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Water Security Scenarios

Planning for Installation Water Disruptions

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Planning for Installation Water Disruptions

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Abstract

The Army's critical missions are at risk from interruption of water supplies. Sufficient amounts of high-quality potable water are a resource without substitute. The Army's Installation Energy and Water Security Policy establishes requirements for installations to sustain critical mission capabilities and to mitigate risks posed by energy and water disruptions that affect installations; this includes coordinating vulnerability and risk assessments of potential disruptions and implementing adequate responses to mitigate identified risks. Resilient installations will develop storage capacity to forestall water shortages and will also have short- and long-term plans to help the installation recover from events and forestall progressing to more severe deficits. This project supports compliance with the water security policy by exploring the range of conditions and responses possible across installations. Multiple scenarios were developed to explore how a 14-day interruption in water supply might affect an installation and to provide preliminary guidance to help installations develop strategies to address water disruptions to critical missions drawing from existing processes used in mission assurance. Researchers investigated types of installations and classes of scenarios most relevant to installation water security planning and explored several scenarios to provide a framework to help installations advance their water resilience and security planning.

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Preface

This study was conducted for the Office of the Assistant Secretary of the Army, Installations, Energy and Environment OASA(IE&E), via Military Interdepartmental Purchase Request (MIPR) 1097857 “Energy Security & Sustainability Projects,” project, “Water Security Scenarios” via work item G63544, “Developing Guidelines for Minimizing Potable Water Loss.” The technical monitor was Dr. Marc Kodack, Office of the Deputy Assistant Secretary of the Army for Energy and Sustainability, ODASA(ES). Technical monitors were Mr. Paul Volkman and Dr. Stephen Dornbos, ODASA(ES).

The work was managed and executed by the Energy Branch, of the Facilities Division, U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Ms. Mariangelica Carrasquillo-Mangual was Chief of the Energy Branch and Ms. Giselle Rodriguez was Acting Chief of the Facilities Division. The Acting Deputy Director of ERDC-CERL was Ms. Michelle Hanson and the Acting Director was Dr. Kirankumar Topudurti.

COL Teresa A. Schlosser was Commander of ERDC, and Dr. David W. Pittman was the Director.

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1 Introduction

1.1 Background

To better evaluate and target investments in water security and resilience, Army policy makers and installation planners need improved tools and methods that support the acquisition and provision of secure, safe water supplies at Army installations. Currently, installations develop Installation Energy and Water Plans (IEWPs), which help them meet the requirements of the Army's water security policy. IEWPs consolidate the energy and water planning processes. A well-developed IEWP increases water security, resilience, and readiness; and ensures mission success. Before drafting an IEWP, installations must evaluate the potential for water allocation. They do this, for example, by documenting the water demand of the installation as a whole and of specific mission-critical facilities; by identifying backup and redundant supplies; by evaluating the condition of the water infrastructure; and by identifying projects that will support water resilience.

However, an IEWP is a "living document" that requires periodic updates. Creating and updating an IEWP requires an efficient, accurate process to collect, analyze, and review the materials needed to meet the requirements outlined in the Army's IEWP Guidance. The Installation Status Report (ISR) is an important tool that supports the Army's shift to developing IEWPs in that it provides data used to assess the condition of installation infrastructure, environmental programs, and support services. Measures within the ISR are reviewed by installation personnel; however, as yet there is no instruction on how to compile ISR responses.

This work was undertaken to support those responsible for completing annual ISRs to maximize successful completion of an IEWP, specifically, ISR sections that pertain to water. The following chapters clarify how the information required to develop an IEWP can be collected and include examples that illustrate how this information can be organized. Each strategy suggested in this report is accompanied by three examples that show how the method could be carried out at diverse installations. In a general sense, the information provided here exemplifies the need for the Army to constantly exchange internal adaptive knowledge, enabling easier recovery from mission disruptive events.

1.2 Objectives

The overall goal of this work was to improve Army planning for water resilience and security through support for processes required to prepare IEWPs. Specific objectives were to

- Develop methods and tools to compile and analyze information about water distribution systems
- Document case studies of historic Army installation water system disruptions, and propose appropriate solutions that follow
- Document these events and their solutions, thereby formalizing the institutional knowledge that is often lost over time.

1.3 Approach

To accomplish the project objectives, researchers

1. Conducted a literature review to research and document
 - a. existing methods for analysis of water distribution system information
 - b. common water disruptions
 - c. categories of installation by functional type.
2. Screened installations for their potential to participate in further studies.
3. Documented a range of water security scenarios.
4. Developed scenarios for each of the selected installations.
5. Prepare project documentation.

1.4 Scope

Although this project focused on three installation types identified through a review of literature and sponsor recommendations, this work could be replicated at other unique installation/mission sites using similar methodology. Additionally, a crucial component of this report is the documentation and standardization of the previously implemented solutions to water supply interruptions. This documentation is intended to enable future replication and Army-wide implementation of successful solutions.

1.5 Report organization

The information contained in this report is intended to provide background information, data collection tools, and scenario examples for installations engaging in water security and resilience planning:

- Chapter 2 provides a brief conversation regarding water security and resilience planning in the Army.
- Chapters 3 to 5 review essential background information to understanding Army structure, its operations, and the broad range of disruptions that could impact an installation's mission.
- Chapter 6 reviews existing methods of data collection that have been used to compile IEWPs.
- Chapter 7 demonstrates how various scenarios may be mitigated on three diverse installations.
- Chapter 8 outlines insights drawn from these scenarios and makes general recommendation on increasing resilience.

2 Water Security and Resilience Planning for the Army

The Army's water supplies for critical missions are at risk of interruption due to natural disasters and human-caused emergencies such as accidents, vandalism, or acts of terrorism. Interruption to an installation's water supply may jeopardize mission capabilities and installation security. Interrupting the water supply also affects the Army's ability to project power and support global operations. This chapter describes the drivers for the increased visibility of water security and resilience planning in the Army, and the need for a far-reaching methodology to help installation personnel support these goals.

2.1 Drivers

2.1.1 Policy

The Secretary of the Army issued the Installation Energy and Water Security Policy (2017) to avert potential problems associated with water disruptions. The policy establishes requirements to sustain critical mission capabilities and to mitigate risks posed by disruptions to energy and water supplies to installations. Specifically, installations must be capable of providing necessary energy and water for critical missions for a minimum of 14 days.

To meet this requirement, installations must increase their resilience by being able to anticipate, prepare for, and adapt to changing conditions; and to withstand, respond to, and recover rapidly from disruptions (Army Directive 2017-07 [Secretary of the Army 2017]). Furthermore, installations must maintain water security, ensure access to reliable supply of water, and be able to protect and deliver sufficient water to meet mission-essential requirements (National Defense Authorization Act for Fiscal Year 2012). To achieve such water resilience and security, an installation must draft an IEWP, which frames the installation's strategy to maintain an emergency supply of water to satisfy the needs of mission-critical facilities and assured access for all missions.

2.1.2 Mission assurance

Continuing availability of the water supply is vital to the critical mission operations on an installation. Water availability is a function of not only

the quantity of water available at the time of need, but also the quantity of water that is of sufficient quality that it can be used after available potable water treatment methods are applied. In the face of such threats to critical missions from disruptions in water quantity and quality, installations must consider appropriate actions to ensure their capacity to maintain an adequate water supply, and to acquire technologies to rapidly recover the ability to sustain operations after a water disruption event. Development of resilient water supply can leverage policies and lessons from Federal and state programs, academic studies, and water industry organizations. To comply with the new guidance, installations would benefit from development of criteria using scenarios to meet the 14-day minimum potable water supply requirement for critical missions located on an installation.

2.1.3 Installation Status Report (ISR)

Installation Status Report – Mission Capacity (ISR-MC) reports annually on the status of vital services and infrastructure enabling our Nation’s installations to execute their missions without interruptions. These reports also provide documentation of interruptions and their sources that enable installation command to plan and learn from past interruptions. Multiple sections within the ISR-MC report focus on water infrastructure, including Critical Mission Sustainment (MS320), Assured Access (MS321), Infrastructure Condition (MS322), and System Operation (MS323). For each of these sections, Army installations receive scores (listed here from worst to best) ranging from Black, to Red, Amber, Green, and Green+. Each section focuses on an important factor that installations must consider when planning maintenance, expansion, or sustainment of their water and wastewater treatment and distribution systems.

Specific measures developed within ISR-MC have informed and influenced the work establishing the foundation for the Water Security Scenarios report. MS323-3a narrowly focuses on the quantitative discrepancies between water demand and supply, and on detecting potential capacity issues and inadequate available supply. It requires each installation to perform a detailed analysis of their water needs and available production, and to determine if expansion to their water treatment or supply is necessary. MS323-3b focuses on the prioritization of water distribution during periods of scarcity and instructs Army installations to establish plans for water use and distribution during both natural and human made water shortages.

2.2 Disruptions to Army installation water

Potable water availability can be disrupted in a number of different ways, with the ability to affect single buildings, entire installations, and even regions. Risks and disasters can include drought, flooding, earthquake, tornado, or hurricane (Figure 2-1); quality degrading events, such as contamination through chemical spills and eutrophication; manmade threats such as industrial accidents, fires, infrastructure failures, and intentional damage to infrastructure (Figure 2-2); and policy conflicts derived from the competition between human and environmental water demands. Drought can cause water supplies to dry up, leaving regions without water or can cause water quality concerns in surface water systems. Flooding can overwhelm or damage infrastructure, resulting in an inability to treat and deliver drinking water for a prolonged period of time. Contamination of potable water sources can render the water unsafe and unusable.

Figure 2-1. Tornado at Fort Leonard Wood, MO in 2010.

Figure 2-2. Water main break at Fort Bragg, North Carolina in August 2017.

Incidents of interruptions to water supplies at Army installations are not uncommon. Flooding has affected many Army installations, e.g., Fort Irwin (2013), Fort Jackson (2015), Fort Benning (2013/2015), Fort Hood (2017), and Fort Leonard Wood (2017). Water supply disruption due to water infrastructure failure has occurred at Fort Bragg (2017) and the U.S. Army Corps of Engineers (USACE) Engineer Research and Development Center, Vicksburg, MS (2017).

However, the Army's Installation Status Report (ISR 2019), which tracks each facility's condition in terms of infrastructure, services, and mission capacity, reports that one-third of the reporting installations in 2017 had no water supply redundancy for potable water. Only 60% of installations can meet critical mission water requirements for a period of 72 hours, which is the longest time period reported.

This indicates that most Army installations could benefit from developing criteria using scenarios to meet the 14-day minimum potable water supply requirement for critical missions located on an installation. Installations must not only take reasonable actions to ensure and sustain water resilience and to maintain water security; they must also prepare for less obvious threats including those caused by residues from ranges and construction on or near the installation, from byproducts of power generation, or

from exposure due to training, traffic, or rail activities occurring in the watershed. Resilient installations must not only have enough storage capacity to avert water shortages; they should have short- and long-term plans to help the installation recover from events and mitigate effects.

Installations face many of the same quantity and quality challenges faced by their industry and municipal counterparts, including biological threats from exposure to sewage and agricultural runoff, pharmaceuticals and personal care products, disinfectants and disinfection byproducts, changes in water chemistry, and exposure to inorganic and organic chemical contaminants from sources such as industry and agriculture. Development of resilient water supply can leverage policies and lessons from Federal and state programs, academic studies, and water industry organizations. Installations must prepare for additional threats, such as intentional or unintentional exposure to chemical and biological agents.

3 Understanding Army Command Structure

3.1 Installation stakeholders

The first step in data collection is to compile stakeholder information. The selection of stakeholders to develop an IEWP requires that the auditor have considerable knowledge regarding Army structure and the ability to recognize the roles each organization plays in the installation's overall mission. Although the mission-critical facility list is constructed by the garrison commander, it is important to identify all installation commands, units, tenants, and other stakeholders in order to determine supporting facilities and infrastructure. Installations can be organized and described based on the Department of the Army command structure. Military missions lend themselves to this organization, though individual installations are often composed of multiple commands or units. This chapter describes the Army command structure and installation stakeholders as a means of deriving a set of points of contact (POCs) to inform IEWP preparation.

3.2 Army command structure

The Army is structured into Major Army Commands (MACOMs), Army Service Component Commands (ASCCs), and Direct Reporting Units (DRUs). Figure 3-1 illustrates the command structure organization.

3.2.1 Major Army Commands (MACOMs)

MACOMs include the U.S. Army Forces Command (FORSCOM), the U.S. Army Training and Doctrine Command (TRADOC), the U.S. Army Materiel Command (AMC), and the U.S. Army Futures Command (AFC). Table 3-1 lists a brief description of each of these commands. Appendix A contains more detailed descriptions.

Figure 3-1. Tree diagram of the Army command structure.*

* MEDCOM was reorganized under the Defense Health Agency in October 2018.

Table 3-1. Major Army Commands (MACOMs).

Command	Mission
U.S. Army Forces Command (FORSCOM)	Trains, mobilizes, deploys, sustains, transforms and reconstitutes assigned conventional forces
U.S. Army Training and Doctrine Command (TRADOC)	Recruits, trains, educates, develops doctrine and established standards
U.S. Army Material Command (AMC)	Provides technology, acquisition support and logistics
U.S. Army Futures Command (AFC)	Modernize the Army for the future

3.2.2 Army Service Component Commands (ASCCs)

ASCCs can be organized into geographically based and functionally based categories, which, respectively, correspond to Geographic Combatant Commands and Functional Combatant Commands. Geographically based commands include the following commands:

- U.S. Army Africa (USARAF)
- U.S. Army Central (USARCENT),
- U.S. Army North (USARNORTH)
- U.S. Army South (USARSO)
- U.S. Army Europe (USAREUR)
- U.S. Army Pacific (USARPAC).

Functionally based commands include the following commands:

- the U.S. Army Special Operations (USASOC)
- the Military Surface Deployment and Distribution (SDDC)
- the U.S. Army Space and Missile Defense (USASMDC)
- the U.S. Army Cyber (USARCYBER).

Table 3-2 lists a brief description of each of these commands. Appendix A contains more detailed descriptions.

Table 3-2. Army Service Component Commands.

Command	Mission
U.S. Army Africa (USARAF)	Serves the U.S. Africa Command (AFRICOM) operations in Africa
U.S. Army Central (USARCENT)	Serves the U.S. Central Command (CENTCOM) operations in the Middle East and Egypt
U.S. Army North (USARNORTH)	Serves the U.S. Army Northern Command (NORTHCOM) operations in the North America

Command	Mission
U.S. Army South (USARSO)	Serves the U.S. Army Southern Command (SOUTHCOM) operations in the Caribbean islands and Central and South America
U.S. Army Europe (USAREUR)	Serves the U.S. European Command (EUCOM) operations in Europe and Russia
U.S. Army Pacific (USARPAC)	Serves the U.S. Army Pacific Command (PACOM) operations in Asia, Australia, and the Pacific Islands
U.S. Army Special Operations Command (USASOC)	Organizes, trains, mobilizes, deploys, and sustains U.S. Army special operations forces to carry out special warfare operations
Military Surface Deployment and Distribution Command (SDDC)	Provides surface delivery of equipment and supplies
U.S. Army Space and Missile Defense Command/Army Forces Strategic Command (USASMDC/ARSTRAT)	Conducts space and missile defense operations and provides continuous oversight control, integration, and coordination of Army forces supporting the U.S. Strategic Command (STRATCOM)
U.S. Army Cyber Command (USARCYBER)	Directs and conducts integrated electronic warfare and cyberspace and information operations

3.2.3 Direct Reporting Units (DRUs)

DRUs include the following commands:

- U.S. Army Intelligence and Security Command (INSCOM)
- U.S. Army Criminal Investigation Command (USACIDC)
- U.S. Army Human Resources Command (HRC)
- U.S. Army Corps of Engineers (USACE)
- U.S. Army Military District of Washington (MDW)
- U.S. Army Test and Evaluation Command (ATEC)
- U.S. Military Academy (USMA)
- U.S. Army Acquisition Support Center (USAASC)
- U.S. Army Installation Management Command (IMCOM)
- U.S. Army War College
- Arlington National Cemetery
- U.S. Army Accessions Support Brigade.

Table 3-3 lists a brief description of each of these commands. Appendix A contains more detailed descriptions.

Table 3-3. Direct Reporting Units.

Unit	Mission
U.S. Army Intelligence and Security Command (INSCOM)	Synchronizes INSCOM unit operations to produce intelligence in support of the Army, Combat Commands, and the National intelligence community
U.S. Army Criminal Investigation Command (USACIDC)	Conducts sensitive investigations, provides protective services and criminal investigative support to all Army investigations
U.S. Army Human Resources Command (HRC)	Executes distribution, talent management, personnel programs, and services
U.S. Army Corps of Engineers (USACE)	Provides engineering services and capabilities
U.S. Army Military District of Washington (MDW)	A geographic command with responsibilities that extend throughout the Washington, D.C. metropolitan area
U.S. Army Test and Evaluation Command (ATEC)	Plans, integrates, and conducts testing and evaluations to provide essential information to acquisition decision makers and Commanders
U.S. Military Academy (USMA)	Educates, trains, and inspires, and prepares Corps of Cadets for a career as an officer in the U.S. Army
U.S. Army Acquisition Support Center (USAASC)	Improves the Army's capability through all stages of materiel development
U.S. Army Installation Management Command (IMCOM)	Manages Army installations to support readiness and mission execution
Army War College	Provides a military education
Arlington National Cemetery	Lays to rest those who have served the Nation
U.S. Army Accessions Support Brigade	Connects the public with the U.S. Army

4 Role of Army Operations in Emergency Water Planning

The IEWP incorporates Installation Energy and Water Security Policy and Department of Defense Mission Assurance goals. Understanding Army operations and how disruptions may impact these operations is key to developing effective resilience projects. This chapter summarizes Army operations and the six warfighting functions, and then gives an overview of how a water disruption might impact each of these.

4.1 Background

The Army is a component of the joint forces and contributes to the system by means of the *unified land operations*. Unified land operations are:

simultaneous offensive, defensive, and stability or defense support of civil authorities tasks to seize, retain, and exploit the initiative to shape the operational environment, prevent conflict, consolidate gains, and win our Nation's wars as part of unified action (DOAHQ 2017).

To execute unified land operations, the Army organizes efforts under the operations structure, which consists of three main components: the operations process, the operational framework, and the elements of combat power.

First, the operations process is the Army's framework for exercising mission command. This is a framework of four main activities that mission command conducts during an operation: planning, preparing, executing, and assessment of the operation. Part of the assessment of the operation is building and maintaining situational understanding of the operational environment. Commanders and staff members use operational and mission variables in their analysis to build their situational awareness. Operational variables include political, military, economic, social, information, infrastructure, physical environment, and time. Similarly, mission variables include mission, enemy, terrain and weather, troops and support available, time available, and civil considerations (DOAHQ 2012). Appendix C lists the operation and mission variables.

The second component of the operations structure is the operational framework, which is a tool used to assist commander and staff in visualizing and describing the application of combat power in terms of time,

space, purpose, and air space. Under this component, the commander considers four factors: area of operations, deep-close-support consideration areas, decisive-shaping-sustaining operations, and main and supporting efforts. The focus here is on the development of main and supporting efforts, which will help define critical missions.

The third tier of the operations structure is the elements of combat power. Combat power consists of eight elements, six of which are collectively defined as the warfighting function (Table 4-1). A warfighting function is a group of tasks and systems united by a common purpose to accomplish missions and training objectives. The combat powers use Information and Leadership as tools to apply the remaining six warfighting functions. These are used to define broad mission categories (DOAHQ 2017).

Table 4-1. Warfighting functions.

Warfighting Function	Description
Mission Command	Tasks and systems that develop and integrate those activities enabling a commander to balance the art of command the science of control to integrate the other warfighting functions
Movement and Maneuver	Tasks and systems that move and employ forces to achieve a position of relative advantage over the enemy and other threats
Intelligence	Tasks and systems that facilitate understanding the enemy, terrain, weather, civil considerations, and other significant aspects of an operational environment
Fires	Tasks systems that provide collective and coordinate use of Army indirect fires, air and missile defense, and joint fires through targeting processes
Sustainment	Tasks and systems that provide support and services to ensure freedom of action, extend operational reach, and prolong endurance
Protection	Tasks and systems that preserve the force so the commander can apply maximum combat power to accomplish the mission

4.2 Impact of disruptions on main operations

Impacts of disruptions can vary in severity depending on their duration and physical scale. For instance, structural damage to a non-essential administrative building may have less impact on key missions than structural damage to a mission-critical administrative building. Installation personnel must also consider operation and mission variables in order to maintain an acceptable level of situational understanding. The following section describes the warfighting functions.

4.2.1 Mission command

Mission Command plays a significant role in the development of operations, maintenance, and management. Mission Command is responsible for conducting the operations process, command post operations, knowledge and information management, civil-military operations, space operations, and command programs. Disruptions in mission command would affect the overall efficiency and organization of an installation. A lack of organization and well-defined operations will result in disrupted missions across all units and tenants on the installation.

4.2.2 Movement and maneuver

Disruptions to activities at Movement and Maneuver facilities can affect tactical actions associated with Force Projection and Deployment. This can limit maneuver support operations, countermobility operations, and mobility operations. Similarly, compromises of training and deployment operations can influence global military efforts, causing increased vulnerability at home and abroad.

4.2.3 Intelligence

Intelligence refers to the creation and dissemination of information within an installation. Intelligence support to Force Generation is a major component of this category; it also contributes to situational understanding through gathering intelligence, surveillance, and reconnaissance. Intelligence and communications contribute to a large portion of the security and safety of an installation. Disruptions in intelligence operations can produce significant threats to the health and safety of onsite tenants.

4.2.4 Fires

Providing fire support and integrating air-ground operations is a major operation for the Army. Delays in providing the support and resources needed for this operation increase the risk to the life, health, and safety of personnel onsite. Access to water and personnel during a fire operation-related incident is critical to containing the threat and reducing the number of injuries.

4.2.5 Sustainment

Sustainment refers to logistics, personnel, and health support. The allocation and organization of resources is critical during an emergency. Predefined emergency resources and POCs can drastically reduce response time. A key component of sustainment is creating and maintaining a critical facilities list and mitigation and response documents for threats. Disruptions to sustainment operations can affect the completion of the mission through interruptions that prolong decision making after the emergency event.

