Reducing "Loss of Utility" Impacts to Critical Facilities

Recovery Advisory 2

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FEMA

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Cover photo: Standby generator

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1. Purpose and Intended Audience

This Recovery Advisory outlines observations from Hurricane Ian in Florida, DR-4673-FL, that provide insights regarding building improvement opportunities. These recommendations are applicable to buildings experiencing similar issues and need not be limited to the state or disaster in which they were observed.

Hurricane Ian caused widespread damage across Southwest Florida to houses, commercial buildings, and critical facilities. Additionally, Hurricane Ian resulted in widespread outages of utilities, including, but not limited to, power, water, and wastewater. The loss of utility service, and in some cases standby generators, severely impacted the ability of critical facilities to operate as intended. For example, loss of potable water was a particularly significant impact of Hurricane Ian. Although many evacuated in advance of Hurricane Ian's arrival, those who remained (e.g., first responders, hospital staff and occupants, those who took refuge in hurricane evacuation shelters [HES][1]) were sometimes left without potable water service.

This loss of potable water service often rendered affected facilities without fire protection and left occupants without proper sanitation facilities (toilets, handwashing, and cleaning). Many endured several days of finding alternative sources of drinking water and water for flushing toilets, but the loss of fire protection capability eventually required some facilities to be evacuated. Hospitals were among the facilities that were hardest hit. Three hospitals in Lee County were forced to evacuate, move patients to alternate hospitals, and halt hospital operations as a direct result of being left without fire protection due to loss of potable water supply. Shutting down hospital operations placed additional strain on the community and hampered its ability to recover more quickly from the event. The closure of hospitals also exposed patients receiving critical care to the risks associated with being evacuated and transported to another hospital.

Essential Facilities vs Critical Facilities

The forthcoming 2024 International Building Code (IBC) and American Society of Civil Engineers (ASCE) standard ASCE 7-22, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE/SEI, 2021), define "essential facilities" as "buildings and other structures that are intended to remain operational in the event of extreme environmental loading from flood, wind, tornado, snow, or earthquakes." Essential facilities are also designated as Risk Category IV structures.

Critical facilities are defined by FEMA as buildings that are essential for the delivery of vital services or protection of a community. Critical facilities include emergency operation centers, healthcare facilities, police and fire stations, schools, and power stations. These facilities

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[1] Hurricane Evacuation Shelter, or HES, is used in this Recovery Advisory as a general term for any hurricane shelter. However, there are more specific terms for the various types of shelters. Refer to Section 5.3 of the Hurricane Ian Mitigation Assessment Team (MAT) report for a discussion of the different shelter types and their definitions. Facilities constructed to provide near-absolute protection in a tornado or hurricane are called safe rooms. Safe rooms are required to be designed to FEMA P-361, *Safe Rooms for Tornadoes and Hurricanes: Guidance for Community and Residential Safe Rooms* (2021) and the International Code Council's (ICC's) standard ICC 500, *Standard for the Design and Construction of Storm Shelters* (2020). These documents provide guidance on backup power, water, and sanitary sewer systems to maintain operations of the safe room in the event of a utility outage.

support critical community lifelines that enable the continuous operation of critical business and government functions and are essential to human health and safety or economic security. For this Recovery Advisory, essential and critical facilities are synonymous. All essential facilities fit within the definition of critical facilities; however, not all critical facilities serving a community, such as a water treatment plant, are designed as Risk Category IV structures.

Critical facilities require utilities to function in order to carry out their critical operations. Hurricane Ian and other recent natural hazard events have demonstrated that critical facilities do not have to be structurally damaged to render them unable to function and perform their critical missions. The loss of utilities can prevent them from functioning even when their building envelopes, structures, and mechanical, electrical, and plumbing (MEP) systems survive an event with little or no damage. A vulnerability assessment of a critical facility should be performed prior to the start of designing projects where the overall goal is to improve utility resilience. The critical facility should be analyzed for the potential loss of its utility systems required to operate as well as its vulnerabilities to physical damage, such as wind, flood, seismic, and other applicable hazards. Reducing a critical facility's vulnerability to service loss can occur either at the utility level (often by strengthening the utility and its distribution system or by providing redundancy) or at a facility level (by providing alternate systems that can provide services normally provided by utilities). This Recovery Advisory focuses on the latter, providing guidance for on-site systems that can temporarily deliver services normally present and enable the critical facilities to function even when utilities are no longer available.

