthquake Engineering Water and Sewerage Committee and the Seismic Risk Committee.

The following paragraphs demonstrate the first two steps of a vulnerability analysis: identifying the system components and the potential effects of earthquake hazards.

Water system description. Water is supplied primarily by the water treatment plant, which draws raw water from the Seismic River. Wells 1 and 2 are operated during peak demand periods in the summer. Standpipes 1 and 2 float on the low-pressure zone. Both pump stations 1 and 2 pump the water up to the high-pressure zone. The reservoir floats on the high-pressure system. Water is delivered to the west side of the Seismic River through two river crossings, one buried and one suspended from a bridge. The average daily system demand is 10 mgd (37.5 ML/d) and peaks at 18 mgd (67.5 ML/d) during the summer. The treatment plant has a capacity of 13 mgd (49 ML/d). Each well has a capacity of 4 mgd (15 ML/d).



Source: Kennedy/Jenks Consultants Engineers and Scientists (1993).

Figure 3-11 Schematic of Seismic City water system

Geologic setting. Seismic City is located in seismic zone 3. Until recently, a magnitude 7.2 earthquake 31 mi (50 km) from the city was considered to be the maximum credible seismic event. However, recent studies have indicated that a magnitude 8.5 earthquake centered 62 mi (100 km) to the west may occur. The Seismic River, which has meandered across a significant part of the valley through the years, has left alluvial deposits along its course. The soils nearer the valley walls and East Hill are of glacial origin and relatively stable.

System components

Well 1

- Constructed 1948
- Founded on liquefiable ground
- Building—unreinforced roof not anchored to walls
- Buried piping—cast iron
- Control cabinets unanchored
- Wall discharge piping—no lateral support or flexibility
- Engine-generator set (added 1975)

Well 2

- Constructed 1983
- Constructed on glacial till
- Building—reinforced masonry, roof anchored to walls
- Buried pipe—ductile iron and flexible coupling
- Electrical cabinets, equipment, and piping adequately supported
- No engine-generator set

Water Treatment Plant

- Constructed 1971
- Constructed on liquefiable material
- Structures—pile supported; yard piping, river intake—no pile support
- Uses reactor (flocculator) clarifiers
- Chlorine supplied in 1-ton (900-kg) containers (unanchored)

The equipment and piping have no special lateral support except for the engine-generator set provided for plant operation, raw-water pumping, and pumping to the system.

Pipelines

- Transmission/distribution in "old" area—constructed 1948
- Transmission/distribution in "new" area—constructed 1971+
- Buried river crossing—constructed 1948
- Bridge/bridge crossing, multispan concrete girder bridge—constructed 1973

Pump Station 1

- Constructed 1957
- Founded on glacial till
- Building—wood frame
- Buried pipe material unknown
- Piping designed to resist pressure at bends (thrust)
- Electrical cabinet anchorage unknown
- No engine-generator set

Pump Station 2

- Constructed 1971
- Founded on glacial till
- Building—masonry reinforcing, roof attachment
- Buried pipe material unknown
- Piping designed to resist pressure at bends (thrust)
- Electrical cabinet anchorage unknown
- No engine-generator set

Buried Reservoir

- Constructed 1961
- Soils in area competent, one side is fill embankment
- Concrete lined
- Concrete roof added 1978
- Access road constructed on unstable hillside

Standpipe 1

- Constructed 1948
- No anchorage
- Foundation appears to be concrete ring wall
- 90 ft (30 m) high, 60 ft (20 m) in diameter
- Outside rigid inlet–outlet pipe connection

Standpipe 2

- Constructed according to ANSI/AWWA D100, Standard for Welded Steel Tanks for Water Storage, using seismic conditions
- Anchorage
- 90 ft (30 m) high, 80 ft (27 m) in diameter
- Pipe connection through bottom, flexible

Probable effects from earthquake hazards. After describing the system components, the next step is to define the probable damage to the components.

Wells. Well 1 will probably be knocked out of operation. The well casing could be damaged through liquefaction. The structure was built before current seismic codes and is on liquefiable soil. The masonry is unreinforced, and the roof is not anchored to the walls. The cast-iron pipe buried in liquefiable soil would not survive. The control cabinets and wall discharge piping are not anchored or supported. The generator, although a good idea, may not be useful if the rest of the facility is damaged.

Well 2 should survive because its building is constructed of reinforced masonry, on good soil, with the roof anchored to the walls. The cabinets, equipment, and piping also are anchored.

Water treatment plant. The structure is founded on liquefiable soil but supported with piles. The structure, built in 1971, should undergo a detailed seismic analysis. The 1-ton (900-kg) chlorine containers are unanchored and will probably roll or topple. The flocculator clarifiers may be damaged by sloshing. The yard piping and river intake will probably fail by ground shaking and liquefaction. Also, equipment and plant piping may be damaged because no lateral support is provided. Standby power is provided.

In summary, the treatment plant structure should survive but would probably be off-line because of damage to the intake, piping, and other equipment. Other problems could be sediment and increased turbidity in Seismic River and the failure of the bridge upstream of the intake, which could damage the intake.

Pipelines. Pipe in the "old" area is mostly cast iron, which could fail in liquefiable soils. Pipe in the "new" area is ductile iron, which may have a somewhat better survival rate if the joints are properly restrained in liquefiable areas. Both the river crossing and the bridge crossing should be assumed to be cut. Contact the owner of the bridge to determine its vulnerability. Also check abutment penetration.

Pump stations. Both pump stations would probably survive, assuming the wood frame structure of pump station 1 is anchored to the foundation. The materials of the buried pipes should be checked, and electric cabinets inspected for proper anchors. The pump stations are vulnerable to power outages if no standby generators are available.

Buried reservoir. Damage to the reservoir probably would result from sloshing on the roof columns and roof. The geotechnical stability of the fill embankment should be evaluated. The access road will most likely be blocked or undermined by a landslide of the unstable hill.

Standpipes. Standpipe 1 will undoubtedly fail for many reasons. Without anchorage, the height-to-diameter ratio is too great (more than 1.5). The foundation does not appear to be adequate and the rigid pipe connections would also fail. Standpipe 2 should survive, as it was constructed according to ANSI/AWWA D100.

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Chapter 4

Mitigation Actions

Vulnerable components identified in the previous chapter can be rendered less susceptible to harm through mitigation actions—actions intended to eliminate or reduce the damaging effects of disasters. Mitigation actions cover a wide variety of activities and can be as complex as retrofitting a treatment plant or as simple as strapping down a chlorine tank or storing enough spare tires.

Before implementing any mitigation actions, ask the following questions:

- How critical is the component to the system?
- What is the age of the component?
- What are present and projected expansion, replacement, or construction programs?
- What is the cost of the mitigation action?

MITIGATION MEASURES FOR SYSTEM COMPONENTS

In the first portion of this chapter mitigation measures for the most probable disaster effects are presented for each category of system components.

Personnel

For any water utility, the key system component is personnel. Personnel safety should be the utility's first responsibility. There are four ways to help mitigate personnel shortages: (1) education, (2) cross-training, (3) replacement, and (4) assuring a safe workplace. Training and practice based on a completed emergency preparedness plan are covered in chapter 6.

Education. Education is the first step in assuring employee safety or, more precisely, minimizing casualties during an emergency. Employees should review the outcome of the first steps of the emergency planning process—the hazard summary and vulnerability analysis. Management and staff must both understand that personnel safety is the first concern in a disaster. Risking their own well-being during an emergency is never a prudent course of action. For example, there have been incidents when improperly protected workers have attempted to rescue a co-worker overcome by a chlorine leak, only to be overcome themselves.

Education for both staff and management is a continuous process. Seek employee input when determining mitigation actions; they are most familiar with system components and processes.

Extend education beyond the workplace as well. Teach employees what to do at home in case of a disaster. Family safety plans help assure quicker return of off-duty employees.

Cross-training. Many critical system components are operated or maintained by only one or two key people. Periodic employee cross-training can assure backup capability for critical tasks or processes. Another example of cross-training would be to prepare administrative or laboratory personnel to assist field crews during an emergency.

Replacement. Often a mutual aid agreement with other utilities can be established to supply replacement personnel. Participating utilities must provide mutual aid partners with a detailed description of the system and its operations as well as a copy of the emergency plan. Joint training exercises should be considered.

Private contractors are another source of replacement personnel. Establish contractual agreements during the planning process. Include hourly rates and specify the types of services they are able to provide. Be sure to provide the contractor with a copy of the emergency plan. The agreements will need to be updated regularly to account for changes in services and rates and modifications to emergency plans.

Personnel support. One key mitigation measure that is often overlooked is simple support of personnel during emergency responses. Such support includes food, drinking water, first aid and medical care, sleeping facilities, and sanitary facilities.

Establish contractual arrangements with a local food catering service. While such an arrangement may not be effective during an area-wide disaster (e.g., an earthquake), it may prove useful during more limited emergencies. Provide stocks of emergency rations (such as military "MREs," or meals-ready-to-eat) and drinking water; replace or replenish these stocks periodically.

Similarly, a well-prepared water utility should contact local vendors for portable toilet/sanitary and shower facilities.

A store of emergency blankets and miscellaneous sundries (e.g., snack foods, soap, dental needs, and over the counter medicines [aspirin, antidiarrheals, etc.]) should also be maintained.

A safe workplace. Utilities need to provide a workplace that is safe for employees during normal operations and as safe as possible in emergencies. This includes meeting applicable USEPA and OSHA regulations and other federal, state or provincial, and local regulations. Specific measures and regulatory programs are discussed in chapters 5 and 6.

Source Water and Transmission

Mitigation measures relating to source water and transmission range from providing alternate sources and protecting wellheads to retrofitting dams or aqueducts. The following section provides mitigation actions for surface water and groundwater sources.

Surface water sources. The components of surface water sources include watersheds, surface sources (such as rivers), reservoirs, and dams.

Large-scale watershed damage from hurricanes, landslides, fires, flooding, or volcanic eruptions is difficult to mitigate. For example, stabilizing slopes vulnerable to landslides could be a Herculean task, and the effort might actually damage the watershed, especially if vegetation is disturbed. The consensus opinion is that watersheds are best left undisturbed. However, these critical areas should be monitored to determine whether conditions exist that could contribute to or exacerbate disaster hazards. Such conditions include illegal dumps, a buildup of combustible material, hazardous material spills, and construction activities that cause erosion. Determine which agency is responsible for fire suppression in the watershed area and coordinate a fire suppression plan. Such a plan should include initial fire notification, discussion on the use of fire retardants, and similar actions.

Mitigation actions for watershed damage or widespread contamination include providing automated monitoring equipment, using alternate sources or intakes, and modified source water treatment at the plant (e.g., additional settling basin capability). Mitigation of smaller-scale watershed or surface water source contamination from hazardous material spills is best handled by an effective emergency spill response plan. This type of plan is discussed in chapter 5. Elements of the plan include notification, containment, and cleanup.

The effects of disaster hazards on open reservoirs can be mitigated by controlling access, identifying alternate sources, providing alternate intake locations, and providing flexible treatment facilities. Access can be controlled by installing fences, gates, and signs; closing unnecessary roads; and increasing security patrols.

Dams must be closely scrutinized because of the potential damage and loss of life posed by failure. Retrofit measures include raising the dam's height to accommodate higher design floods and seiches, increasing spillway capacity to provide for design floods, and improving structural strength to withstand seismic forces. As an example, in 1988 the Bear Valley Dam (Southern California) was converted from a concrete multiple-arch dam to a gravity dam. Earlier studies revealed that an arch dam could be overstressed by seismic design loads for the area. During the 1992 Landers/Big Bear earthquakes (7.2 and 6.7 on the Richter scale), the retrofitted structure survived 15 seconds of horizontal forces that were greater than half the structure's weight (Denning 1993). Another example is the East Bay Municipal Utility District's (California) rehabilitation of earthquake-prone hydraulic fill dams during the 1970s.

Intake structure damage can be mitigated by providing temporary bypass pumps, having filtration materials (boom floats, screens, etc.) on hand, providing multiple intakes, strengthening the structures to resist wind or earthquake hazards, and assuring that access to the structures is available by alternate means, such as boats. Valves or other methods to drain or shut off flow to the system should be redundant (i.e., failure of any one component will not put the entire facility out of service), hazard-resistant, and properly maintained.

One important alternate source of emergency water supplies is an interconnection with an adjacent water system. For more information, refer to the section on mitigating disaster effects on distribution components later in this chapter.

Groundwater and wells. Methods of mitigating groundwater contamination include identifying alternate water sources, providing shutoff valves, maintaining adequate setbacks from sewage pipes and disposal systems, and installing wellhead protection and well seals. A spill response plan and hazardous waste disposal plan are also recommended to mitigate groundwater contamination. Note that, although earthquakes can produce changes in hydrogeology, deeper aquifers are less susceptible to this problem.

Many natural-disaster hazards can cause power outages to the well pumps (and other system components). Water utilities should request that electric power to well pumps receive a high priority for service and provide appropriate information to their electric utility. Equipping pump stations with backup electrical power generators and adequate fuel is also a prudent mitigation measure. Refer to the following section on treatment for additional electric power mitigation actions.

Mitigation actions for the pump station structure and equipment are the same for similar system components such as treatment plants. These actions are discussed in the section on treatment, which follows.

Wells are vulnerable to earthquake hazards. Mitigation actions can be applied to the following subcomponents:

Casing. Wells should not be installed in liquefiable soils or soils subject to lateral spreading that could bend the casing. If such soils are unavoidable, mitigation actions might include the following:

- Stabilize the liquefiable layer
- Use double well casing
- Use a submersible pump (straight drive shaft not required)

Well screens and slotted casing. Provide a good-quality well screen to avoid sanding problems with slotted casings.

Connecting pipes. Provide flexible piping to mitigate settlement or relative movement hazards.

Well pump materials. To prevent pump and motor castings from breaking during ground shaking, use ductile-iron or steel castings.

Electric power. Anchor transformers, controls, and standby generators.

Treatment

Treatment facilities contain a number of highly complex components that are critical to system operation. During the design phase of water treatment facilities a redundant component philosophy should be employed.

Under a worst-case scenario the treatment plant will be off-line. In fact, in some cases it may be necessary to isolate the facility from the system, as in cases of contamination at the plant itself. Confirm that isolation valves are installed and their locations well marked. Mitigation for the off-line scenario includes providing alternate treatment, such as increasing production in another facility in the system or identifying alternate sources of treated water from adjacent systems. Another measure is to provide a bypass with disinfection capability.

Treatment facilities should generally be fire resistant and all appropriate fire prevention measures should be implemented. Contact the local fire department for support and request regular facility inspections.

Treatment facilities are often located near flood plains or in flood-prone areas. Facility design should include a hydrologic and hydraulic analysis.

Mitigation of potential hazards effects for treatment components is discussed in the following sections. Additionally, refer to the AWWA publication *Water Treatment Plant Design* (see bibliography) for a detailed discussion of the behavior and design of treatment plants subject to earthquake hazards.

Facility structures. Treatment plant structures and other water system structures, such as pump stations, are often single-story, symmetrical, shear-wall buildings that perform well in earthquakes, high winds, and other disasters. Design considerations and mitigation actions include the following:

Earthquake

- Use reinforced masonry and other hazard-resistant construction
- Avoid liquefiable soils for structure foundations
- Avoid using dissimilar foundation types when adding onto a structure

Earthquake and wind

- Make sure roof and wall connections and roof and foundation connections are adequate
- Correct modifications that may have weakened structures such as removed bracing or bearing walls cut for doors

Vandalism

- Install adequate locks, window security, and lighting
- Install intrusion-prevention devices, such as electronic keys, identification-card checkers, 10-key code units, joint 10-card/10-key checkers, and noncontact-type identification-card checkers to control access to the strategic facilities of the system (AWWARF and JWWA 1993)
- Install situation display monitors that consist of closed circuit television systems with high-sensitivity image pickup tubes, including camera and sound collectors, as well as alarm systems with ultrasonic, heat, or beam sensors and magnetic switches to detect intruders (AWWARF and JWWA 1993)

Electrical power and instrumentation. Standby power should be available for such critical components as pumps and controls. Establishing a duplicate power supply from a separate power distribution point following different routing is one method. Specific mitigation actions for electrical power and instrumentation components and backup power include the following:

Transformers. Anchor ground level units to foundation pads and protect from flooding. Securely anchor pole-mounted transformers to the pole and assure that the pole is secure in the ground. Transformer aerial conductors must be protected from swinging shorts in earthquakes and high winds.

Emergency generators. Depending on expected seismic acceleration, generators may be anchored directly to the floor or anchored via snubbers on vibration-isolated bases. Figure 4-1 shows a collapsed spring vibration isolator. Store (and maintain) portable generators at various locations throughout the distribution system to avoid a complete loss of standby power. All emergency generators must be regularly inspected and tested under load. Assure that all emergency generators have sufficient fuel, appropriate cooling, fully charged starting batteries, and secure exhaust routing.

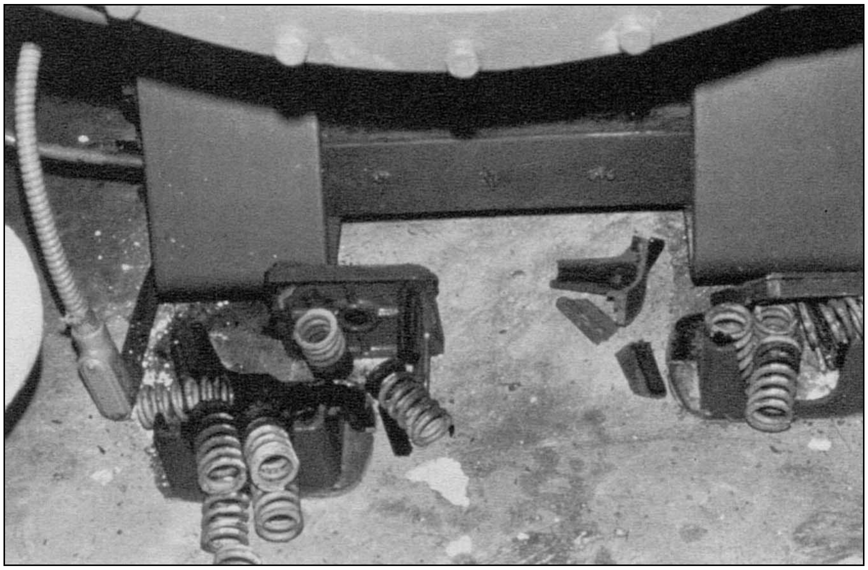
Electrical cabinets. Anchor electrical cabinets to the floor and restrain the top of the cabinet using angle clips or other secured structural element.