4.2.6 Protection

Safety and security are key considerations and a major operation on military installations. Protection measures include conducting operational area security, personnel recovery operations, air and missile defense, force health protection, as well as chemical, biological, radiological, nuclear, and enhanced high explosive (CBRNE) safety techniques. Beyond mission fulfillment, the life, health, and safety of an installation's personnel is one of the most important considerations on an installation. Disruptions to any protection measures would result in increased vulnerability to an installation's tenants and to its mission.

5 Types of Water Disruptions to Consider

The description of water disruptions contains an extensive list that should be included in the IEWP. Installations should research the history of disruptions on site as well as the potential for disruptions based on regional conditions and system parameters. For instance, the effect of multiple disruptions may be equal in the case of a partial loss or total loss of water supply, however, the mitigation strategies to address them may differ. Often a single disruption reverberates throughout an installation and can cause 2nd and 3rd order effects through the water distribution system. The data in Table 5-1 give a broad overview of potential damage, loss or shortage to select system components.

Table 5-1. Potential disruptions to system components by hazard.

System Components - Likely Damage, loss, or shortage due to hazard	Earthquakes	Hurricanes	Tornadoes	Floods	Forest or Brush Fires	Volcanic eruptions	Other Severe Weather	Waterborne Disease	Hazardous Material	Structure Fire	Construction Accidents	Transportation Accidents	Nuclear	Vandal, riots and 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	•		•	•	•	•								•

SOURCE: (NIST 2015)

5.1 Types of water disruptions

Disruptions can be categorized as either natural or manmade. Natural disruptions refer to climate or natural system-induced events or population change. Manmade disasters are either intentional or unintentional and can be further broken into two additional categories pertaining to accidents or infrastructure related events.

Figure 5-1. Types of water disruptions (natural and manmade).

5.2 Natural disruptions

This section is drawn from Emergency Response Planning for Military Water Systems. The severity of natural disruptions can vary depending on factors such as seasonality, duration of the event, and intensity of the incident. The following sections outline major hazards, their classification levels, and their potential effects on water distribution systems (USACHPPM 2005).

5.2.1 Hurricanes

Hurricanes are considered to be a threat to water systems above ground (e.g., storage tanks, uncovered treatment processes); exposed transmission lines, which could cause a loss in power; and underground water systems via physical destruction of infrastructure (e.g., water main breaks). Hurricanes also foster contamination due to the increased risk of flooding.

5.2.2 Nor'easter

Violent winter storms, such as nor'easters, can produce large amounts of snow and rain. This can affect water distribution lines above ground, water systems underground, and administration and operations on an installation. With respect to the latter, the primary concerns here include access to the base and the safety of onsite personnel. Other concerns include damage or delays in water distribution caused by cracks in pipes when the ground freezes. Nor'easters also create excessive snowmelt, which can produce effects similar to flooding.

5.2.3 Tornadoes

Tornadoes can cause extensive structural damage to critical aboveground water system components and can disrupt procedures in such administrative and operational facilities including water treatment plants, buildings, electrical transmission lines, telemetry system components, exposed transmission piping, transportation systems, and communications systems. Loss of power and structural damage are major concerns of a water distribution center. Conversely, high winds and infrastructure damage can affect accessibility and mobility on an installation.

5.2.4 Floods

Levels of precipitation high enough to create flooding can overload water treatment processes and contaminate the water supply. Flooding can also affect surface water by transferring chemical and microbiological contaminants into the water supply. Emergency administration and operations may also be delayed due to loss of electricity, transportation, and communications.

5.2.5 Fires

Fires tend to occur in areas affected by dry weather or drought because fire spreads easily through dry vegetation. Structural fires are a major concern on installations and can be caused by storms, accidents, or acts of vandalism. Fires can damage electrical transmission lines, deplete potable water supplies, rupture older pipes due to increased water demand, and disrupt administrative and operational procedures. Buildings constructed during the World War II-era are especially vulnerable because of their wooden construction.

5.2.6 Severe weather

Examples of severe weather include periods of harsh cold/heat, blizzards, high winds, and ice storms. Severe weather can be a threat to administrative and operational procedures as well as to water distribution infrastructure. Frozen pipes and/or damage to supply lines can interrupt distribution and daily activities of an installation. Debris created by severe weather can compromise the safety of personnel on site and can decrease the mobility and access to facilities on site.

5.2.7 Earthquakes

Earthquakes can cause severe damage to water systems by damaging pipes, hydrants, buildings, basins, and chemical containers. Note that oscillating levels in water tanks can also cause structural damage to support beams. Debris and damage created by earthquakes can decrease the mobility and access to facilities on site as well as compromise the safety of personnel.

5.3 Manmade disruptions

Manmade disruptions can either be intentional or unintentional. Intentional disruptions can occur at any point in the water distribution system and typically target the water supply or infrastructure. Note that intentional disruptions can be malicious or part of scheduled maintenance, such as replacing aged pipes or repairing leaks (EPCOR 2018). Unintentional disruptions can be further broken down into two additional categories: accidents and infrastructure failures. Accidents may include vehicle collisions, damage caused during construction, hazardous material spills, or aviation accidents. For example, accidents can be sparked by personnel discontent or training. Other unintentional disruptions can be associated with infrastructure components, such as water main breaks, cyber security failures, or poor maintenance (USACHPPM 2005).

5.3.1 Population change

Demand plays a significant role in system pressure maintenance and water age. Low demand is equally as problematic as high demand. Decreased demand in an oversized system can reduce the quality of water. Decreased flows can make it challenging to maintain adequate pressure across a system and can incur additional infrastructure and maintenance costs. Conversely, increased demand of water may produce water shortages. In some

cases, supply may be available, but the proper infrastructure capacity to distribute the additional flow may not be present.

5.3.2 Water contamination

Water contamination concerns include viral, bacteriological, and toxicological agents, which can cause waterborne diseases. This may be caused by missing or failed backflow preventers, natural changes in the source water chemistry, or cross contamination. Water contamination increases the vulnerability of the life, health, and safety of installation personnel.

5.3.3 Source disruption

One type of manmade disruption is a source disruption, which can be defined by a decrease in quality or quantity. These changes in quality and quantity can be driven by activities such as pollution or increases in demand.

Reduction in source water quality is a manageable disruption as long as the installation is equipped with modern treatment facilities capable of adjusting intensity of water treatment based on the quality of source water. Often, methods of mitigation require investment into infrastructure and technology to address the specific water quality issue.

A reduction in the quantity of water can pose a challenging management scenario. In many cases, the quantity of water is reduced at not only the installation but also regionally making alternative sourcing difficult.

5.3.4 Infrastructure disruption

Infrastructure disruption can be intentional or unintentional. Unintentional infrastructure disruptions most often occur in the form of water main breaks and leaks. These types of disruptions are typically addressed by using valves to create distribution zones, which allow the disruption to be isolated from other parts of the system. Losses in pressure in the system result in stagnant water, the inability to supply, and possible water quality issues. A well-maintained and monitored system is desirable but, due to high costs of upgrades, it is often unattainable. Disruptions caused by infrastructure failures can be a persistent issue and a sign of a poorly maintained water distribution system. Intentional disturbances can be caused by vandalism or in the form of a scheduled maintenance, such as, upgrading distribution lines or performing mitigation exercises.

5.3.5 Technology

A disruption in technological capabilities or a lack of technological upgrades can be the source of further disruptions. Secure systems are essential to warding off cyber security attacks and preventing security breaches. Additionally, maintaining and monitoring supporting systems is a key to providing high-quality water. For instance, maintenance failures in electronic systems or water quality systems can exacerbate damages, cause infrastructure disruption, or diminish water quality. It is recommended to invest in high-quality security measures as well as training for personnel to operate and protect security systems.

5.3.6 Personnel

Personnel can be a source of both intentional and unintentional water disruptions. Poor training can increase the likelihood of accidents and disturbances in water distribution. Specifically, poor security training can increase a systems' vulnerability to intentional disruptions. Similarly, employee dissatisfaction can influence the quality and quantity of a capable workforce, which could affect the proper, timely allocation of water in an emergency.

5.3.7 Diversity in spatial distribution

A well-planned water distribution system is designed in way that allows the pipes to maintain water in good condition, and that allows zones or areas of the system to be isolated in the event of a disturbance. Unfortunately, planning a distribution system to meet these two criteria can lead to oversizing for capacity, which can itself result in water quality issues. Looping the distribution systems has the advantage of lower operating costs and a decreased need to flush. However, looped systems are more expensive to install, engineer, and have a higher risk of breaking during a natural disruption such as an earthquake. A poorly planned system can be difficult to flush when disturbances result in poor water quality and may not lend itself to the required mitigations.

6 Existing IEWP Planning Methods

At the time of this writing, three major organizations have developed methods for collecting IEWP information: Pacific Northwest National Laboratory (PNNL), the Applied Research Planning Support Center (USACE ERDC-ARPS), and the Construction Engineering Research Laboratory (USACE ERDC-CERL).

6.1 Pacific Northwest National Laboratory (PNNL)

The Department of Energy's (DOE's) PNNL has drafted *The Installation Energy and Water Security Assessment Guide*, which is a four-step guide designed for Directorate of Public Works (DPW) personnel to assess risks, analyze opportunities, and prioritize solutions for installation energy and water (E&W) security and resilience. This guide begins with scoping and goal setting, followed by onsite data collection, data analysis, and finally, solution prioritization.

Figure 6-1 illustrates the four objectives outlined by PNNL, beginning with Scoping and Goal Setting (Section II). Note that this method further divides the Onsite Data Collection (Section III) and Data Analysis (IV) into three modules:

1. Module A: Critical Mission Sustainment,
2. Module B: Critical Mission Risk Reduction, and
3. Module C: Installation Risk Reduction.

These modules are then considered in Solution Prioritization (Section IV) and given a Risk Reduction Score. The data listed in Table 6-1 exemplify this method.

Figure 6-1. Assessment guide organization.

Table 6-1. Mock Solution Screening Matrix.

No.	Solution	Solution Contributes to Critical Mission Sustainment Requirement Y = 3, N = 0	Solution Reduces Critical Mission Risk Y = 2, N = 0	Solution Reduces Installation Risk Y = 1, N = 0	Number of Missions Supported	Risk Reduction Score (Sum)
1	14 day refueling plan	3	2	1	5	11
2	Liquefied natural gas storage	3	0	1	5	9
3	Alternate water source (non-potable)	0	0	1	0	1
4	Micro grid - not linked to installation	3	2	0	2	7
5	Utility owned onsite power generation	3	2	1	3	9
6	Indoor light-emitting diodes fixtures for critical facilities	3	0	1	5	9
7	HVAC* setbacks at critical facilities	3	0	1	2	6
8	Backup for offsite tower	3	2	0	1	6

Source: The Installation Energy and Water Security Assessment Guide

*Heating, Ventilating, and Air-Conditioning (HVAC)

6.2 Applied Research Planning Support Center (ARPSC)

The ARPSC is a component of the USACE Engineer Research and Development Center. ARPSC is a major contributor to the development of IEWPs. ARPSC has completed six IEWPs in Fiscal Year 2019 (FY9), and has eight more in progress, scheduled for completion in FY20. The ARPSC planning process considers five main components of water use: (1) consumption and hygiene, (2) building mechanical, (3) industrial operations, (4) irrigation and facilities maintenance, and (5) leaks and infiltration. ARPSC has worked in conjunction with the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) energy team on past IEWPs, e.g., for Fort Belvoir, VA and Fort Detrick, MD, where they conducted two workshops to guide their data collection. The first workshop presented the pre-visit site data and the second workshop explored solutions. A majority of the report and data collection was completed before the first workshop, where installation POCs were contacted and requested to provide data or institutional knowledge.

Figure 6-2 shows a generalized water supply, distribution, and use model that highlights the area of consideration when planning for water supply resilience. The Consumption and Hygiene block identifies areas where household uses of water can be economized and protected, thus providing secure housing for mission-critical personnel. The Building Mechanical block focuses on climate control and fire suppression, which are a significant portion of building mechanical considerations. This method also determines if industrial operations incorporate internal recycling and water use minimization to reduce treated water demand for these operations. The Irrigation and Facilities Maintenance block is also a large water user that is considered when analyzing an installation's water needs. Finally, leaks and infiltration are also considered.

6.3 Construction Engineering Research Laboratory (ERDC-CERL)

The ERDC-CERL water team developed methods and tools during the IEWP development for Fort Bragg, which was informed by the ISR low-cost/no-cost recommendations (Appendix D). This method emphasizes pre-site data collection based on existing installation plans, physical and demographic parameters, water resource inventory, water demand analysis, and an infrastructure assessment. This team uses the workshop method developed by the Fort Bragg IEWP team and ERDC-CERL, which is also mentioned as a method for stakeholder engagement in the ARPSC overview, above.

Figure 6-2. Generalized water supply, distribution, and use.

6.3.1 Installation plans

The IEWP Guidance contains an extensive list of installation planning requirements that should be referenced, if developed and available, as input for the IEWP (ACSIM 2018). Chapter 8 of this report also lists these plans. Of greatest benefit are plans that provide supporting information for estimating both current and future water consumption, determining system condition, and developing projects to increase resilience. Documents that are typically developed by installations and have proven to be useful include: Installation Master Plans, Installation All Hazard's Assessment, Water and Wastewater 5-Year Assessment, and 5-Year Capital Investment Plans.

6.3.2 Physical and demographic parameters

Physical and demographic parameters are essential to understanding water use on an installation. Physical parameters such as location or climate zone provide insight into the socio-political dynamics of water use in the region and how the geographic location contributes to water availability for the installation. Demographic characteristics, such as historical and projected population growth, enable estimates and projections of water use into the future.

6.3.2.1 Location

The geographical location of an installation provides a regional context for water supply and demand. Political, social, economic, and environmental dynamics of the installation's neighboring communities define potential opportunities and limitations to an installation's missions and operations. Watersheds do not exist within a vacuum; they are susceptible to the activities around them. It is important to consider the broader context in which the installation is situated.

6.3.2.2 Climate zone

Climate affects water consumption due to the relationship of heating/cooling degree days on space conditioning (cooling tower water demand), potential increase in water demand for personal hygiene, and the effects of temperature and precipitation on irrigation. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) climate zone map (Figure 6-3) can be used to classify installations by climate zone. There are eight thermal climate zones (1–8) and three moisture regimes (A–C) for a total of 24 possible zones. Climate Zone 1 is the warmest, and Climate Zone 8 is the coldest. Moisture regime A is moist, B is dry, and C is marine (ASHRAE 2017).

Figure 6-3. Map of ASHRAE climate zones.

Source: ASHRAE 2017

Additional climate data can be collected from the National Weather Service (NWS) website, including 10-year averages of monthly snow and rainfall, and average monthly temperatures. Data are also available for the average depth of a given weather phenomenon and average monthly wind speeds. Information gathered from the NWS can be used to provide context for installation data.

6.3.2.3 *Building characteristics*

Building square footage is used to calculate the water use intensity (WUI) that applies to Army-mandated annual goals for reduction in water use, that is, gallons/square feet of building area. Building area data is available from the real property database accessed through (Army) Headquarters Installation Information System (HQIIS). The ideal analysis of WUI would be calculated as it relates to and end use factor, such as number of building occupants, produced unit, or activity (such as a training activity that requires water). However, water use per square foot is often used as method of analysis when information regarding the occupancy or water using activity cannot be provided.

6.3.2.4 *Population*

An installation's population is comprised of civilians and contractors who work on the installation; military personnel and family members who work and sometimes live on the installation; and installation visitors, including military who are temporarily assigned, for example, to attend training courses. The Army Stationing and Installation Plan (ASIP) system tracks historical population and contains future population projections. The ASIP Common Operating Picture (COP) report contains 15 years of historic population data and 5 years of projected population data for military and civilians. Table 6-2 details the subcategories contained in the ASIP COP.

Table 6-2. Categories of ASIP COP data.

Full-Time Military	Army Military, PCS Students Military, Other Military
Part Time Military	TDY Students & Trainees Military, Transient Military
Full-Time Civilians	Army Civilians, Army Local Nationals, PCS Students Civilian, Contractors, Other Civilians
Part Time Civilians	TDY Student Civilians, Transient Civilians
Reserve Component Military	Reserve Component Military
Source: HQDA (2009)	

The Defense Manpower Data Center (DMDC) tracks the number of personnel who live off post, down to the tenth of a mile radially, by using mailing addresses. DMDC uses personnel data received directly from the Defense Enrollment Eligibility Reporting System (DEERS)* to track demographics throughout the Army and U.S. Department of Defense (DoD). DMDC can create a radial correlation of Common Access Card (CAC) cardholders to an installation up to a specified distance, but within that distance they are not able to track the installations that the CAC cardholders may visit.

Data from DMDC can be useful to estimate possible CAC visitors at an installation but is most accurate for remote installations. As such, DEERS data that presently accounts for CAC cardholders could also be enough for remote installations. Coastal and metro area installations, where radial distances overlap, would present a significant level of error in estimating “which serving population is visiting which installation.” The DMDC can calculate these data for every installation quarterly, but such an effort would require a significant increase in quarterly workhours (i.e., at least 1 hour for every installation).†

6.3.2.4.1 Effective population

Defining the effective population (EP) is the method that is used to evaluate water and utility demand from sources such as ASIP. The CERL method mirrors a method provided in Fort Bragg’s Long-Range Component of its Real Property Master Plan. The data in Table 6-3 comprise a mock representation of how EP can be calculated. Here EP is a percent of the population served by installation utility systems during a 24-hour period. Therefore, those who live on post receive an existing factor of 1, whereas those who live off post receive an existing factor of 0.33. The existing factor is calculated based on the percentage of time the category of personnel is anticipated to stay on base. More specifically, non-residents of the base are only expected to stay on base for 8 hours, or one-third of a 24-hour day (Parsons 2008).

* Family member and visiting retiree population is tracked through DEERS.

† Personal communication between Laura Curvey, ERDC-CERL and Scott Seggerman, DMDC, DAP Division, Manpower Branch, Team Leader. March and April 2013.

Table 6-3. Mock effective population (EP) analysis.

	Population	Existing Factor	EP	Population	Future Factor	EP
On-Post Population						
Military on post	20	1	20	22	1	22
Dependents on post	14	1	14	11	1	11
Subtotal on post			34			33
Off-Post Population						
Military living off post	33	0.33	11	34	0.33	11.33
Civilians off post	16	0.33	5.33	19	0.33	6.33
Subtotal off post			16.33			17.66
Total	83		50.33	86		50.66
Source: Real Property Master Plan Long-Range Component, section 10: Utilities Assessment						

6.3.3 Water source

This method considers various parameters of an installation's water supply. This includes the constraints of the primary water source, any secondary or backup sources, and the water rights related to the consumption of those supplies. These are important variables to consider because they help establish a baseline understanding of the water reserves in the area.

6.3.3.1 Water source type and description

An installation's water treatment personnel can identify the water sources for the site. If the water treatment plant is privatized, the utility privatization contractor will have a more in-depth description of their water sources. Additional information about the water source can often be found on the state or county's Department of Natural Resources' website. The Safe Drinking Water Act (SDWA) requires states to develop a Source Water Assessment Program (SWAP). SWAP assessments are often useful in determining the number of potential sources of contaminants and the vulnerability of the water supply to contamination.

6.3.3.2 Secondary or backup water supplies

In the event of a disruption to an installation's primary water source, potential secondary water supply sources should be identified, particularly those that fall within the fence line. A significant number of installations fall under riparian water rights. Water sources within the fence line allow the installation to draw from the source at their own discretion. Backup water supplies can include wells, bottled water, or reservoirs in addition to a second point of distribution system supply of potable water.

Local water utilities may be part of a larger utility network that draws on the same water resource. In these cases, it should be noted that neighboring water utilities are not a reliable backup in the event of a regional disruption, unless clearly stipulated in a legally binding document. Typically, a Memorandum of Understanding (MOU) is developed to determine how water will be allocated under the agreement; however, this is not legally binding and may not be a reliable source of backup water if a disaster were to occur on a regional scale.

6.3.3.3 *Water rights*

The creation, definition, and control of private water rights is a state responsibility. This accounts for the great diversity of water rights regimes. Each of the 50 states and each territory is free to develop its own system of water rights. Generally, states have adopted either a riparian or appropriation doctrine to address surface waters and rely on a doctrine of absolute ownership, reasonable use, or appropriations for groundwater regulation.

Army Directive 2014-08 (Water Rights Policy for Army Installations in the United States [Secretary of the Army 2014]), requires annual reporting of installation water rights. IMCOM, AMC, ARNG, and Office of the Chief of the Army Reserve (OCAR) Commands are required to report the summary status for their installations. The reports require installations to:

Locate and retain existing water rights records; create an index for each record; maintain landscape; determine the amount of water they use; summarize their state's water rights legal landscape; determine the amount of water they use, the amount necessary to maintain essential services, and all available water sources; identify current/past water rights conflicts or ongoing adjudications; and file timely reports (Secretary of the Army 2014).

In the event that an installation has not answered the G-9's Annual Water Rights Data Call, the following list may be helpful in assessing their standing:

1. What types of water rights does the installation or facility possess for both surface and groundwater across the installation or facility (e.g., Federal reserved, adjudicated appropriative, riparian, established surface water or groundwater district, judicially or administratively imposed decree, legislative, etc.)?

2. For installations with water rights other than Federal reserved water rights, describe whether the installation has or does not have documentation to support the establishment and maintenance of those surface and/or groundwater rights. This includes locations with water rights derived under state law. Identify any locations where water is being used without state permits or formally documented federally reserved rights.
3. Describe any current or anticipated water rights litigation, adjudication, or disputes with other landowners, water rights holders, or state or local governments or regulatory agencies.
4. What information gaps do the installation personnel believe exist with respect to the installation's water rights?
5. Please report any water rights issues that may be obstacles to accomplishing the installation's mission.
6. Please identify if the installation has performed an assessment of long-term water needs relative to current water rights. Summarize any findings from such assessments.

6.3.4 Water demand

6.3.4.1 Water resilience planning

Water resilience planning calls for the identification of backup sources of water for mission-critical facilities, and also for assured access, i.e., provision of a redundant source of water for the entire installation. The IEWP Guidance requires 1 year of historical water demand data to establish a baseline for assured access.