This Recovery Advisory is intended for owners and operators of critical facilities; architects and engineers who design them; various state, local, tribal, and territorial planners; and emergency managers who deal with critical facilities whether in support of emergency preparedness, planning, response, and disaster recovery efforts or administration of mitigation grants and operations. It also provides valuable considerations and guidance for utility providers. Readers are encouraged to review the entire document to gain an understanding of the general principles; consultation with a design professional may be needed for implementation. Note that this Recovery Advisory provides recommendations that are primarily applicable to critical facilities.

1.1. This Recovery Advisory Addresses

- Considerations for Utilities Needed to Operate Critical Facilities
- Electricity
- Fuels and Combustible Gases
- Potable Water
- Sanitary Sewer
- Useful Links and Resources

2. Considerations for Utilities Needed to Operate Critical Facilities

Municipal or private providers bring electricity, water, fuel, and communication and information technology (IT) services to critical facilities and dispose of liquid and solid waste that critical facilities generate. Critical facility operations can become severely limited or terminate completely in the event of a utility or service outage. The effects of the loss of a utility can be instantaneous, as with the loss of electricity, or the effects can be felt after some delay, as with potable water and sanitary sewer. The loss of some utilities and services, such as waste collection services, may not be felt for several days. Figure 1 illustrates some of the typical utilities that serve most critical facilities. Some critical facilities, such as hospitals, may have over 30 different utility systems. Although only the main utility systems are covered herein, some of the same general concepts can be applied to other systems as applicable.