Motors. Provide automatic shutdown capability to avoid voltage or phase fluctuation that may cause damage.

Batteries. Batteries for backup instrumentation power or starting generators should be firmly anchored to prevent toppling. They should be raised off the floor to prevent potential water damage. Inspect and service all batteries at regular intervals.

Telemetry. A radio system with adequate backup power can provide a replacement for broken cables or downed phone lines. Provide lightning-strike protection if needed.

Computers. Larger computers located on top of a special computer floor can be base isolated to prevent damage from a floor collapse. Also, the floor can be strengthened to resist seismic forces. Desktop computers should be secured to desks with commercially available restraints. Be sure to back up computer files and store them at separate locations.



Source: D.B. Ballantyne.

Figure 4-1 Collapsed spring-vibration isolator supporting emergency generator, Whittier, Calif.

The effects of computer failure can be minimized by providing the following elements:

- Off-site backup for the computer system
- A preventive maintenance program for hardware
- An uninterruptible computer power supply
- Adequate computer room security
- Compatible computer hardware components
- Written procedures for testing software and operational problems
- Adequate training for programmers
- Control of operating files and documentation by data processing personnel
- Virus prevention
- Adequate system and network security
- Lightning strike protection
- Anchored, suspended ceilings

Equipment, Chemical Storage, and Piping

Most equipment and chemical storage containers in a treatment plant will become damaged from sliding and toppling. Simply anchoring or restraining equipment and containers can prevent much of the damage. Equipment supported on legs should have angle braces installed on the legs for additional strength. Waterproof plastic sheeting should be stockpiled in case equipment or chemicals become exposed to the elements. An adequate supply of critical spare parts and tools should be maintained, in a number of secure storage locations if possible.

Piping damage due to sliding or toppling equipment can also be reduced by anchoring. Providing flexible connections can reduce piping damage as well. Some specific subcomponents and mitigation actions are described below.

Chlorine and chemical containers. Chlorine cylinders (150-lb [70-kg]) should be stored in the vertical position and restrained at the top and bottom. One-ton (1,000-kg) containers should be stored horizontally and secured in cradles or anchored with chain binders or nylon straps. Check with tank and container manufacturers (or the Chlorine Institute, see bibliography) for the proper method of restraint. Figure 4-2 shows temporary restraint used after the 1991 Costa Rica earthquake.

Chlorine systems can be designed and constructed with numerous automatic control systems. Such systems can indicate the extent and location of a leak, actuate chlorine scrubbers, close valves, shut down equipment, and isolate affected areas. Consider using sodium hypochlorite as an alternative to chlorine.

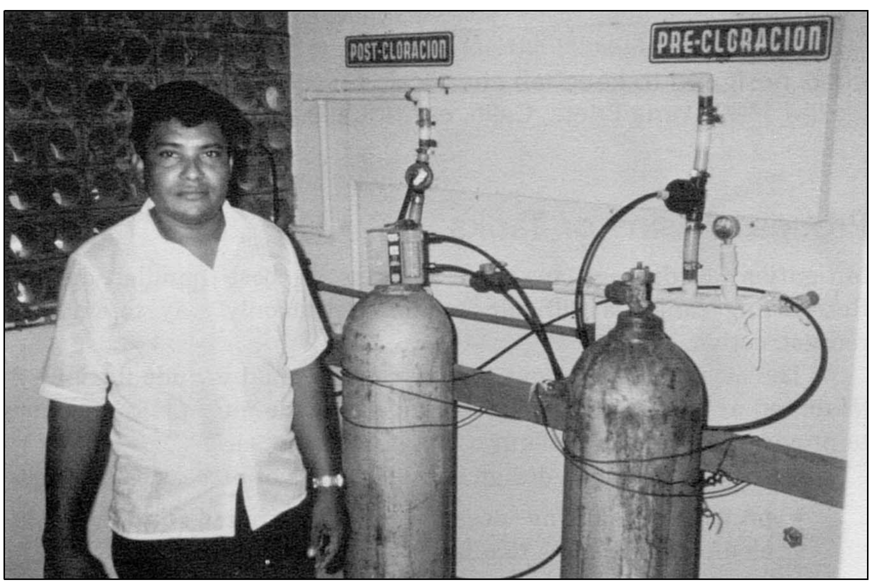
Buried tanks. Tanks subject to sinking or floating in liquefiable soils or during flooding can be restrained to reduce damage. Soils can also be stabilized.

Piping supported on rods from ceilings. To resist damage from swinging, support piping in three directions at right angles. Do the same for chlorine tubing.

Pipe appurtenances. Appurtenances such as valves rising vertically from pipe can act as pendulums that amplify ground motion. These should be appropriately anchored.

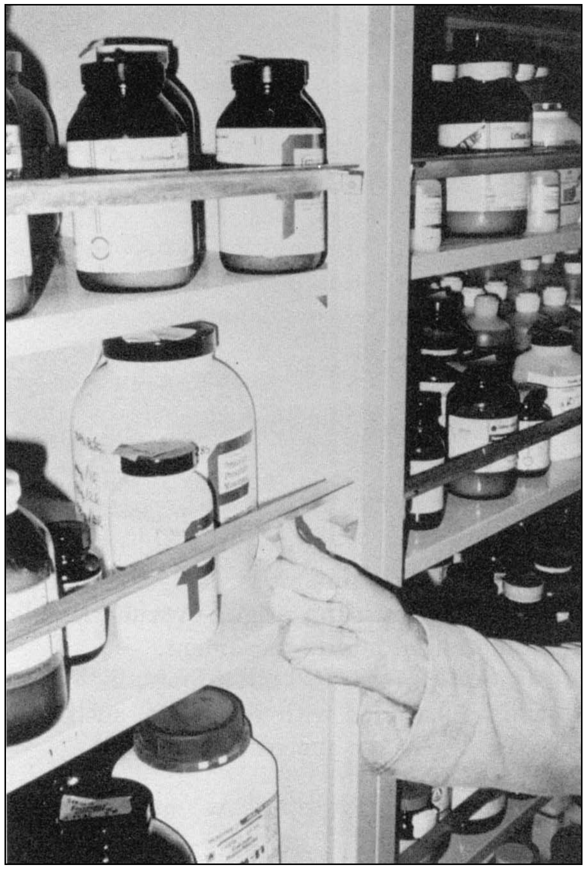
Buried piping at building edge. Provide flexible connections for differential settlement and differential lateral movement.

Laboratory equipment and chemicals. Laboratory equipment and chemicals stored on shelves should be provided with restraints such as shallow curbs or a bar installed across the face of the shelves (Figure 4-3).



Source: *D.B. Ballantyne.*

Figure 4-2 Chlorine cylinders at a Costa Rican water treatment plant were replaced and temporarily restrained after connections were broken when the cylinders toppled during an earthquake



Source: D.B. Ballantyne.

Figure 4-3 Brackets designed to keep lab chemicals on shelf, Rinconada water treatment plant. Photo taken after the Loma Prieta, Calif., earthquake

Process Basins or Tanks

Mitigating damage to process tanks is best handled during the design phase. Retrofitting tanks is difficult and often involves substantial and expensive reconstruction.

The design of treatment facility tanks should include flexibility and redundancy. For example, provide multiple connections between tanks to provide alternative piping configurations for tanks in series.

Specific earthquake design considerations for process tanks include the following:

- Provide breakaway design or other appropriate methods for submerged elements or baffles to allow easy replacement
- Use appropriate codes and design methods for concrete tanks
- Perform a geotechnical investigation, stabilize the soil as necessary, and use the appropriate foundation
- Design with neutral buoyancy, keep the tank full, or use piles to hold the tank in place

Storage Tanks

As with process basins, the best time to implement disaster mitigation features for storage tanks is during the design stage. Refer to such tank standards as ANSI/AWWA D100 and ANSI/AWWA D110. Design considerations include the following:

- Use appropriate design values for earthquake, wind, and other live loads
- Perform geotechnical, geologic, and seismological studies to evaluate foundation designs
- Provide adequate freeboard baffling and strength against sloshing
- Provide correctly positioned isolation valves
- Allow pipe flexibility
- Make provisions for security, such as fences, gates, lighting, alarms, and locked valves and hatches
- Ensure access is available in case of flooding or other disaster hazards

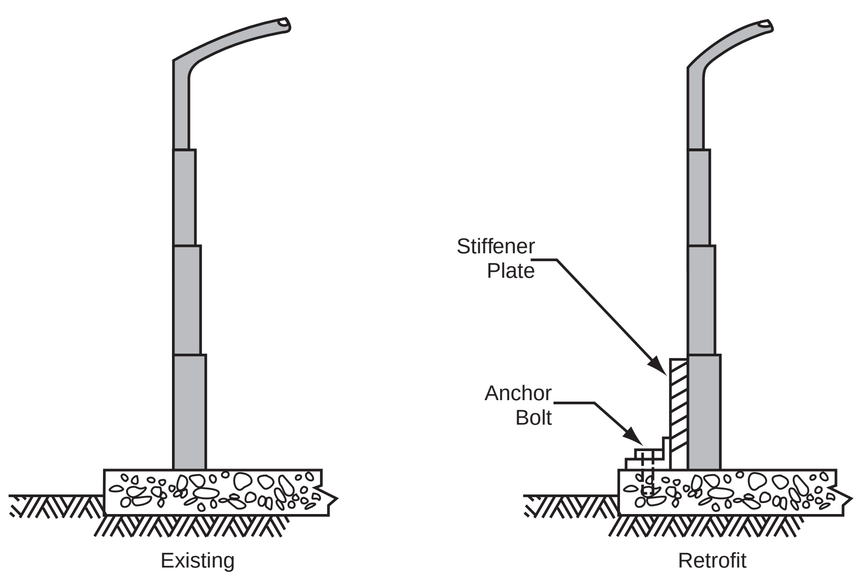
Existing tanks should be evaluated for structural soundness and performance during disasters. Specific mitigation actions for existing tanks of various types include those listed below.

Wire-wrapped concrete tanks. Check for vertical-cracking delamination and water corrosion staining on the outside of the tank. Check for installation of seismic cables.

Steel standpipes and ground storage tanks. Install or upgrade anchors or stiffeners (Figure 4-4). Upgrade the foundation if inadequate. Check the capability of walls to handle additional stress.

Horizontal tanks. Upgrade support to carry loads in three directions at right angles.

Elevated steel tanks. Upgrade with additional foundation strength, base isolation, and lateral support. Upgrade the steel structures and allow the bracing to yield before a connection failure.



Source: American Society of Civil Engeineers, Technical Council on Lifeline Earthquake Engineering 1983.

Figure 4-4 Mitigation option for water storage tanks

Distribution System

Owing to their large numbers and widespread dispersal, mitigating disaster effects on distribution system components can be difficult. One key to assessing or locating any impacts to the system will be accurate and up-to-date system plans, which should be maintained in a number of locations.

Mitigation measures for pumping stations were discussed in the source water and transmission section. Computers may be useful for gathering and managing regional network information to determine problem areas and damage. They can also be effective in monitoring and controlling emergency control systems and maintaining equipment and supply inventories. The case study included here presents an example of how such a system works.

Case Study: OP/NET Control System

On Oct. 17, 1989, the service area of California's East Bay Municipal Utilities District (EBMUD) was hit by an earthquake measuring 7.1 on the Richter scale. The EBMUD system has over 300 facilities, including hydroelectric stations, treatment plants, rate-control valves, pumping stations, reservoirs, and 3,700 mi (5,954 km) of pipeline network controlled by a distributed control system (OP/NET).

The OP/NET control system is set up so that each facility has a remote terminal unit (RTU), which monitors local conditions, provides local control, and transmits data to an area control center (ACC). These ACCs, in turn, provide local logic for control of all operating facilities in the area as well as a communication system to transmit all information from the ACCs to the central Oakland, Calif., control center (OCC). At the OCC, the information from each ACC is centralized and the entire system is operated 24 hours a day.

Damage from the earthquake to facilities totaled $3.7 million. The earthquake resulted in about 200 main breaks, mostly 4–12 in. (102–305 mm) in diameter, with only two serious main breaks. Aqueduct damage was sustained by one 60-in. (1,524-mm) diameter line. Structural damage was sustained by the new headquarters building.

Power was lost in the central control center and control shifted to the five ACCs until backup power was brought on.

The actual benefits the OP/NET provided during the Oct. 17, 1989, earthquake included the following:

- immediate identification of problems as they occurred
- expedited assessment of priorities by knowing where problems were
- maintenance of customer service without interruption or contamination, even though about 200 main breaks occurred
- documentation of the earthquake event showing how each communication line, electric power connection, hydraulic surge, reservoir level, and other monitors reacted to the earth movement at the over 300 facilities

Earthquake design principles included the following:

- equipment tie-down
- battery backup and emergency generators at the ACCs and the OCC; batteries at all facilities to keep the RTUs and instruments powered
- fire protection
- redundant computers to ensure over 99.9 percent uptime
- distribution control

Source: Adapted from Instrumentation and Computer Integration of Water Utility Operations, *1993. Originally excerpted from Way, Jacobs, and Browne 1989; and Gilbert, Dawson, and Linville 1989.*

Pipelines, valves, and other appurtenances. Methods of design and types of material can mitigate disaster effects on these essential distribution system components.

Pipeline design, construction, and upgrading. As with other distribution system components, mitigating hazards for these devices is best accomplished during the design and construction phase. Refer to the appropriate AWWA pipe standard for guidance. Some general considerations include:

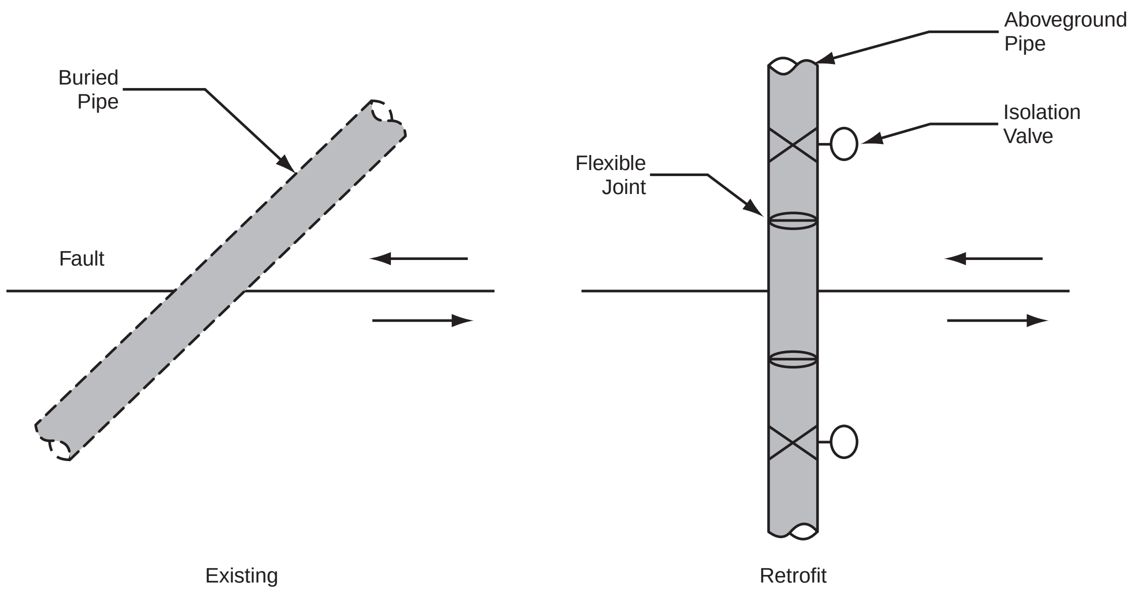
- Use the most current pipe material available (pipe materials are continually being improved)
- Avoid installing pipe in liquefiable soils and areas prone to flooding and landslides
- Use pipe materials suitable for the soil conditions and expected hazard
- Route pipelines at right angles when crossing known faults
- Use flexible expansion joints at fault crossings and where soils change to liquefiable soils
- Use compressible backfill material and shallow cover when crossing known faults to permit pipe/soil movement
- Stabilize soils with vibroflotation, stone columns, grouting, compaction, or other methods
- Use pile supports where required
- Provide operational flexibility and redundancy
- Build in emergency response capability, such as isolation valves, check valves, and automatic shutoff valves
- Maintain a rigorous cross-connection control program

Upgrading existing pipelines should begin with the critical segments identified in the vulnerability assessment. When upgrading pipeline segments, use the design considerations listed above for new pipelines. See Figure 4-5 for an example of a damage-mitigation procedure.

Performance of pipe materials. The performance of pipeline materials and joint types during earthquakes has been documented in many studies. The following summarizes some key results of these studies.

In general, steel, ductile-iron, and polyethylene pipe tend to successfully accommodate more ground deformation than cast-iron or asbestos–cement pipe. Restrained joints provide continuity to pipelines and can withstand moderate ground movement. Bell-and-spigot-style joints allow flexibility but can easily be pulled apart.

High-performance pipelines, such as electric-arc welded steel, restrained joint segmented steel, polyethylene, or restrained joint ductile-iron, can accommodate permanent ground deformation up to approximately 20 in. (500 mm). Average- to high-strength materials, such as restrained joint PVC or restrained joint concrete cylinder pipe, can handle approximately 4 in. (100 mm) of permanent ground deformation. Average-strength pipelines, such as unrestrained joint ductile-iron, PVC, concrete cylinder, reinforced concrete, cement, asbestos–cement, and segmented steel pipe, can accommodate ground deformation of less than 1.5 in. (40 mm) or up to the bell-and-spigot insertion length allowance. Average- to low-strength pipelines (tolerating less than 0.75 in. [20 mm] of ground deformation) include cast iron, vitrified clay, unreinforced concrete, and gas welded steel. Low-strength (less than



Source: American Society of Civil Engineers, Technical Council on Lifeline Earthquake Engineering.