6.3.4.2 Installation water demand

Installation-wide water use data may be available from several sources. Installations report water consumption data to the Army Energy and Water Reporting System (AEWRS) on a monthly basis. Data are reported in categories of potable, alternate, and industrial, landscape, or agricultural (ILA) water. The cost of water is also reported for each category.

Installations that produce water from an on-post water treatment plant will also track monthly treated water. Likewise, water withdrawn from on-post wells should be documented on a monthly basis.

Water bills should be available for installations that purchase water. Bills are generally available on a monthly basis. There may be several accounts

or sites billed at an installation. More detailed water demand data is available from installation water meter databases, which may be maintained by the DPW or contract operators. Water meter data is desirable at least on a monthly basis, if not more frequently.

6.3.5 Infrastructure

Infrastructure assessments are a critical component of hazard mitigation. The location, condition, and capacity of an installation's water assets provides insight into the level of resiliency the installation has against water disruptions. Specifically, utility assessments will prioritize the following:

1. Utility privatization status of water and wastewater distribution systems, including pipes, pumps, storage tanks, and lift stations,
2. Drinking water and wastewater treatment plants capacity and resiliency,
3. The spatial distribution of infrastructure, pressure zones, and supply points,
4. Infrastructure redundancy and interconnections, including single points of failure and functional redundancy, and
5. Supporting infrastructure, such as cooling towers, fire protection systems, and emergency generators.

The following sections outline the data sources used to conduct utility assessments.

6.3.5.1 Installation Status Report-Infrastructure (ISR-I)

The ISR-I assesses the condition and mission capability of installation assets and identifies the funding necessary to improve facilities. This report is compiled by installation personnel and is updated annually.

6.3.5.2 Real property data sources

Real property databases, such as HQIIS and Planning Resource Infrastructure Development and Evaluation (PRIDE), provide standardized datasets for Army facilities and infrastructure, which in turn provide identifiers such as facility number, category code, and building area. Field surveys may be conducted to supplement or verify this data and to assess conditions and confirm uses of critical infrastructure.

6.3.5.2.1 Buried No Longer (BNL)

The American Water Works Association tool, *Buried No Longer (BNL)*, provides a data-informed method for developing a capital investment strategy for water and wastewater distribution systems. *BNL* applies survey data about size, material, and age of distribution piping to generate projections of expected remaining system life and asset investment strategies. *BNL* analysis has been completed for several Army installations using data contained in GIS files of water distribution systems. The BNL tool is available to members of the AWWA.

6.3.5.2.2 Capital Investment Plan (CIP)

The installation's CIP provides a list of planned major projects. This plan can provide insights regarding infrastructure upgrades and future renovations. The CIP is available from the DPW or the (Army) Utilities Privatization (UP) contractor.

6.3.5.2.3 Operations and Maintenance (O&M)

Historic O&M data can be an indicator of system condition. This information can be found in the work order/service order database, which is accessible through General Fund Enterprise Business Systems (GFEBS). In privatized water/wastewater systems, historic O&M will be available from the UP contractor.

7 Scenario Developments

Three water disruption case studies were developed to provide examples of the data/process needed to complete pre-site data collection for IEWP preparation. These case studies represent a range of installation types, geographic locations, and water disruptions.

Scenario 1 is as an example of a large installation with many compounding factors and significant mission-critical needs. Scenario 2 is an industrial installation, a small facility with a small population. Scenario 3 is an installation with intermittent population and fluctuations in water needs month to month or year to year depending on specific mission op tempo. Additionally, the location for Scenario 3 is an Army National Guard site, which has unique functionality and installation design.

7.1 Selection of water disruptions

Three different types of disruptions were selected, corresponding to the specifics of the three unique installations. The disruption at the Scenario 1 Power Projection Platform installation is an inland flood (a common risk for many installations), based on a recent historical event. The disruption at the Scenario 2 installation is a less common but water-intense scenario of an explosion in a conflagrating fire situation. This is of interest to any installation working with, producing, or storing flammable material. The Scenario 3 disruption involves the potential for chemical contamination of the water source, whether naturally occurring or by malicious intent. Investigation of such a risk can expose vulnerabilities throughout the distribution system and in many cases is a measure of infrastructure security and resiliency, which is important to all installations.

7.2 Selection of mitigation measures

The IEWP Guidance describes a five-step process to ensure IEWP plans achieve their goals. The steps in the process are (1) Identify Requirements, (2) Assess Risk and Opportunities, (3) Generate Solutions, (4) Develop Implementation Plan, and (5) Execute and Evaluate. The scenarios explored in this report focus on step 3 of the IEWP process, Generate Solutions.

Baseline WUIs were estimated and the risks and threats to the installations were identified for each scenario outlined in this report. An energy

baseline was not generated for these scenarios. Best management practices were then evaluated for each of the acknowledged risks. Suggested mitigation projects were conceptualized from these best management practices.

Scenario 1 outlines various strategies, some of which include installation and tenant preparation, hardening of facilities, and landscape modification. Similarly, Scenario 2 takes a preventive approach and suggests protective construction methods, vulnerability assessments, and safety and training for personnel. Scenario 3 suggests increased physical security, online/inline monitoring, and active emergency response planning for cases where water contamination is a possibility.

7.3 Scenario 1: Power Projection Platform

7.3.1 Installation overview

Fort Bragg is an Installation Management Command (IMCOM) installation with U.S. Army Forces Command (FORSCOM) units located approximately 12 miles northwest of Fayetteville, North Carolina. Camp Bragg was established in 1918 as an artillery training ground for World War I. After the war, Camp Bragg became Fort Bragg, a permanent military installation that was used for testing artillery weapons until WWII when more modern warfare training was needed. The installation is now the home of the airborne and special operations forces (U.S. Army 2019a). Fort Bragg supports 261,449 individuals, including over 53,000 trainees each year from Army, Army Reserve, Air Force, National Guard, and other branches of service (DoD 2017).

7.3.1.1 Mission/stakeholders

As a Power Projection Platform (PPP) installation, Fort Bragg's primary missions are mobilization and training. To accomplish these missions, Fort Bragg is home to more than 20 units or tenants: U.S. Army Forces Command, XVIII Airborne Corps, U.S. Army Special Operations Command, U.S. Army Reserve Command, Joint Special Operations Command, U.S. Army Civil Affairs and Psychological Operations Command (Airborne), 82nd Airborne Division, 108th Air Defense Artillery Brigade, Dental Health Activity, 419th Contracting Support Brigade, 406th Army Field Support Brigade, 192nd Ordnance Battalion (EOD), 50th Signal Battalion, U.S. Army Security Assistance Training Management, Army Golden

Knights, 4th Reserve Officers Training Corps (ROTC) Brigade, Joint Interoperability Division, Airborne and Special Operations Test Directorate, 139th Infantry Regiment – North Carolina National Guard, Womack Army Medical Center, and 3-58th Airfield Operations Battalion (U.S. Army 2019b).

7.3.1.2 Primary assets

Primary assets are categorized by facility group type. These facility group classifications are drawn from the Installation Water Demand (IWD) Model spreadsheet tool (HQUSACE 2010). The IWD organized facilities based on their Category Codes to mitigate the risk of placing the same building in multiple categories.

The categories are applicable here because they allow each facility group to be ranked as a different water customer. Categories 14-18 are not included in this study because their classifications are non-water using entities. Across the Army, facility groups generally have similar WUI values. Table 7-1 lists Army WUI by facility group.

Table 7-1. Army water use intensities by facility group.

Facility Group	Function	Army Median WUI
1	Industrial and Maintenance	0.19
2	Housing (Family)	1.41
3	Housing (Transient)	1.97
4	Housing (Barracks)	2.41
5	C&C: Non-food (Indoor)	1.05
6	C&C: Food	6.19
7	High Energy	0.36
8	Medical	1
9	Administration and Operations	0.43
10	Other Training and Schools	0.39
11	Storage	0.15
12	High Water User Facilities	24.39
13	C&C: Non-food (Outdoor)	14.6
19	Dependent Schools	0.92
20	Irrigated Lands	0.5
21	Miscellaneous	26.65
Source: Jenicek, et al 2018		

Fort Bragg manages 161,000 acres; these grounds are primarily used for training and deployment of the airborne and special operations forces. There are 462 buildings with water meters at the installation. Primary assets include classrooms, training grounds, dining facilities, barracks, and restroom facilities. Table 7-2 lists the metered buildings at Fort Bragg by their facility group and square footage.

Table 7-2. Fort Bragg metered buildings by facility group.

Facility Group	Function	Number of Buildings	Buildings Size (sq ft)
1	Industrial & Maintenance	90	1,916,390
2	Family Housing	1	4,634
3	Transient Housing	3	261,934
4	Barracks	75	3,540,011
5	C&C: Non-food (Indoor)	44	1,231,943
6	C&C: Food	10	230,619
7	High Energy	12	235,018.88
8	Medical	13	1,427,708.6
9	Administration & Operations	171	3,772,141.5
10	Training & Schools	24	605,229.64
11	Storage	12	400,023.74
12	High Water Use	2	4,806
13	C&C: Non-food (Outdoor)	N/A	N/A
19	Dependent Schools	5	399,150
20	Irrigated Land	N/A	N/A
21	Miscellaneous	N/A	N/A

7.3.1.3 Regional overview

The bulk of the installation is located within Cumberland County, but it also crosses into Harnett, Hoke, and Moore County. These counties are in North Carolina's Coastal Plains region, the state's largest geologic area. This region is defined by its rich soil, sandy hills, and numerous wetlands. Fort Bragg straddles the Sandhills and Inner Coastal Plains sub-regions where land is typically 900-1,000 ft. above sea level.

The International Energy Conservation Code (IECC) classifies this region as Climate Zone 3, Mixed-Humid. Mixed-Humid regions see more than 20 in. of precipitation annually and monthly outdoor temperatures average below 45 °F (7 °C) during the winter months.

Since the 1960s, Cumberland County has experienced steep increases in yearly precipitation and average daily maximum temperature. The National Oceanic and Atmospheric Administration (NOAA) has projected these trends to continue well into the year 2080 (NOAA 2013a).

7.3.1.3.1 Water rights

Fort Bragg's region has limited restraints governing water rights. The state has adopted riparian landowner rights. Riparian laws state that property owners whose land borders a body of water have the right to use that water on their land. Riparian landowners are allowed "reasonable use" of adjacent waters as long as they do not interfere with the abilities of other riparian users' rights. In North Carolina, these riparian doctrines apply to both surface and groundwater. There are additional laws regulating the use of groundwater wells for recharge, injection, and disposal. Further regulations may be applicable depending on the class of well and whether a single well draws more than 100k gallons per day.

Fort Bragg receives municipal water. State regulations enforce a water quality standard with quarterly bacteriological testing and annual nitrate and nitrite testing.

7.3.2 Water sources

The Cape Fear River Basin is the sole water source for both water suppliers that serve the installation. The basin spans roughly 68,884 acres and comprises 21,300 miles of freshwater streams and 31,135 acres of freshwater lakes and reservoirs (NCWRC 2015). Approximately 20% of the state's population lives within the boundaries of the Cape Fear River Basin, which serves 26 counties and 114 municipalities. The section of the basin that supplies the installation is 1,630 square miles.

The Cape Fear River Basin flows southeast from Piedmont through the Coastal Plains region before reaching the Atlantic Ocean. There are six hydrologic sub-units within the Cape Fear River Basin. Fourteen reservoirs in the upper sub-basins manage the water supply, flood control, and recreational uses (NCDENR 2009).

Twenty-three water systems draw surface water from the Cape Fear River Basin. These systems provide water to another 55 water systems so a total of 78 water systems depend on the basin (NCDENR 2009). These systems

are unrestricted in their withdrawals unless they exceed 2 million gallons per day. There are 105 U.S. Geological Survey (USGS) gage stations monitoring the river to ensure a reliable stream flow to meet this demand.

7.3.2.1.1 Water infrastructure

Fort Bragg's water distribution system is privatized. In addition, the fort purchases water from two off-post suppliers, Fayetteville Public Works Commission (PWC) and Harnett Regional Water, each servicing the installation on an alternating schedule through the week. Both providers draw from the Cape Fear River Basin and supply the post through a shared 36-in. water main that crosses the installation boundary. A separate 12-in. connection is able to provide supplemental demand for emergency situations. There are two distinct feeds, but the distribution lines are an isolated, looped system. Apart from supply points, the water system is entirely underground.

Treated water is distributed within the installation through 24 chlorination stations, eight elevated storage tanks, six active water tanks, four valve connections, two booster stations, and one ground storage tank. The system spans over 400 miles and is reliant on a stable water pressure.

7.3.2.1.1 Wastewater

A network of 14 sub-basins carries Fort Bragg's wastewater to a Harnett County Pumping Station with a 12 MGD capacity. This wastewater is subsequently directed to the Harnett County Wastewater Treatment Plant (HCWWTP). The entire wastewater system consists of 165 lift stations, 4,733 manholes, and 1,644,435 linear feet of combined gravity sewers and force mains.

7.3.3 Potential causes of water disruptions

The water and wastewater systems at Fort Bragg are subject to disruptions due to natural and manmade causes. Each of these risks may create sustained water service disruptions that delay the installation's ability to fulfill its mission.

7.3.3.1 Natural disruptions

The Coastal Plains region most frequently faces tornadoes, hurricanes, and thunderstorms with high winds, lightning, and hail. Since 1975, North Carolina has had 26 hurricanes, eight flooding events, four tornadoes, and one drought (FEMA 2019).

The National Center for Disaster Preparedness at Columbia University provides a descriptive risk index for every county in the United States. The “U.S. Natural Hazards Index” catalogues a county’s natural hazard risk, from 0-22, by aggregating historic and projected data for various hazards. This index places Cumberland County at a level 15 due to high vulnerability from flooding, hurricanes, and wildfires. The area has a medium risk to tornadoes, and low risk for snowfall, landslide, earthquake, and heat wave events.

Table 7-3. Cumberland County hazard index.

County Name	Cumberland
State Name	North Carolina
Hazard Index	15
Wildfire Hazard	High
Volcano Hazard	None
Tornado Hazard	Medium
Snowfall Hazard	Low
Landslide Hazard	Low
Hurricane Hazard	High
Earthquake Hazard	Low
Drought Hazard	None
Heat Wave Hazard	Low
Avalanche Hazard	None
Flood Hazard	High
Source: Columbia University (2019)	

7.3.3.2 Regional groundwater disruptions

The installation draws on surface water for potable end uses but Cumberland County is susceptible to groundwater disruptions. Natural disasters can litter waterways with debris and downed trees, but the greatest contamination threat comes from overflowing sewer systems and runoff from nearby industrial plants, animal waste, and chemicals from farms and residential areas. Fort Bragg is located downstream from the Piedmont Triad and Research Triangle industries as well as hog farms. Chemical plants,

animal farms, utility facilities, and leaking underground storage tanks (USTs) located upstream of waterways are supply contamination hazards.

Groundwater is also susceptible to contamination saltwater intrusion in coastal aquifers. When groundwater is pumped in excess, the “flow of freshwater toward coastal discharge areas” is reduced and “saltwater is drawn toward freshwater zones” (USGS 2017).

Regional groundwater supplies may also experience groundwater draw-down which “can lead to increased occurrences of saltwater intrusion, aquifer overdraft, groundwater depletion, and land subsidence” (Tularam and Krishna 2009).

7.3.3.3 Manmade disruptions, unintentional

Human error, as a result of improper use of tools or inadequate training, and infrastructure failures can create additional water system vulnerabilities. In 2017, a water main break forced the installation to release all non-essential personnel and to cancel all elective surgeries at Womack Hospital. Bottled water was provided to personnel that remained on post and water lines were flushed and sampled for 24 hours following completion of the repair (Norwood 2017).

7.3.3.4 Manmade disruptions, intentional

Recent technological advancements and intelligence warfare have augmented the importance of acknowledging and preparing for intentional attacks at Army installations. Cyber-weapons, physical terrorist attacks, and labor strikes all pose threats to Army installations and their water utility systems. Each of these threats may endanger the water supply or its infrastructure and supporting personnel.

7.3.4 Disruption case study: Flooding

7.3.4.1 Flooding at Fort Bragg

The National Flood Insurance Program has zoned the county as an “AE” area. AE zones are areas “subject to inundation by the 1%-annual-chance flood event.” Between 2012 and 2018, Fort Bragg experienced five flooding incidents.

A recent flooding example followed Hurricane Florence, which reached land in September of 2018, creating excess water events throughout the region. In addition to an approximate 20 in. of rainfall, the Cape Fear River experienced storm surges, which brought the river approximately 20 ft. higher than usual. Water infrastructure was also threatened by trees that were uprooted in the storm. Fallen trees disrupted power lines and over 600,000 individuals were without electricity for 4 days during the disruption (Williams 2018); electricity-dependent utilities were also compromised.

7.3.4.2 Impacts

Flooding events pose significant threats to water infrastructure and its supporting electricity grid. Installations with a PPP are uniquely impacted by this type of water disruption. Units and tenants at the installation with mobile assets or an emphasis on deployment service may be able to leave post for the duration of the incident. Contrastingly, units stationed at the installation for training may have to cease all operations until there is a solution to the disruption. The responses to a flooding disruption are explored further in Table 7-4.

Table 7-4. Disruption impacts by tenant/unit type.

Scope	Training Units	Deployable Units	Long-Term Tenants (Emergency Facilities, Households, etc.)
Short Term	Temporarily halt all training until disruption is addressed.	Temporarily leave the installation for the duration of the disruption.	Shelter in place.
Long Term	Temporarily relocate training or use backup supplies to remain in place.	Temporarily relocate to coop site for the duration of the disruption and restoration timeframe.	Deploy backup services while disruption is addressed.
Narrow Scope	Temporarily halt all training until disruption is addressed.	Temporarily leave the installation for the duration of the disruption.	Shelter in place.
Wide Scope	Temporarily relocate training or use backup supplies to remain in place.	Temporarily relocate to coop site for the duration of the disruption and restoration timeframe.	Shelter in place and use mutual aid agreements and utilities contracts to provide additional services in place of disrupted services.

7.3.5 Proposed mitigations

Suggested mitigation actions can be summarized in three broad categories, Installation and Tenant Preparation, Hardening of Facilities and Critical Infrastructure, and Landscape Modification.

7.3.5.1 Installation and tenant preparation

Installations can use vulnerability assessments and all-hazards reports to identify threats to their water supply and treatment facilities and infrastructure. Once risks are identified, units and tenants should be adequately prepared for them. Each installation stakeholder should have materials detailing the resources available to them in the event of each identified threat. These materials should also dispel any misinformation about the available resources; for instance, if units expect the DPW to provide bottled water in the event of any disruption, the installation should clarify the events that may cause such disruptions. In addition to providing materials for units and tenants, installations may hold installation-wide or unit-wide disruption drills to identify vulnerabilities and failures in current mitigation plans. Furthermore, units with deployable assets should begin reviewing temporary sites for deployment given differing disruptions.

7.3.5.2 Hardening of facilities and critical infrastructure

Several critical water and wastewater infrastructure components are vulnerable to significant damage if they lose electricity or become overwhelmed with water. Electricity-dependent infrastructure, like the electricity panels on substations, should be flood-proofed.

Additionally, installations must consider their ability to maintain assured access to water treatment and pumping systems in an excess water event. When water rapidly enters sewers and overfills streams, as is common in flooding events, wastewater treatment and groundwater well systems are easily overloaded. These system overloads can mean that a sewer system must manage water loads more than twice the amount they were built to handle. In 2012, when “Superstorm Sandy hit New York City ... 10 of DEP’s 14 wastewater treatment plants were damaged or lost power and released untreated or partially treated wastewater into local waterways,” and “collectively, wastewater treatment plants operated at more than twice their normal flow rate at the height of the storm” (Mulroy 2017). Furthermore, road closures in the installation’s city can delay timely repairs to

pumps and valves. Emergency bypass pumps and designated onsite wastewater treatment equipment may allow the installation to diminish the immediate impacts of the disruption.

7.3.5.3 Landscape modification

As the installation grows and more impervious structures are developed, careful attention should be given to preserving natural drainage corridors. Natural drainage corridors more readily allow floodwaters to be absorbed into the ground and offer a modicum of filtration along the way. A decentralized network of green infrastructure can convey storm and floodwaters away from buildings and toward the proper channels.

7.3.6 Scenario 1 summary

This scenario highlights the risk and that a Power Projection Platform may face during an excess water event using Fort Bragg and flooding as a case study. Power Projection Platform installations train and mobilize soldiers for deployment. In the event of a water disruption, training units, deployable units, and long-term tenants will have varied needs given the scope and duration of the disruption. A flooding event at Fort Bragg could temporarily halt instruction and deployments or it may force units to relocate until the disruption is addressed. In preparation for water disruptions, Power Projection Platform installations should ensure that the installation and its tenants are prepared for and informed about the disruption as well as the installation's procedures for such an event. To mitigate disruptions that may threaten both electric and water infrastructure, such as flooding, installations should harden critical facilities and infrastructure against identified vulnerabilities and consider modifying the landscape to direct disruption effects to a predetermined area.

7.4 Scenario 2: Industrial installation

7.4.1 Installation overview

The Army's Organic Industrial Base (OIB) consists of 23 ammunition plants, manufacturing arsenals, maintenance arsenals, and maintenance depots that service materiel that directly affects U.S. Soldiers, sailors, airmen, and Marines. These installations were established from 1813 to 1961. No new sites have been established in the last 58 years. Recent trends in OIB modernization include operations and production lines, capital improvements, automation, and facilities (USAMC 2015). For instance, Lake

City Army Ammunition Plant (LCAAP) recently announced improvements to modernize their water treatment options. This will include building a new water treatment plant adjacent to the existing facility, increasing the life cycle estimates to 50 years (USACE-NWK 2018).

The OIB is funded through the Army Working Capital Fund (AWCF), meaning that the cost to operate the industrial installations is paid by the income brought in through the industrial processes. Additional costs such as fire, emergency services, security, and other operational expenses are appropriated through AWCF. These costs are not directly supporting industrial operations but, rather, are expenses that keep the installation functioning (USAMC 2015).