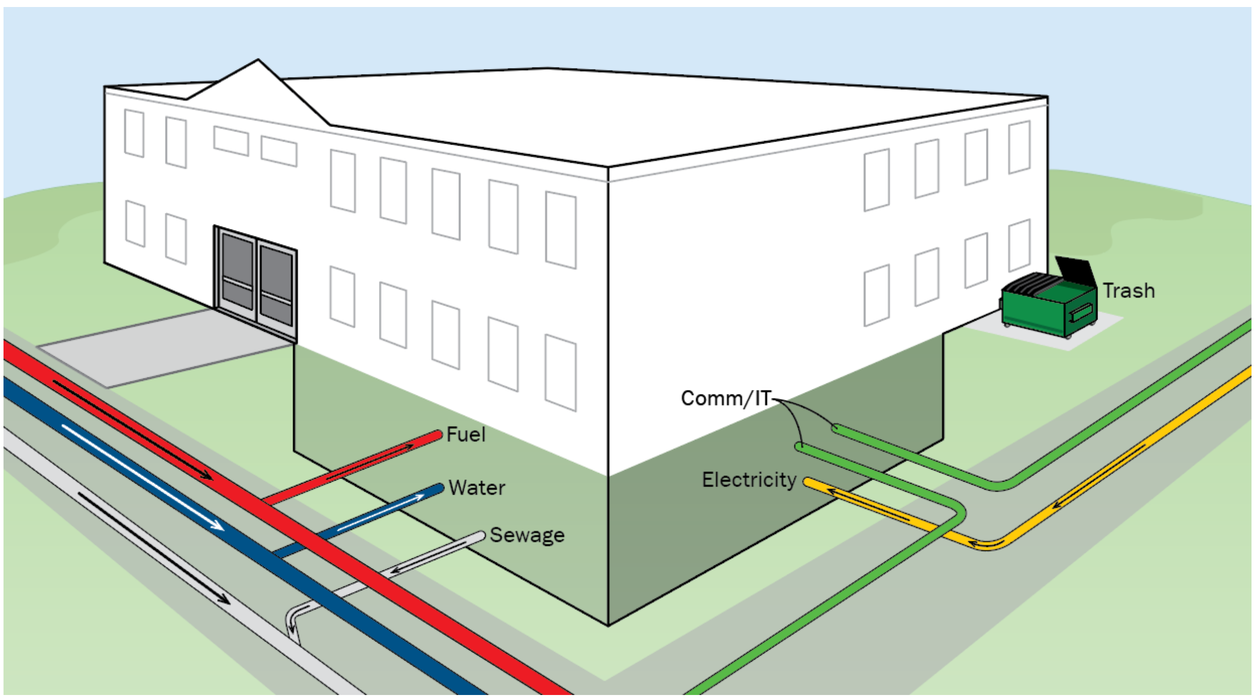

Figure 1: Utilities that serve critical facilities

For critical facilities to continue to operate during the loss of services provided by utilities, measures must be in place to accommodate those losses of service. The measures must have the capacity to provide the necessary services for the duration of the outages. When planning for continued operations through a utility outage, critical facilities should identify the following:

- What utilities are needed for a critical facility to perform its intended function/mission?
- What portion(s) of operations would be impacted by loss of service from the various utilities?
- Which building functions/operations need to remain at full capacity?

- Which building functions/operations, if any, can be reduced or shutdown while enabling the critical facility to remain operational and perform its mission?
- How many people might reasonably be expected to be on site performing, or being part of, the critical mission? Note that some critical facilities, such as emergency operations centers (EOCs) and HESs, may have orders of magnitude of additional people on site during a natural disaster or other critical operations compared to normal operations. This significant increase in occupancy must be accounted for by the various utility systems.
- What are the projected durations of the utility outages that the critical facility must overcome while remaining operational?

Continuity of Operations Planning

A Continuity of Operations Plan, or COOP, is a planning tool for individual departments and agencies to ensure continuity of critical functions during a wide range of emergencies.

FEMA offers a template for use in developing a COOP. This template helps agencies to define their critical functions, analyze vulnerabilities, plan for emergencies, and maintain and update the COOP based on lessons learned. The template is available at https://www.fema.gov/pdf/about/org/ncp/coop/continuity_plan_federal_d_a.pdf.

3. Electricity

Most critical facilities rely on a public utility grid that transmits and distributes power over long distances from where the power is generated to where it is consumed. Those long distances leave utility power supplies vulnerable to a variety of natural hazards, even for sophisticated redundant networks.

Modern building codes and standards acknowledge the vulnerability of utility power and require that most buildings have emergency power to supply select loads when normal power is interrupted. In many occupancies, code-required emergency power is dictated by what is needed to detect fires and enable occupants to exit a building quickly and safely. Those requirements are contained in the National Fire Protection Association's (NFPA's) NFPA 101, Life Safety Code, and are referred to as Life Safety loads. In other facilities, emergency power is needed for smoke control or to support firefighting actions. Although codes and standards, such as Article 708 Critical Operations Power Systems (COPS) of the National Electrical Code (NFPA 70), have been developed for power systems for critical operations, most facilities that provide essential or critical services are not covered by those codes and standards and the code requirements that govern their design will not allow them to function when normal power is lost.

Accommodating the loss of utility power requires determining *what* equipment must operate for a critical facility to function, *how* much power that equipment draws, and *how* best to provide that power. For this document, required equipment is considered equipment that must operate to allow a critical facility to provide critical services without placing building occupants at undue risk.

3.1. Determining Electrical Requirements

The electrical requirements of critical facilities vary greatly. The requirements for a hospital, fire station, or an EOC differ greatly from those of an HES. Determining the electrical needs of a facility requires knowing what equipment needs to be powered, when that equipment needs to operate, and for how long. FEMA P-1019, *Emergency Power Systems for Critical Facilities* (2014) contains extensive guidance on determining electrical needs.