Figure 4-5 Mitigation options for pipelines at fault crossings

0.4 in. [10 mm] tolerance) pipelines include cast iron or vitrified clay with mortared or leaded joints.

Valves and other appurtenances. Provide positive flexible connections to reduce earthquake effects. A proactive preventive maintenance program for all valves and other appurtenances is also a critical element in any mitigation program. Such a program should include identifying critical valves, locating them in the field, and establishing locating reference points. Valve inspection and repair should be conducted regularly.

Repair. Quick repair of broken mains and service lines is crucial during emergencies. Maintain adequate stockpiles of such materials as repair clamps, sleeves, pipe, and valves. This is especially important for materials that have long delivery lead times. All materials should be stored properly and protected from disaster hazards. Utilities should also maintain and have ready access to miscellaneous hand tools and debris-removal equipment.

System Control

Implement reliable system monitoring and control systems. The monitoring system should gather information on pressures and flows. The control system should allow isolation of areas damaged in earthquakes.

Interagency Connections

An interagency distribution system connection is a physical connection between water sources operated by adjacent water agencies (Boyle 1980). A typical interconnection consists of valves and a meter emplaced in a simple in-ground vault or aboveground pump house. If the two water systems operate at significantly different pressures, a pump or regulator will be needed at the interconnection to accommodate the pressure differential. A written agreement between agencies should specify the conditions of use, necessary notifications before use, construction and maintenance responsibilities, and operational procedures. Raw water transfer between agencies may also be considered.

Administration, Transportation, and Communication

Administration facilities, equipment, and records are vital to the operation of a water system. Structures that house administrative functions should meet applicable building codes or should be retrofitted to meet minimum disaster needs. This will not only protect the structures, equipment, and records located inside, but will help protect personnel as well.

Many of the specific recommendations for mitigating disaster effects found in the earlier discussion of treatment facilities can also apply to administration facilities. It is crucial to maintain backup copies of customer information, system maps and records, and the emergency plan at secondary locations. General facility and computer system (including control systems) security must be maintained.

Damage to the transportation system, including roadways and vehicles, can occur in many disasters. Mitigation actions include identifying alternative methods of access to system facilities, confirming that vehicle storage structures are disaster-resistant and have auxiliary power (Figure 4-6), and maintaining adequate supplies of fuel and spare parts.

Communication disruptions due to phone and electric outages are difficult to mitigate. The most common alternative is to communicate by two-way radio. Be sure to have enough radios and batteries. Mitigating effects on telemetry were discussed in the earlier section on treatment. Communication lines need to be open to other lifeline agencies and the mass media. Consider contacting amateur radio groups to provide emergency communications.

COSTS AND SCHEDULING

After the 1989 Loma Prieta earthquake, Kocher (1990) stated "the first lesson that we learned early was that when doing emergency planning, consider the worst thing that could occur and decide whether or not you can afford to protect against it."

As suggested, mitigation actions should begin with the identification of critical components vulnerable to probable disaster hazards. The costs of the actions can be justified by comparing them to estimated losses that would result from the given disaster. Of course, expensive projects such as retrofitting structures may take several years to complete. Lower cost mitigation actions for less critical components should be completed as soon as possible.

Source: Ray Sato.

Figure 4-6 Truck crane damage in Hurricane Iniki, Kauai, Hawaii

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Chapter 5

Developing the Preparedness Plan

INTRODUCTION

The preceding chapters of this manual described hazards associated with various disasters, the effects of hazards on system components, and methods to prevent or reduce potential damage to system components during disasters. However, even the best prepared systems will incur some damage from disasters.

In this chapter, information described in previous chapters is used to develop an emergency preparedness plan. This critical resource is integral to effective disaster preparation; and disaster preparation is essential to protecting the safety and health of utility personnel and the public and the integrity of the water supply. Before finalizing your emergency preparedness plan, contact the appropriate government agencies (e.g., State Emergency Response Commission [SERC], Local Emergency Planning Committee [LEPC], or Federal Emergency Management Agency [FEMA]) to assure proper communication and coordination.

Emergency preparedness plans are also known as emergency operations plans or emergency response plans. This manual uses the word *preparedness* to focus on that aspect of dealing with emergencies and disasters. A thorough emergency preparedness plan backed with adequate training will ensure quicker recovery from disaster.

BASIC PRINCIPLES OF A PLAN

There are three basic principles that should be recognized when developing an emergency preparedness plan; it should (1) use or reference existing resources, (2) be concise and logical, and (3) be coordinated with other agencies.

Existing Resources

The emergency preparedness plan should reference only existing, in-place resources. The plan should *not* be based on mitigation actions or system improvements that have not yet been completed. For example, do not list a portable generator as a standby power source if the generator has been budgeted but not purchased. The emergency preparedness plan should not be revised until the generator is installed, tested, and fully integrated into the system. Subsequent improvements will engender additional plan revisions and refinement.

Concise and Logical

The emergency preparedness plan should be as concise and logical as possible. The wording should be straightforward and terminology should be familiar to personnel who will implement the plan. The information in the plan should be presented in a logical order with the most important information, such as the communication chart and emergency telephone numbers, readily accessible.

Coordination With Other Agencies

An effective emergency plan requires the cooperation of many agencies and lifeline utilities. Water systems depend on the electric, transportation, and communications networks to function. A list of other key agencies and organizations is given later in this chapter.

Although a water system cannot operate for the long term without the support of other entities, systems should not rely on outside assistance during disasters. This is one reason why water systems should have standby power and radio communications. Water utilities should also be prepared to assist other utilities or agencies as needed. For example, water utility field crews may be asked to help road crews clear blocked streets if access is the most immediate need in a disaster.

ELEMENTS OF A PLAN

An emergency preparedness plan is a working document that should be used before, during, and after a disaster. The plan is the logical outgrowth of, and developed from, the hazard summary, vulnerability analysis, and implemented mitigation actions. The following sections describe basic information that should be contained in a plan. Although the elements are presented in a recommended order, individual systems may modify, add, or delete sections as necessary. The contents of a plan may be dictated by state, provincial, or local regulations or guidelines. Required emergency preparedness plans and other regulatory programs are also described in this chapter.

Mission, Goals, and Objectives

This section of the plan presents the water system's philosophy regarding emergency planning and response. It provides a focus for system personnel while they are planning for and responding to disasters. An example of a mission statement is

> The mission of the water system is to be a safe provider of life-sustaining potable water to the community under normal conditions as well as during emergencies.

Goals and objectives provide specific ways to accomplish the mission. Goals and objectives should be specific enough to authorize staff actions to restore water to priority areas, but still general enough to allow flexibility as a situation changes.

As an example, in the 1992 Contra Costa County (California) risk management and prevention program, the following three goals are identified:

- *Prevent* chemical accidents from occurring by identifying potential causes and taking corrective action
- *Prepare* for chemical accidents that, nevertheless, may occur by developing emergency-response plans and training programs
- *Protect* the public in the event of such an accident by ensuring that residents will be notified immediately of the accident and the appropriate protective action will be taken

As another example, consider the following introduction from the City of Norfolk (Virginia) emergency operations manual:

The purpose of this document is threefold. The following are considered as departmental objectives in order of occurrence:

1. Minimize damaging effects of natural disasters upon the water production, water distribution, and sewerage collection systems of the City of Norfolk.
2. Provide local and area assistance where and when required during and after natural disasters and phenomena.
3. Restore the water production, water distribution, and sewerage collection system to working order as quickly as possible in the event of natural disasters and phenomena.

The plan will identify necessary functions for departmental personnel to quickly, efficiently, and safely restore essential utility services.

Plan Activation

Timely emergency response can minimize the effects of disaster hazards. Some disasters (e.g., hurricanes and floods) provide a measure of warning while others, such as earthquakes, give little or no warning. Prompt, accurate notification of a disaster is crucial—the sooner the utility is notified, the sooner the emergency response plan can be activated.

Warnings and alerts. The National Weather Service issues warnings about hurricanes and other severe weather. The US Geological Survey may issue warnings about potential earthquakes and volcanic eruptions. The US Army Corps of Engineers may issue warnings about flooding. State or provincial health departments will issue warnings of waterborne diseases. Other state or provincial agencies may issue warnings for hurricanes, floods, or potential earthquakes and eruptions. Be sure you have key agency phone numbers available and confirm that the utility is on their emergency contact list.

One or more designated utility employees should be officially responsible for monitoring warnings and advisories and then conveying this information to key staff. Otherwise, personnel could receive faulty information based on rumor or inaccurate reports. An emergency plan should have specific actions triggered by specific warnings. For example, a hurricane warning affecting your system's area should trigger several planned actions. The following actions were taken by the Charleston (South Carolina) Commissioners of Public Works 48 hours before Hurricane Hugo struck in 1989 (Hill 1992):

- Checked inventory of emergency repair equipment and supplies
- Stocked service trucks with service and repair supplies

- Checked communications equipment
- Filled elevated tanks and isolated them from the distribution system
- Test-ran emergency generators and topped them off with fuel
- Shut down exposed pipe at river crossings where possible
- Fueled all vehicles
- Set pressure-reducing valves (PRVs) in manual mode in anticipation of loss of electric power
- Made arrangements for field delivery of food to work crews
- Notified media of emergency operations locations and phone numbers
- Allowed emergency crews to take care of personal business
- Lined up work crews and schedules
- Sandbagged critical areas, building entrances, and pump stations
- Moved vital records to the emergency operations command post

Generating a preset list of crucial actions—and responsible personnel and chains of command—before a disaster strikes is vital. It would be easy to overlook a critical task while trying to develop such a list in the hurried moments before (or during) a disaster; again—prior planning is essential.

Sudden emergencies. Unfortunately, few disasters provide adequate warning. One of the key factors to successfully implementing a utility's plan and reducing the impact of a disaster depends on quick response. For this reason, automated system controls and/or personnel must be able to recognize and respond to an emergency situation. Automated notification may be generated by a supervisory control and data acquisition (SCADA) system or other telemetry/computer system. The following is a list of critical system parameters that should be monitored to provide vital information before, during, and after a disaster:

- Pressure change
- Flow change
- pH change
- Tank elevation
- Chlorine residual
- Power failure
- Other obvious damage
- Unauthorized access

System personnel should also be trained to observe and report any unusual changes in the above parameters. In addition, it is helpful to create a checklist of steps to take in case of an emergency, like the checklist of security measures given in the case study on page 57.

Often a water utility receives initial notification of a problem from external sources such as customers, personnel from other agencies, laboratories, emergency response crews, or the media. In fact, one component of interagency emergency planning coordination should be instructions on how to report a water system

Case Study: A Checklist of Security Measures

When ensuring the safety of any facility, utility managers should consider the credo "detect, delay, and respond" (Danneels, J.J. 2000. Methodology for Improving the Security of the Water Infrastructure. Water Surety Workshop. Sandia National Laboratories. Albuquerque, N.M.). This means that some saboteurs will be deterred if they think what they might do would be detected; others will be deterred if they are delayed for a significant amount of time before reaching their end goal—they fear being caught in the act. If an intruder does obtain his or her goal of sabotage, whether it is contamination of the water or physical destruction of system facilities, then utility staff and local law enforcement must respond quickly and appropriately to minimize the consequences of the saboteur's actions.

After conducting a risk assessment to determine the vulnerable aspects of your utility, the potential for intrusion at those vulnerable points, and the priority for protecting those assets, you are better prepared to respond in an active mode rather than in a reactive mode. Some actions a utility can consider taking to harden its facilities against an attack include the following:

Short Term

- At your office, well houses, treatment plants, and vaults, make it a rule that doors are locked and alarms are set.
- Make security a priority, and emphasize it at employee and safety meetings.
- Tell your employees to ask questions and make note of strangers who are in your facilities or call in threats.
- Limit access to facilities. Indicate restricted areas by posting Employees Only signs.
- Increase lighting in parking lots, treatment bays, and other areas that seldom have people present.
- DO NOT leave keys in equipment or vehicles at any time.
- Invite local law enforcement to become familiar with your facilities, and establish a protocol for reporting and responding to threats.
- Discuss detection, response, and notification issues with public health officials, and establish protocols for them.
- Establish a chain of command and an emergency call list to be used in emergency situations.
- Provide copies of your operational procedures to local law enforcement and emergency management personnel.

Long Term

- Install motion sensors and video cameras to monitor, detect, and record events. They can be tied into a supervisory control and data acquisition system for remote monitoring.
- Install intrusion alarms that cover remote buildings and grounds.
- Limit access to water supply reservoirs.
- Develop a clear policy so all employees know how to deal with trespassers.
- Fit hydrants and valve boxes with tamperproof caps and lids.
- Install pass-code locks instead of keyed locks so access numbers can be changed as necessary, e.g., when an employee is terminated. (Make sure, however, that emergency response personnel and law enforcement personnel receive the updated access codes.)
- Fence and lock vulnerable areas such as wellheads, reservoir vents, and meter pits.
- Mark equipment with logos and distinctive paint jobs.
- Integrate early warning monitoring systems into water transport, treatment, and distribution systems so that an operator will be notified immediately of changes in chemical characteristics, flows, pressures, and temperature.
- Design and install valves that open and close slowly.
- Know your employees and who it is you are hiring. Make it a standard procedure to conduct background checks on all new employees.
- Install firewalls in computer systems, and change access codes frequently.
- Conduct and attend training activities to prepare your staff to detect, delay, and respond appropriately.

Source: Journal AWWA*, May 2001*

emergency. Refer to Figures 5-1 and 5-2 for sample forms to distribute to customers or to municipal or other agency personnel likely to see or become involved in water system emergencies.

Personnel receiving calls from outside, particularly from the general public, need to be trained to collect all necessary information during the first call. Rarely can a caller be contacted again for additional information. Refer to Figure 5-3 for a sample notification report. Automated computer response systems should also be considered.

Following notification of an emergency, appropriate utility staff must be contacted. A communication chart like the one shown in Figure 5-4 should be developed. All emergency calls should be logged and/or recorded in an emergency message log (Figure 5-5).

Communication Chart

A communication chart should list all utility staff (and alternates) who will direct emergency response actions. As shown in Figure 5-4, the chart should include job titles, telephone numbers, and major system responsibilities. Others to include on the communication chart include additional system personnel, other utilities, regulatory agencies, priority customers, and media contacts for general public notification. Include alternative communication methods, such as radios and cellular phones, if normal telephone communication is disrupted. One way to relay actual conditions at a remote site is via videotape or Internet-based digital camera. The tape or direct Web feed can be used by the emergency response command center to monitor site conditions and actions.

Water utility personnel. Be sure to include home addresses and telephone numbers of all utility personnel, as well as any cross-training each employee has completed. For example, a laboratory technician may have been trained to assist a field crew during emergencies or employees may have to be contacted in person if telephone service is interrupted. Refer to Figure 5-4 for a sample personnel list form.

In general, the following three groups are needed in an emergency (AWWARF and JWWA 1993):

- *Command/liaison group* directs the response, making decisions on appropriate actions and communicating with other groups, agencies, and the public
- *Field investigation group* works to identify the cause and extent of the emergency
- *Treatment response group* performs the repairs and other emergency-response actions required

During smaller or localized emergencies, the groups' functions may overlap. For example, during an isolated main break, a field crew at the site may perform all three functions. In larger, widespread disasters, the responsibilities of the three groups are more distinct.

Other agencies. List those agencies or organizations, such as contractors, with whom you have standing agreements to provide mutual assistance. Refer to Figure 5-6 for a sample form and list. See also Figure 5-7 for other departments and agencies to notify, and other utilities or lifelines whose priority service list your system should be on.

Priority customers. Priority customers identified in the vulnerability analysis need to be notified if disaster hazards could affect the quality or quantity of their

EMERGENCY TELEPHONE NUMBERS

______________________________WATER SYSTEM

The following events may constitute a WATER SYSTEM EMERGENCY:

1. Loss of service
2. Escaping water
3. Sudden changes in color, clearness, taste, or odor

If you observe any of these potential emergency conditions, please telephone the____________ ______________________ water system immediately.

Telephone Numbers

Business office ____________________________

Operations control center ____________________

After-hours service _________________________

If there is no answer at any of the above numbers, please contact the police department at ________________________________ .

Source: Washington State.

Figure 5-1 Sample water system emergency notification form to be used by the general public

EMERGENCY REPORTING INSTRUCTION

In the event of an emergency that appears to involve water service, please fill out the form below and contact the ___________________________________ water system immediately.

Telephone numbers appear at the bottom of this form.

1. Person calling in emergency ____________________Telephone number _____________

   Time call was received ____

2. Location of emergency____

   Street and house/building number ____

   Other (approximate location, distance from landmark, etc.) _______________________

   ____

3. Condition at scene (check appropriate box[es])

   ☐ Escaping water: ___ Seepage ___ Free-flowing ___ Gushing

   ☐ Flooding: ___ Roads ___ Intersections ___ Property ___ Buildings

   ☐ Erosion: ___ Banks ___ Foundations

   ☐ Electrical power: ___ Interruptions ___ Total loss of power

   ☐ Change in water quality: ___ Taste ___ Odor ___ Color ___ Clearness

4. Actual/potential damage

   Briefly describe the situation ____

   ____

   ____

5. Access restrictions, if any ____

   ____

   ____

6. Assistance already available (who, what they are doing, etc.) ______________________

   ____

   ____

   ____

EMERGENCY TELEPHONE NUMBERS

Business office _______________________________________

Operations control center _______________________________

After-hours service ____________________________________

Signature of person who filled out form: ____

Source: Washington State.

Figure 5-2 Sample water system emergency notification form to be used by other agencies

EMERGENCY NOTIFICATION REPORT

Part 1 — Facts Related to Emergency

1. Person or department calling in emergency ____________________

   Phone number/radio frequency ____________ Date/time call received ____________

2. Location of emergency

   Street and house/building number ____________________

   Other (approximate location, distance from landmark, etc.) ____________________

   ____

3. Condition at scene (check appropriate box[es])

   ☐ Escaping water: ___ Seepage ___ Free-flowing ___ Gushing

   ☐ Flooding: ___ Roads ___ Intersections ___ Property ___ Buildings

   ☐ Erosion: ___ Banks ___ Foundations

   ☐ Electrical power: ___ Interruptions ___ Total loss of power

   ☐ Change in water quality: ___ Taste___ Odor___ Color___ Clearness

4. Actual/potential damage

   Briefly describe the situation ____________________

   ____

   ____

5. Access restrictions, if any ____________________

   ____

6. Assistance already available (who, what they are doing, etc.) ____________________

   ____

   ____

   ____

Part 2 — Assess Emergency

1. Personnel analyzing emergency ____________________

   ____

2. Reported results of investigation ____________________

   ____

3. Time assessed ____________________

Part 3 — Emergency Action Taken (Refer to emergency response plan.)