7.4.1.1 Mission/stakeholders

LCAAP is a 3,935-acre facility located in Jackson County, MO, 20 miles east of Kansas City, MO. It is one of 16 installations of the Joint Munitions Command and one of 23 OIBs under AMC. The site began construction in 1940 and began operations in 1941. LCAAP is an industrial base under the Joint Munitions Command (JMC), which oversees the operations of ammunition plants, depots, staff and directorate offices. LCAAP's primary mission is to produce small caliber munitions for the Warfighter. Oversight and production are currently contracted out to a private defense company (USAMC 2012). The only other unit on base is the 325th Medical Detachment, which uses LCAAP as a training facility.

7.4.1.2 Primary assets

The site contains a total of 542 structures, 408 buildings, 43 magazines, nine warehouses, 11 igloos, and has an overall storage capacity of 707,000 square feet. LCAAP has a staff of 27 Department of the Army civilians and one soldier for contract oversight. It is also the operations center for the North Atlantic Treaty Organization test center and has the following capabilities (U.S. Army 2019b):

- Small arms cartridges
- Percussion and electric primer
- Pyrotechnics manufacturing
- Small caliber ammunition
- Explosives demilitarization and disposal
- Reliability testing of small caliber ammunition.

Table 7-5 projects the WUI by facility group for 2020. This data uses 2012 baseline water data from the Missouri Department of Natural Resources data and population data to estimate WUI factors by county. These estimates can be used to calculate the volume of water needed in an emergency.

Table 7-5. Projected 2020 WUI.

Water Use Categories	WUI (MGD)
Family Housing	1.01
Barracks	0.667
Dependent Schools	0.108
Medical	0.080
Industrial/Maintenance	0.088
Lodging	0.0170
Administration/Moderate Users	0.638
Community and Commercial: Non-food-related (indoor)	0.090
Community and Commercial: Food-related	0.014
Storage	0.001
High Water Use Facilities	0.020
Irrigated/Improved Land	0.003
Other Uses	0
Losses	0.291
Baseline Annual Average	3.029
<i>Source: Drew Ahern. 2014. Lake City Regional Demand 2014 (Unpublished report).</i>	

7.4.1.3 Regional overview

Missouri enforces a riparian water law, which permits landowners to use the water on their land in any way that is deemed legal or reasonable until restricted by a court. There are no prior appropriations, water laws, or statutory watercourses on LCAAP property. There are no known judicial holdings or Federal reserved water rights for LCAAP.*

The ambiguity of water rights in the state stems from the vague definition of “reasonable” amounts of water withdrawal. The concept of reasonable withdrawal is fluid and context specific. For instance, what is considered reasonable during a wet season may not be reasonable during a drought. This increases the stress on assured access to water for LCAAP.

* Steven Brockman, 2013. Interview by Jennifer Patterson. Unpublished. Accessed 20 March 2019.

Similarly, as the surrounding urban areas grow and resources become scarce, what is considered a sustainable amount of water withdrawal will change. Riparian water law is also economically restrictive in the sense that it discourages the development of long-term, high water withdrawal projects. This is contingent upon legislation that could prevent the installation from withdrawing large volumes of water for future use, thereby halting production.

Additional issues include aging public water supply systems, erosion, sedimentation, flooding of the Missouri River, water contamination from pharmaceuticals/chemicals, sewage intrusion, and urban sprawl (MO DNR 2002).

LCAAP is located in ASHRAE Climate Zone 4A (Mixed-Humid). This increases its vulnerability to flooding, tornadoes, and severe weather. Missouri is subject to strong seasonality because of its unchallenged topography and inland geographic location.

In the summer, temperatures can rise to 90 °F or higher on an average of 40 to 50 days in the west and north and 55 to 60 days in the southeast. The average temperature in January can range from a low of 12° F to a high of 24° F. The average annual precipitation ranges from 34 to 50 in. The seasonality can greatly influence the amount of precipitation in a given month. For instance, the amount of precipitation generated in June is almost five times greater than January. Snowfall in counties north of the Missouri River on average range from 18 to 24 in. In southern counties, this figure can drop to 8 to 12 in. (Decker 2019).

Due to its geographic location and level plains, Missouri reports approximately 30 tornadoes each year. It ranks number 7 in frequencies, 12 in fatalities and, 9 in economic loss (based on all tornadoes between 1950 and 1994) in the Nation. Annually, 30 % of tornadoes in the region are classified as F2 or F5 (strong/violent) tornadoes (Decker 2019).

The record of historic daily averages (Figure 7-1) for the region's maximum temperature shows a gradual increase in the projected temperature growth. Overall, temperatures are projected to increase approximately 3 to 4 °F by 2045 (NOAA 2013a).

Figure 7-1. Average daily maximum temperature.

Source: NOAA (2013b)

Precipitation projection trends show little change through 2045 (Figure 7-2). However, the frequency of spikes increases over time, indicating the greater chance of heavy rains and droughts in the future (NOAA 2013b).

Figure 7-2. Total annual precipitation.

Source: NOAA (2013b)

Jackson County is part of the Lower Missouri-Crooked Watershed, which drains into roughly 11 counties in Missouri and one county in Kansas. The region is composed of 62 community drinking water systems serving roughly 1 million residents. The Lower Missouri-Crooked Watershed contains two high yield aquifers, the St. Francois and Ozark aquifers. However, 96% of the water use is allocated from surface water and only 4% is acquired from groundwater sources (MO DNR 2016). In Jackson County, 87% of the water use is for power generation and is passed through a cooling system at least once (USGS 2005). The watershed has 10 impaired water bodies, three lakes and seven streams including the Missouri River, which is located in the region adjacent to the LCAAP (MO DNR 2016).

7.4.2 Water sources

LCAAP is in the Lower Missouri-Blackwater-Lamine River basin of the Osage Plains region. The Blue River, Little Blue River, and Sniabar Creek are the major tributaries of the Missouri River, which directs most of the water drainage in Jackson County. The installation itself is located on the Little Blue River Floodplain. Smaller surface water bodies within this region include the West Fire Prairie Creek, Ditches A and B, small ponds on the eastern and southwestern portions of the site, a 30-acre lake on the eastern end of the site, and various manmade lagoons for disposal of wastewater. Ditches A and B were constructed from the West and East Fire Prairie Creeks to redirect floodwater toward the Missouri River. The western half of LCAAP is designated a groundwater recharge zone, where the water table elevation is higher, while the eastern half is a groundwater discharge zone (Weston 1990).

The groundwater near LCAAP contains traces of volatile organic compounds, various explosives, perchlorates, and heavy metals, including lead, arsenic, and chromium due to contamination from lagoons, landfills and burn pits (Asberry and Himes 2010). The primary source of water for the installation is from 12 onsite wells (Table 7-6), three of which are being remediated due to contamination. Air strippers were installed to treat three wells in January 1990 and an additional four wells were treated in 1992 using the same method. In the fall of 1992, eight off-post groundwater-monitoring wells were installed in strategic locations as an added measure to prevent against contamination that originated from LCAAP (LCAAP 2016).

Backup water supply to serve the housing units and water for the installation can be purchased from Independence, MO. Scenarios where water must be purchased typically occur when the system is shut down for maintenance.*

Table 7-6. Active well inventory on the base.

Facility ID No.	Facility Name	Type	Pump Capacity (GPM)	Yield (GPM)
WL 12128	WELL # 1 17AA	GW	350	150
WL 12127	WELL # 3 17EE	GW	200	—
WL 12130	WELL # 5 17GG	GW	250	150
WL 12132	WELL # 8 17K	GW	200	100
WL 12133	WELL # 9 17KK	GW	250	100

*Drew Ahren. 2014. *Lake City Regional Demand 2014*. Unpublished report.

Facility ID No.	Facility Name	Type	Pump Capacity (GPM)	Yield (GPM)
WL 12134	WELL #10 17MM	GW	250	225
WL 12135	WELL #11 17N	GW	400	400
WL 12136	WELL #12 17P	GW	400	400
WL 12426	WELL #20 17CC	GW	210	—
WL 12429	WELL # 2 17BB	GW	125	200
WL 12430	WELL # 7 17JJ	GW	250	150
WL 12435	WELL #22 17DD	GW	275	—
Source: MO DNR (n.d.)				

LCAAP has four storage tanks (Table 7-7) and a total of 1,300,000 gallons of water stored on base. The Lake City Army Treatment Plant, which can produce a maximum flow of 3,125 gpm, has a minimum storage (detention) of 616,773 gallons (MO DNR 2016).

Table 7-7. Water storage infrastructure (storage tanks).

Facility Name	Quantity (GAL)	Type
Elevated Tower 9A 150K	150000	Elevated
Elevated Tower 9B 150K	150000	Elevated
Ground Tank 9D 500K	500000	Ground
Clearwell 500K	500000	Underground
Source: MO DNR (n.d.)		

7.4.3 Potential water disruptions

7.4.3.1 Natural disruptions

Since 1953, Missouri has experienced 69 disaster declarations, 29 of which occurred in Jackson County. The most likely natural disaster are severe storms and floods (Figure 7-3). Events that are designated as severe storms can include thunderstorms, damaging winds, tornadoes, large hail, flooding, and winter storms. Jackson County alone follows similar statewide trends where the most frequent natural diastases are severe storms and floods. The most recent incidents occurred in 2015, where Jackson County experienced severe storms, tornadoes, straight-line winds, and flooding (FEMA 2019).

Figure 7-3. Frequency of hazards in Missouri since 1953.

Using Columbia University’s “U.S. Natural Hazards Index,” Jackson County ranks a 14 on a scale of 22. Its highest threats include tornadoes and flooding, with low to moderate chances of snowfall, landslides, heat waves, or wildfires (Table 7-8).

Flooding can cause significant damage to structural and electrical assets. This can impact the production process, which would disrupt the broader mission of the base. Similarly, tornadoes can cause significant physical damage to the buildings, infrastructure and landscape surrounding the base. It is important to recognize that military buildings are required to be built to resist natural disaster, such as tornadoes, however aging infrastructure maybe expose vulnerabilities in structural integrity of the site’s real property.

Table 7-8. Columbia hazard index classification.

County Name	Jackson
State Name	Missouri
Hazard Index	14
Wildfire Hazard	Low
Volcano Hazard	None
Tornado Hazard	High
Snowfall Hazard	Medium
Landslide Hazard	Medium
Hurricane Hazard	None
Earthquake Hazard	Low
Drought Hazard	None

County Name	Jackson
Heat Wave Hazard	Medium
Avalanche Hazard	None
Flood Hazard	High
Source: Columbia University (2019)	

The most commonly occurring natural hazards in the region are tornadoes and flooding. In 1957, the county experienced an F-5 tornado that caused 37 deaths, 176 injuries, and \$2.5 million in damages. In 2013, the state conducted a vulnerability analysis and determined a 48.78% likelihood of another such occurrence. In conjunction with other factors such as annualized historic loss, population growth, and housing shifts, the county is ranked as “moderate” in terms of tornado vulnerability (SEMA 2013).

Table 7-9. Environmental Monitoring and Assessment Program (EMAP) tornado impact analysis.

Subject	Detrimental Impacts
Health and Safety of Persons in the Area at Time of Incident	Localized impact expected to be severe for incident areas and moderate to light for other adversely affect areas.
Health and Safety of Personnel Responding to the Incident	Localized impacts are expected to limit damage to personnel in the areas at the time of the incident.
Continuity of Operations	Damage to facilities/personnel in the area of the incident may require temporary relocation of some operations.
Property, Facilities, and Infrastructure	Localized impact to facilities and infrastructure in the area of the incident. Some severe damage possible.
Delivery of Services	Localized disruption of roads, facilities, and/or utilities caused by incident may postpone delivery of some services.
The Environment	Localized impact expected to be severe for incident areas and moderate to light for other areas affected by the storm or HazMat spills.
Economic and Financial Condition	Local economy and finances adversely affected, possibly for an extended period.
Regulatory and Contractual Obligations	Regulatory waivers may be needed locally. Fulfillment of some contracts may be difficult. Impact may temporarily reduce deliveries.
Reputation of or Confidence in the Entity	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective.
Source: SEMA (2013)	

7.4.3.2 Manmade disruptions, unintentional

Two known accidents have occurred on LCAAP in the last 10 years. The first incident was an explosion on 1 March 2011 that left five people injured (MSIAC 2011). It is believed that the explosion was accidentally caused by an employee, who was severely injured as a result (KMZU 2011).

Similarly, on 11 April 2017 an explosion occurred in the mixing building, which resulted in one fatality and four injuries. The facility is owned by the service but operated by Orbital-ATK, a private defense company contracted by the Army. The base employs both Federal and civilian workers; all five workers were employed by the company (MSIAC 2017).

7.4.3.3 Manmade disruptions, intentional

The base currently conducts an annual full-participation antiterrorism exercise, in which they simulate both an incident and response based on the installation's Antiterrorism Plan. This plan was produced in collaboration with the installation's Fire and Police Departments, AMR Ambulance Service, Life Flight Eagle Air Ambulance, the Jackson County Emergency Management Office, and the City of Blue Spring Police Department. Participation was extended to production facilities to create a more comprehensive, interagency coordinated response. Annual drills allow the base to simulate various incidents and update their plan and regional partnerships as needed (Griechen 2015).

7.4.4 Disruption case study: Explosion

7.4.4.1 Risks and response measures

Explosions at an ammunition plant can cause significant damage due to the high volumes of volatile and hazardous materials in the surrounding area. There have been two known incidents at this site that have resulted in the loss of life and the interruption of the plant's mission. Though these incidents are rare, their impacts are substantial and require significant amounts of water and planning. Susceptible areas of production can include dryers, mills, reactors, air/material separators, and storage vessels. To prevent an explosion, it is important to consider ignition control, the removal of residual dust, training plan personnel, and management of the adaptations made based on the original National Fire Prevention and Control Act (Grandaw 2015). Table 7-10 outlines a range of water needs de-

pending on building type, size, and severity of the explosion. These numbers were calculated using National Fire Protection Association (NFPA) fire flow regulations and can vary between installations.

Table 7-10. Amount of water needed to expel an explosion by building type.

Building Type	Bldg. Area sq ft	Fire Flow (GPM)		Total Gallons Needed	
		Low	High	Low	High
Small Caliber Loading Plant (Under 40 mm)	442284	6000	8000	1440000	1920000
Production Plant Support Building	62745	2750	6750	330000	1620000
Power Plant Building	625	1500	1500	180000	180000
Heating Plant Building	21695	1500	4000	180000	960000
Explosive Manufacturing Plant	4607	1500	2000	180000	240000
Production Plant Support Building	39315	2250	5500	270000	1320000

7.4.4.2 Impacts

Army ammunition plants rely on profits produced from production to sustain operations. Explosions, even small ones, can affect water lines and assets. Water disruptions that limit production in any way would be classified as a high impact disruption. As the primary producer of small caliber ammunitions for the U.S. Army, any disruption to production would impact other missions across all Army installations.

Impacts that are more general can be categorized by mission types. Impacts within these groups can vary depending on the timescale of the incident, the severity of the event, and the mission assigned at the given time.

7.4.5 Proposed mitigations

Industrial explosions pose a significant threat to the life, health, and safety of onsite personnel. Strategies to mitigate this hazard include, but are not limited to, protective construction methods, vulnerability assessments, and safety and training for personnel. Protective construction methods may include designing control rooms, and upgrading buildings where flammable vapor, dust, or other explosive materials are located. This new construction should consider the thermal resistance of the construction material and glass glazing to reduce the chance of structural damage. Other design features may include barricades, shields, and testing chambers for high-risk operations. Vulnerability modeling includes techniques such as blast load prediction, explosive safety and quantity distance (ESQD) assessments, and antiterrorism and force protection assessments.

Finally, personnel training and workplace atmosphere create a safe and consistent environment for production (ABS Group 2019).

A tactic that is currently being employed and should be further expanded upon are exercises in which the base can implement strategies in real time. For instance, LCAAP has certified two of their police officers through a 45-day training and a resident U.S. Army Civilian Police Academy Course that focuses on law enforcement, antiterrorism, physical security, and force protection skills. In addition to these concepts, the academy provides students with fundamental Army civilian field certification, which includes but is not limited to basic law enforcement and first responder skills, knowledge of authority and jurisdiction, constitutional law, weapons, armed and unarmed use of force, first aid, and hazard material response. These courses can be accessed at the U.S. Army Police School at Fort Leonard Wood (Jackson 2018).

7.4.6 Scenario 2 summary

Scenario 2 uses the Lake City Army Ammunition Plant (LCAAP) as the example for water loss mitigation for an industrial base. LCAAP is located in Jackson County, MO, roughly 20 miles east of Kansas City, MO. LCAAP only houses one unit, the 325th Medical Detachment, and is responsible for producing the small caliber munitions, which is contracted out to a private defense company.

LCAAP contains a total of 542 structures and only 28 onsite personnel. The base obtains a majority of its water from wells located on site and purchases additional water from Independence, MO to serve housing units. The riparian law within Missouri allows landowners to use the water on their land in any way that is deemed legal or reasonable until restricted by a court.

The most likely natural disasters are thunderstorms, damaging winds, tornadoes, large hail, flooding, and winter storms. This area of Missouri is also highly vulnerable to tornadoes. However, given the unique function of an industrial base, this study chose to examine the effect and mitigation strategies for an explosion. This manmade water disruption can cause significant damage due to the abundant amounts of hazardous materials on the site. Any disruption in the production process poses a threat to the financial stability of the base, which is responsible for generating funds to keep the base operational.

Strategies to mitigate this hazard include, but are not limited to, protective construction methods, vulnerability assessments, and safety and training for personnel. Real-time exercises to mimic emergencies are encouraged and can aid in emergency response strategies and organization.

7.5 Scenario 3: Training installation

7.5.1 Installation overview

Camp Atterbury is an Indiana Army National Guard (IN-ARNG) installation roughly 4 miles west of Edinburgh, IN and approximately 30 miles south of Indianapolis, IN. Camp Atterbury was established in 1942 with a mission of preparing troops for deployment during WWII. It transitioned from an Army installation to the Indiana National Guard in 1968 and now supports an average population of 4,300 per year. This includes trainees from National Guard, Army Reserve, other branches of service both active and reserve, Department of Homeland Security (DHS), state and local police, and ROTC members (HQDA 2009).

7.5.1.1 Mission/stakeholders

Camp Atterbury's two principal missions are transient training and mobilization (Mobilization Force Generation Installation, MFGI). The site also serves as an emergency response hub in the event of a disaster declaration.

Units at Camp Atterbury include: Asymmetric Warfare Cell (417), RLB (76th UAS [Unmanned Aerial System] Training), Armory, Wolf Ops, Installation Support Unit, UTES/CSMS, IDOC, Crane Credit Union, IGIR DOIM HUB, MP, J1 MED, R R, MOB Planning, DoD-EC, RTI, A-M HQS Annex, Navy (Seals), Air Guard, DPTMS/RTLP/ITAM, FED P_C (244), State P C (245), LCI – SSSC (324), Jeanie's Sew Shop (427), PAO/Museum 436 CAVMH, IDHS, MEDCOM/DENTCOM, DNR, DOL, DOIM, INARG Resiliency Camp Bike Hub, Army Wellness Center (341), Troop Support MWR DPCA, Housing Billeting Lodging, 157th IN BDE, and DPW.

7.5.1.2 Primary assets

Camp Atterbury currently controls over 33,000 acres of maneuver training area and live firing ranges. The primary assets used by training units for long-term stays are three Contingency Operating Locations (COL) and Forward Operating Bases (FOB). The FOBs include barracks, classrooms, shower and bathroom facilities, and dining facilities (DFAC).

The installation is comprised of approximately 662 buildings and covered structures in total as determined from the most currently available National Guard PRIDE real property database (an alternative to the Army Headquarters Installation Information System, HQIIS real property data). Note that HQIIS could not provide accurate data for Camp Atterbury; however, it is the most readily available when studying a facility remotely. A key difference between PRIDE and HQIIS is the lack of building floor data in PRIDE, which is necessary for fire flow demand calculations. Many building numbers in PRIDE also had multiple category codes, occasionally splitting buildings in terms of use. This explains why the original mission-critical list of 41 buildings may actually include more “buildings” from this point on.

Roughly 15% of the Camp Atterbury real property (facility area) is mission critical (MC). A list of critical infrastructure was provided by the installation. Of the 41 structures on the mission-critical list, 37 were identifiable in the PRIDE database while four were not found. Table 7-11 lists (and Figures 7-4 and 7-5 show) facility group categories by number of buildings and square footage across the entire installation and for MC facilities.

Table 7-11. Camp Atterbury buildings by facility group (total and mission critical).

Use Cat.	Description	Total Bldgs.	MC Bldgs.	Total Area (sq ft)	MC (sq ft)
1	Industrial and Maintenance	18	4	157,013	58,345
4	Housing (Barracks)	116	0	770,589	0
5	Community and Commercial: Non-food (indoor)	23	2	81,015	4,128
6	Community and Commercial: Food	36	1	182,447	11,962
7	High Energy	18	1	116,595	5,100
8	Medical	4	4	26,660	26,660
9	Administration and Operations	126	18	462,981	86,901
10	Other Training and Schools	181	6	357,099	136,267
11	Storage	86	5	305,200	40,017
12	High Water Use Facilities	13	0	15,037	0
14	Unpaved Surfaces	2	0	3,841	0
18	Community and Commercial: Non-food (outdoor)	22	0	8,537	0
21	Miscellaneous	17	1	10,514	566
	Sum	662	42	2,497,528	369,946

Figure 7-4. Camp Atterbury buildings by facility group (total and mission-critical).

Figure 7-5. Camp Atterbury area by facility group (total and mission-critical).

Total water demand was calculated based on permanent meter (billed) data. Therefore, “The total water demand (billed)” is the most accurate measurement available of total water consumed. Total water demand was also estimated via calculation from PRIDE real property data and the WUI values of 9 different Army installations, “Total water demand (9-Army, WUI)”. Using the 9-Army WUI values, water demand of just the MC facilities was calculated, “MC water demand (9-Army, WUI)”. Lastly a more specific calculation of WUI values was used, based on Camp Atterbury specific water meter data. The estimations of water demand were therefore

calculated again for both total and MC buildings, “Total water demand (Custom CA WUI)” and “MC water demand (Custom CA WUI)”. Figure 7-6 displays our billed data on the monthly time scale against all our other estimations. These demands can be used to inform water security planning as discussed in the disruption case study later in this section.