Healthcare facilities are particularly challenging. *Healthcare Facilities and Power Outages* (FEMA 2019a) provides guidance for state, local, tribal, territorial, and private-sector partners on improving healthcare facility resilience to power outages. FEMA developed that guide in collaboration with the U.S. Department of Health and Human Services Office of the Assistant Secretary for Preparedness and Response and other partners to meet, in part, the requirements of Section 1208 of the Disaster Recovery Reform Act.

The following guidance will help identify *what* equipment must be operational to enable a critical facility to function.

3.1.1. LOADS REQUIRED BY CODES/LIFE SAFETY PROTECTION

Code-required loads are those required by building codes and standards to supply life-safety equipment, equipment that reduces hazards, and equipment that helps conduct rescue or fire-fighting operations.

Exit and Egress Lighting: Codes require that designated exit doors be identified and egress routes be illuminated so occupants can safely leave a building even when utility power is lost. However, code requirements typically only require emergency supplies for exit and egress lighting to last 1.5 hours, which can be provided by batteries. For critical or essential facilities that must remain operational for longer periods, standby or emergency power that can supply exit and egress lighting for longer durations should be provided.

Fire Detection, Alarm, and Communication Equipment: Fire detection, alarm, and communication equipment detects the presence of fire or smoke, either through automatic means, manual fire alarm initiation, or the operation of fire suppression systems such as sprinklers; provides alarms to notify building occupants of a fire; and communicates the detection of a fire to alert emergency personnel. However, like exit and egress lighting, the emergency power supplies required by code for fire detection, alarm, and communication equipment are often of relatively short duration. Standby or emergency power that can supply fire detection, alarm, and communication equipment for longer periods should be provided for critical facilities that must remain operational beyond code-required minimum durations.

Fire Pumps: Fire pumps for fire suppression systems boost water system pressures and ensure adequate water flow to sprinklers for fire suppression. When fire pumps are only powered from electrical utilities and not from standby or emergency power sources, local fire officials may limit how long facilities equipped with fire pumps can remain occupied when utility power is lost. If critical facilities must remain operational beyond that period, standby power to fire pumps should be provided. Diesel-driven fire pumps, which do not need electrical power to operate, are an alternative when supplying fire pumps from standby power sources is not practical.

3.1.2. LOADS REQUIRED FOR FUNCTION

Some systems are not required by code but are needed to allow a critical or essential facility to provide critical services without placing building occupants at undue risk.

Lighting: For most facilities, code-required lighting will not be adequate for operations during prolonged power outages. For example, code requirements for egress lighting range from an average initial illumination of 1 foot-candle (fc) to 10 fc for stairs. By contrast, office areas are typically illuminated to 50 fc and corridors at 15 fc.

FEMA P-1019 considers illumination levels of 30% to 50% of the normal lighting levels to be appropriate for most areas to function at a base level. For areas where visual tasks are demanding, such as hospital operating rooms and intensive care units, full lighting levels should be provided.

Power requirements for lighting are generally low and do not place large demands on standby power systems.

Heating, Ventilation, and Air Conditioning (HVAC): HVAC equipment controls the temperature and humidity levels within a building and provides fresh air for ventilation. In cold climates, heating is required for both occupant protection and to prevent damage from frozen pipes. In hot climates, air conditioning (AC) equipment is needed when interior temperatures and humidity levels must be kept within specific levels. Code research completed when FEMA P-1019 was developed circa 2014 found that while model building codes generally required that buildings be heated and provided with ventilation, they did not require buildings to be air conditioned.

With few exceptions, HVAC systems components require power to operate and, if they need to operate when utility power is lost, require standby power.

HVAC systems components that provide fresh air to buildings that require power can include supply fans, exhaust fans, and controls. HVAC systems components that provide heat can include furnaces, air handling units (AHUs), boilers, circulating pumps, and controls. They may also include electrical heating coils, variable air volume (VAV) boxes, or motorized dampers to control air flow rates to individual areas; equipment to chemically treat make-up water in hydronic (hot water) systems; and fuel oil pumps.

Many HVAC systems components do not draw large amounts of power and, in some cases, can be supplied from existing standby power systems. Exceptions are cases where standby power systems are sized to only supply code-required loads and heating systems that use electrical heating coils.