1. Immediate action taken (If emergency response plan is used, note page[s].) ____________

   ____

continued next page

Source: Washington State.

Figure 5-3 Sample water system emergency notification report to be completed and used by water system personnel

2. Is immediate action ☐ Permanent ☐ Temporary
3. Was an emergency crew dispatched ☐ Yes ☐ No
   Time arrived on scene ____________________
4. Note all other actions that will be necessary to bring facility back in line _______________

Part 4 — Persons/Department Notified of Emergency

Position	Name	Work Telephone	Home Telephone	Time of Call
☐ General manager				
☐ Engineer				
☐ Operations supervisor				
☐ Office manager				
☐ Public relations or media contact				
☐ Fire department				
☐ Police department				
☐ Highway department				
☐ Local elected official (mayor, commissioner, etc.)				
☐ State or provincial drinking water department				
☐ Department of emergency services				
☐ State quality control				
☐ Local health department				
☐ Other (refer to system personnel and support call-up lists)				
☐ Priority customers				

Signature of person who filled out form ______________________________

Source: Washington State.

Figure 5-3 Sample water system emergency notification report to be completed and used by water system personnel (continued)

WATER SYSTEM PERSONNEL — EMERGENCY CALL LIST*

For each of the following categories, list the names of water system personnel responsible for making decisions in specific emergency situations in ranking order. Include job titles, telephone numbers, and major water system responsibilities and expertise.

		Name	Title	Work Telephone	Cellular Telephone	Home Telephone	Major Responsibility and Expertise
Quality and treatment:	1.						
	2.						
	3.						
	4.						
Source water	1.						
	2.						
	3.						
	4.						
Storage:	1.						
	2.						
	3.						
	4.						
Distribution:	1.						
	2.						
	3.						
	4.						
Pressure and pumping facilities:							
	1.						
	2.						
	3.						
	4.						

Source: *Washington State.*

Figure 5-4 Sample water system emergency communication report to be completed and used by water system personnel

EMERGENCY COMMUNICATIONS MESSAGES LOG

Date	Time In	Time Out	To/From	Type of Message	Message

Source: Washington State.

Figure 5-5 Sample water system emergency messages log to be maintained by water system personnel

SUPPORT CALL LIST

The following agencies/organizations have standing agreements with this water system whereby they will provide assistance on request in an emergency.

Organization	Address	Name	Telephone	Type of Assistance to Be Provided	Required Authorization

Approved ______________________ Date ______________________

Source: *Washington State.*

continued next page

Figure 5-6 Sample water system emergency support call form and list to be completed and used by water system personnel

SUPPORT CALL LIST

Suppliers
- pipe, valve, and fitting vendor
- pipe bedding and concrete
- lumber yard
- chemicals and chemical feed pumps
- shoring
- pumps and electrical
- hardware store
- fuel
- tires
- signing
- heavy equipment
- rental center
- all contract vendors (emergency number can be a provision of the contract)

Contractors
- excavation
- general contractor
- electrical
- pump
- water hauler
- communications
- computer
- telemetering
- traffic control

Agencies
- State Emergency Response Commission (SERC)
- Local Emergency Planning Committee (LEPC)
- Federal Emergency Management Agency (FEMA)
- wastewater/stormwater utility
- neighboring utilities
- emergency services
- safe drinking water program
- laboratories
- Red Cross
- ham radio club
- electrical/telephone utility
- fire department

Special Contractor/Equipment List
- concrete saw
- auxiliary power (pumps, garage, office computer, and communication)
- portable lights
- alternate transportation (boat, snowmobile, snowcat, helicopter, and freight company)
- portable rest rooms
- catering/restaurant
- showers
- warm/cool resting place
- chain saws
- sump pumps
- chlorine test kits

Source: Washington State.

Figure 5-6 Sample water system emergency support call form and list to be completed and used by water system personnel (continued)

OTHER DEPARTMENTS/AGENCIES TO NOTIFY

City Hall

- city manager/administrator
- elected officials
- fire department/district
- police department/sheriff
- wastewater/stormwater utility
- street/road/highway department
- engineer
- insurance/safety officer
- dispatcher

Other

- one-call system
- emergency services
- local/state health departments
- newspaper (news desk and traffic reports)
- radio (news desk and traffic reports)
- television (news desk and traffic reports)

Priority-Service Lists That Should Include Your Utility

- wholesale supplier
- electric utility
- telephone utility
- sewer utility
- emergency-response center
- chemical supplier
- fire department/district
- hazardous-material spill response

Source: Sander.

Figure 5-7 List of other departments and agencies to notify in an emergency delivered water. The water utility representative communicating with these customers should have a specific contact person. This is not the first person who answers the phone but someone designated as an official contact or alternate. The system representative should determine if the customer's alternate source of potable water is available or functioning. Refer to Figure 5-8 for a sample priority service form and Figure 5-9 for a sample priority service list. Be sure to update the list at least annually.

Similarly, prior arrangements should be made with those business or commercial customers that are capable of significantly reducing or totally curtailing their normal water use during an emergency.

General public. The general public is usually notified of disaster information through mass media, such as radio, television, and newspapers. The water system's communication chart should include telephone numbers of all local media outlets. Also, as part of the planning process, local media should be issued an emergency telephone number or an alternate method of contacting the utility system. It is helpful to prepare sample public notifications, such as a boil-water order, beforehand. The notifications can be modified as necessary to fit the situation. See Figure 5-10 for a sample water shutoff notification. Finally, the system should designate an official spokesperson and/or media contact. Other methods for notifying the public include mobile public address systems, sirens, leaflets, and computerized phone dialing systems.

Agreements With Other Agencies or Organizations

The preparedness plan should also include any written agreements with other agencies, utilities, or response organizations. Include interconnection agreements with other systems if they are in force. Particularly important are contracts with private suppliers and contractors. Usually, these contracts detail the nature, conditions, and cost of contracted services. Most contracts typically have an expiration date, so they must be updated periodically. One important administrative tip—try to get all service contracts on the same renewal schedule and designate a person to confirm they are updated before expiration. Some utilities require 24-hour access and emergency phone numbers from their suppliers as part of their annual bidding package and contract.

Disaster-Specific Plans

Specific emergency preparedness plans should be developed for the most likely disasters. For example, a Southern California-based water utility could develop specific preparedness plans for an earthquake, a hazardous materials spill, and a brush fire. A system in the southeastern United States may develop specific plans to deal with a hurricane, a flood, and a chlorine leak. The items included in a specific disaster plan are based on the hazard summary, the vulnerability analysis, and mitigation actions.

Hazard summary. A disaster-specific plan must include the results of the hazard summary for each disaster. The summary can be presented in a few paragraphs or with a form. Refer to Figure 2-4 in chapter 2 for a sample. For each disaster, include the hazards specifically applicable to the system. For example, for an earthquake, provide an estimate of the magnitude of fault rupture, or horizontal and vertical accelerations at each site of concern. Other information could include the location of faults, areas with liquefiable soils, and slopes subject to sliding. The estimates provide the basis for determining the system's vulnerable components.

PRIORITY-SERVICE FORM

Individuals/organizations located at the following service connections are critically dependent on an uninterrupted supply of water. In the event of an emergency affecting their primary source, the following actions must be taken:

1. Notify the customer immediately. Verify that the second source, if any, is functioning.
2. Take the indicated emergency action, if required.

Name	Address	Telephone	Reason for Requesting Priority Service	Alternative Source Available Yes No	Emergency Action(s) to Be Taken

Approved ______________________________ Date ____________________________________

Source: Washington State.

Figure 5-8 Sample water system emergency priority-service form to be completed and used by water system personnel

PRIORITY-SERVICE LIST

	Quality Problem	Quantity Problem	Reduce Use
Medical/Dental Facilities			
Hospital	X	X	
Clinics and offices	X		
Emergency clinics/outpatient facilities	X	X	
Kidney dialysis patients	X	X	
Blood bank	X		
Public Facilities			
Schools and preschools	X	X	
Day-care centers	X	X	
Emergency shelters	X	X	
Stadiums, arenas, and convention centers		X	X
Parks and cemeteries		X	
Wholesale suppliers		X	
Emergency-operations centers	X	X	
Fire and police stations/jails	X	X	
Large Users			
Large industrial users		X	
Wholesale customers	X	X	
High-rise buildings		X	
Contractors		X	
Steam plants		X	
Sawmills			X
Nonessential users			X
Food and Beverage Facilities			
Dairies	X	X	X
Soft drink bottlers	X	X	
Breweries and wineries	X	X	
Bakeries	X		
Restaurants	X	X	
Food processors	X	X	X
Critical Businesses			
Beauty shops		X	
Dry cleaners		X	
Fish markets	X		
Newspapers (printing facilities)		X	
Large computer facilities		X	
Hotels and motels	X	X	
Hatcheries	X	X	
Photo processors		X	
High-degree-of-hazard users (cross-connection potential)		X	

Source: Sander.

Figure 5-9 List of possible individuals and organizations requiring priority service

WATER SHUTOFF NOTIFICATION

The ____________________________________ water system will be turning the water off in your area in order to make necessary repairs to the system.

Area to be shut off ____

____

____

____

Date(s) of shutoff ____

____

____

Time(s) of shutoff ____

____

Reason for shutoff ____

____

____

Date of notice ____

If you have any questions about the above information, please call _______________________

Source: Washington State.

Figure 5-10 Sample form for notifying public of a water shutoff

Vulnerability analysis. Provide specific estimates of damage to system components as determined in the vulnerability analysis. Continuing with the earthquake example, the analysis would list probable damages due to such hazards as pipeline breaks or treatment plant damage. Include a map of the system with the preparedness plan. Be sure that critical components are identified.

Mitigation actions. List the mitigation and preparedness actions that should be implemented to minimize hazard impacts. A list of suggested mitigation actions, such as retrofitting a building to withstand seismic forces or relocating a section of pipe that crosses a fault, should be maintained in the plan. When a mitigation action has been completed, the plan should be updated. Again referencing the earthquake example, preparedness actions might include maintaining generators and isolation valves and testing radio communications.

Hazardous Material Spills

Many facilities that use hazardous materials—including water utilities—are required by a host of federal, state, and local regulations to develop and implement emergency spill response plans. Depending on your location (state or province) and the specific hazardous material (typically chlorine or anhydrous ammonia), your utility *may* be subject to one or more of the following regulatory programs:

Emergency Planning and Community Right-to-Know Act (EPCRA)—Many provisions of the Emergency Planning and Community Right-to-Know Act (EPCRA) can affect water utilities. If hazardous materials are present in quantities exceeding a threshold level, utilities may be required to

- Prepare emergency response plans (EPCRA Sections 301–303)
- Notify the appropriate SERC or LEPC (EPCRA Section 304)
- Submit hazardous material inventory information (EPCRA Section 311–312)

OSHA Process Safety Management of Highly Hazardous Chemicals Standard—If your utility is subject to OSHA requirements (and many publicly owned utilities are not), you may be required to develop a plan to prevent or minimize the consequences of a catastrophic release of hazardous materials from a process. This regulation is aimed at protecting the health and safety of on-site workers during a hazardous materials release.

Clean Air Act Amendments of 1990 Accidental Release Prevention Program [Section 112(r)]—The Clean Air Act Amendments of 1990 Accidental Release Prevention Program requires that certain facilities take preventive action to avoid accidental chemical releases and prepare to mitigate the consequences of such accidents should they occur. The main component of this program is the preparation and submittal of a risk management plan (RMP) that includes a process hazard analysis. Such an analysis requires identification of hazards, release assessment, and evaluation of off-site impacts. This regulation is aimed at protecting the health and safety of the public beyond the boundaries of a facility.

As referenced, the two most *common* hazardous chemicals used by water utilities covered by these regulations are chlorine and anhydrous ammonia. (Note that depending on the specifics of your operation, threshold quantities of other hazardous chemicals may be present.) Table 5-1 presents the applicable threshold quantities for chlorine and anhydrous ammonia (the quantities listed in this table are applicable as of Aug. 1, 2001; please check for updated quantities prior to program implementation).

Table 5-1 Applicable threshold quantities for chlorine and anhydrous ammonia

Chemical	EPCRA Section 302	EPCRA Section 304	EPCRA Section 311/312	CAA Section 112(r)	OSHA PSM
Chlorine	TPQ – 100 lb	RQ – 10 lb	TPQ – 100 lb	2,500 lb	1,500 lb
Ammonia (Anhydrous)	TPQ – 500 lb	RQ – 100 lb	TPQ – 500 lb	10,000 lb	10,000 lb

RQ – reportable quantity, TPQ – threshold planning quantity

While a detailed discussion of the individual program requirements is beyond the scope of this manual, the following is a *brief* overview of general program requirements:

EPCRA Sections 301–303

- Identify facility uses of hazardous materials
- Describe both on- and off-site emergency response procedures
- Designate a community and facility coordinator to implement the plan
- Outline emergency notification procedures
- Describe how to determine the area likely to be affected by a release
- Describe local emergency equipment and facilities
- Outline evacuation plans
- Provide a training program for first responders
- Detail methods and schedules for practicing emergency response plans

EPCRA Section 304

- Notify LEPC or SERC if there is a release of a hazardous chemical into the environment that equals or exceeds the RQ

EPCRA Section 311–312

- Maintain material safety data sheets (MSDS) for hazardous chemicals
- Submit inventories of hazardous chemicals to LEPC, SERC, and/or fire department

OSHA PSM

- Compile process safety information
- Conduct process hazard analyses
- Develop normal and emergency operating procedures
- Conduct appropriate training
- Develop and implement an emergency response plan
- Conduct compliance audits

CAA Section 112(r) RMP

- Prepare risk management plans that include
  - Hazard assessment
  - Accident prevention program
  - Emergency response program

There are a number of excellent references and extremely useful model plans (for such commonly used chemicals as chlorine) available; a partial list is provided in the section titled "Other Resources."

Component-Specific Plans

Preparing a water system for the most probable disasters can mitigate much of the potential damage to the system components. For critical components, such as a treatment plant, a plan specific to that component should be developed. The component-specific plan will address the hazard effects and mitigation and preparedness actions that may not be covered in a disaster-specific plan.

Component-specific plans are similar in content to disaster-specific plans. Component specific plans should include a hazard summary, vulnerability analysis, and mitigation and preparedness actions that relate to a specific component. Figure 5-11 illustrates a sample form that can be used for a facility vulnerability analysis.

Disaster Recovery Accounting

A utility should identify and document all costs related to each specific emergency. It may be possible to recover all or a portion of these costs through federal, state, or provincial disaster relief funding. One method to clearly identify costs related to a disaster is to use a preplanned, emergency work order numbering system. All costs related to any specific operation are charged to that account number. Many work orders may be used during one natural disaster because there may be many different projects in progress to restore the entire system. But for rigorous cost accounting, all emergency work orders should be specifically coded to identify them as being related to the emergency.

It also helps to use an operating and damage report form to track the work. Such records can be invaluable for assessing the damage of a disaster and evaluating the response. The records also indicate if followup actions are needed. A sample form is shown in Figure 5-12. Photos and videotape are excellent methods to document actions.

Distribution List

A distribution list identifying the individuals possessing copies of the emergency plan should be maintained. The list will allow tracking of all plan updates and modifications.

Updating A Plan

Just as the nature and operations of a water system do not remain static, neither should a utility's emergency preparedness plan. The plan should be updated periodically or when major modifications occur, such as the introduction of a new facility. Staff responsibility for updating the plan should be identified.

VULNERABILITY ANALYSIS

Facility ____

Failure description ______________________________________

1. Failure Detection

Is failure detectable by

a) telemetry system? Yes ___ No ___

b) routine inspection? Yes ___ No ___

c) service complaint? Yes ___ No ___

2. System Impact

a) Is facility a source? Yes ___ No ___

b) Does facility have an alternate operating mode? Yes ___ No ___

c) If so, is alternate facility a full replacement? Yes ___ No ___

d) Does failure cause

1. loss of service? Yes ___ No ___
2. loss of fire protection? Yes ___ No ___
3. low service pressure? Yes ___ No ___
4. other effects to system? Yes ___ No ___

Describe ____

5. damage to property? Yes ___ No ___

Describe ____

____

e) Does failure cause loss of storage capacity? Yes ___ No ___

f) Does failure degrade water quality? Yes ___ No ___

g) Are other system facilities affected? Yes ___ No ___

List ____

____

Source: Washington State.

continued next page

Figure 5-11 Sample form for facility vulnerability analysis

3. Facility Vulnerability

a) Is routine inspection and maintenance required? Yes ___ No ___

Frequency of inspection ______________________________

Frequency of maintenance ______________________________

b) Does facility require electric power? Yes ___ No ___

Failure history ______________________________

c) Is auxiliary power available? Yes ___ No ___

d) Is facility protected against vehicle vandalism? Yes ___ No ___

Describe

____

____

e) Is facility protected against vehicle accident? Yes ___ No ___

f) Does this facility require special protection from

1. flood Yes ___ No ___
2. high wind Yes ___ No ___
3. cold weather Yes ___ No ___
4. hot weather Yes ___ No ___
5. fire Yes ___ No ___
6. other Yes ___ No ___

g) Under which disaster conditions listed on the hazard summary could this facility potentially fail?

____

____

h) Does normal operation depend on chemicals? Yes ___ No ___

If yes, list

____

____

Source: Washington State.

continued next page

Figure 5-11 Sample form for facility vulnerability analysis (continued)

If yes, list means of transportation ____

____

____

i) Is facility susceptible to other impacts?