Figure 7-6. Camp Atterbury water demand (total and mission-critical).

Figure 7-7. Camp Atterbury water demand by facility group (total and mission-critical).

7.5.1.3 Regional overview

7.5.1.3.1 Political

Camp Atterbury straddles three counties (Johnson, Brown, and Bartholomew). The bulk of the land and all the main cantonment area are within Bartholomew County.

7.5.1.3.2 Geographic and hydrologic

Camp Atterbury lies in a unique physiographic region of Indiana. Its main cantonment area is within the Atherton Outwash Region (Robinson and Risch 2006). The area consists of major pre-glacial drainage ways which were originally flowing northwest but were then blocked by ice and filled in with glacial till. In some places over the cantonment area, the valleys are filled with more than 100 ft. of unconsolidated deposits (Fenelon et al. 1994). The area is also characterized by narrow, flat-topped divides and deep V-shaped valleys with a local relief between 125 and 250 ft.; the area is well drained by a dendritic stream pattern (Fenelon et al. 1994).

During glacial advances and retreats, the Scottsburg Lowland became a principal discharge route for meltwater and outwash, which filled the area with outwash deposits ranging from 50 ft. to more than 100 ft. in thickness (Fenelon et al. 1994). Unconsolidated deposits in all formations have potential to act as groundwater sources. Availability of this ground water for development and its pumping potential is beyond the scope of this work. Bedrock under most of the installation is Mississippian shale, Devonian limestone, and dolomite (Fenelon et al. 1994). This is to say that multiple layers of groundwater exist beneath Camp Atterbury and occur in varying supply capacities and in some cases are very deep (greater than 500 ft).

7.5.1.3.3 Climate

The state of Indiana faces greater challenges of water inundation and flooding than of drought. In general, precipitation in the spring and summer has been above average for 2 decades. Though water is a more prevalent concern with severe flooding, having occurred periodically in recent years, it is predicted that future increases in evaporation rates may increase the intensity of naturally occurring droughts (Frankson et al. 2016).

7.5.2 Water sources

Potable water is supplied to Camp Atterbury by Princes Lakes Water Department, a public water supplier located in adjacent Nineveh Township, Indiana. Two water mains supply the installation, and each is master metered. There is also a master meter to FOB 3. In total, there are nine billing meters across the site.

It has been recently identified that the existing system has deficiencies at the raw water wells, water treatment plant, storage locations, and within the distribution system.* An installation technical memorandum on the subject offers alternatives and potential solutions. The deficiencies are generally aging parts and infrastructure needing repair/replacement to increase efficiencies and decrease failures, rather than a capacity problem. This indicates a need for routine maintenance, upgrades to equipment, infrastructure and water main looping, and improved water plans.

To clarify ownership and responsibility of the contractor-operated system, it is important to define ownership of the system components so that repairs can be properly assigned to the responsible parties:

- Wells: Princes Lakes
- WTP: Princes Lakes
- Water tower and tank: Camp Atterbury
- Distribution system: Camp Atterbury within the fence line; Princes Lake outside of the fence line.

7.5.3 Potential water disruptions

A potential vulnerability is rooted in the outsourcing of potable water. The utility supplying water to Camp Atterbury is the sole source of water to the installation. Without the option of onsite proprietary wells or water sources there is the chance of supply disagreements and shortages between the installation and surrounding towns and cities, which share the same groundwater source.* Wells are not within the fence line of the installation and some appear to have graffiti indicating a potential for security breach to the system.

* Commonwealth Engineers. 2018. Technical Memorandum. Subject: Camp Atterbury Water and Wastewater Utilities Assessment. Indianapolis, IN: Commonwealth Engineers, Inc.

Additional vulnerabilities to consider at Camp Atterbury include the location of a major water main beneath a large public road/highway. A risk to water availability on the installation would be posed by a hazardous spill on the road or a major road construction project disrupting the supply. There are also climate-related risks, which have been emphasized earlier and throughout other sections of this report. The potential for flooding and drought exists in the area and can put strain on aging infrastructure as well as limit available supply.

Most of these vulnerabilities can be condensed into the risk of general disruption to supply. This is further discussed in the next section, which is specifically concerned with chemical contamination, either accidental or intentional.

7.5.3.1 Source water contamination

Contamination of Camp Atterbury's water source can occur anywhere within the aquifer's watershed. The entire recharge zone, as well as any well locations that demonstrate contact with the aquifer for the purposes of water or any other extraction purpose, pose a potential area of threat. Examples include mining, which may introduce chemical, saline, or even bacteria-laden waters into the otherwise mostly clean groundwater source. This may also be as simple as overpumping the aquifer system, which can result in a high concentration of salts at the bottom of the water source. Additionally, this may include surface contaminant leaching over time through the soil in amounts significant enough to permeate and affect ground water quality.

7.5.3.2 Accidental contaminant input

Accidental contamination refers to water pollution, which typically occurs during or after water treatment. An overdosing of chlorine is a potential scenario where poor operation of a treatment facility could lead to contamination. Pipe failures throughout the distribution system and subsequent interactions between the surrounding soil and potable water may also cause accidental contaminant inputs.

7.5.3.3 Intentional contaminant input

Intentional contamination can occur at many locations throughout the watershed and distribution system. Most likely points of contamination in the

line of transmission would be the pump stations and well locations. These areas could be targeted if they are housed in low security structures. Here a contaminant not typically removed through water treatment could be added intentionally to contaminate the potable water. Similarly, an individual could introduce chemical contamination at the source of potable water at the beginning of the treatment process. Lastly, an individual seeking to do harm may locate large distribution mains, manholes, or other more opportunistic bursts in mains as a path to introduce harmful chemical contaminants into the distributions system, which conveys water directly to the building faucets and spigots. These chemicals of malicious intent can be difficult to detect and even more difficult to remove.

7.5.3.4 Distribution system failure

A distribution system failure refers to both human-caused and naturally occurring susceptibilities to the system. Human problems include poor design of infrastructure that leads to loss of pressure, cross connections, or other poor engineering that can result in an inflow of contamination from the surrounding soil. This may also include construction site work, which results in an unintentional contamination event.

Naturally occurring events, which can weaken the distribution system, include drought, flooding, hurricanes, and other natural disasters. All these events can cause breakages, loss of pressure, and contamination.

7.5.4 Disruption case study: Contamination

7.5.4.1 Groundwater contamination

The disruption that was investigated is groundwater contamination that would affect all users of Princes Lake water system. This type of threat has several possible sources for occurrence, including but not limited to:

- Natural
 - Seismic event which disrupts the surrounding geology and alters the aquifer's chemical composition.
 - Changes in water chemistry due to a lack of dilution or lack of recharge to the water from drought or otherwise.
- Unintentional Manmade
 - Pollution such as legacy chemical plumes which begin to seep into the aquifer.

- Industry, mining, or construction in the area, which may unintentionally contaminate the aquifer.
- Intentional Manmade
 - Chemical or biological contaminant purposely introduced to groundwater sources.

7.5.4.2 Effects

Camp Atterbury relies on the delivery of potable water from outside the fence line. Water disruptions that contaminate and therefore limit the delivery of a safe water supply would disrupt all water needs for a minimum of 3 days (time it takes to flush/clean and replace the water in the distribution system). Missions that need to occur without interruption and any critical training taking place at the installation would need to rely on temporary/backup water sources.

7.5.5 Proposed mitigations: Contamination

7.5.5.1 Physical security

Physical security to protect against a contamination occurrence, the following proposed mitigations should be explored. (Note that these are mostly preventive measures.)

Physical security of the distribution system is one of the first and most reasonably inexpensive actions to effectively reduce the threats associated with intentional contamination. Locked doors, locked gates, and impassable fencing surrounding structures such as wells, pump houses, storage tanks, and treatment facilities can go a long way to protect against threats. Special key or card access only to specified individuals can also prevent malicious activity. In high-risk situations, security guards may also be considered. This may protect against purposeful human influence on the distribution system.

7.5.5.2 Online/inline monitoring

The use of online source water monitors, which continuously monitor the water distribution system in situ, can be an active step in early detection of potential contaminants. Strategic placement of monitoring equipment can better protect the entire distribution system from threat. This is a more proactive approach than the implementation of daily, or even hourly source water sampling required by national drinking water standards,

which can take hours or longer to analyze. Online monitoring occurs continuously, at a rate more frequent than every hour. Monitoring results are intended to provide real-time output that eliminates the time lag between the occurrence of contamination and the notification of responsible officials and facilitates a quicker emergency response.

Potentially harmful contaminants can reach consumers whether contamination occurs at the water source or within the pipe. Since it is not feasible to monitor every node in the distribution system, monitoring locations should be selected to cover the entire water supply in a way that allows the earliest possible notification of a threat taking into consideration hydraulic demand patterns, water quality condition, and water leakage (Wu et al. 2007). Best possible locations fall into three categories: water treatment output locations, water quality deterioration areas (dead ends), and representative locations that reflect the region. While the first two location types can be identified on a map, the third type is determined by a model. The model should consider both hydraulic and chemical properties of the distribution system. This type of optimization is outlined in Appendix G.

Parameters to be monitored are often a function of the region under study and/or the underlying water quality concerns for the area. It is recommended that at least two parameter measurements be used to identify the number of potential contaminants to best capture any possible threat. The two recommended parameter measurements here are daphnia population and basic water-monitoring systems such as pH, temperature, and combined turbidity and conductivity. Daphnia are an appropriate parameter since they are a biological indicator that reacts to contamination much like a human would. Appendix H summarizes an outline of such a system. It is likely that treatment plants already measure “water-parameters” on a regular basis, but unlikely that the measurements occur in real-time. Appendix I includes examples of such systems as well as more sophisticated options (including daphnia) that can be installed and adapted to the current computer readouts and warning systems at the plant.

Once monitoring locations are determined and monitoring equipment for desired parameters selected, a warning system needs to be put into place to convey warning information to the officials in charge of response activities. Without real-time output of dangers, contamination could go unnoticed potentially causing harm.

7.5.5.3 *Response plan*

If the water quality monitoring system is alerted, the responsible officials should first determine if the system alert is a false alarm or bona fide emergency. In the event of an emergency, actions outlined in the Emergency Response Plan (ERP) should be carried out. The plan should include event documentation materials, notification of affected individuals, testing and cleanup procedures, and re-institution of safe supply notifications.

Arguably the most important step is cutting off water supply to the affected users to limit accidental usage of contaminated waters and to prevent any further contamination of otherwise unaffected areas of the distribution system. The next step in response should be the distribution of notification materials. This process should be relatively automatic and delegated to officials throughout the installation for further dissemination. Materials should be prepared in advance of an emergency so that emails, phone calls, signage, and alerts can be disseminated with ease upon notification of a threat. Mission-critical facility stakeholders should be aware of the locations of contingency supplies, and of the processes to access those supplies.

For example, once notified of an event, installation personnel should refer to an existing response plan that includes knowledge about and access to the affected location(s) and the ability to respond appropriately. This may include sending certain personnel home (non-essential), securing bottled water supplies, limiting water use in other ways, or accessing a secondary water source to supply mission-critical areas. Water demand data can inform decisions about amount and location of required backup supply. In the case of Camp Atterbury, roughly 0.8 million gallons would be required to support mission-critical facilities for 14 days.

7.5.6 **Scenario 3 summary**

Camp Atterbury has a system that can maintain the installation's water supplies at normal demand and that is projected to be capable of sustaining a population in the event of an emergency. The installation draws water from an aquifer that is not in a threatened state and has other groundwater sources that have been identified as potential alternative water sources. Areas of improvement include responses to chemical emergencies, specifically through the use of a notification system, which should be

implemented. Additionally, a replacement supply option needs to be identified and sourced. Though alternative emergency supplies are available, the acquisition, treatment, and distribution of that supply would need to be planned for and/or created.

8 Strategies for Increasing Resilience

The DoD defines mitigation as “actions taken in response to a warning or after an incident occurs and are intended to lessen the potentially adverse effects on a given military operation or infrastructure” (DoD 2019). Successful mitigation strategies must consider the scope and duration of a disruption event (Figure 8-1). A disruption with a limited scope and short duration will have a relatively low impact and require less mitigation than a disruption that affects more people/processes for a longer period.

Figure 8-1. Disruption mitigation matrix.

	Narrow Scope	Wide Scope
Short Duration	Low Impact	Low-Moderate Impact
Long Duration	Moderate-High Impact	High Impact

Water disruption mitigation strategies address issues of water quantity and quality. Installations should engage stakeholders to identify their vulnerabilities, and the associated consequences of a disruption to critical facilities, in order to understand the many ways that polluted or diminishing water supplies can adversely impact the installation’s ability to complete its mission.

The following planning requirements can also assist in determining existing vulnerabilities and facilities that require water and/or electricity flow (ACSIM 2018):

- Installation Master Plan
- Emergency Preparedness Plan
- Energy Emergency Preparedness and Operations Plan
- Energy Security Plan
- Capital Improvement Plan
- Continuity of Operations Plan
- Fueling Plan
- Operations and Management Plan
- Resource Management Plan
- Water Management Plan
- Water Resource Management Plan
- Emergency Action Plan
- Emergency Response Plan

- Public Notification Plan
- Emergency Management Plan
- Emergency Operations Plan
- Physical Security Plan
- Potable Water System Master Plan.

8.1 Time-contingent response strategies

Mitigation strategies can be broadly categorized as either risk mitigation or crisis management. Risk mitigation focuses on alleviating the consequences of a disruption while crisis management focuses on the process through which a sudden disruption is handled. Effective strategies should incorporate both aspects.

8.1.1 Risk mitigation: Before a disruption occurs

In certain circumstances, increasing resilience may be as simple as accommodating the threat of a risk by constructing equipment more mindfully or by adjusting maintenance schedules. Other instances require more drastic measures, like relocating critical facilities and infrastructure to avoid direct contact with a risk. For this reason, Best Management Practices (BMPs) for mitigation typically fall into one of four categories: Accommodate and Maintain, Harden and Protect, Relocate, and Accept or Abandon (Table 8-1).

Table 8-1. Mitigation Best Management Practices (BMPs).

Strategic Approach	BMPs	
	Rehabilitate Existing Structures to Higher Standards or Strength	Build New Climate-Resilient Structures
Accommodate and Maintain	Extend, strengthen, repair or rehabilitate over time. Adjust Operation and Maintenance (O&M) practices.	Design and build to allow for future upgrades, extensions or regular repairs.
Harden and Protect	Rehabilitate and reinforce. Add supportive or protective features. Incorporate redundancy.	Use more resilient materials, construction methods, or design standards. Design for greater capacity or service.
Relocate	Relocate sensitive facilities or resources from direct risk.	Site in area with no, or lower, risk from climate impacts.
Accept or Abandon	Keep as is, accepting diminished level of service or performance.	Construct based on historic climate conditions, accepting possibly diminished level of service or performance.
Source: "Approaches to Climate Change Adaptation Options," AECOM (2017)		

Mitigation strategies are most effective when they offer context sensitive solutions. Each of these BMPs has benefits and drawbacks. In some situations, simply adjusting the systems operation and management approaches can adequately reduce a facility's vulnerability. Projects that incorporate redundancy measures or involve the use of more resilient materials to harden and protect assets may be most suitable to address physical threats. Infrastructure or facilities that are consistently threatened by flooding or other natural disasters may require relocation to continue operating at full capacity. Lastly, in certain circumstances, it may be prudent to accept a level of inefficiency or to abandon an asset. This option may be most acceptable when there are other assets in place to replace or support mission functions without the failing asset. Each mitigation plan should include metrics to measure mitigation performance. These metrics will help evaluate the mitigation plan after an incident.

8.1.1.1 Best management resiliency practices by function

Another way to contextualize BMPs is by function, by grouping facilities together by similar operations and water requirements that may all be improved by similar best practices. These generalizations offer introductory considerations for facility modifications but should not be the only considerations given to improve facility resilience. Appendix D addresses resiliency practices by function. It is recommended to use the 21 facility group categories first referenced in the Water Demand Model.

8.1.1.2 Diversify water supply

With growing populations both on and off post, Army installations are forced to consider reliable strategies to meet the needs of their tenants. The 2011-2017 drought in California and similar situations around the world highlight the vulnerability of single water sources.

Installations should review opportunities to draw water from multiple sources. This may require the revision of their water rights or an MOU to secure adequate supply. If one water supply is unavailable due to quality or other disruptions, having a separate, discrete supply reduces infrastructure vulnerabilities and improves readiness. In addition to considering additional freshwater sources, installations should plan to include water storage, storm water capture, and recycled wastewater as potential supply options.

8.1.1.3 Multiple pipe connections

Installations should also explore multiple main supply points for the installation. A single point of failure vulnerability is created when pipe networks rely on one supply point to feed water to the installation. Looping water systems is a way to reinforce a system that allows installations to isolate a building without cutting off water supply to buildings beyond the point of isolation.

8.1.1.4 Electricity

Electricity is a key component to supporting the resilience of water on an installation. Pumps and lift stations require electricity to help move water and wastewater across the base. A cascading event, such as an electricity blackout, can create a water disruption. Installations must consider ways to communicate and maintain water service if electric service is lost. Installations can prepare for a loss of service by establishing clear communication practices for emergency situations and by installing backup generators for critical water infrastructure systems.

8.1.1.5 Physical security considerations

The interconnected nature of water systems leaves them increasingly vulnerable to physical attack. Pollutants in a water tower or distribution system can spread rapidly and affect all users downstream of the source of contamination. Damage to water infrastructure, intentional or unintentional, could cease operations for days. Natural disasters can have significant physical impact on water assets.

Fortunately, water systems may be physically protected by barriers, aerial coverage, and onsite electricity generation. Fencing and landscaping provide physical barriers to accessing water infrastructure. Special consideration should also be given to aerial coverage. Disguising a water tower as a building or using a dense tree canopy can decrease the visibility of the infrastructure from the sky and make it harder to target for attack.

8.1.1.6 Best practices for cybersecurity

The Water Information Sharing and Analysis Center (ISAC), in conjunction with the DHS Industrial Control Systems Cyber Emergency Response Team (ICS-CERT), the FBI, and the Information Technology ISACs, developed 10 best practices to reduce exploitable cybersecurity weaknesses and

attacks. These best practices may enable water Supervisory Control And Data Acquisition (SCADA) systems to more readily detect issues, prevent vulnerabilities, and avert the resulting impacts (WaterISAC 2015):

1. Maintain an Accurate Inventory of Control System Devices and Eliminate Any Exposure of this Equipment to External Networks.

“Network segmentation entails classifying and categorizing Information Technology (IT) assets, data, and personnel into specific groups, and then restricting access to these groups;” any of these channels should be eliminated to reduce network vulnerabilities.

2. Implement Network Segmentation and Apply Firewalls.

“Network segmentation entails classifying and categorizing IT assets, data, and personnel into specific groups, and then restricting access to these groups;” segmentation enables malware to be isolated when it is detected. Firewalls filter network access and can detect risky connections.

3. Use Secure Remote Access Methods.

If remote access is required, access should be secured with the use of a Virtual Private Network (VPN) and by “limiting the number of Internet Protocol (IP) addresses that can access the network.” A VPN is not infallible; if the devices connected to the VPN are insecure and become infected with malware, they can introduce that malware to the network.

4. Establish Role-Based Access Controls and Implement System Logging.

Control and access to network resources can be defined based on the level of access each job function needs to perform its duties. Permissions controls like this enable cybersecurity teams to track network intrusions and suspicious activities before problems arise.

5. Use Only Strong Passwords, Change Default Passwords, and Consider Other Access Controls.

Passwords should have a minimum of eight characters and include both uppercase and lowercase letters, numerals, and special characters. Passwords should be changed regularly to maintain password strength. Default passwords should be changed when new software is installed, this is especially true for administrative accounts and system control devices. Multi-factor authentication and account lockouts after too many incorrect password attempts further bolster password security.

6. Maintain Awareness of Vulnerabilities and Implement Necessary Patches and Updates.

Cyber systems often require updating or patches to implement security protocols and changes that address recently discovered threats. When computer systems are not updated with the latest patch, their vulnerability increases. Using a system that monitors and applies system patches and updates can minimize this threat; a system that does this automatically can ensure that critical updates are not missed.

7. Develop and Enforce Policies on Mobile Devices.

Mobile devices, especially personal electronic devices, can expose cyber systems to external, malicious, actors via compromised applications and networks. Policies that limit the use of mobile devices and their capabilities on workplace networks can decrease this risk. Policies should be enforced for contractors and all other employees.

8. Implement an Employee Cybersecurity Training Program.

When the people who use cyber systems are not educated in cybersecurity, their actions may create additional vulnerabilities or lead to cyberattacks. Conversely, when employees are trained in cybersecurity practices, they may notice vulnerabilities and report them to the appropriate authorities before they become problematic. Employees should receive cybersecurity trainings throughout their tenure, starting with the first time they use a cyber-system and intermittently as needed.

9. Involve Executives in Cybersecurity.

Involving executive level management in cybersecurity enables executives to communicate cybersecurity threats or incidents and in turn secure more funding for cybersecurity measures. Consistent communication throughout the cybersecurity process also allows information to be shared in a timely manner and without speculation. If a Chief Information Security Officer role is established to meet this end, the chief must be authorized to make cybersecurity purchasing decisions.

10. Implement Measures for Detecting Compromises and Develop a Cybersecurity Incident Response Plan.

Intrusion detection systems (IDSs), intrusion prevention systems (IPSs), antivirus software, and logs work together to detect and indicate compromised systems. Once these detection instruments note an infection, an incident response plan can limit the damage and recovery time of a cyber-attack. Effective cybersecurity response plans are a “product of collaboration between all departments that would be stakeholders in a cybersecurity incident.” They should also include contingencies in case cyber systems need to go offline or turn to manual operations. As with all emergency response plans, cybersecurity incident response plans should be routinely reviewed and updated to ensure relevance and usability when incidents occur. If possible, a Computer Security Incident Response Team (CSIRT) may be formed to manage cybersecurity threats and the formation and exercises of an incident response plan.