The HVAC systems components required to air condition a building depends on the type of AC system used. There are two common types: DX (direct expansion) systems and chilled water systems. DX system components include interior AHUs and exterior compressor and condensing units. Chilled water systems include interior AHUs and either air- or water-cooled chillers. Water cooled chillers are used with evaporative cooling towers that are connected to the chillers by condenser water loops or they may be connected to geothermal loops. Both DX and chilled water systems may have VAV boxes.

For both AC systems, power is needed for AHUs and HVAC controls and, when present, VAV boxes. DX systems require power for the exterior compressor and condensing units. Chilled water systems require power for the chillers, chilled water pumps, and, when present, the cooling towers and condenser water or geothermal pumps.

Dedicated Air Conditioning: AC systems are often needed to serve areas that contain heat-generating equipment such as IT network server rooms and communication equipment rooms. Dedicated AC systems units are typically DX style and require power be provided to their AHUs and compressor and condensing units.

AC equipment is often the single largest electrical load in a facility and can place large demands on standby power systems. When a critical facility must be air conditioned, standby power systems often must be doubled, tripled or larger in size, Because of the large electrical demand AC requires, providing AC only to the portions of a critical facility that need to be air conditioned to allow the facility to function and provide critical services is often appropriate.

3.1.3. POTABLE WATER SYSTEMS

Plumbing fixtures generally need about 30 pounds per square inch (psi) of water pressure to operate, and in many facilities, potable water from a utility is delivered with adequate pressure to meet that need without relying on utility power. Since codes often limit the operating pressure of potable water systems to 80 psi, static water pressures drop approximately 5 psi per floor, and additional pressure is lost when water flows through pipes, buildings over five stories often need booster pumps to provide sufficient water pressure to the upper floors. To maintain a potable water supply throughout a structure, the booster pumps will require standby power to operate when utility power is lost.

Producing domestic hot water when utility power is lost requires that additional equipment be supplied by standby power systems, including fuel-fired domestic hot water boilers, electric water heaters, and, when used, domestic hot water circulator pumps.

The electrical demand for standby power is greater when water service is interrupted and critical facilities must rely on on-site water sources. In addition to providing power to booster pumps and equipment for domestic hot water, power may also be needed for well pumps, lift pumps to fill elevated storage tanks, and, when the quality of the water produced from on-site water sources dictate, treatment equipment such as reverse osmosis systems. Alternative sources of potable water are discussed further in Section 5 of this Recovery Advisory.

3.1.4. SANITARY SEWER SYSTEMS

Sewer lift pumps are needed in buildings that discharge sewage to municipal sewer lines that are at higher elevations. Lift pumps, also called macerator or grinder pumps because they must handle solids and liquids, are normally placed in sewer sumps that have storage capacity that can handle the effluent produced for short periods. Although the duration depends on the volume of the sumps and on the rate that effluent is produced, storage durations of 4 to 8 hours are not uncommon. For power outages that exceed storage durations, sumps can overflow and contaminate the building unless standby power is provided to the lift pumps.

Municipal sewer or wastewater systems often have lift pumps, particularly in areas where local topography prevents sewage from being conveyed by gravity. Like lift pumps within buildings, municipal sewer pump stations have sumps, generally called wet wells, where sewage can collect when the lift pumps cannot operate. Municipal lift stations can often accommodate longer-duration outages than the sewer sumps within buildings. Twelve to 24 hours of storage is not uncommon. When lift stations lose power for longer durations, sewage levels in municipal wastewater collection systems can rise and can eventually enter buildings that are connected to the municipal system, particularly buildings that are not equipped with backwater valves. Further discussion of lift pumps for sanitary sewer lines is provided in Section 6 of this Recovery Advisory.

3.2. Duration of Service

Although the loss of utility power generally happens immediately, the impacts of a loss of utility power are not all felt at once. Loss of power is often noticed immediately when lights go out or computers shut down, but the effects of the loss of utility power on other systems may not be felt for several hours or occasionally days. Consequently, considering the duration of the loss of power or the duration that critical facilities must operate when not supplied by the electrical utility is critically important.