1. debris in water Yes __________ No __________
2. low pressure Yes __________ No __________
3. high pressure Yes __________ No __________
4. other ____

j) Is facility dependent on other system facilities? Yes___ No___

List ____

____

____

4. Facility — Supervisory Control Dependency

a) Is facility dependent on telemetry for

1. control Yes ___ No ___
2. status reporting Yes ___ No ___
3. data logging Yes ___ No ___
4. other ____

b) When control fails, does component

1. stop? Yes ___ No ___
2. remain in last command position? Yes ___ No ___
3. revert to local control? Yes ___ No ___

5. Personnel

a) Can normal repair be undertaken by

1. all personnel? Yes ___ No ___
2. a special few? Yes ___ No ___
3. one? Yes ___ No ___
4. outside contractor? Yes ___ No ___

Source: Washington State.

Figure 5-11 Sample form for facility vulnerability analysis (continued)

OPERATING AND DAMAGE REPORT

This report must be filled out in detail and turned in. It must be signed by the responsible foreman and supervisor on completion of repair/emergency.

Part 1 — General Information

1. Date of this report ______________

   Date and time water system became aware of break or problem ________________________
2. Location of break or problem ____
3. Person or persons who notified water system of break or problem ______________________

   ____

   Position(s) ____
4. Location and custody of book, card, memo, etc., containing information relative to this report

   ____

Part 2 — Pre-Action Information — Assessing the Emergency

1. Time/date crew arrived at scene ____
2. Names of crew persons at scene ____
3. Nature of problem and/or cause of break. If unknown, state probable cause and detail facts supporting conclusions ____
4. What damage was done? ____
5. What damage was done to adjacent property? ________________________________

   ____

Part 3 — Emergency Action Taken

1. What emergency action(s) was taken to control situation at the scene?

   ____

   ____

   ____

Source: Washington State.

continued next page

Figure 5-12 Sample damage report form

2. Names of crew persons making emergency repairs ________________________________

____

3. Time/date emergency repairs were made and service was restored ___________________

____

4. Materials used for repair ____

____

5. Is further action needed? If so, explain ____________________________________

____

____

Part 4 — Supplemental Information

1. If quality problem, what disinfection procedures were followed? _____________________

____

____

____

____

Is further action needed? Yes ___No ___Action_________________________________

2. Were water quality samples taken?

Yes ___ No ___	Parameter	Date	Results
	________	________	________
	________	________	________
	________	________	________
	________	________	________
	________	________	________

3. Were any photos taken? Yes ___ No ___ By whom? _____________________________

4. Size and location of valves operated or work necessary to effect shutdown (diagram) _______

____

Source: Washington State.

continued next page

Figure 5-12 Sample damage report form (continued)

5. Size, kind, type, pressure rating and/or class pipe appurtenance

____

6. Date of installation ___________________________ Life expectancy ___________________
7. Date of last inspection of pipe or appurtenances ___________________________________
8. Is main subject to excessive pressure or pressure changes? _________________________
9. History of prior trouble within ______________ feet and dating back to _________________
10. Present condition ____
11. Condition and type of joints ____
12. Type of soil in ditch and characteristic of ground cover around existing water main

____

13. Depth of pipe (top of pipe to street surface) ___________________________________
14. Size of hole in street ____
15. Type and thickness of street surface ____

____

IMPORTANT: WHERE IT APPEARS THAT DAMAGE CLAIMS MAY ARISE, FILL OUT AND ATTACH SUPPLEMENTARY SHEETS WITH ALL INFORMATION POSSIBLE AND DRAW A DIAGRAM ON SEPARATE SHEET SHOWING AS MUCH DETAIL AS POSSIBLE, LOCATION, AND ADDRESS OF DAMAGED PROPERTY

Crew Leader _____________________________ Supervisor _____________________________

Source: Washington State.

Figure 5-12 Sample damage report form (continued)

REFERENCES

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Chapter 6

Emergency Response, Recovery, and Training

Without a detailed emergency preparedness plan and adequate training, an emergency can quickly become a disaster. Unfortunately, few emergencies go "by the book" or exactly as planned. A good example is the treatment plant fire documented in the video *Planning for Emergencies* (NEWWA 1990). In this case, a utility's emergency preparedness plan forecasted the loss of the treatment plant due to an earthquake but not a fire. When a welding spark ignited a fire, the treatment plant soon was engulfed in smoke and flames.

Although the system had to improvise its emergency response, much of the preparedness planning was applicable and could be used. For example, the valves designated to isolate the plant in case of an earthquake were used in the fire emergency. The utility also implemented a prearranged mutual aid agreement with an adjacent water system to provide an alternate source of water.

The case study found on page 86 is an example of a small system's emergency-preparedness response and recovery.

EMERGENCY RESPONSE AND RECOVERY

The following general steps are recommended when an emergency strikes a system.

Step 1: Analyze the Type and Severity of the Emergency

Before initiating any emergency response actions, analyze the type and severity of the emergency. Based on the previously conducted hazard summary and system vulnerability analysis, the results of this analysis should lead to the most prudent and effective response. Perhaps the first step in the evaluation should be to determine the status of critical components. For example, rather than responding to a reported leak in the distribution system, it may be more important to isolate a storage tank or start backup power generators.

Step 2: Provide Emergency Assistance to Save Lives

The next priority is to initiate immediate actions required to safeguard the lives and health of employees and the public. If an earthquake has damaged a reservoir dam and failure may be imminent; it may be more important to first evacuate people in the flood path and then begin repairs to the dam. A chlorine leak or damaged water tower could lead to a similar conclusion to first evacuate, then repair.

Step 3: Reduce the Probability of Additional Injuries or Damage

When emergency conditions threatening immediate injury or loss of life have been eliminated, repairs or temporary mitigation actions should be initiated. These actions may be the most critical factor in reducing or minimizing additional damage. Examples of such actions could be to open outlet valves to lower a reservoir if a dam is weakened or deenergize downed electric lines. During this phase, the public should be kept apprised of boil water orders or other emergency notifications. The case study beginning on page 90 describes an emergency response to flood damage and the subsequent public communication process.

Step 4: Perform Emergency Repairs Based on Priority Demand

After reducing the probability of additional injuries or damage, the next step is to carry out repairs or other actions that will provide service to priority customers or meet priority demands (e.g., fires, medical facilities, potable water distribution points, etc.). Figures 6-1 and 6-2 illustrate emergency water supply methods.

Step 5: Return System to Normal Levels (Recovery)

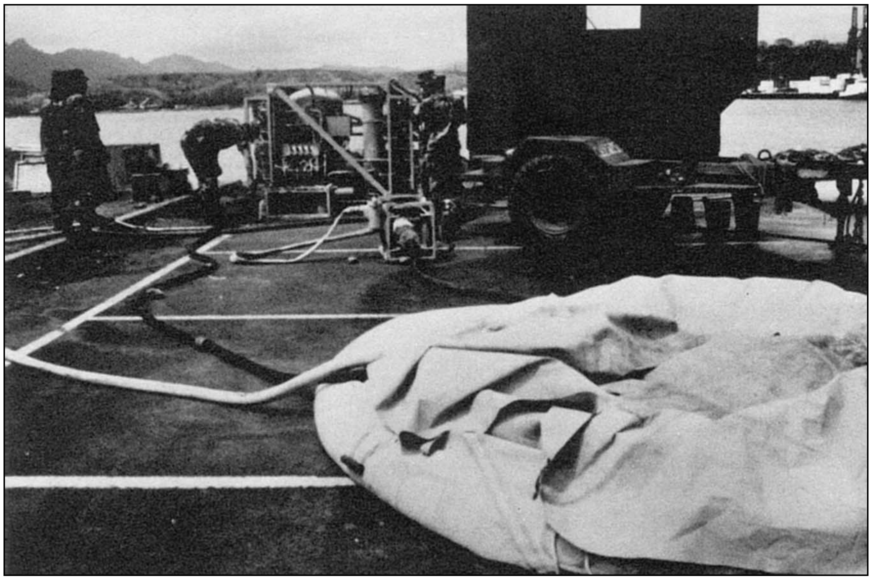
Finally, as control is regained, perform less urgent repairs in order of priority. Lift the boil-water or reduced-use orders *only* when the quality and quantity of the water supply is assured. The state or provincial department of health may have the final approval.

Long-term recovery considerations include the following (Pickett et al. 1991):

- Repair options, such as abandonment or replacement at another location
- Redundancy of pipelines and other facilities
- Relocation away from newly observed fault areas
- Rate structure change reflecting cost of mitigation activities
- Personnel training and procedures for recovery
- Review and update of communications systems and standard designs that are no longer appropriate
- Shared use with other agencies, such as emergency equipment and laboratory facilities

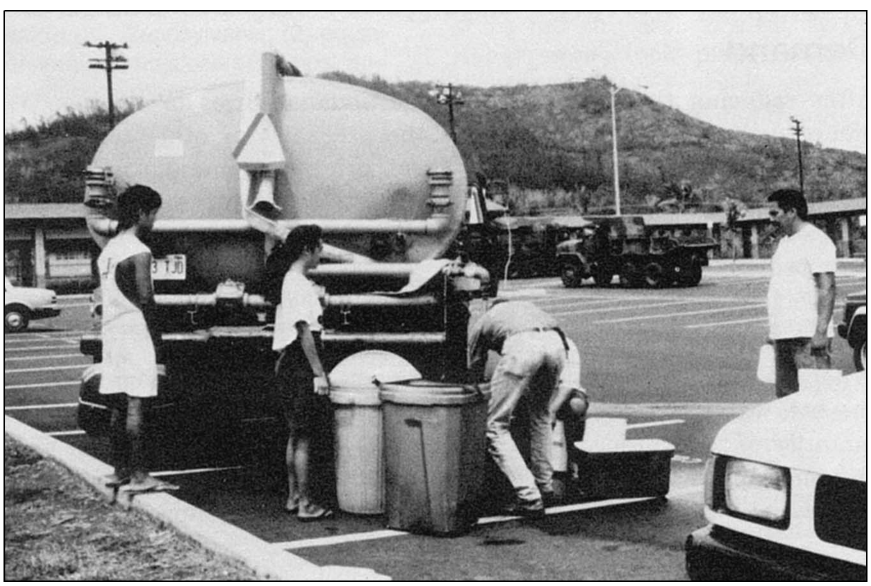
Step 6: Evaluate Response and Preparedness Plan

Even during a crisis, a utility should review its responses and compare them to those outlined in the preparedness plan. Preplanned actions may not be as effective as anticipated and real-time modifications may be in order. Once the crisis has passed



Source: *Ray Sato.*

Figure 6-1 Portable water treatment plant filling up inflatable storage in Kauai, Hawaii



Source: *Ray Sato.*

Figure 6-2 Emergency potable water provided by tanker truck in Kauai, Hawaii

Case Study: Hurricanes in Hawaii

There are three phases that encompass a disaster event. The first phase includes things that you do before an event. The second is the event itself. And the third phase includes things you do after the event. What you do during all three phases is very important.

Before It Happens — Preparedness

In most cases you won't know when a disaster or emergency will occur. You get called after it happens. A tree falls and takes out a power line. Someone backs into a fire-plug. The power company drills one of your water mains while trying to plant a pole. These things happen every day, and we react to them with a certain degree of preparedness. A similar degree of preparedness will help you when a big disaster occurs, such as when Hurricane Iniki blew.

Common sense prepares you to handle some emergencies. That is why we stock repair clamps, pumps, emergency lighting, generators, and so forth. If you don't prepare for emergencies, you will have a disaster on your hands.

So what has this got to do with hurricanes? You should be prepared for emergencies to some degree every day; that is what I call preparedness. You should have a certain amount of emergency gear, know where you can get more, and have people that you and your crew will follow. That philosophy helps you to make decisions and helps your crews to make decisions when you're not around.

There are really two types of preparedness. The first is a general preparedness. General preparedness ensures that you have a certain amount of emergency gear on hand and that your people are trained to use it.

The second type of preparedness is specific to the impending event. It begins with a warning. You start to kick this in when the weather reports indicate that a tropical storm or a hurricane is developing and may be heading your way. When a watch is issued, we start assembling the emergency gear. We also start to discuss our specific plans. Most of the emergency gear is just ordinary equipment that we use every day and misplace every day. Where are the chain saws, the abrasive saws, the generators? Get all the trucks and equipment fueled up. Check the domestic water emergency generator. Is the emergency radio link to corporate headquarters operational? Put a generator in the repeater shack. Put it in the shack beforehand because you may not be able to drive there later.

While It's Happening

Only foolish people drive around with video cameras during the storm or go to the beach to look at the storm surge. These people only get themselves into trouble. They usually expect others to save them when they get into trouble. Get in a safe, sheltered area and stay there.

When It's Over — The Work Begins

Our instructions to our employees are for them to report to work as soon as they and their families are secure.

For us on the sugar plantation, not much is done until the next morning. During Iniki, we did make some plans on the radio, but we decided to keep off the roads and spend the time handling our own problems.

What happens after a disaster event are largely recovery activities, but before this happens a few top-priority things need to be done. One of the most important things is to get your communications system up. The second is to get the domestic water system going. The third is to get some power at key installations so that work can be done. The fourth is to assess damage and to try to prevent further damage from occurring.

At McBryde Sugar Company, radio communications are essential. It seems that nothing much gets done unless we can talk about it on the radio. We run a multichannel VHF synthesized frequency radio that allows us to talk over our repeater as well as a couple of simplex frequencies (radio to radio). The system also

continued next page

Case Study: Hurricanes in Hawaii (continued)

allows us to monitor the National Oceanic and Atmospheric Administration (NOAA) frequencies, police, county government, Kauai Electric, and anyone else operating in the VHF frequencies.

From the earlier Hurricane Iwa, we learned that off-island communications are a must during the recovery effort. Commercial telephones would not be working. Shortly after Iwa, three operators using ham radio techniques and gear found three VHF repeater sites that fulfilled certain criteria. Each of the sites would need to be company controlled and each of the sites would have to be easily accessible. The objective was to provide communications between A&B in Honolulu and its subsidiaries on Kauai and Maui. The sites selected included McBryde's existing repeater site on the south side of Kukuiolono Park, the Matson's Terminal on Sand Island, and a leased site in someone's backyard in Kula. All of these sites are easily accessible, even if roads are blocked.

Recovery — Insurance

With emergency systems operating, the task of putting things back together began. Before you can fix anything you need to find out what's broke. With major damage to our hydroelectric plants at Wainiha and Kalaheo and to our Koloa factory, we began a program of equipment testing after discussions with our insurance people. We also had major damage to our coffee-processing facility, shops, warehouse areas, irrigation pumping stations, and about 30 miles of power lines. Virtually everything was broken or bent.

We formulated some plans and discussed our proposed actions with our insurance adjustors. We think that developing a good relationship and understanding with your insurance company is a critical aspect of any recovery effort. Develop a work philosophy that is mutually agreeable and follow it. Discuss any deviation before doing it. Work with the insurance company.

We initiated a program of testing all electrical gear before energizing it. If it tested bad, we set up a program to repair or replace the item with the insurance adjustor's approval. Recovery work at McBryde included the resheathing of our Wainiha Hydro building, rewinding of the two generation units and the exciters, replacing most of the meters and relays, and replacing the circuit breakers. Our Kalaheo Hydro building also required a new roof, rewinding of the generator and exciter, and rebuilding or replacement of all meters, relays, and switch gear. Insurance paid for the replacement of the transformers.

The Koloa factory was extensively damaged. Electrical repair work included replacement or cleaning of many of the motor control centers. The mill control panels were also replaced. Many sections of roof are also being replaced.

Recovery still continues and we expect to be busy with recovery work for another year.

Cooperation With Others

The period immediately following the disaster is the period when a lot of emergencies are being handled, and all stops are being pulled to help and to get help from others. It's important to cooperate and help others because you will probably need their help in return. It's nice to drive up to a reported pipe break and find a water department crew there fixing your leak. In return, when they need a backhoe, you send one. Kauai Electric used a section of one of our circuits to feed Kalaheo. These relationships are not developed after the disaster but long before in everyday business.

Source: Randall J. Hee,
McBryde Sugar Company, Ltd.

and the system is operating normally, the preparedness plan, response actions, and outcomes should be thoroughly evaluated.

Step 7: Revise Plan as Necessary

Following the "lessons learned" evaluation, it may be necessary to modify the preparedness plan. Any changes to the plan, response actions, or facilities should be made promptly. Remember that the preparedness plan should not reflect any facility or equipment changes until they occur.

TRAINING

Any training program, including those directed at emergency response, must have a purpose, appropriately selected trainee personnel, and proper instruction and supporting materials. Training can be conducted in-house and/or through outside sources.

Purpose

The purpose of emergency preparedness training is to (1) educate system personnel about disaster hazards and their effects on the system and (2) practice emergency response.

Trainee Personnel

The personnel selected for specific training should be those who can most benefit from it. Staff should not attend a course if the training does not apply to their position. The exceptions are for cross-training and general interest courses such as home safety or disaster response. As with all training, course records should be maintained. A separate listing of employees and their emergency capabilities (e.g., first-aid trained, CPR trained, etc.) should also be kept with the emergency plan.

Training Courses

Before developing any in-house training courses, evaluate existing curricula. Numerous educational and training courses are available through LEPCs, SERCs, FEMA, local colleges, and the American Red Cross. AWWA offers a number of training courses, videos, and curricula pertaining to emergency preparedness and safety.

Develop a program whereby attendees can apply and disseminate course content to other utility staff. Course handouts, curricula, summaries, and similar informational pieces can be distributed to appropriate personnel or used during in-house training.

Keep in mind that an effective training program need not be time consuming. Even a few hours per week over a one- or two-month period may be sufficient to train one group of employees. Some key factors to consider include

- System size
- Probable disasters
- Complexity of the system or component
- Type of staff undergoing training
- Critical nature of system operation
- Availability of existing training programs

- Type of instructors available
- Education and experience of staff
- Joint training with neighboring systems and other area governmental agencies

An appropriate environment can enhance any training experience. If feasible, a utility should provide as many of the following features as possible to support in-house training efforts:

- A well-equipped training room dedicated for training, including lectures and classroom activities
- Videocassette player and monitor
- Personal computers and all requisite supporting software
- Maps showing the layout of the water utility
- Detailed system drawings

Training Exercises

Training and practice are *essential* for an effective emergency response. They allow personnel to practice emergency response, recovery, and evaluation. Training exercises can be conducted solely with utility personnel or jointly with other utilities or agencies.