8.1.1.7 Training

Mitigation training practices range from informational sessions with installation tenants to practicing drills that test and improve the mitigation plan(s). Clear communication between tenants and the installation DPW, Directorate of Emergency Services (DES), and Directorate of Plans, Training, Mobilization, and Security (DPTMS) is important to ensure that crises are handled effectively. Furthermore, installations can test the validity of their mitigation plans by cutting off the supply to specific units or sections of the base before a water disruption occurs. The involved parties should review the weaknesses and strengths of the existing plans after each drill and modify as needed.

8.1.2 Crisis management: During a disruption

Certain crises take time to arise; in their early stages these can be classified as potential crises. Poorly maintained water infrastructure is a potential crisis. If left alone, eventually the infrastructure will fail and may lead to a disruption. Other crises arise with little to no warning. Installations and their tenants can navigate sudden crises by having a response plan in place and by knowing the people to contact for further instruction or information. Installations can also partner with their local and state hazard mitigation offices.

Appendix D includes example forms detailing information an installation should know prior to a disruption event and the contact information for state hazard mitigation officers. This material can be published in an emergency response incident handbook but should also be readily available for appropriate tenants.

8.1.3 Plan evaluation: After the disruption

Stakeholders and administrative offices should review the proceedings of the disruption at the conclusion of an event. This is the time to note any risk mitigation strategies that failed or were successful. It is also an opportunity to identify interdependencies that were previously unknown and to address inefficiencies in service restoration plans.

8.2 Additional support for critical missions

While mission-critical facilities and infrastructure benefit from mitigation strategies implemented at the installation scale, additional strategies can enable these facilities to remain operable during a water disruption.

8.2.1 Supplemental utility measures

Sustaining critical missions during a water disruption may demand different levels of response based on the type of interruption. If the main water system becomes compromised, a discrete supply and treatment system can create flexibility and increase resiliency. This is one of the benefits of on-site water treatment and storage. Similarly, water systems may fail or become inoperable if the electrical grid becomes compromised. Onsite energy generation and supply may decrease the consequence of this vulnerability. The type of resource used to mitigate a disruption may vary

based on the duration and scope of the disruption. Table 8-2 provides a variety of options with which to address a disruption.

Table 8-2. Resources to consider for mission-critical facilities by event type.

	Narrow Scope	Wide Scope
Short duration	<ul style="list-style-type: none"> • Reverse osmosis water purification units • Tanker trucks • Bottled water • Redundant & backup supplies • Wells • Use portable toilet facilities • Neighboring water utilities (mutual aid agreements) • Energy generator 	<ul style="list-style-type: none"> • Redundant & backup supplies • Bottled water • Water buffalos • Tanker trucks • Energy generator • Micro grid
Long duration	<ul style="list-style-type: none"> • Reverse osmosis water purification units • Tanker trucks • Use portable toilet facilities • Wells • Water warehousing/reservoir • Pre-position emergency power generation capacity in critical buildings to maintain continuity of services 	<ul style="list-style-type: none"> • Water cistern system • Renewable energy sources • Interconnection with neighboring utilities • Distribution system looping • Deep well • Reverse osmosis water purification units

8.2.2 Security measures

Physical and cyber security are always matters of concern on Army installations. Reinforcing standard security measures for water infrastructure and assets can reduce the vulnerability of these specific assets. Simple additions such as fencing and perimeter walls, gates, restricted site access, proper lighting and signage, and surveillance measures can be used to restrict access to vulnerable areas. These security measures also range in intensity and can be modified to an installation's level of need. For instance, the fence or perimeter wall can range from a simple chain linked fence to a perimeter wall with a fence topping. Gates can be manned by security guards or electronically operated with card readers.

Beyond additional access prevention methods, additional measures should be taken with individual system components to prevent the degradation of an entire system. For example, backflow preventers enable water to flow in one direction and one direction only. Doing this protects potable water systems from contamination or pollution, however, backflow preventers may not exist at all connections or may be dysfunctional. Additional security measures that can be taken include installing a contamination warning

system or a contamination monitoring system. Routine sampling and analysis can decrease the likelihood of a contamination incident as well.

Another layer of protection can be installed via cybersecurity measures. The *Handbook of Water and Wastewater Systems Protection* suggest that these additional measures should be taken to protect a water/wastewater SCADA system (Panguluri et al. 2011):

- Be proactive in testing software by testing source and binary application code using security scanners with assessments and certifications.
- Employ a variety of network-based intrusion prevention and detection systems combined with network behavior analysis, firewalls, enterprise antivirus, and threat management devices (secure gateways, application firewalls, and managed security services).
- Implement a variety of host-based security measures such as endpoint security, network access control, and system integrity checking tools, application control, and configuration hardening tools.
- Establish vulnerability management by employing penetration testing and ethical hacking techniques, followed by patch and security configuration management and compliance measures.
- Implementing measures such as identity and access management, mobile data protection and storage and backup encryption, content monitoring/data leak prevention, and VPNs.
- Initiate the use of tools and measures such as log management, event management, media sanitization, mobile device recovery and erasure, security skills development, security awareness training, forensics tools, governance, risk and compliance management tools, and disaster recovery and business continuity planning.

These additional physical and cyber security measures can be incorporated into current water/wastewater systems to decrease the vulnerability of an asset.

8.3 Funding for increased resilience

Funding sources available for projects to increase water resilience include several categories of military appropriations and also several programs that permit private investment in military infrastructure systems. Each of these categories is listed below.

8.3.1 Sustainment, Restoration and Modernization (SRM)

The facility SRM account includes funding for operation and maintenance and disposal of real property on installations. The program includes funds to repair or renovate existing facilities and demolish excess facilities of an “excessive age” or those that have seen damage due to “fire, accident, or natural disaster.” O&M funds are available for salaries and minor construction projects and are useable during the current Fiscal Year. SRM projects are typically submitted to the higher headquarters (AMC, IMCOM, National Guard Bureau, or Army Reserve) for ranking.

8.3.2 Military Construction (MILCON)

For new or replacement facilities, or those exceeding \$2 million, MILCON funds may be available. MILCON is a process of acquiring both the authority and resources to meet facility requirements identified by the planning process. The use of MILCON funds requires a 5-year planning horizon.

8.3.3 Energy Resilience and Conservation Investment Program (ERCIP)

The ERCIP is a special category of MILCON that was created to fund projects that “improve energy resilience, contribute to mission assurance, save energy, and reduce the U.S. Department of Defense’s (DoD’s) energy costs” through the “construction of new, high-efficiency energy systems and technologies or through modernizing existing energy systems” (ASD 2019). ERCIP has traditionally funded small projects that promise a significant payback in reduced energy costs but can also be applied to projects that conserve water. This funding source can be used for smaller projects to increase water efficiency and improve resilience.

ERCIP funds are appropriated as one of two categories, Construction or Planning and Design. Each category has its own stipulations for funding schedules, project type, and obligations.

8.3.3.1 Construction funds

“Construction funds are for executing planned ERCIP projects. Construction funds are typically obligated through a Design/Build or Design/Bid/Build contract. ERCIP construction funds are available for obligation for 4 years following the year of appropriation. ERCIP construction funds may be combined with prior year ERCIP construction funds, so long

as the prior year funds are still available for obligation. ERCIP construction funds may not be augmented by any other funding source.”

8.3.3.2 Planning and design funds

“Planning and Design (P&D) funds are for planning and architectural & engineering services required to prepare ERCIP projects for execution. ERCIP P&D funds may be obligated for 4 years following the year of appropriation and may be combined with prior year ERCIP P&D funds so long as the prior year funds are still eligible for obligation.”

ERCIP projects must be catalogued in an annual report. For military installations, these reports should include the following details (10 U.S. Code § 2914. 2019):

1. The title, location, scope of work, original project cost estimate, and the current working cost estimate
2. Both the original expected savings-to-investment ratio and simple payback estimates measurement and verification cost estimate, and a current, to the date of publication, update
3. A brief description of the measurement and verification plan
4. Rationale for how the project would enhance mission assurance, support functions, and address known vulnerabilities.

8.3.4 Energy Savings Performance Contract (ESPC)

ESPCs are joint ventures between an Energy Service Company (ESCO) and Federal agencies, in this case an Army installation. As a team, the installation and ESCO work to “improve the energy [and water] efficiency of existing facilities and implement new renewable energy capability where economics permit” (ASA[IE&E]) 2016). While an ESPC is in place, an installation must perform annual energy audits to determine if performance guarantees, as outlined in the contract, are being met.

There are four key benefits to an installation using an ESPC task order (USACE 2016):

1. Savings guarantees are mandatory.
2. Savings must exceed payment each year.
3. Measurement and verification are mandatory.

4. The task order allows for the replacement of older systems with newer more efficient systems.

Furthermore, the ESCO is responsible for the costs of implementing energy and water savings measures, i.e., expenses associated with conducting audits, acquiring and installing equipment, and training personnel. In return, the ESCO receives a share of any energy and water savings directly resulting from implementation of such measures during the term of the contract. Examples of the types of integrated energy and water projects this funding source can support include decentralization of domestic hot water systems, solar water heaters, water and steam distribution systems, water wells, retention ponds, upgrades to Heating, Ventilating, and Air-Conditioning (HVAC) systems, chiller plant improvements, etc.

Information and assistance about pursuing an ESPC is available from the DOE's Federal Energy Management Program (FEMP).

8.3.5 Utility Energy Service Contract (UESC)

Through participation in available incentive programs, Federal agencies can leverage their utility budgets to implement energy, water, and renewable measures that are essential to meeting Federal mandates, facility goals, and operations and maintenance objectives.

As authorized by the Energy Policy Act of 1992, P.L. 102-486 (codified as 42 U.S.C. 8256), a UESC is a limited-source contract between a Federal agency and its serving utility for energy and water efficiency improvements and demand-reduction services.

A UESC between a customer agency and a franchised serving utility can be put in place for the utility to provide energy management services such as:

- Assessing project potential
- Designing solutions
- Providing project financing
- Installing the measures
- Providing performance assurance.

A UESC is developed with a design-build team approach. An agency establishes an internal team that is composed of technical, acquisition, and legal staff. Typically, technical staff identifies the need and initial scope and

works with the utility to ensure that the assessed potential and recommended solution are technically and economically feasible and meet the agency mission and facility functionality. The contracting officer, acquisition staff, and legal counsel ensure that the project is developed in accordance with laws and regulations at a fair and reasonable price” (EERE 2020).

8.3.6 Other funds

Critical mission facilities are often the responsibility of specific units on an installation. It is possible that a unit can fund projects to increase the resiliency of their building. This may include small projects such as acquiring a backup generator or installing a water meter. Examples of these units are facilities that operate 24/7 year-round and cannot relocate to another facility. Disruption of the mission is not acceptable and, hence, units are willing to invest to maintain backup /redundant utilities.

9 Conclusions and Recommendations

The Army's critical missions are at risk from interruption of water supplies. High-quality potable water in the required amounts is a resource for which there is no substitute. Interruption to an installation's water supplies will jeopardize mission capabilities and installation security. Interrupting water supplies also affects the Army's ability to project power and support global operations.

To avert potential problems associated with water disruptions, the Secretary of the Army recently issued the Installation Energy and Water Security Policy (2017) that establishes requirements to sustain critical mission capabilities and to mitigate risks posed by disruptions to energy and water supplies that affect installations.

To meet this requirement, installations must take reasonable actions to sustain sufficient capacity and technologies to efficiently recover from water disruptions (water resilience) and to maintain sufficient water availability to sustain critical missions (water security).

To achieve such water resilience and security, each installation must draft an IEWP, which frames the installation's strategy to maintain an emergency supply of water to satisfy the needs of mission-critical facilities and assured access for all missions. Before drafting the IEWP, the installation will need to evaluate its water infrastructure by documenting the water demand for the installation as a whole and for specific mission-critical facilities; identifying backup and redundant supplies; evaluating infrastructure condition, and identifying projects to support water resilience. This work was undertaken to provide additional resources to assist installations with the above.

9.1 Summary

The information contained in this report was intended to provide background information, data collection tools, and scenario examples for installations engaging in water security and resilience planning. The overall goal of this work was to improve Army planning for water resilience and security through support for processes required to draft IEWPs. Specific objectives were to develop methods and tools to collect, analyze, and compile data and information into an actionable report.

This project accomplished these goals by compiling background information on categories of data collection (units/stakeholders, water disruptions, mission effects, strategies for increasing resilience, and establishing the installation baseline). A series of data collection tools were created to simplify the data collection process. Water disruption scenarios for three installations were developed as examples of the range of events, mission effects, and mitigation that can apply to water resilience. The scenarios demonstrate the process required to meet assured access, backup for mission-critical needs, and resilience to disruption.

9.2 Significance

The requirement for an IEWP is new, as is the Army's guidance for preparation. Although the IEWP draws on (and replaces) some existing plans, the complexity of the information and analysis required to prepare an IEWP make this a challenging effort. The description of methods, development of tools, and three example scenarios provide a starting point for an installation motivated to draft the IEWP in-house.

9.3 Assumptions and limitations

The greatest assumption for drafting an IEWP is that the required data will be available. For many enterprise data systems, this is true. However, specific information and data for water end use is often scarce. In the absence of specific end use data, averages and assumptions can be used. This should be noted so that margin of error is easily recognized.

Although this project focused on three installation types identified through a review of the literature and sponsor recommendations, this work could be replicated at other unique installation/mission sites using similar methodology. The diversity of the scenario sites — force projection platform, OIB, and Army National Guard site — demonstrates the versatility of the methods and tools for supporting the diversity of sites across the Army.

Portions of an IEWP may be classified. This work refrained from including any real data that would limit the distribution of the report. Installations must consider the sensitivity of the data and information contained in the IEWP and classify accordingly. A classified attachment/appendix can be used to allow the remainder of the IEWP a non-classified status.

9.4 Applications for water security and resilience methods/tools

Methods and tools for water security and resilience scenarios are useful for preparation of both routine installation reports and plans and for meeting policy requirements.

9.5 Improving the tools

The survey tools developed under this project have been piloted using Survey123 at Fort Leonard Wood (Appendix J). These light, adaptable platforms are an improvement over pen-and-paper tools. The benefits from using apps on tablets are speed and elimination of transfer errors. The National Renewable Energy Laboratory (NREL) showed that collecting data in the field with mobile tablets speeds audits and can reduce overall cost of Level III auditing by 53% (Macumber et al. 2015).

An additional benefit to tablet data collection is the immediate possibility of cleaning, formatting, and analyzing data that are already in an electronic format. Data collection and processing are easily the most time-intensive steps of IEWP preparation. Any methods and tools that can ease this burden will free installation personnel to focus on the underlying problem of providing assured access, backup water for critical missions, and resilient water systems.

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Acronyms and Abbreviations

Abbreviation	Term
AEWRS	Army Energy and Water Reporting System
AFC	U.S. Army Futures Command
AFRICOM	U.S. Africa Command
AMC	U.S. Army Materiel Command
ARPSC	Applied Research Planning Support Center
ASCC	Army Service Component Command
ASCOPE	Areas, Structures, Capabilities, Organizations, People, and Events
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASIP	Army Stationing and Installation Plan
AWCF	Army Working Capital Fund
BMP	Best Management Practice
BNL	Buried No Longer
CAC	Common Access Card
CBRNE	Chemical, Biological, Radiological, Nuclear, and Enhanced High Explosive
CENTCOM	Central Command
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
CHP	Combined Heat and Power
CIP	Capital Investment Plan
COL	Contingency Operating Locations
COP	Common Operating Picture
CSIRT	Computer Security Incident Response Team
DEERS	Defense Enrollment Eligibility Reporting System
DES	Directorate of Emergency Services
DFAC	Dining facilities
DHS	Department of Homeland Security
DMDC	Defense Manpower Data Center
DoD	U.S. Department of Defense
DOE	Department of Energy
DPTMS	Directorate of Plans, Training, Mobilization, and Security
DPW	Directorate of Public Works
DRU	Direct Reporting Unit

Abbreviation	Term
E&W	Energy and water
EMAP	Environmental Monitoring and Assessment Program
EMCS	Energy Management Control System
EMS	Energy Management System
EP	Effective Population
ERCIP	Energy Resilience and Conservation Investment Program
ERDC	U.S. Army Engineer Research and Development Center
ERP	Emergency Response Plan
ESCO	Energy Service Company
ESF	Emergency Support Functions
ESPC	Energy Savings Performance Contract
ESQD	Explosive Safety and Quantity Distance
EUCOM	European Command
FEMA	Federal Emergency Management Agency
FEMP	(DOE) Federal Energy Management Program
FOB	Forward Operating Bases
FORSCOM	U.S. Army Forces Command
GFEBs	General Fund Enterprise Business Systems
HCWWTP	Harnett County Wastewater Treatment Plant
HMGP	Hazard Mitigation Grant Program
HQIIS	(Army) Headquarters Installation Information System
HVAC	Heating, Ventilating, And Air-Conditioning
IDS	Intrusion Detection System
IECC	International Energy Conservation Code
IEWP	Installation Energy and Water Plan
ILA	Industrial, Landscape, or Agricultural
IMCOM	(U.S. Army) Installation Management Command
INSCOM	(U.S. Army) Intelligence and Security Command
IP	Internet Protocol
IPS	Intrusion Prevention System
ISAC	(Water) Information Sharing and Analysis Center
ISR	Installation Status Report
IT	Information Technology

Abbreviation	Term
IWD	Installation Water Demand
JMC	Joint Munitions Command
LCAAP	Lake City Army Ammunition Plant
MACOM	Major Army Command
MC	Mission Critical
MILCON	Military Construction
MOU	Memorandum of Understanding
NFPA	National Fire Protection Association
NOAA	National Oceanic and Atmospheric Administration
NORTHCOM	(U.S. Army) Northern Command
NREL	National Renewable Energy Laboratory
NWS	National Weather Service
O&M	Operations and Maintenance
OAKOC	Observation and Fields of fire, Avenues of approach, Key terrain, Obstacles and movement, Cover and concealment
OCAR	Office of the Chief of the Army Reserve
OIB	Organic Industrial Base
P&D	Planning and Design
PACOM	U.S. Army Pacific Command
PNNL	Pacific Northwest National Laboratory
POC	Point of Contact
PPP	Power Projection Platform
PRIDE	Planning Resource Infrastructure Development and Evaluation
PWC	Public Works Commission
ROTC	Reserve Officers Training Corps
RPA	Real Property Assets
SCADA	Supervisory Control And Data Acquisition
SDWA	Safe Drinking Water Act
SOUTHCOM	U.S. Southern Command
SRM	(Facilities) Sustainment, Restoration and Modernization
SWAP	Source Water Assessment Program
TRADOC	U.S. Army Training and Doctrine Command
UAS	Unmanned Aerial System
UESC	Utility Energy Service Contract

Abbreviation	Term
UP	(Army) Utilities Privatization
USAASC	U.S. Army Acquisition Support Center
USACE	U.S. Army Corps of Engineers
USACIDC	U.S. Army Criminal Investigation Command
USARAF	U.S. Army Africa
USAREUR	U.S. Army Europe
USARPAC	U.S. Army Pacific
USARSO	U.S. Army South
USASOC	U.S. Army Special Operations
USEPA	U.S. Environmental Protection Agency
USEUCOM	U.S. European Command
USGS	U.S. Geological Survey
USMA	U.S. Military Academy
USPACOM	U.S. Pacific Command
UST	Underground Storage Tank
VPN	Virtual Private Network
WUI	Water Use Intensity

Appendix A: Department of the Army Command Structure

A.1 Major Army Commands (MACOMs)

MACOMs include:

- U.S. Army Forces Command (FORSCOM), which trains, mobilizes, deploys, sustains, transforms, and reconstitutes assigned conventional forces, providing relevant and ready land power to combatant commanders,
- TRADOC, which recruits, trains, and educates the Army's Soldiers, develops leaders, supports training in units, develops doctrine, established standards, and builds the future Army,
- U.S. Army Materiel Command (AMC), which provides technology, acquisition support and logistics to ensure dominant land force capability for Soldiers, the United States and our Allies, and
- U.S. Army Futures Command (AFC), which will modernize the Army for the future, integrate the future operational environment, develop and deliver future force requirements, design future force organizations and deliver materiel capabilities.

A.2 Army Service Component Commands (ASCCs)

ASCCs include:

- U.S. Army Africa (USARAF), which provides mission command and employs forces to set the theater, conducts security force assistance, and provides support to joint and international partners to achieve USAFRICOM Theater Campaign Plan objectives,
- U.S. Army Central (USARCENT), which is the assigned ASCC to the USCENTCOM and provides continuous oversight and control of Army operations throughout USCENTCOM,
- U.S. Army North (USARNORTH), which is the assigned ASCC to USNORTHCOM and provides continuous oversight and control of Army operations throughout USNORTHCOM,
- U.S. Army South (USARSO), which is the assigned ASCC to the U.S. Southern Command (USSOUTHCOM) and provides continuous oversight and control of Army operations throughout USSOUTHCOM,

- U.S. Army Europe (USAREUR), which is the assigned ASCC to the U.S. European Command (USEUCOM) and provides continuous oversight and control of Army operations throughout EUCOM,
- U.S. Army Pacific (USARPAC), which is the assigned ASCC to the U.S. Pacific Command (USPACOM) and provides continuous oversight and control of Army operations throughout EUCOM less the Korean Peninsula,
- U.S. Army Special Operations Command (USASOC), which is the assigned ASCC to the U.S. Special Operations Command (USSOCOM),
- SDDC, which is the assigned ASCC to the U.S. Transportation Command (USTRANSCOM),
- U.S. Army Space and Missile Defense Command/Army Forces Strategic Command (USASMD/ARSTRAT), which is the assigned ASCC to the U.S. Strategic Command (USSTRATCOM) and provides continuous oversight control, integration, and coordination of Army forces supporting USSTRATCOM, and
- U.S. Army Cyber Command (USARCYBER), which is an operational level Army force, with USARCYBER designated by the Secretary of the Army as an ASCC to U.S. Cyber Command (USCYBERCOM), directs and conducts integrated electronic warfare, cyberspace, and information operations as authorized, or is directed to ensure freedom of action in and through cyberspace and the information environment, and to deny the same to our adversaries.

A.3 Direct Reporting Units (DRUs)

DRUs include:

- INSCOM, which synchronizes the operations of all INSCOM units to produce intelligence in support of the Army, Combatant Commands, and the National intelligence community,
- U.S. Army Criminal Investigation Command (USACIDC) conducts sensitive or special investigations as directed by the Secretary of the Army of the Chief of Staff of the Army, plans for and provides security (protective services) for DoD and Department of the Army officials as designated by the Secretary of the Army of the Chief of Staff of the Army, provides criminal investigative support to all Army elements including forensic support, maintains overall responsibility for Army investigations of controlled substances, conducts and controls all Army investi-

- gations of serious crimes, less serious crimes, upon request, or as necessary for effective Army law enforcement, and fraud, and other crimes arising in Army procurement activities,
- HRC, which executes distribution, strategic talent management, personnel programs and services Army wide to optimize Total Force personnel readiness and strengthen an agile and adaptive Army,
 - U.S. Army Corps of Engineers, which provides engineering services and capabilities in support of National interests,
 - MDW, which is a geographic command with responsibilities that extend throughout the U.S. National Capital Region (NCR) – Washington, D.C. metropolitan area,
 - ATEC, which plans, integrates, and conducts: experiments, developmental testing, independent operational testing, and independent evaluations and assessments to provide essential information to acquisition decision makers and Commanders,
 - U.S. Military Academy (USMA), the mission of which is to educate, train, and inspire the Corps of Cadets so that each graduate is a commissioned leader of character committed to the values of Duty, Honor, Country, and is prepared for a career of professional excellence and service to the Nation as an officer in the U.S. Army,
 - U.S. Army Acquisition Support Center (USAASC), which supports the readiness of the Army by continually improving the Army's capability through all stages of materiel development by developing a professional acquisition workforce and supporting the acquisition community at all levels,
 - IMCOM, which manages Army installations to support readiness and mission execution, provide equitable services and facilities, optimize resources, sustain the environment, and enhance the well-being of the Military community,
 - U.S. Army War College, the goal of which is to produce graduates skilled at critical thinking and solving complex problems in the global application of Landpower, to provide high-quality Professional Military Education, aggressively Conduct, Research, Publish, Engage in Discourse, and Wargame, conduct strategic leadership development, and to attract, recruit, and retain high-quality faculty and staff,
 - Arlington National Cemetery, which, on behalf of the American people, lays to rest those who have served our Nation with dignity and honor, treating their families with respect and compassion, and connecting

guests to the rich tapestry of the cemetery's living history, while maintaining these hallowed grounds befitting the sacrifice of all those who rest here in quiet repose, and

- U.S. Army Accessions Support Brigade, which is the tactical arm of Army marketing, is charged with Connecting America's People with America's Army through three historic and unique battalions, including the U.S. Army Parachute Team (Golden Knights), the U.S. Army Marksmanship Unity, and the U.S. Army Mission Support Battalion, and operationally aligns under the Army Marketing and Research Group.

Appendix B: Mission Definitions

Operation	Tasks	Source
Movement and Maneuver	Perform Tactical Actions Associated with Force Projection and Deployment	AUTL
	Conduct Tactical Maneuver	AUTL
	Conduct Tactical Troop Movements	AUTL
	Conduct Direct Fires	AUTL
	Occupy an Area	AUTL
	Conduct Mobility Operations	AUTL
	Conduct Countermobility Operations	AUTL
	Employ Obscurants	AUTL
	Conduct Maneuver Support Operations	AUTL
Intelligence	Intelligence Support to Force Generation	AUTL
	Support to Situational Understanding	AUTL
	Perform Intelligence, Surveillance, and Reconnaissance	AUTL
	Support to Targeting and Information Superiority	AUTL
	Coordination with telecommunications and information technology industries	ESF 2
	Restoration and repair of telecommunications infrastructure	ESF 2
	Protection, restoration, and sustainment of cyber and information technology resources	ESF 2
Fires	Integrate Fires	AUTL
	Provide Fire Support	AUTL
	Integrate Air-Ground Operations	AUTL
Sustainment	Provide Logistics Support	AUTL
	Coordination of incident management and response efforts	ESF 5
	Issuance of mission assignments	ESF 5
	Resource and human capital	ESF 5
	Incident action planning	ESF 5
	Financial management	ESF 5
	Social and economic community impact assessment	ESF 14
	Analysis and review of mitigation program implementation	ESF 14
	Aviation/airspace management and control	ESF 1
	Transportation safety	ESF 1
	Restoration/recovery of transportation infrastructure	ESF 1

Operation	Tasks	Source
	Movement restrictions	ESF 1
	Support to access, traffic, and crowd control	ESF 13
	Damage and impact assessment	ESF 1
	Energy infrastructure assessment, repair, and restoration	ESF 12
	Energy industry utilities coordination	ESF 12
	Provide Health Service Support	AUTL
	Public health	ESF 8
	Medical	ESF 8
	Mental health services	ESF 8
	Mass Care	ESF 6
	Mass fatality management	ESF 8
	Conduct Internment/Resettlement Operations	AUTL
	Emergency assistance	ESF 6
	Disaster housing	ESF 6
	Human services	ESF 6
	Provide General Engineering Support	AUTL
	Infrastructure protection and emergency repair	ESF 3
	Infrastructure restoration	ESF 3
	Engineering services and construction management	ESF 3
	Emergency contracting support for lifesaving and life-sustaining services	ESF 3
	Comprehensive, incident logistics planning, management, and sustainment capability	ESF 7
	Resource support (facility space, office equipment and supplies, contracting services, etc.)	ESF 7
	Nutrition Assistance	ESF 11
	Animal and plant disease and pest response	ESF 11
	Food safety and security	ESF 11
	Natural and cultural resources and historic properties protection and restoration	ESF 11
	Safety and well-being of household pets	ESF 11
	Provide Personnel Support	AUTL
Conduct Mission Command	Conduct the Operations Process	AUTL
	Conduct Command Post Operations	AUTL
	Conduct Knowledge Management and Information Management	AUTL
	Conduct Civil-Military Operations	AUTL
	Execute Command Programs	AUTL
	Integrate Space Operations	AUTL

Operation	Tasks	Source
	Integrate Inform and Influence Activities	AUTL
	Establish and Maintain Discipline	AUTL
	Conduct Cyber Electromagnetic Activities	AUTL
	Conduct Information Protection	AUTL
	Emergency public information and protective action guidance	ESF 15
	Media and community relations	ESF 15
	Congressional, international, and external affairs	ESF 15
	Tribal and insular affairs	ESF 15
Protection	Employ Air and Missile Defense	AUTL
	Conduct Personnel Recovery Operations	AUTL
	Perform Fratricide Avoidance	AUTL
	Conduct Operational Area Security	AUTL
	Apply Antiterrorism Measures	AUTL
	Conduct Survivability Operations	AUTL
	Provide Force Health Protection	AUTL
	Conduct Chemical, Biological, Radiological, and Nuclear Operations	AUTL
	Employ Safety Techniques	AUTL
	Implement Operations Security	AUTL
	Provide Explosive Ordnance Disposal Protection Support	AUTL
	Facility and resource security	ESF 13
	Security planning and technical resource assistance	ESF 13
	Public safety and security support	ESF 13
	Support to wild land, rural, and urban firefighting operations	ESF 4
	Lifesaving assistance	ESF 9
	Search and rescue operations	ESF 9
	Environmental short- and long-term cleanup	ESF 10

Appendix C: Operation and Mission Variables

Variable	Description
Political	Describes the distribution of responsibility and power at all levels of governance—formally constituted authorities, as well as informal or covert political powers.
Military	Explores the military and paramilitary capabilities of all relevant actors (enemy, friendly, and neutral) in a given operational environment.
Economic	Encompasses individual and group behaviors related to producing, distributing, and consuming resources.
Social	Describes the cultural, religious, and ethnic makeup within an operational environment and the beliefs, values, customs, and behaviors of society members.
Information	Describes the nature, scope, characteristics, and effects of individuals, organizations, and systems that collect, process, disseminate, or act on information.
Infrastructure	Is composed of the basic facilities, services, and installations needed for the functioning of a community or society.
Physical environment	Includes the geography and manmade structures, as well as the climate and weather in the area of operations.
Time	Describes the timing and duration of activities, events, or conditions within an operational environment, as well as how the timing and duration are perceived by various actors in the operational environment.
Mission	Commanders and staffs view all the mission variables in terms of their impact on mission accomplishment. The mission is the task, together with the purpose, that clearly indicate the action to be taken and the reason, therefore. It is always the first variable commanders consider during decision making. A mission statement contains the “who, what, when, where, and why” of the operation.
Enemy	The second variable to consider is the enemy—dispositions (including organization, strength, location, and tactical mobility), doctrine, equipment, capabilities, vulnerabilities, and probable courses of action.
Terrain and weather	Terrain and weather analysis are inseparable and directly influence each other’s impact on military operations. Terrain includes natural features (such as rivers and mountains) and manmade features (such as cities, airfields, and bridges). Commanders analyze terrain using the five military aspects of terrain expressed in the memory aid Observation and Fields of fire, Avenues of approach, Key terrain, Obstacles and movement, Cover and concealment (OAKOC): observation and fields of fire, avenues of approach, key and decisive terrain, obstacles, cover and concealment. The military aspects of weather include visibility, wind, precipitation, cloud cover, temperature, and humidity.

Variable	Description
Troops and support available	This variable includes the number, type, capabilities, and condition of available friendly troops and support. These include supplies, services, and support available from joint, host nation and unified action partners. They also include support from civilians and contractors employed by military organizations, such as the Defense Logistics Agency and the AMC.
Time available	Commanders assess the time available for planning, preparing, and executing tasks and operations. This includes the time required to assemble, deploy, and maneuver units in relationship to the enemy and conditions.
Civil considerations	Civil considerations are the influence of manmade infrastructure, civilian institutions, and activities of the civilian leaders, populations, and organizations within an area of operations on the conduct of military operations. Civil considerations comprise six characteristics, expressed in the memory aid ASCOPE: areas, structures, capabilities, organizations, people, and events.
Source: (DOAHQ 2012)	

Appendix D: Recommendations to Reduce Strategic Risk

The following low-cost/no-cost recommendations, as indicated by the Installation Status Report Mission Command (ISR-MC), benefit both mission-critical facilities and the entire installation by prioritizing assured access, and sound operations and maintenance plans.

D.1 Assured access

To minimize loss of assured access:

- Coordinate with the electricity/natural gas/water provider at least quarterly for formal planning engagements, planned outage communication, critical energy/water requirements communication, emergency response exercises, contractual agreements and in-person interaction.
- Identify the source or sources of water used by the installation.
- Compile and maintain a permanent record containing all existing documentation that establishes the installation's water rights.
- If the installation uses propane, diesel, wood chips, fuel oil, coal, etc. as a primary energy source, ensure that contract language states that the installation full capacity supply will continue to be delivered in the event of a widespread energy utility supply outage (electricity and/or natural gas) and/or natural disaster such as flood, tornado, hurricane, etc.
- Conduct planning to evaluate whether enough water will be available to support projected water needs in the next 10 years.

D.2 Infrastructure condition

Evaluate infrastructure condition:

- Ensure that all third party electrical/natural gas/water provider contracts (such as privatized utilities and energy services contractors) for energy management systems (EMSs) and Energy Management Control Systems (EMCSs) require appropriate cybersecurity controls.
- Implement an annual O&M program for electrical, natural gas, and water system infrastructure, including regular inspections, maintenance, & O&M recordkeeping.

D.3 Systems operation

Ensure the security of systems operation:

- Develop/update various energy-related plans in-house: Energy Security Plan Emergency Response Plan; Continuity of Operations Plan (updated in the last 2 years); Fueling Plans (i.e., Generator Refueling and Vehicle Refueling); Energy Vulnerability Assessment; Real Property Master Plan (updated in the last 5 years); Capital Improvement Plan; Service Restoration Plan; Installation Utilities Management Plan; and Installation Energy Plan.
- Implement installation energy security planning, including the following components: Roles and responsibilities/staffing; Required training (licenses, certifications); Active risk management; Communication with mission owners, tenants and utilities; Necessary Memorandums of Understanding (MOUs) and mutual aid agreements; Exercises to be conducted; Resulting plan(s) updated annually and approved by the Commander; Coordination with other planning efforts.
- Evaluate whether qualified personnel (licensed and certified) are available to operate/maintain/repair the on-site electrical, natural gas, other fuel source (propane, fuel oil, coal, etc.), and water system components.
- Implement the following components of an emergency operations plan or planning process: Identify and staff water program and system personnel roles and responsibilities; Provide training for water program and system staff on emergency response; Plan for providing water during service interruptions to ensure continuity of operations; Plan for exercising emergency response to water service disruptions; Plan for water service restoration procedures; Communicate with mission owners, tenants, and utilities for water service disruptions and restoration; Document necessary MOUs and mutual aid agreements; and, ensure that the plan has been updated in the last 2 years.
- Develop and implement a water management plan, including the following components: Progress toward water conservation/efficiency goals; Participation in local/regional water planning organizations to ensure water source availability; Evaluation of water supply to meet current and future needs; Evaluation of water system infrastructure condition; Readily available and up-to-date maps, as-built drawings, SOPs; Sustainment, modernization, and/or replacement plans; Cost/performance improvement plans; Coordination with other planning efforts; Updated upon changes in installation conditions.

- Coordinate with the U.S. Army Public Health Command to conduct or update an annual installation water system vulnerability assessment. Updates can also be completed by installation staff.
- Document the process or procedure to resolve conflicts between water requirements and amount of water available (External coordination).
- Document a process or procedure to prioritize water distribution during periods of scarcity (Internal coordination).
- Perform annual exercises of the energy and water systems emergency operations plans and/or periodic energy and water system emergency restoration exercises.

Figure D-1. Mitigation lifecycle.

Source: (ISR 2019)

Mitigation for critical facilities and installations is a continuous cycle. As threats evolve and capabilities shrink or expand, installation authorities and tenants should re-evaluate their security needs and abilities.

Appendix E: Mitigation

E.1 Best management infrastructure resiliency practices by facility group type

No.	Facility Group	Major Category Codes and Subcategories	Best Management Resiliency Practices
1	Industrial & Maintenance	22 – Production 214 – Maintenance – Tank/Automotive 216 – Maintenance – Ammo/Explosives/Toxics 310 – Science Laboratories	Take proper hazardous waste management precautions Personnel safety training Establish emergency protocols Maintain backup water storage for fire protection
2	Family Housing	711 – Family Housing – Dwellings 713 – Family Housing – Trailer Site	Reduce consumption demand by upgrading fixtures and appliances Install rain barrels and other means of water storage for unplanned disruptions Secure a backup generator Consider relocation if disruption becomes excessively long
3	Transient Housing	720 – Unaccompanied Personnel Housing	See Family Housing
4	Barracks	721 – Unaccompanied Personnel Housing – Enlisted Personnel 724 – Unaccompanied Personnel Housing – Officer Quarters	See Family Housing
5	Community & Commercial: Non-food (Indoor)	730 – Community Facilities – Personnel Support 740 – Community Facilities – Morale, Welfare, and Recreation	Install water efficient fixtures and appliances Reduce water consumption and hours of operation during disruptions Restrict irrigation during disruption Install backup generators and water storage at facilities that double as emergency shelters Organize bottled water and wastewater services where needed Restrict usage of high-water-consuming appliances, fixtures, and assets
6	Community & Commercial: Food	722 – Unaccompanied personnel housing – Mess facility 740 – Community Facilities – Morale, Welfare, and Recreation	See Community & Commercial: Non-food (Indoor)
7	High Energy	131 – Communications – Buildings 172 – Simulation Facilities 317 – Electronics, Communication, & Electric Equipment	Maintain adequate water supplies for cooling towers Harden/protect electrical systems Create emergency communications plan Enforce cybersecurity regulations Regularly maintain server content

No.	Facility Group	Major Category Codes and Subcategories	Best Management Resiliency Practices
8	Medical	51 – Medical Center/Hospital 54 – Dental Clinics 55 – Dispensaries/Clinics	<p>Equipment that is required for emergency functioning during or immediately after an event, such as emergency generators and fuel tanks, should be installed well above the Design Flood Elevation</p> <p>Harden or relocate at-risk critical equipment to prepare for region-specific common natural disasters such as flooding or tornadoes</p> <p>Ensure a high-performance envelope to improve thermal performance and prevent low interior temperatures/freezing if heating is lost in winter months or overheating if cooling or ventilation is inoperable in summer months</p> <p>Implement gas-fired onsite cogeneration (Combined Heat and Power [CHP]) to provide efficiency and redundancy for power generation in the event of grid loss or diesel generator issues (CHP infrastructure is on the roof, as are emergency diesel generators)</p> <p>Communicate plans to all personnel, and conduct frequent training and exercise (especially with first responders)</p> <p>Maintain an onsite water supply, e.g., independent water treatment plant and wells for domestic water supply and fire protection</p> <p>Use non-potable water for HVAC, if appropriate</p> <p>Source: (HHS 2014).</p>
9	Administration and Operations	39 – Research, Development, and Test Operations 61 – Administration Buildings 131 – Communications Buildings	<p>Stock backup supplies</p> <p>Design disaster execution plans and include methods for communications sans electricity</p> <p>Develop and test risk assessment models</p> <p>Perform regular maintenance on facilities and infrastructure</p> <p>Complete disaster scenario training to prepare workers, review and revise as needed</p>
10	Other Training and Schools	171 – Training Buildings	See Administration and Operations
11	Storage	43 – Cold Storage 44 – General Supply Buildings 423 – Ammunition Storage	Secure backup supplies for continuous operation (alternative supply and storage solutions for energy and water utilities)
12	High Water Use Facilities	14 – Wash Buildings 723, 730 – Laundry Buildings, Shower 740 – Car Wash 740, 750 – Swimming Pools	<p>Install water efficient fixtures and appliances</p> <p>Restrict water consumption during disruptions</p>
18	Community & Commercial: Non-food (Outdoor)	750 – Community Facility – MWR Exterior	Install generators and water storage at facilities that double as emergency shelters

No.	Facility Group	Major Category Codes and Subcategories	Best Management Resiliency Practices
19	Dependent Schools	73046 Dependent School	<p>Replace high-risk buildings with current code buildings</p> <p>Build new or replacement buildings outside of high hazard zones</p> <p>Construct vertical evacuation structures</p> <p>Enhance and practice evacuation procedures</p> <p>Structural retrofits for buildings</p> <p>Nonstructural retrofits for building elements and contents</p> <p>Elevate flood-prone buildings</p> <p>Construct flood walls or berms</p> <p>Flood-proof existing buildings improve storm water drainage systems, levees or channels</p> <p>Remodel buildings with fire-safe construction details</p> <p>Implement defensible space and fuel reduction measures</p> <p>Enhance and practice evacuation procedures</p> <p>Implement or improve lahar warning systems</p> <p>Enhance and practice evacuation procedures</p> <p>Public education programs to improve understanding of hazards</p> <p>Enhance emergency planning and recovery planning</p> <p>Obtain flood or earthquake insurance</p> <p>Install generators in schools designated as shelter</p> <p>Source: (Goettle and Associates, Inc. 2014)</p>
20	Irrigated Land	<p>179 – Parade Field</p> <p>7504 – Golf Course</p> <p>7603 – Cemeteries</p> <p>932 – Landscape Plantings, etc.</p>	<p>Use native landscaping</p> <p>Restrict irrigation and water use during disruptions</p>
21	Miscellaneous	<p>16 – Harbor and Coastal Facility</p> <p>69 – Other Administrative Facility</p> <p>88 – Fire and Other Alarm Systems</p> <p>134 – Navigation and Traffic Aids – Others</p> <p>831 – Sewage – Industrial Waste Treatment and Disposal</p> <p>833 – Solid Waste Handling Facility</p> <p>841 – Potable Water Supply/Treatment/Storage</p> <p>843 – Water, Fire Protection</p> <p>844 – Water Supply/Storage Non-Potable</p>	<p>Reduce repair costs through appropriate preventive maintenance</p> <p>Create and follow long-term plans to accommodate systems upgrades and part replacements as needed</p> <p>Maintain backup supplies</p>

Note that engaging with the tenants of a given facility and with the individuals responsible for maintenance and operational functions should yield additional practices to conserve water and mitigate disruptions.

E.2 Crisis management

Preparing a mitigation plan for an installation requires a collaborative effort, which must include key stakeholders from the administrative offices as well as relevant tenants and groundskeepers. The following material provides sample questions for interviews, focus group discussions, surveys, and multi-stakeholder dialogues as installations prepare their crisis management plans.

E.2.1 Risk analysis and management for critical asset protection

Before a disruption event occurs, the installation DPW and units or tenants should identify their assets, the threats these assets face and the associated consequences, and the vulnerability of assets to each threat, and then perform an analysis of risk and resiliency (Figure E-1). Performing these tasks will help determine the risk the installation and its assets face while highlighting the critical facilities that are the most vulnerable and should be prioritized for resiliency upgrades.

Figure E-1. Identification of assets.

SOURCE: RAMCAP Process, adapted from ASME-ITI

E.2.2 Contingency plan development

If the main water service is disrupted, a contingency plan outlines protocols for continuing operations until the disruption is addressed. While the contingency plan may be left to the installation command to prepare, units and tenants responsible for missions or assets can also create contingency plans. These plans should include the following components (Agardy 1975):

- A designated contingency response organization team composed of a director, coordinator, equipment supervisor, communications supervisor, transportation supervisor, public health supervisor, and chemicals supervisor.
- A prioritized list of assets.
- A list of threats each asset faces.
- Detailed instructions explicitly stating the responsibilities and assignments for each member of the team, including current contact information for each individual should also be included. This section will need to be regularly updated to maintain relevance.
- Detailed training program for the personnel involved in carrying out the plan.
- Maps of the utilities systems and the access roads to scattered components of the systems.
- A list of the equipment available to the utility as well as the equipment required to meet the contingency. This list should also contain information about chemical stockpiles.
- A time component, which should consider the quantity of water, energy, or other supplies that will be required if the disruption lasts for a few hours, a day, a week, or longer.
- A list of local and regional coordination elements such as police and fire departments, the local office of civil defense, and the names and locations of support utilities.
- The plan should be well circulated; specifically, with tenants/units that may need to use it as well as with the local and regional agencies that might be called upon to support the water utility in case of an emergency.

As with all mitigation plans, the contingency plan should be regularly revised and updated to improve practices and maintain relevance.