One training option is a tabletop exercise. This is a valuable and cost-effective format that allows practice in "what if" scenarios such as, "What if a magnitude 6 earthquake hit at 3 a.m. and took out the main transmission line, damaged the water treatment plant, caused several main breaks in the older part of town, and knocked out power?" Another training tip is to practice with the assumption that a key staff person(s) is not able to respond. This method allows you to see how successful your cross-training efforts have been.

On-site exercises usually involve specific activities such as running emergency generators, practicing communications, and isolating parts of the system. Experience with safety programs at water and wastewater systems indicates that, even though safety equipment is available and clearly marked, many staff members are unaware of the equipment's location and proper use. Hands-on training exercises are intended to correct these deficiencies.

One of the most valuable features of a training exercise is to identify problems or gaps in the emergency preparedness plan. Incorporate improvements, modifications, or additions into the next update of the plan.

Ongoing Training

Training should be ongoing to reinforce previous training and introduce new staff to the program. It's an unfortunate fact of human nature that as soon as training ends, people begin to forget what they were taught. Additionally, staff turnover can decrease the number of trained personnel. Finally, new problems, new techniques, and changes in equipment can diminish system readiness.

Ongoing training can be complex and involved or consist of something as simple as a monthly luncheon seminar, a monthly bulletin, or periodic lectures by outside speakers to reinforce certain elements of the training program.

Case Study: Flooding in New Jersey

Initiating Disaster Procedures

After an 11-in. (28-cm) rainfall on Friday and Saturday, Aug. 27 and 28, 1971, the Raritan-Millstone Filter Plant of the Elizabethtown Water Company, Elizabethtown, N.J., with a capacity of 150 mgd (568 ML/d) was inundated and completely inoperable.

Late Saturday afternoon, all neighboring water suppliers were contacted and arrangements were made with them for substantial water supplies during the emergency. The principal water suppliers dependent on the Elizabethtown Water Company for all or part of their water supply were contacted and asked to switch to their own supplies or to others' during the emergency. Service from the company's wells, which were not seriously affected by the flooding, were also increased as much and as soon as possible.

During the course of the night on Saturday and into Sunday, August 29, the operating and planning departments worked continuously to arrange for the help that would be needed as soon as personnel could regain access to the plant. Besides alerting the company's crews and supervisory personnel, arrangements were made during the night for (1) electrical technicians from as far away as Connecticut and Pennsylvania; (2) equipment (such as generators, bulldozers, pumps, and heaters) and operating personnel from contractors; (3) stone from a local quarry for road washouts; (4) diesel fuel to replace fuel affected by the flood; and (5) miscellaneous parts and other supplies. All were to be available as near dawn on Sunday, August 29, as possible. All other maintenance employees were sent home to rest. They would report back to work at 5:00 a.m. to complete the task ahead. By virtue of this planning, the employees were able to start work immediately when they were physically able to enter the plant at 5:00 a.m.

Also, on Saturday night, August 28, after talking with members of the State Department of Environmental Protection, the company's executives decided to recommend that all customers throughout Elizabethtown Water Company's system boil their drinking water until further notice. This determination was made as a precautionary health measure to avoid any possible problems that could arise from negative pressures in flooded areas and from the fact that the company's clearwells at the Raritan–Millstone plant were flooded.

From 8:00 p.m. on August 28, until approximately midnight, telephone calls were made to all police departments and health and sanitation officers in each community served. These community representatives were asked to inform the public by the most expeditious means possible that drinking water should be boiled until further notice as a precautionary measure. At 8:30 p.m. on August 28, radio releases were issued directly to every radio station serving the area, major radio stations in metropolitan New York, the Associated Press, and United Press International. The outlets were asked to inform all residents in the Elizabethtown Water Company service area of the boil-water order. These messages were also carried on television, in local newspapers, and announced at church services on Sunday morning.

Restarting Facilities

When the plant was reentered at 5:00 a.m. on Sunday, 190 tons (173,000 kg) of stone were required to rebuild the road to the low-lift station before any repairs to equipment at the station could begin. All engines (including diesels) were inoperative. They had to be dried and have some parts replaced before any service could be restored at this location. Similar problems existed at the high-lift station to a slightly lesser degree. Repair work took place at both locations simultaneously.

At about 3:00 p.m. on Tuesday, three days after the flooding, the Department of Environmental

continued next page

Case Study: Flooding in New Jersey (continued)

Protection, in conjunction with the company's laboratory, agreed that almost all customers would no longer have to boil their drinking water. A radio release to this effect was sent to all radio stations. There was one local area that, because of its elevation, was subject to a greater possibility of negative pressure and thus residents there were advised to continue boiling water until further testing. During the afternoon of the following day, laboratory results indicated that boiling would no longer be needed in this area. At that time a release was issued to the radio stations reaching those areas and the appropriate municipal officials were also notified.

By mid-morning of Wednesday, September 1, the Raritan–Millstone plant was producing 90 mgd (340 ML/d). This was more than adequate to provide complete service to all retail customers served by the company and to begin service to other water utilities ordinarily served. With the 90-mgd (340-ML/d) production, the storage reservoirs were refilled and pressures built up to normal.

Communications

Throughout the entire emergency, the company's switchboard was manned continuously, and at no time were calls backed up to a point that personnel were not able to answer in a relatively normal period of time. Most of the calls were from residents wanting to know whether or not they would still have to boil water and, if so, how long to boil it. Other calls, received to a lesser extent, had to do with low water pressures and questions concerning a lack of water service. As the situation improved, the number of calls regarding the taste of chlorine or discolored water increased somewhat. During the period from 6:30 p.m. on August 28 through 5:00 p.m. on September 3, 9,346 phone calls were handled.

In addition to the commercial office, the executive offices were continuously manned as a command center throughout the emergency. There was always at least one corporate officer available to talk with the press and with officials of the communities regarding their specific problems. Throughout this period, these executives were in constant communication with the health officers and police and fire departments of the communities served.

Source: Ring (1973).

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Appendix A

South Carolina's Guidelines for Hurricane Procedures

PREPAREDNESS & PROCEDURE

The hurricane season in South Carolina begins each year on June 1 and ends November 30. Since 1900, 146 tropical storms or hurricanes have passed near enough to significantly affect some portion of the state. On the average, there are about three storms every two years, with the highest probability of a storm affecting the state occurring in late summer. Even at minimum force, these tropical storms are capable of inflicting major property damage to coastal and inland regions of the state.

The sudden surge of high water that accompanies a hurricane passage, called storm surge, is usually the greatest cause for the loss of life during a hurricane passage. The storm surge associated with weaker storms may be only a few feet, but may be as high as 15 or 20 feet or more during major hurricanes.

Because they are guardians of public health, water plant operators need to be prepared for emergencies associated with this seasonal hazard. It is imperative that citizens be protected from the spread of waterborne disease both routinely and during emergency situations.

The following precautionary measures should be followed by persons responsible for safeguarding public drinking water facilities:

Before Storm

1. Check thoroughly all auxiliary and standby equipment. It is essential that this equipment function properly during emergency conditions. If possible, equipment should be automatically controlled to ensure operation if evaluation is necessary.
2. Stock adequate fuel supplies to operate auxiliary equipment for a 10 to 14 day period. An acceptable alternative is to make short term contracts with suppliers to hold fuel in reserve during the hurricane season.
3. Stock spare parts which are critical to the operation of the plant, wells or auxiliary equipment.
4. Maintain in good repair all mechanical equipment at water plants and wells, including booster pump stations.

S.C. Department of Health and Environmental Control
Environmental Quality Control District Offices

24-Hour Emergency Number
(803) 253-6488

Division of Water Supply
(803) 734-5310

Area	District	Telephone
1	Appalachia I	260-5569
2	Appalachia II	241-1090
3	Appalachia III	596-3800
4	Upper Savannah	223-0333
5	Catawba	285-7461
6	Central Midlands	737-7015
7	Lower Savannah I	648-9561
8	Lower Savannah II	648-9561
9	Wateree	778-1531
10	Pee Dee	662-3522
11	Waccamaw	448-1902
12	Trident	554-5533
13	Low Country	522-9097

5. Stock sufficient supplies of chlorine or hypochlorite and other necessary treatment chemicals to carry the system through a 10 to 14 day period.
6. If continuous chlorination is practiced then it is advisable to slightly increase the dosage of chlorine to insure a slightly higher chlorine residual within the distribution system.
7. Keep all ground storage reservoirs and elevated tanks as near to full capacity as possible upon receiving hurricane warnings. In the event of imminent landfall, provisions should be made to valve off those tanks and distribution lines located on barrier islands or in areas where breaching of waterlines is possible. An updated distribution map showing the location of all valves should be maintained.
8. Tape or board-up windows and tie down or secure any supplies or materials to prevent them from becoming airborne during the hurricane.
9. Know emergency procedures and emergency interconnections with nearby public water systems. Frequent communications with adjacent utilities in case of a mutual need is critical to the welfare of both your community and neighboring ones.
10. After hurricane warnings are received notify the Department of Health and Environmental Control (DHEC) when emergency procedures have been completed. This should be done by calling the District Director of the local Environmental Quality Control (EQC) Office. The EQC office should be made aware of how and where to contact persons in charge during emergency conditions.

After Storm

1. Survey all damage and make sure all water is being properly treated once hurricane warnings have been lowered or normal services are restored. Any areas where contamination of the water system may have occurred should be reported immediately to the local EQC office so bacteriological and/or chemical samples can be taken and analyzed.

2. Following a storm which significantly impacts an area where extended power outages have occurred, DHEC will be monitoring all public water systems. Advisories will be issued including boil water notices when necessary, as information becomes available.
3. In the event that it becomes necessary to safely disinfect the water at the customers tap, the following procedures can be used for safely disinfecting water for potable use:

DISINFECTION BY HEAT

A. Strain water through a clean cloth into a container to remove any sediment or floating matter. If water is clear, omit this step.
B. Boil the water vigorously for at least one FULL minute.
C. After allowing the water to cool, it is ready to use. If desired, a pinch of salt added to each quart of boiled water, or pouring it back and forth from one clean container to another several times, will improve the taste.

CHEMICAL DISINFECTION

Use liquid chlorine laundry bleach from the home laundry or grocery store. **Do Not** use a bleach that has a fragrance or scenting agent, like a lemon scent. Read the label to find the percentage of chlorine available then follow this table:

Available Chlorine	Drops To Be Added Per Quart**	
	CLEAN WATER	CLOUDY WATER
4 to 6 percent *	2	4
7 to 10 percent	1	2
If not known	10	20

*Common household chlorine laundry bleach (Clorox, Purex, etc.)

**1 teaspoon equals approximately 100 drops.

A. Mix thoroughly by stirring or shaking water in container.
B. Let stand for 30 minutes.
C. A slight chlorine odor should be detectable in the water; if not, repeat the dosage and let stand for an additional 15 minutes before using.
D. Water is now safe to use.

4. Any sustained damage to the water system should be immediately reported to the local EQC office. Reports concerning any minor damage should be reported within a few days or as soon as possible after the hurricane. Let the local district offices know if assistance is needed from the Department of Health and Environmental Control (DHEC).

Your local DHEC representatives will be working closely with Emergency Preparedness officials to respond to your needs following a hurricane or another disaster.

Please maintain and update your Emergency Preparedness plan as needed. Get to know your local DHEC representatives and local Emergency Preparedness director. If you have any questions, please contact the appropriate EQC district office (see map) or the Water Supply Division, located in Columbia.

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Hurricane Preparedness & Procedures

Water Facilities

Hurricane Information

For illustration purposes only.

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OTHER RESOURCES

American Water Works Association

Emergency Planning: The Big Picture for Water Utilities—This documentary-style video presents dramatic, first-hand accounts of water utilities' responses to catastrophic events. (1995)

Minimizing Earthquake Damage: A Guide for Water Utilities—This handbook helps you assess your system's seismic vulnerability and find ways to minimize damage. (1994)

Preparing for Water Main Breaks—Water main breaks are a fact of life in the water supply profession, and preparation is key to fast response (video). (1997)

Responding to Water Main Breaks—This video presents the five-step preparation pentagon to show you how to implement safe, efficient procedures for working a main break. (1997)

Safety First: Water Utility Security—This video analyzes security issues and precautions needed to protect employees and the public water supply. (1998)

The Risk Management Program Rule: The Basics of Compliance—This instructive video takes you step by step through compliance with the EPA's Risk Management Rule and its effect on your safety program. (1999)

Compliance Guidance and Model Risk Management Program for Water Treatment Plants—Step-by-step guide for compliance with EPA's Risk Management Rule; includes forms, checklists, etc. (1999)

US Environmental Protection Agency

Chemical Emergency Preparedness and Prevention Office (CEPPO)—http://www.epa.gov/ceppo/

Chemical Accident Prevention and Risk Management Programs [Clean Air Act (CAA) Section 112(r) information]—http://www.epa.gov/ceppo/acc-pre.html

This site contains a wealth of information regarding the CAA Risk Management Program, including guidance documents, fact sheets, and RMP submittal.

Preparedness—Emergency Planning and Community-Right-to-Know—http://www.epa.gov/ceppo/crtk.html

This site includes technical guidance documents and information on submitting required reports.

Emergency Response—http://www.epa.gov/ceppo/emerg.html

This site describes CEPPO role during emergencies and details the federal contingency plan.

Counter-terrorism—http://www.epa.gov/ceppo/cntr-ter.html

This site contains the latest information regarding counter-terrorism efforts of EPA and other federal agencies.

US Department of Labor—Occupational Safety and Health Administration (OSHA)

Process Safety Management—http://www.osha-slc.gov/SLTC/processsafetymanagement/index.html

OSHA home page for information regarding the Process Safety Management regulation. Featured items include full-text regulations, guidance documents, hazard information bulletins, and training information.

Miscellaneous Government Agencies

Federal Emergency Management Agency—http://www.fema.gov

This is the home page for the federal government's emergency response agency. It contains the latest news on disasters, disaster preparedness, resources (including family safety), and maps.

Centers for Disease Control and Prevention—Bioterrorism Preparedness and Response—http://www.bt.cdc.gov/index.asp

News, resources, and links regarding bioterrorism.

National Response Center—http://www.nrc.uscg.mil/index.html

The NRC is the sole federal point of contact for reporting oil and chemical spills. The site also contains spill information, statistics, and links.

U.S. Geological Survey—National Earthquake Information Center—http://www-neic.cr.usgs.gov

This site provides a wealth of information concerning earthquakes and earthquake preparedness.

Other Resources

The Chlorine Institute—http://www.cl2.com

General safety and health information regarding chlorine. Information pamphlets available for download.

National Safety Council—Chemical Process Safety—http://www.crossroads.nsc.org/chem_proc_safety.cfm

This site hosts a variety of features related to chemical process safety, including informational articles, fact sheets on chemical safety, accident investigations, regulations and standards, reports, studies, and training.

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NOTE: Note: *f.* indicates figure; *t.* indicates table.

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M3, *Safety Practices for Water Utilities,* Fifth Edition, 1990, #30003PA

M4, *Water Fluoridation Principles and Practices,* Fourth Edition, 1995, #30004PA

M5, *Water Utility Management Practices,* First Edition, 1980, #30005PA

M6, *Water Meters—Selection, Installation, Testing, and Maintenance,* Fourth Edition, 1999, #30006PA

M7, *Problem Organisms in Water: Identification and Treatment,* Second Edition, 1995, #30007PA

M9, *Concrete Pressure Pipe,* Second Edition, 1995, #30009PA

M11, *Steel Pipe—A Guide for Design and Installation,* Fourth Edition, 1989, #30011PA

M12, *Simplified Procedures for Water Examination*, Second Edition, 1997, #30012PA

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Security Analysis & Response For Water Utilities

American Water Works Association

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OVERVIEW

AWWA Manual M19, *Emergency Planning for Water Utility Management*, was prepared to guide utility managers in preparing for all types of emergencies that may affect a utility's ability to provide a reliable supply and quantity of safe water for drinking, food preparation, bathing, and other purposes. The guidance provided in Manual M19 addresses both natural disasters, such as floods, earthquakes, tornadoes, hurricanes, and high winds, and human-induced emergencies caused by theft, vandalism, accidents, and terrorism. Because major disruptions to utility operations are more commonly caused by natural events than human-induced events, the emphasis in Manual M19 is on the former.

The events of September 11, 2001, force the intensified consideration of the terrorist threat. Water utilities have, until now, considered the likelihood of an attack on their systems to be very low and few measures have been implemented to mitigate such a threat. This supplementary publication provides guidance on the assessment of human-induced security risks and preparation of response plans appropriate for the risks identified in the security assessment.

Two points cannot be overemphasized regarding the use of guidance in this document or other security checklists. First, involvement of outside professionals in completion of security assessments is usually invaluable because they are trained to look for weaknesses in a system and can provide an objective evaluation of threats and vulnerabilities. Second, a completed security assessment and response plan is useful only if the utility staff and supporting agencies maintain continued vigilance.

Hazard Assessment

The sources of human-induced security risks to water utilities can include vandals, past and present employees and other individuals, domestic extremist groups, or foreign-based terrorist organizations. The two main types of threats discussed in this document are physical and contaminant threats.

No specific set of hazards or threats is applicable to all utilities but instead depends on the unique characteristics of each utility. Although a checklist of potential biological and chemical threats is included in this section, and more detailed checklists may be made available from other sources, each utility must use such lists with caution, making sure that differences in source of supply, treatment processes, distribution system configuration, and control systems are fully considered.

Vulnerability Assessment

The vulnerability assessment defines priorities for response activities. All elements necessary for a utility to produce safe and sufficient water must be evaluated for vulnerability to disruption. These elements of the utility supply system generally fall into the categories of:

- Raw water supply facilities
- Treatment facilities
- Distribution facilities
- Operation and control facilities and systems

- Staff and personnel systems
- Support systems, including chemicals, power, and communication

It is recommended that public trust be considered a critical asset of the utility. A separate aspect of the security assessment is evaluation of the potential for disruption of the quantity and quality of the water supply system at various locations of vulnerability within the system. Special emphasis is given to vulnerability to biological or chemical contamination of water and the agents associated with this contamination. In addition, the utility now must consider the consequences of **intentional** chemical or biological contamination of the water, injury to facility personnel, or damage to the system.