E.2.3 Service restoration planning

Each critical facility should have a service restoration plan; this plan will describe the process to restore water services to the facility. Before developing the plan, installations should rank their critical facilities and determine the most prioritized of the critical facilities. Installations with privatized utilities will need to coordinate with their provider to understand their ranking for service restoration and their options for critical facilities.

E.2.4 Opportunities for local collaboration

Crises often have widespread effects. While a water service disruption event may only directly affect one community, damaged infrastructure or debris from the event may create risks for nearby locations. Where possible, collaborations between local agencies should be considered.

E.2.4.1 State hazard mitigation officers

The Federal Emergency Management Agency's (FEMA's) State Hazard Mitigation Officers coordinate hazard mitigation efforts at the state level. These officers collaborate with state and local agencies interested in using the Hazard Mitigation Grant Program (HMGP) that was introduced by section 404 of the amended Robert T. Stafford Disaster Relief and Emergency Assistance Act.

Each state has its own officer; current officers are listed here:

<https://www.fema.gov/state-hazard-mitigation-officers>.

E.2.4.2 Neighboring municipalities

Mutual aid agreements should be established with neighboring municipalities. These agreements can foster good will between adjacent municipalities and installations while providing much needed assistance in times of disruptions. Army installations may be able to offer shelter in regional weather events or provide search and rescue teams while municipalities may offer support by way of additional fire trucks, water tanks, and etc.

E.2.4.3 Water providers

The American Water Works Association (AWWA 2014) suggests that:

“Every public water supply and wastewater utility should assess the likelihood and consequences of a supply disruption, identify critical vulnerabilities, and consider alternative power or supply redundancy to mitigate service disruptions lasting up to 72 hours or longer if public health, environmental, or economic impacts are severe” (AWWA 2010).

Furthermore, AWWA states water UP should have a “robust emergency response plan” with special considerations for public communications in the event of an electric supply disruption. Army installations with privatized suppliers should ensure that their providers have such plans in place and should review them for situational awareness.

The U.S. Environmental Protection Agency (USEPA) has created several documents for water and wastewater UP to help with emergency preparedness; these documents cover a variety of topics ranging from harmful algae bloom to natural disaster responses.

All-hazards resilience program for waste/wastewater UP:

<https://www.epa.gov/waterresiliencetraining/waterwastewater-utility-all-hazards-bootcamp-training%23all-hazards>.

Incident Action Checklists are available here: <https://www.epa.gov/waterutilityresponse/incident-action-checklists-water-utilities>.

Resilient Strategies Guide for Water Utilities: [https://www.epa.gov/crwu/resilient-strategies-guide-water-utilities#/.](https://www.epa.gov/crwu/resilient-strategies-guide-water-utilities#/)

Appendix F: Facility Groups for Water Use Intensity

Use categories	
1	Industrial and Maintenance
2	Housing (Family)
3	Housing (Transient)
4	Housing (Barracks)
5	Community and Commercial: Non-food (indoor)
6	Community and Commercial: Food
7	High Energy
8	Medical
9	Administration and Operations
10	Other Training and Schools
11	Storage
12	High Water Use Facilities (Special Category tab)
13	Paved Surfaces
14	Unpaved Surfaces
15	Other Land: Non-Irrigated (Special Category tab)
16	Fuel Dispensing and Storage
17	Utility Lines
18	Community and Commercial: Non-food (outdoor)
19	Dependent Schools
20	Irrigated Land (Special Category tab)
21	Miscellaneous

Appendix G: Optimizing Online Monitoring in Water Distribution System (Wu et al. 2007)

IV. OPTIMIZING ONLINE MONITORING IN WATER DISTRIBUTION SYSTEM

The method of water age index of node is adopted for water quality online monitoring, which integrates water age of node with the attributes of the pipes. On the basis of calculated water age index, the pipe attributes are converted to water age according to affection of pipe attributes to water quality. The water age of node gained by hydraulic calculation combining with converted water age from the pipe affection can be expressed as water quality of the node. Water quality online monitoring points are selected by assessing the interrelationship between these nodes.

The principle of optimizing online monitoring using water age index is that, if node i and j has absolutely the same water age index, then consider them has the same or nearly same water quality. That is to say that node j can standards for node i . Given a standard for monitoring CC (criteria concentration), the node with the greatest volume of coverage will be monitoring points [10].

If select $CC=0.6$ as the selecting criteria, the procedure of selection of monitoring points is following as below:

$$\text{First, } L = (I(i)), i = 1, 2, \dots, n; \quad (1)$$

Where L is the number of selecting points

$$I(i) = \begin{cases} 1 & \text{choose node } i \text{ as monitoring point} \\ 0 & \text{not choose node } i \text{ as monitoring point} \end{cases}$$

The monitored water flow Q can be obtained

$$Q = \sum_{i=1}^n DC(i) = \sum_{i=1}^n \left\{ I(i) \sum_{j=1}^n d(j) \cdot R[CC](i, j) \right\} \quad (2)$$

Where $DC(i)$ is the demand coverage in node i ; $d(j)$ is the flow in node j ;

$$[R[CC]] = \begin{cases} 1 & \bar{C}\bar{C} \leq T_k(i,j) \leq 1/\bar{C}\bar{C} \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

where $T_k(i,j) = T_{\lambda_j} / T_{\lambda_i}$ $i, j = 1, 2, \dots, n$

$[R[CC]]$ is matrix of monitoring coverage for water age index of nodes; T_{λ_j} is water age index of node j , T_{λ_i} is water age index of node i ; $T_k(i,j)$ is the ratio of water age of node i and water age of node j . This ratio of water age index of the two nodes can represent clearly the correlation of water quality of the two nodes.

Because the consumption of water is changing according to different water supply scenarios, so the locations of selecting monitoring nodes are different when the scenarios change. Then a weight factor C is introduced for different scenarios. Assuming there are k scenarios of the water distribution in a cycle. The consumption of water is described as D_i , water supplying time as t_i then

$$C = [C_1, C_2, \dots, C_k] \quad (4)$$

$$\text{Where } C_i = D_i t_i / \sum_{i=1}^k D_i t_i$$

At last the objective function of optimized monitoring locations and the constraints are given as:

$$\begin{cases} \max Q_m = \sum_{i=1}^k \alpha_i C_i Q_i \\ \sum_{i=1}^n l(i) \leq N \end{cases} \quad (5)$$

Where Q_m is maximum water coverage flow, Q_i is the flow of node i , $l(i)$ is selected monitoring points, k is number of scenarios, N is the number of water nodes, and based on this equation, the selected monitoring points, which have maximum demand water coverage, can be obtained; these selected monitoring points are the optimised points [11].

Water quality monitoring network is based on a steady hydraulic model; each node's flow and water direction meet the continuity and energy equations as following [12]:

$$\begin{cases} \sum \pm q_{ij} + Q_i = 0 \\ \sum h_{ij} - \Delta H = 0 \end{cases} \quad (6)$$

Where Q_i is the water flow in the node i ; q_{ij} is the pipe water flow which connected with node i , j is the

node connected with node i . h_{ij} is the pipe water head loss based on loops k ; ΔH is the head loss caused by cut down loops k .

The steps of optimizing water quality online monitoring point are as following:

- 1). Hydraulic modelling to get each pipe's water quantity and flow direction under a scenario.
- 2). Define a new list of the node according to the water flow direction.
- 3). Formulate water age index ratio matrix
 - Choose a node in the water supply network
 - Identify all nodes that linked with the selected node, constitute a correlation matrix.
 - Identify the relationship between the selected node and its upstream nodes. Get these pipes' flow of relevant nodes, calculate passing time through pipes.
 - Divide pipes into ordinary cast iron pipe and ductile iron pipe, setup pipe material value λ , calculate each node water age index by its λ , the ratio of water age index of associated nodes and water age index of selected node form ratio matrix for water age of nodes
- 4). Choose appropriate monitoring criteria, selected 0.6 as monitoring standards. That is if the water age index ratio is higher than 0.6, the selected monitoring point can represent water quality of the relevant nodes.
- 5). Normalize the water age index ratio matrix according to selected criteria
- 6). Define the monitoring points, which the nodes have the maximum quantity, meanwhile identify all the nodes related with the point.

Appendix H: Daphnia Water-Monitoring System for Chemical Contamination Detection

How to Protect Water Distribution Online - Results using Extremely Hazardous Chemicals

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Abstract

This safety of water supplies for civilian and military organisations is an important objective to avoid toxic contamination of civilians and soldiers. Chemical warfare (CW) agents and especially organophosphorous nerve compounds are the most toxic of known chemical agents. A continuously working test system with Daphnia magna as a sensitive organism is used to monitor drinking water. Both small doses (allowable for short-term water ingestion) and graduated higher concentrations induced toxic reactions leading to alarms in the Daphnia Toximeter System. The system is sensitive to a wide range of CW-agents and their toxic hydrolysis products. Concentrations which are below acute human toxicity could be discovered in a very short time with the actual time depending on the applied concentrations. In every case alarms occur within two hours at concentrations which are considered allowable for drinking water in exceptional conditions.

The Measurement

The graph (to the right) displays an example of Daphnia's "alarm" behavior. The "median speed" shows strong deviation from normal behavior after the addition of the neurotoxin "sarin." Depending on the concentration, a typical effect of neurotoxins is that the movements strongly increase right after the treatment. The effect in this study is reversed after some minutes: Most of the Daphnia will die later. The alarm parameters, not on display here, such as height and survival, are involved in the release of the alarm.

The Organism

The Results

The table (right) shows the tested substances, the concentrations and the reaction times using the bbe Daphnia Toximeter as a sensor. The evaluation of behavioral parameters drastically reduces the time interval between toxication and alarm.

Toxic Effects of CW-Agents in a Daphnia-Toxicometer-System

[illegible]

The Instrument

A CCD camera takes pictures of the measuring chamber (chamber is covered by the door (4)). The behavior of the daphnia gives information about the quality of the water (and above all, a warning if toxic substances are present). For this reason, it is necessary to determine whether the daphnia behave in an unusual way or not. Various parameters are suitable to characterize movements. The following parameters are used: swimming speed, median speed, speed distribution, velocity class, height, distance of moving, median and fractional dimension.

Conclusions

- Daphnia react very sensitively to the neurotoxins Sarin, Tabun, Soman and Cyclosarin
- Daphnia react at concentration levels which are below the 'allowable' concentrations
- The bbe Daphnia Toximeter can detect these concentrations
- The evaluation of behavioral changes leads to much earlier alarms than the simple distinction between 'active' and 'not active'

Appendix I: Summary of inline Water-Monitoring Technologies

Table 1 – Summary of some advantages and limitations of various reviewed technologies.

Sensor	Advantages	Limitations	Source
J-Mar Biosentry™	<ul style="list-style-type: none"> Directly integrated into the water supply through continuous, slip-stream flow analysis Process is virtually instantaneous providing for real-time detection and classification Fully automated and remotely accessible, and minimal maintenance requirements 	<ul style="list-style-type: none"> Does not provide viability data System cannot differentiate between live and dead organisms, motile or non-motile, organic or inorganic 	(USEPA, 2010)
UV–VIS spectro:lyser™	<ul style="list-style-type: none"> Fully submersible UV/Vis probe suitable for monitoring wide range of liquids Single probe can be used to measure multiple parameters, including COD, COD-filtered, BOD, TOC, DOC, UV-254, NO₃, NO₂, ozone, H₂S, TSS, and turbidity 	<ul style="list-style-type: none"> When the instrument was installed at the intake of a treatment plant, where surface water is monitored, fouling of the flow-cell observed Flow velocity determined the rate of sediment build-up 	(van den Broeke, 2005, USEPA, 2010)
Hach Event Monitor (Guardian Blue™)	<ul style="list-style-type: none"> Distribution and plant personnel can troubleshoot remotely Programmed to recognise future occurrences of the same event and notify operations 	<ul style="list-style-type: none"> The instrument has little maintenance problems however has created several false alarms 	(Hohman, 2007)
YSI Sonde™	<ul style="list-style-type: none"> Simultaneous measurement of conductivity, salinity, temp, depth, pH, dissolved oxygen, turbidity, chlorophyll and blue-green algae 	<ul style="list-style-type: none"> Despite best practices sometimes not possible to clean sonde to a point where the standard is not contaminated by some small amount 	(Atkinson and Mabe, 2006)
Censar™	<ul style="list-style-type: none"> Provides an immediate on-site measurement with good sensitivity at natural levels Ideal as early warning of algae blooms Simultaneously measures colour, turbidity, and temperature 	<ul style="list-style-type: none"> Depth sensor can be affected by biological fouling that grows in the water passage tube Limited parameters measured 	(USEPA, 2009)
s::can Water Quality Monitoring Station™	<ul style="list-style-type: none"> On-line access to all sensor readings Applicable for wastewater, drinking water, and environmental water Multiple parameters measured 	<ul style="list-style-type: none"> Colour measurement not highly sensitive Some issues with running system without the use of air cleaning have been identified 	(Chow et al., 2008)
TOXcontrol™ (microLAN)	<ul style="list-style-type: none"> Real-time assessment of microbial populations; quick response time High sensitivity of <i>Vibrio fischeri</i> to cyanide 	<ul style="list-style-type: none"> <i>Vibrio fischeri</i> less sensitive to sodium fluoroacetate 	(Zurita et al., 2007; Mons, 2008)
Algae Toximeter (BBE)	<ul style="list-style-type: none"> Precise determination of algae concentrations in water Highly sensitive with regard to detection of herbicides and their by-products 	<ul style="list-style-type: none"> Lag time in cultivating slow-growing algae 	(de Hoogh et al., 2006; Mons, 2008)
Daphnia Toximeter™ (BBE)	<ul style="list-style-type: none"> Highly sensitive biological system for early detection of potentially dangerous unknown substances Low maintenance 	<ul style="list-style-type: none"> Not suitable for finished (chlorinated) water as <i>Daphnia magna</i> is sensitive to chlorine Adjustable high sensitivity may lead to false positive alarms in some cases 	(de Hoogh et al., 2006; Jeon et al., 2008; Mons, 2008)
ToxProtect™ (BBE)	<ul style="list-style-type: none"> Rapid detection of toxic substances in water Capable of detecting low levels of cyanide High toxic response relation between fish and humans exists 	<ul style="list-style-type: none"> Incapable of detecting considerably high levels of fluoroacetate Maintenance time, size required to house fish stocks 	(van der Gaag and Volz, 2008; Mons, 2008)
Fish Activity Monitoring System (FAMS)	<ul style="list-style-type: none"> Round-the-clock monitoring of fish activity for continuous water quality monitoring Quicker response time after event occurrence 	<ul style="list-style-type: none"> Maintenance time, size required to house fish stocks 	(van der Gaag and Volz, 2008; Mons, 2008)
Surface enhanced Raman spectroscopy	<ul style="list-style-type: none"> Non-invasive and reagentless Highly specific microbial identification 	<ul style="list-style-type: none"> Spectral deviations caused by metabolic or environmental factors needs to be smaller than spectral deviation between strains 	(Sengupta et al., 2006; van der Gaag and Volz, 2008)
Laser tweezer Raman spectroscopy	<ul style="list-style-type: none"> Allows discrimination between different strains if bacteria and single <i>Bacillus</i> spores Bacteria selected from random growth phases can be classified 	<ul style="list-style-type: none"> Associated biochemical and biomolecular methods required at same time to confirm effectiveness of Raman spectral method 	(Xie et al., 2005; van der Gaag and Volz, 2008)
Surface acoustic wave (SAW) devices	<ul style="list-style-type: none"> Highly specific and low-cost Array-based sensors and data processing schemes provide increased utility 	<ul style="list-style-type: none"> Reduced sensitivity and stability suggests they are not ready to fully replace analytical methodologies 	(van der Gaag and Volz, 2008)

Source: Storey et al. (2010)

Appendix J: Building Audit Form

Fill in the date and time of survey.

Name of Interviewee

Provide the first and last name of the person you are interviewing.

Facility Number

Please provide the facility number that is used in HQIS, if possible.

Facility Name

Provide the Real Property Assets (RPA) Name of this facility. (If the RPA Name is unavailable at this time use the Building Name.)

Location of Facility (Optional)

Drop a point on the building.

Does this facility have a water meter?

- ☐ Yes
- ☐ No

Is this meter currently functioning?

- ☐ Yes
- ☐ No

What type of sprinkler system does this building have?

Wet pipe are classic sprinklers, dry pipe are filled with air, foam is filled with foam, pre-action are dry pipes held from piping by an electrically operated valve (used in libraries and data centers), deluge sprinklers are unpressurized dry piping and open sprinkler heads (used in aircraft hangers, power plants and chemical storage).

Built Year

Provide the year this facility was built, ex. "1995."

Number of Floors

The basement counts as one floor. The mezzanine counts as one floor.

Total Square Footage

Aggregate the square footage of each floor to obtain the gross square footage of the building.

Hours of Operation

Indicate the hours that this facility is in use.

Provide the date of the last building renovation.**Describe what was renovated with respect to water and wastewater assets.**

Are there currently plans to demolish this building?**Provide the expected date of demolition.****Number of occupations (people per week)**

Estimate the number of building occupants that this facility has experienced this week (Monday- Sunday). This includes anyone who works in, lives in, or has visited this building.

Example: 10 people per day X 7 days = 70 people per week

Number of Mission-Essential Occupants (people per week)

From the number of occupants provided above, how many are essential to continuing the mission of this facility.

Example: 3 essential people per day X 7 days = 21 essential people per week

Backup Generators**Does this facility have a backup generator?**

- ☐ Yes
☐ No

If yes, how many backup generators does this facility have?**Generator #: Type**

Generator #: Capacity (kilowatts)

Generator #: Is this generator portable?

Ground Water Wells

Does this facility have any ground water wells?

- ☐ Yes
- ☐ No

If yes, how many groundwater wells does this facility have?

Well #: Describe the type of well.

Well #: What is the well's depth (ft.)?

Well #: what is the well's pumping rate (gpm)?

Chillers

Does this facility have a chiller?

- ☐ Yes
- ☐ No

If yes, how many chillers does this facility have?

Are these chillers centrally located?

- ☐ Yes
- ☐ No

Chiller #: Is this chiller currently in use?

- ☐ Yes
- ☐ No

Chiller #: Is this an open loop or closed loop system?

- ☐ Open Loop
- ☐ Closed Loop

Chiller #: What is the brand and model of the chiller?

Chiller #: What is the inflow rate (gpm) of the chiller?

Chiller #: What is the temperature difference (°F) of the chiller?

Is this chiller directly attached to asbestos cement pipes?

- ☐ Yes
- ☐ No

Cooling Tower

Does this facility have a cooling tower?

- ☐ Yes
- ☐ No

If yes, how many cooling towers does this facility have?

Are these cooling towers located within/adjacent to the facility?

- ☐ Yes
- ☐ No

Cooling Tower #: Is this cooling tower currently in use?

- ☐ Yes
- ☐ No

Cooling Tower #: Is this an open loop or closed loop system?

- ☐ Open Loop
- ☐ Closed Loop

Cooling Tower #: What is the brand and model of the cooling tower?

Cooling Tower #: What is the inflow rate (gpm) of the cooling tower?

Cooling Tower #: What is the temperature difference (F) of the cooling tower?

Is this cooling tower directly attached to asbestos cement pipes?

- ☐ Yes
- ☐ No

Boiler

Does this facility have a boiler?

- ☐ Yes
- ☐ No

If yes, how many boilers does this facility have?

Are these boilers located within/adjacent to the facility?

- ☐ Yes
- ☐ No

Boiler #: Is this boiler currently in use?

- ☐ Yes
- ☐ No

Boiler #: Is this an open loop or closed loop system?

- ☐ Open Loop
- ☐ Closed Loop

Boiler #: What is the brand and model of the boiler?

Boiler #: What is the inflow rate (gpm) of the boiler?

Boiler #: What is the temperature difference (F) of the boiler?

Is this boiler directly attached to asbestos cement pipes?

- ☐ Yes
- ☐ No

Wash Racks

Does this facility have a wash rack?

- ☐ Yes
- ☐ No

How many wash racks does this facility have?

How often are these wash racks used?

How many vehicles are typically washed per month?

What is the brand and model of the wash rack?

Additional notes.

Lift stations

Is this building connected to a wastewater lift station(s)?

- ☐ Yes
- ☐ No

How many lift stations are associated with this facility?

Do these lift stations have backup generators?

- ☐ Yes
- ☐ No

Do these lift stations serve other buildings?

- ☐ Yes
- ☐ No

Is this facility a hospital?

- ☐ Yes
- ☐ No

Estimate the number of beds occupied this week

This will provide an estimate of how many patients are admitted.

Describe large water users that are specific to this facility.

Do not include boilers, hillers, and cooling towers.

Does this facility have a DFACE/café?

- ☐ Yes
- ☐ No

Estimate the number of meals served today.

This will be used as an estimate for meals served per day.

Estimate the number of patrons that visited this café today

This will be used as an estimate for patrons per day.

Describe any large water users that are specific to this facility.

Do not include boilers, chillers, and cooling towers.

Is this facility a fire station?

- ☐ Yes
☐ No

Does this facility have a tanker?

- ☐ Yes
☐ No

How many tankers does this facility have?**What is their capacity? (Gallons)****Describe any large water users that are specific to this facility.**

Do not include boilers, chillers, and cooling towers.

Additional Notes.

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<p>The Army's critical missions are at risk from interruption of water supplies. Sufficient amounts of high-quality potable water are a resource without substitute. The Army's Installation Energy and Water Security Policy establishes requirements for installations to sustain critical mission capabilities and to mitigate risks posed by energy and water disruptions that affect installations; this includes coordinating vulnerability and risk assessments of potential disruptions and implementing adequate responses to mitigate identified risks. Resilient installations will develop storage capacity to forestall water shortages and will also have short- and long-term plans to help the installation recover from events and forestall progressing to more severe deficits. This project supports compliance with the water security policy by exploring the range of conditions and responses possible across installations. Multiple scenarios were developed to explore how a 14-day interruption in water supply might affect an installation and to provide preliminary guidance to help installations develop strategies to address water disruptions to critical missions drawing from existing processes used in mission assurance. Researchers investigated types of installations and classes of scenarios most relevant to installation water security planning and explored several scenarios to provide a framework to helps installations advance their water resilience and security planning.</p>					
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