Mitigation

Vulnerable components of a water supply system can be rendered less susceptible to harm through mitigation actions—actions intended to eliminate or reduce the damaging effects of disasters. Mitigation actions cover a wide variety of activities and can be as complex as retrofitting a treatment plant or as simple as erecting fences or changing locks and passwords after an employee is terminated. Mitigation actions will depend on the hazard and vulnerability analyses. This section discusses mitigating vulnerability through refined information sharing practices and reduced access to the "target."

Development of a Response Plan

Depending on the characteristics of vulnerability for a given water utility, a response plan must be prepared to define measures that will be implemented to either minimize likelihood of an undesirable event or mitigate its impact. Changes in security systems, monitoring practices, physical facilities, and operations are dependent on the nature of the particular threats. A critical component of all response plans is an emergency response plan that defines responsibilities and resources both within the utility and external to the utility. Those resources external to the utility may be local (police, fire departments, emergency response teams, medical and public health agencies and facilities, etc.), regional or state (regulatory agencies, health departments, emergency preparedness offices), or national (US Environmental Protection Agency [USEPA], the Federal Bureau of Investigation, the Centers for Disease Control and Prevention [CDC], the Federal Emergency Management Agency [FEMA], etc.). The systems established pursuant to the Presidential Decision Directive 63 on Critical Infrastructure Protection are given special coverage.

Crisis Communications

Part of the response plan must be avenues and timing of communication with the utility customers. These customers will fall into different categories depending on the amounts of water used and the extent to which their operations are dependent on potable water supply. Examples of large water users with critical dependence on water supplies are hospitals, schools, and fire departments. Communication with the general public is also critical, particularly related to health and safety issues. A comprehensive communication program and responsibility for implementation of the program must be established prior to a disruption or contamination of water supply.

Summary

The American Water Works Association and the authors of this supplement recognize that water utility security issues are receiving more attention and importance than they did prior to September 11, 2001. The reliability and safety of public water supplies are of highest concern to the citizens whose health and well-being are dependent on this water; the professionals whose vocation is to obtain, treat, distribute, and protect this water; and all units of government responsible for protecting and maintaining the public health. Because of this heightened concern and awareness, it is likely that water system security will be enhanced in coming years through the development and application of many new tools and practices, particularly in the areas of monitoring/early warning, treatment technologies, distribution system controls, and security systems. This means that utility managers must continue to review and upgrade their approaches and technologies to better serve the nation's water system security needs.

While security assessments, response plans, and security systems are critically important and valuable, the effectiveness of these tools depends on the skills and diligence of the staff applying the tools. The effectiveness of water utility staff in implementing a security response plan can be measured by the degree to which the culture of the staff has become more security-conscious. The mission of a water utility is to deliver water of unquestioned safety to its customers. This means that the security of the water system must be considered at least equally with any other events that disrupt utility operations.

1 HAZARD ASSESSMENT

According to the President's Commission on Critical Infrastructure Protection (1997), three attributes are crucial to water supply users:

1. There must be adequate quantities of water on demand.
2. It must be delivered at sufficient pressure.
3. It must be safe to use.

Actions that affect any of these three factors can be debilitating for the infrastructure. The first two attributes are directly influenced by physical damage. The third attribute, water quality, is susceptible to physical events as well as the introduction of microorganisms, toxins, chemicals, or radioactive materials.

Terrorism can strike all of the system components individually or in various combinations. Damages associated with most of the hazards identified in Manual M19 can result from terrorist activity, which can range from major events that cause severe damage and disruption of system operations to minor incidents that may not impact normal activities.

A hazard is defined here as any individual, group, or event that could destroy the facility, halt or suspend operations, otherwise threaten the public health, harm employees, publicly embarrass a utility, require a utility to expend a great deal of time or money, or cause general panic. In preparing the hazard (or threat) assessment, security assessment specialists generally look at who or what constitutes a threat and how the identified individual, group, or event could attack a particular system. It is important to consider all potential threats, because assuming the worst may result in overlooking more likely attempts.

1.1 Who Poses a Threat

The terrorist's goal is to achieve notoriety for his or her cause. This can be through massive loss of life as was the case in the plane hijackings of September 11, 2001. Beyond the obvious human tragedy, the net result of these actions includes significant economic impact on industry, the federal government, and state and local governments as they scramble to provide additional law enforcement and National Guard presence. The key to terrorism's success lies not in the act itself but in the ensuing lack of confidence or feeling of insecurity for the citizens at large.

The actual goal of the terrorist is usually not directly associated with the target selected. The usual desire is to instill a general sense of fear in citizens to disrupt their normal activities and way of life. Consumer uncertainty can significantly impact a national economy. Public perception of the safety of infrastructure, as well as the infrastructure itself, are both important assets to be protected. The following paragraphs describe who may pose a threat to the potable water system.

Vandal. A vandal often has a goal in mind, but not necessarily a target; thus, the crime may be of opportunity. Some typical examples of such a crime are graffiti or broken windows. However, a vandalism problem can become much more serious if the paint used to write graffiti on a reservoir is then dumped into the reservoir, posing a threat to the health of the consumer.

Individual. An individual is someone working independently. Although the motivations of individuals can vary widely, the target is clearly defined as the final water user or the facility itself. Individuals who purposely threaten infrastructure are often mentally ill and may target victims based on ethnicity, beliefs, or other characteristics.

In 1974, a Yugoslav immigrant, Muharem Kubergovic, was the first person to acquire and threaten to use chemical agents against the United States. When apprehended in his home, police found 100 lb (45 kg) of explosives and multiple chemicals used in the manufacturing of chemical weapons. Kubergovic bought the chemicals and equipment from ordinary supply houses (Smithson 2000).

Insiders. With their detailed knowledge of the facility and water system, past or present employees and contractors pose some of the most serious threats. Motivations of this group may include revenge or the venting of anger manifested from a real or imagined problem.

Domestic extremist groups. Cults and extremist groups with a political agenda pose a threat to water systems. In the past, food has been contaminated with Salmonella with the objective of affecting voter turnout. The Aum Shrinrikyo cult in Japan spent $30 million on a poisonous gas plant for use in terrorist activities. Better know for the sarin gas attack, the cult also developed anthrax and attempted to use it as a weapon against a civilian population in downtown Tokyo (Smithson 2000).

State-supported terrorist organizations. These organizations usually have a large number of followers and the greatest financial and technological resources. The use of some chemical and biological weapons of mass destruction are limited to these groups because of the significant resources required for their development. Known nations with the capabilities to produce weapons of mass destruction are North Korea, China, India, Pakistan, Iran, Iraq, Syria, Libya, and Russia (Department of Defense 2001).

1.2 Types of Threats

This section describes two types of threats against a water utility: physical and contaminant threats.

Physical. Many observers believe that a physical event that destroys or disrupts a water system's components is a much more likely scenario than a contamination event. For instance, explosive materials are readily available and require a lower level of education compared to the development and deployment of contaminants.

Potential types of physical attacks are listed below.

Aerial attack includes physical attacks on the treatment facility or the use of airplanes to drop contaminants into open reservoirs or sources (the latter example combining physical and contaminant attacks).

Cyber-terrorism attacks on the data acquisition system (supervisory control and data acquisition [SCADA]) are another threat. A terrorist could disguise the data, neutralize the chlorine, or add no disinfectant, thus compromising disinfection and allowing the addition of microbes usually not considered a threat, such as salmonella (when chlorine residual is present). Alternatively, attacks on the central control systems could create a large number of simultaneous main breaks by opening and closing major control valves too rapidly. Because many SCADA and control networks are not connected to the Internet, this threat is most likely to come from a disgruntled employee with access to the system.

Explosives could be used at any number of locations to compromise the pumping, storage, or transmission of water. Explosives, which can be developed or obtained, pose less of a risk to the attacker compared to biological and chemical weapons. Explosives also require a comparatively lower level of education. A bomb explosion within the distribution system will require immediate response and redirection of water to prevent contamination and draining of the system.

Fire may be one of the easiest methods of sabotage because needed materials are readily available. It is effective because destruction of the computer control system, pumps, or motors or compromising of the structure pose a significant barrier to the operation and timely restart of a plant. Furthermore, once the city water supply is reduced, the ability to fight other fires is compromised, seriously impacting the safety of other critical infrastructure.

Personnel attacks on the plant staff could lead to multiple personnel injuries that would leave a plant without a skilled operational workforce. A hostile takeover could also allow for a cyber-terrorism attack.

Contaminants. The following section outlines biochemical toxins; microbial agents; industrial chemicals; nerve, blood, and blister agents; and radioactive materials that could potentially contaminate potable water systems. The chemistry of each toxin, chemical, and microbial agent is specific. Some are neutralized by chlorine, others are effectively removed through the drinking water treatment process, and all have different thresholds for the appearance of symptoms, infection, and lethality.

Biochemical toxins require a very small volume compared to other chemicals. Still, many are difficult to develop in quantities large enough to pose a lethal threat to municipal water systems; however, smaller, nonlethal doses may be used to induce sickness or terrorize the population. Table 1 includes a list of potential toxins and their sources.

Microbial agents include bacteria, virus, protozoa, and other microbes. Experts and the US government believe biological weapons are within the reach of terrorists. However, the education level, monetary resources, and risks required to produce these agents are higher than those required for physical methods of terrorism. The high microbial concentrations place the developer of such weapons at high risk. Table 2 provides a partial list of potential bacterial and viral agents.

Industrial chemicals are yet another threat due to large, readily available supplies. Several factors are important in the analysis of a chemical threat: volume of water to be contaminated, solubility of contaminant, lethal dose, and volume of water that must be ingested to constitute a lethal dose. Fortunately, the vast majority of industrial chemicals make poor candidates as a lethal, undetectable agent. Often the lethal dose required to contaminate a water supply requires a very large quantity or is even insoluble at the required concentration. Furthermore, many toxic chemicals have disagreeable colors, tastes, and odors that would alert the consumer to their presence.

Although poisoning the water supply through the use of industrial chemicals is difficult, it is not impossible to make the water unfit for consumption or simply terrorize the target population.

War agents such as nerve, blood, choking, and blister agents include sulfur, mustard, and sarin gases among many others. These have been developed by multiple countries for use generally as incapacitating or discomfort agents. They are not considered as likely toxic water contamination threats due to the high concentrations required.

Nerve agents are the most deadly within this category, as they are 100 to 1,000 times more lethal than pesticides made with organophosphorous chemicals (Smithson 2000).

Radioactive material is another method of contamination. The primary radiological threat is the use of conventional explosives to spread radioactive contamination over a limited area or strategic terrain. This could include highly radioactive materials, such as spent fuel traveling to the Yucca Mountains for containment or low-level radioactive materials, including uranium-238, iradium-192, cesium-137, strontium-90, or cobalt-60. Using radioactive materials to contaminate drinking water presents a challenge, requiring large quantities of materials, many of which are insoluble in water, heavy, and would settle out before reaching the target or would be trapped in filters. Furthermore, radioactive material poses a safety concern for the attacker.

Table 1 Biological Toxins

Agent	Source
Abrin	Plant (Rosary Pea)
Aconitine	Plant (Monkshood)
alpha-Conotoxin	Cone Snail
alpha-Tityustoxin	Scorpion
Anatoxin-A(s)	Blue-Green Algae
Batrachotoxin	Arrow-Poison Frog
Botulinum toxin	Bacterium
C. perfringens toxins	Bacterium
Ciguatoxin	Marine Dinoflagellate
Diphtheria toxin	Bacterium
Maitotoxin	Marine Dinoflagellate
Microcystin	Blue-Green Algae
Palytoxin	Marine Soft Coral
Ricin	Plant (Castor Bean)
Saxitoxin	Marine Dinoflagellate
SEB (Rhesus/Aerosol)	Bacterium
Shiga toxin	Bacterium
T-2 toxin	Fungal Myotoxin
Taipoxin	Elapid Snake
Tetanus toxin	Bacterium
Tetrodotoxin	Puffer Fish
Textilotoxin	Elapid Snake

Source: US Army Medical Research Institute of Infectious Disease. 2001.

Table 2 Potable Water Pathogens

Scientific Name	Common Name	Availability in Environment
Bacillus anthracis	Anthrax	Infected cattle, goats, swine, sheep, horses, mules, dogs, cats, wild animals, and birds
Brucella melitensis & *Brucella suis*	Brucellosis	Infected cattle, goats, swine, sheep, horses, mules, dogs, cats, fowl, deer, and rabbits
Vibrio cholerae	Cholera	Human excrement and shellfish
Clostridium perfringens	Clostridium Perfringens	Soils, water body sediment, intestinal tracts of fish and mammals, crabs, and other shellfish
Cryptosporidium parvum	Cryptosporidiosis (Crypto)	Calves
Encephalomyelitis Virus	Encephalomyelitis (VEE)	Rodents and horses
Picornaviridae & Reoviridae	Enteric Viruses	Humans
Burkholderia mallei	Glanders	Horses
Yersinia pestis	Plague	Prairie dogs, chipmunks, black rats, deer mouse (mice?), certain species of ground squirrels, and coyotes
Chlamydia psittaci	Psittacosis	Birds
Coxiella burnetii	Q Fever	Cattle, sheep, and goats
Salmonella typhimurium	Salmonella	Fowl, swine, sheep, cattle, horses, dogs, cats, rodents, reptiles, birds, and turtles
Shigella dysenteriae	Shigellosis	Sewage
Variola Major & Variola minor	Small Pox	Centers for Disease Control and Russia Biological Lab
Francisella tularensis	Tularemia	Wild rabbits and most other wild and domestic animals
Ebola & Hantaviral among others	Viral Hemorrhagic Fever (VHF)	Ticks and rodents

Source: Prescott, L.M., J.P. Harley, and D.A. Klein. 1999.

2 VULNERABILITY ASSESSMENT

This section adds consideration for terrorist activities to the four basic steps in a vulnerability assessment:

1. Identify and describe the separate components of the water supply total system.
2. Estimate the potential effects of probable disaster hazards on each component of the system.
3. Establish performance goals and acceptable levels of service for the system.
4. If the system fails to operate at desired levels under potential disaster conditions, identify key or critical system components responsible for the condition.

2.1 Step One: Identify Major System Components

Key elements of the total system should be listed and described as components under the following general headings: (1) administration and operations, (2) source water, (3) transmission system, (4) treatment facilities, (5) storage, (6) distribution system, (7) electric power, (8) transportation, and (9) communications.

Describe system components with as much detail as possible. Typical items included in a general description are pressure zones, location of pressure-relief valves, pipe sizes, pipe material and ages, typical distance between hydrants, and major valve locations.

In addition to these physical components, an additional item to be considered is the public confidence and reputation of the utility. An important asset of water treatment and distribution systems is the public perception and confidence in the end product. This must also be considered vulnerable to terrorist attack.

2.2 Step Two: Determine the Effects of Probable Disaster Hazards on System Components

The effects of a terrorist event on a water utility can result in a wide range of consequences. For example, an explosive device detonated at a noncritical location may not cause any appreciable damage to the facilities and therefore not endanger the capability of the facility to process water. Conversely, chemical contamination of the system can result in long-term disruption of service until it can be cleaned and returned to service. The range of consequences that could be attributed to terrorist activities include:

- Disruption of water treatment, storage and delivery, and delivery components
- Introduction of biohazards and toxins into the water system
- Injury to facility personnel
- Injury to general public
- Damage to utility property or equipment
- Damage to private property
- Hazardous waste disposal problems — what happens to contaminated water if it is flushed from the system?

In addition, terrorist activity may focus on more than one part of the system, using damage in one area to divert the response team or to magnify the consequences of damage to another element of the system.

2.3 Step Three: Establish Performance Goals and Acceptable Levels of Service for the System

A water system is considered a lifeline because water is essential to the safety and health of the population it serves. A utility should develop specific goals and acceptable levels of service under disaster and recovery conditions. The acceptable goals for system service should consider the effects of terrorist activity. Taken individually, the effects are identical to those caused by various natural and human-induced hazards. Specific goals to consider are life safety, fire suppression, public health needs, and commercial and business uses.

2.4 Step Four: Identify Critical Components

Identifying the critical components of the system or its subcomponents is the final step in the vulnerability analysis. Critical components are those most vulnerable to failure or partial failure because of an intentional act or natural disaster. Failure of a critical component will reduce the system's ability to meet minimum health and safety performance goals. To identify those components that would fail in an intentional attack, run a desktop exercise of an attack scenario and then focus on those components whose failure would render the entire system inoperative—these are the most vulnerable components.

Consideration of critical components should include public perception of the value of a safe water system. In most cases, confidence in the safety of the water system and financial support are closely linked. The public will most likely choose to provide support for security measures if it is perceived that a well-conceived security master plan is in place.

2.5 Critical Review of Existing Security Systems

The purpose of security systems is to limit vulnerability. It is important to assess existing security measures and their integration with previous steps to determine the effectiveness of these systems. Do the existing security measures protect major and critical system components and do they minimize risk? The security review should include facility inspection, a review of documents and operations (policies, plans, and standard operating procedures), and interviews with employees.

3 MITIGATION

Mitigation actions to reduce system vulnerability to terrorism are very similar to methods discussed at length in other publications about mitigating vandalism or natural hazards. However, mitigation actions also include elements that prevent unwarranted access to a system's components, which in some cases may be contrary to the ease of access (e.g., reaching an intake by boat) that is necessary for mitigating an unintentional disaster. The extent to which these measures are applied will directly depend on the acceptable amount of risk and the likelihood of the hazard materializing, which are determined by the hazard analysis and vulnerability assessment.

3.1 Mitigation at the Source

Standard mitigation measures relating to source water and transmission range from providing alternate sources and protecting wellheads to retrofitting dams or aqueducts. Mitigation actions for watershed damage or widespread contamination include providing automated monitoring equipment, using alternate sources or intakes, and modifying source water treatment at the plant. Controlling access, identifying alternate sources, and providing flexible treatment facilities can also mitigate the effects of deliberate contamination of reservoirs. Access to reservoirs and other outlying system components, such as pump houses and tanks, can be controlled by installing fences, gates, and signs; closing unnecessary roads; and increasing security patrols.

3.2 Preventing Access to Facilities

To prevent access to facilities, install adequate locks, window security, and lighting. Install intrusion-prevention devices, such as electronic keys, identification-card checkers, and 10-key code units, to control access to the strategic facilities. If you have the personnel to perform constant monitoring or can contract with a security firm, you can also install closed-circuit television monitoring systems or alarm systems with ultrasonic, heat, or beam sensors and magnetic switches to detect intruders. Be sure to change passwords when employees are dismissed or a contractor's job is done, both on electronic keys and on computer systems.

Don't forget about controlling access to chlorine and other chemical systems, and design and construct these systems with automatic control systems that can indicate the extent and locations of a leak, actuate chlorine scrubbers, close valves, shut down equipment, and isolate affected areas.

3.3 Distribution System Issues

Because of their large numbers and widespread dispersal, controlling access to distribution system components can be difficult. One key to accessing or locating any attacks on the distribution system will be accurate and up-to-date system plans, which should be maintained in numerous locations.

Work with your local fire department to be sure there is adequate alternative pumpage capability and water supply in the event of loss of flow to fire hydrants in an emergency situation. Consider what action should be taken to provide these redundancies if a pump house becomes disabled, either by loss of power or through destruction of the pumps, and where the water would come from if a storage tank were drained or a main break interrupted the flow.

Mitigation activities should take into account what happens to contaminated water if it needs to be flushed from the system. Does exposing it to the air cause even more potential for dispersal of the contaminant? Is the water normally released to a storm drain or waterway?

3.4 Staff Role in Preventing Terrorism

In addition to the mitigation techniques identified, facility personnel can also play a very important role in preventing terrorism and acts of sabotage to facilities. In the wake of recent terrorist actions, a new sense of patriotism has emerged. Facility personnel who previously may have been hesitant to take an active role in security activities are now generally eager to be involved in facility security. Most Americans are recognizing that they can play a role in protecting the citizens of the United States at home. Include the front line employees when discussing what could happen and what action to take—these people are the eyes and ears of the system and may be the first to spot trouble.

Water utilities should be much more careful in disseminating information regarding facility operations, plant and system layouts, and emergency response and crisis management plans. These could prove useful to terrorists wishing to identify system vulnerabilities.

Two factors that will reduce water system susceptibility are the reduction of information regarding facility operations and preventing access to the target through countermeasures.

Reduction of Information**.** Information concerning the plant and distribution system layouts and emergency response and crisis management plans could help terrorists identify system vulnerabilities. These sources of information should be removed from public libraries, the Internet, and other available locations. Furthermore, those that legitimately claim to need access to such documents should be scrutinized.

Countermeasures

Access control can include a variety of systems designed to control the movement of persons or vehicles. Access control may include guards, locks and keys, or access cards.

Physical barriers may have been established to prevent an intrusion or attack but usually function to hinder or slow the attack. Such measures may include hardened construction, vandal-resistant glazing, and doors. Fencing is not a good barrier, as it is only considered to provide a 6- to 10-second delay. Physical barriers in regard to contaminants may include backflow protection, filters for airborne particulates on plant and reservoir vents, or specially designed reservoir vents to prevent the pumping of a contaminant into the distribution system.

Detection through some type of monitoring system provides notification that an undesired intrusion (physical or contaminant) has occurred. Examples include name badges to identify unauthorized personnel, closed-circuit cameras, motion detectors, security guard scrutiny, or sensors in the distribution system. Detection should be as far away from the asset as possible to allow time for the response. Closed-circuit television systems make excellent assessment devices. Assessment refers to the verification of the detection system. For instance, personnel can use monitors to help assess the situation after an alarm goes off.

Once the utility decides which countermeasures to implement, any physical improvements should be combined with updated policies and procedures to ensure full optimization of the system.

4 RESPONSE PLANNING FOR PUBLIC DRINKING WATER SYSTEMS

All elements of a water treatment plant are susceptible to human disruption, including the raw water source, the treatment facility, the operations and control facility and systems, and the support facilities and systems such as chemical feed, power supply, and communications equipment. A preparedness plan and a response plan can be developed based on the results of the vulnerability assessment. The exact content of each response plan hinges on the vulnerability and the risk for any given water utility. A response plan must define the measures that will be implemented to minimize the likelihood of an event or to mitigate its impacts.

According to the Studies in Urban Security Group (SUSG) at the College of Architecture and Urban Planning in Ann Arbor, Michigan, the development of an emergency response plan for the contamination of a public water system may be subject to federal, state, or local regulations or guidelines (Rycus, Snyder, and Meier 1989). Presidential Decision Directive 63 required that federal agencies develop and implement plans to protect the nation's critical infrastructure (President 1998). The Safe Drinking Water Act Amendments of 1986 and the Emergency Planning Community Right to Know Act of 1986 require that each state appoint a State Emergency Response Commission, whose responsibilities include designating emergency planning districts within the state.

Following the designation of the emergency planning districts, Local Emergency Planning Committees (LEPCs) should be formed. These committees should consist of representatives of public agencies, such as water and wastewater utilities, fire departments, health officials, law enforcement, and government officials. The LEPC then reviews the responsibilities of the water service during storms, floods, earthquakes, fires, explosions, nuclear reactor spills, aircraft crash, hazardous material incidents, power failures, and civil disturbances when formulating the response plan for human disturbance.

Manual M19 provides utilities with information helpful in formulating a response plan. In addition, the SUSG study states that a response plan should contain:

- A legal and administration basis
- A classification of emergency conditions

- Provisions for command and control, communications, emergency supplies and distribution, threat management, and plan review and revision (Rycus, Snyder and Meier 1989).

Many utilities may already have a response plan. The authors of the new or revised response plan should verify that the plan contains the most current contact names, phone numbers, and e-mail addresses; that the content is the product of a proper and complete vulnerability and risk assessment; and that it contains the components listed in this supplement.

4.1 Define Emergency Status

In developing a response plan, the term *emergency* must be defined, preferably with variations in degrees of alert/emergency status. The SUSG study defines four levels of severity:

1. Normal operations/minor emergencies: Required responses do not extend beyond the water department, so an "emergency response" is not warranted.

2. Alert condition: In situations where a major emergency may be forthcoming, the system director may declare an alert condition. An alert condition triggers the assembly of key decision-makers and operational personnel to assess and monitor the situation.

3. Emergency condition: In a situation where disruption or contamination is imminent or has occurred and where the full resources of the system, augmented by external resources (e.g., fire, police, public health), are required for appropriate response, the system director should declare an emergency condition. Under this condition, a full response plan would be implemented.

4. State of emergency: At this most serious level, especially involving the community at large, declaration of a state of emergency would be appropriate. Typically, only the governor of the applicable state can declare this condition, and it implies that the broadest resources available will be applied to the problem (Rycus, Snyder, and Meier 1989).

4.2 Developing an Emergency Response Plan

This section details the nine general steps that should be considered in the development of a response plan for a public drinking water system. When developing a response plan for a specific water utility, it is important to evaluate each of the following steps, investigate the relevance of each step to the specific water utility, expand on the information, and provide any useful information.

Step 1: Gather command group at a designated location. The SUSG study recommends that the command group include persons with specific expertise, such as the chief operator of the water utility, a staff member capable of providing technical support, staff member for administrative support, the head of engineering, the director of laboratories, and the director of security. The group should be organized according to an established chain of command.

The command group members should meet at a prearranged location, or Emergency Operations Center (EOC), that contains working communications equipment, including a computer with information on distribution system plans, source water plans, any secondary or tertiary utility plans, the Internet, a telephone, and a radio (Rycus, Snyder, and Meier 1989). This location will be the main operations center. A backup location should also be established in the event the primary location cannot be used.

Step 2: Conduct preliminary assessment to determine the nature, extent, and severity of the disturbance. A plan for assessing a disturbance should be prepared in advance. The assessment should address control around the perimeter of the utility's assets and an internal review of water treatment plant data encompassing the laboratory, water treatment plant performance, disinfection contact times, chemical feed, and other relevant data. The personnel who participate in the assessment should have an intimate understanding of plant operations and the significance of the data.

Water utilities are not required to monitor their facilities for biological, chemical, or radiological contaminants or cyber interference. However, continual monitoring, routine testing, and careful observation are recommended to prevent contamination of supplies or interference with operation and to facilitate prompt mitigation of any disturbance. The local department of health or the laboratory that performs the analyses should immediately report any contamination or suspicious test results to a designated member of the command group, most likely the water utility supervisor. Any information from the laboratory data will enhance the assessment.

One way to determine the threat posed if a chemical contamination occurs within the utility is a Computer-Aided Management of Emergency Operations (CAMEO) database. Many SERCs have access to a CAMEO database, which includes information on chemicals, transportation of the chemicals, and other information to better prepare for response to chemical emergencies. The USEPA's Chemical Emergency Preparedness and Prevention Office and the National Oceanic and Atmospheric Administration Office of Response and Restoration developed CAMEO. The USEPA also published a document about SERCs and the involvement of the CAMEO program titled *Secrets of Successful SERCs* (USEPA 1993).

Based on the results of the assessment, the command group should decide whether to declare a water utility alert or a water utility emergency and, if necessary, implement the appropriate emergency response.

Step 3: Assemble specialized groups: Specialized groups should be assigned before the emergency occurs. This will save time and expedite the group's response actions. The assignments of the specialized groups may include:

- Situation assessment
- Laboratory analyses
- Law enforcement and security
- Public information/media communications
- Emergency water supply
- Emergency evacuation
- Human health reporting/assistance
- Repair/recovery

A secured and current membership list for each group should include each member's position, name, and phone numbers. This list should also be included within the response plan.

Step 4: Alert other officials: If an emergency situation is declared, the command group should request further assistance from the appropriate law enforcement or other government agencies, including:

- Police—Exterior investigation, directing traffic, security
- Fire department—Emergency fire protection
- Emergency medical system—Emergency health care
- Public Health Department—Emergency health investigations
- USEPA—Environmental impact aid
- FEMA—Emergency response aid
- Department of Transportation—Infrastructure aid
- State National Guard—Additional manpower and security
- Other water agencies

Step 5: Communicate with the media: At the onset of an alert, emergency condition, or state of emergency, the designated media spokesperson should be notified. This assignment should be given to a person who can communicate effectively with the media. A media center should be established for both written and verbal press releases. It is also important to monitor media coverage. Sensible public information and communications during an emergency are crucial to the implementation of any type of response plan. See section 5 for more information.

Step 6: Consider human health: If an alert, emergency condition, or state of emergency has been called, it is important to identify the areas most likely to be affected. If health concerns exist, local government officials, local water departments, hospitals, health departments, emergency medical teams, and fire departments must be notified. Depending on the type and severity of the situation, federal agencies such as the Department of Public Health, FEMA, USEPA, and the CDC may also have to be alerted.

Step 7: Determine alternative sources for emergency water supplies: An emergency situation may require the use of water from other sources, such as unaffected reservoirs, fire stations, or independent water supplies. It is important to identify the available sources of emergency water supplies before the need arises. A plan for emergency water distribution and for conveying the water to the consumers should be developed. It is also important to set priorities for where the emergency water will be distributed and how it will be used.

Utilities may choose to partially neutralize the risk of a break in service through a number of avenues:

- Partitioning the distribution system so that certain areas can be shut down without affecting a large proportion of the entire system.
- Estimating tank truck availability and inflatable water storage units (internal and external to the utility) for providing emergency water.
- Estimating hospital and sensitive-user water needs and ensuring water supply to these users in case of an emergency.

Step 8: Establish relationships with nearby water utilities and supporting utilities: Maintaining relationships with other water suppliers will expedite a utility's ability to tap into alternative sources of supply in an emergency. Such resources may include independent or private water utilities and purveyors, bottling companies, and some large water-using industries that have their own supplies.

Step 9: Plan and implement countermeasures and recovery measures: Determine the anticipated types and extent of laboratory tests and establish a testing plan.

Additional Information for the Response Plan

- Formulate an extensive list of the area laboratories, with phone numbers and individual contact names.
- Formulate a list of contacts with appropriate state and local government agencies and other companies such as power utilities and bottling companies.
- Annually review and update the response plan.
- Maintain evaluation forms and require proper completion if contamination has occurred.

4.3 Threat Management

Threat management is a major part of preventing an emergency situation. In the event of a threat, either written or oral, it is necessary to record the contents of the threat and quickly notify the command group to evaluate the threat. Each water utility should have an evaluation form that should be filled out by the employee who receives the threatening call or letter.

5 CRISIS COMMUNICATION

In times of extreme crisis, such as the events of September 11, 2001, citizens appear more trusting of governments (and, by extension, utilities). They look to mass media, particularly television, to bring them vital information about how to behave and protect themselves. Therefore, it is critical for utilities to have an effective, efficient plan in place to guide communications with media, and hence with their public, in the event of crisis. Utilities should not rely on politicians to communicate crises but should keep state, local, and federal agencies continually updated on the crisis.

It is critical for the utility to communicate in a way that fosters trust and confidence. The utility must be first to release information about how the crisis has impacted the drinking water supply. Delayed release of information can result in loss of life, accusation of cover-up, and ultimate loss of public trust. In a crisis situation, the guiding principle for utilities is, "Be the first to deliver the bad news." Effective crisis communication has no room for images and egos—it is only about saving lives and protecting the public health.

While the crisis communication plan is being developed, its proposed content and direction should be reviewed with the public (through public meetings, discussion groups, civic club meetings, public libraries, etc.) to confirm that it meets specific public needs for information. Each segment of the utility's public will have its own needs for information and information delivery, and every effort should be made to accommodate these special needs. For example, the frail elderly may have one set of crisis concerns, pregnant women another, infants and young children yet another. The utility should develop a list of sensitive stakeholders, contacts, and phone numbers based on the public review findings. The list must be kept current.

One beneficial outcome of the public review is building a constituency of credible sources with which to partner in case of crisis. Potential candidates for credible sources include local universities, the League of Women Voters, parent–teacher organizations, the medical profession, and environmental groups.

5.1 Preparing for a Crisis

The following steps should be taken to prepare for a crisis:

1. Develop a communication policy and a plan of action for use in case of a crisis.
2. Form a "crisis team" and define member roles and responsibilities. The team should include representatives from top management, operations, public affairs, government affairs, legal, insurance, human resources, finance, and others.
3. Compile a list of contact numbers (e-mail might not be available in a crisis) for each team member and all top management members.
4. Identify primary and backup spokespersons for the organization. Spokesperson should be authoritative without appearing arrogant.
5. Notify all utility personnel that only the designated spokesperson should speak with the media.
6. If the utility use an outside public relations firm, define its roles and functions. If the utility does not maintain an in-house staff of public communicators, prearrangements should be made to use an outside firm in the event of a crisis. Should a crisis occur, the utility's public relations staff will be very busy. Staff members must be prepared ahead of time with such basic tools as scripts covering various crisis scenarios, lists of frequently asked questions, and media kits, including background information on all possible crisis threats (such as various biological elements).
7. Develop media (television, newspaper, and radio), community, and government contact information (phone, fax, and names of key contacts) and keep it current.

8. Create a “media” office location and backup location. Provide the office with appropriate supplies and equipment to handle electronic communication, faxing, phoning, and overnight mailing. Also provide television, radio and VCR capability for monitoring media coverage and recording it. Determine security and access rights for both nonemergency and emergency situations. Be prepared to set up a podium with an appropriate backdrop. Set up a work area with phones for press.
9. Involve the public to determine which groups might require specific direct communication and if the plan can be improved so as to best serve customers’ health and safety needs in time of crisis.

During a Crisis

These steps should be taken during a crisis:

1. Activate the “media” office. Communicate activation with security and implement appropriate access rights.
2. Collect everything known about the crisis situation and put it in writing for review by the crisis team. Update the report regularly.
3. Contact external public relations firm if appropriate.
4. Immediately after review (within one hour of the event), develop and distribute the initial media statement. Immediately update utility’s web page with this and future press releases. Provide media with name and phone number of spokesperson to reduce potential for rumors and inaccurate information.
5. Communicate individually with specific special interest groups of the utility, including:
   - Stockholders
   - Advisory groups
   - Governmental entities and elected officials
   - City council
   - Medical community
   - Others as identified in the public involvement effort
6. Maintain files of all hard copy, electronic, media, and video communications during the crisis event.
7. Provide crisis response office staff with lists of phone numbers and contacts.
8. Provide frequent updates to employees regarding the crisis event and the utility’s responses and press releases. Post the list of phone numbers for crisis team members.
9. Request that all employees refer media requests to the designated spokesperson.
10. Establish a schedule of crisis team meetings (morning and afternoon) to update information and issue responses to media and employees.
11. Provide media with background information, including information about how the utility protects public health and safety.
12. Request support from AWWA and other appropriate federal, state, and local organizations.
13. Work with previously established partners from the medical community to issue joint statements and press releases. Make joint television appearances.

Some general guidelines for dealing with the media include:

- The spokesperson must be in control of his or her emotions, remain calm, appear authoritative but not arrogant, and be extremely polite.
- Anticipate likely questions. Understand the perceptions/fears of the public. Address fears by offering facts, not conjecture. Do not answer "what if" questions. Do not use emotional statements or industry jargon.
- It may be necessary to communicate with the public before all facts are known. Be humble. State priorities (e.g., getting the situation under control) and assure the audience that the utility staff is doing everything it can.
- Assume that there is no such thing as "off the record."
- Avoid conjecture or assigning blame. Both could result in rumors, embarrassment for the utility, and future litigation against the utility.
- Keep communications succinct so as not to confuse or dilute the main message.

SAMPLE THREAT EVALUATION FORM

Type of threat indicated by caller: ____

Specific details of threat: ____

____

____

____

Caller's sex (circle one) Male Female Not sure

Caller's age (circle one) Under 10 10-20 Over 20 Not sure

Describe the voice of the person placing the threat: ______________________________

____

____

____

Describe any background noises or unusual sounds during the phone call: ____________

____

____

____

Did the caller name any organization? ____

____

____

____

Did the caller give any other information? _____________________________________

____

____

____

Name of person completing this form: ____

Date and time threat was received: ____

Evaluation form based on Rycus, Snyder, and Meier (1989), Threat Evaluation Form.

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