Table 1 summarizes electrical equipment that must operate for a critical facility to function during short-, intermediate-, and long-duration utility outages. Because the services that critical facilities provide and their reliance on electrical equipment vary greatly, what constitutes short-, intermediate-, and long-duration outages should be determined by the individual critical facility owners and operators, given their mission(s). However, for the illustrative and guidance purposes of this Recovery Advisory, short-duration outages are generally considered those that last 24 hours or less; intermediate-duration outages are generally considered those that last 24 to 72 hours; and long-duration outages are those that last 72 hours or longer. These durations are consistent with the guidance provided by FEMA P-1019.

Table 1: Electrical Equipment Needed for Critical Facility Functioning during Short-, Intermediate-, and Long-Duration Outages

Short-Duration	Intermediate-Duration	Long-Duration
Code Required/Life Safety ▪ Exit Signs ▪ Egress route illumination ▪ Fire Detection & Notification ▪ Smoke Control Equipment ▪ Fire Pumps & Jockey Pumps Illumination ▪ Operation centers ▪ Rest rooms ▪ Mechanical & electrical rooms ▪ Corridors & Stairwells Communication/IT ▪ EMS/Fire/Police ▪ Telephone HVAC Equipment ▪ AHU Circulation Fans ▪ HVAC Controls (min)	Short-Duration Equipment and Services Plus Illumination ▪ Shelter areas MEP ▪ Sewer lift pumps ▪ Potable water (well, booster) pumps ▪ Sump pumps ▪ Water treatment (on-site water sources) HVAC Equipment ▪ Supply & Exhaust Fans ▪ Local Air Conditioning ○ Operation centers ○ First Aid areas ○ Special needs areas ○ Cooling rooms ○ Communication/IT server rooms ▪ Environmental Management & Control Systems Communication/IT ▪ Network Servers & Routers	Short- and Intermediate-Duration Equipment and Services Plus HVAC Equipment[a] ▪ Boilers ▪ Air cooled chillers/water cooled chillers/cooling towers ▪ Hot water circulating pumps ▪ Chilled water circulating pumps Communication/IT ▪ WiFi

AHU = air handling unit; EMS = emergency medical services; HVAC = heating, ventilation, and air conditioning; IT = information technology; MEP = mechanical, electrical, and plumbing

[a] Flanged piping connection can allow portable boilers and chillers to provide hot and chilled water to HVAC equipment when it is impractical to supply HVAC equipment from standby power sources.

3.3. Alternate Electrical Sources

Accommodating the loss of utility power requires on-site energy sources sufficient to enable the facility to perform its critical functions for the community, region, or state for the duration of the loss. Energy can be provided by on-site generation, portable generation, stored energy devices, or combinations of these three. On-site generation is typically provided by standby or emergency generators, often powered by diesel engines but occasionally powered from liquid propane (LP) or natural gas (NG) units. Stored energy is nearly always provided by battery energy storage systems (BESS), which can range in size from tens of watthours for small devices such as emergency lighting fixtures to tens of megawatt hours for large systems. For on-site generation, renewable energy sources such as wind and solar systems are being considered more frequently. However, their reliance on wind or sunlight requires energy storage systems that enable them to operate through periods when wind turbines or photovoltaic (PV) arrays are not generating electricity.

For a standby energy system to power a critical facility, it must have the capacity to supply all critical loads for the duration of the power loss or for the minimum required time it is to remain operational without potentially having public utility power. The electrical needs of a critical facility and the ability of standby power systems to meet those needs must be determined and addressed.

Short-Duration Outages: Alternate electrical sources for short-duration outages include standby generators, and, when adequate storage is achievable, BESS. When BESS is used, the maximum electrical demand and the minimum charge state anticipated at the onset of the loss of utility power should be considered.

Intermediate-Duration Outages: Alternate electrical sources for intermediate-duration outages include standby generators, standby generators augmented with BESS, and possibly standby generators augmented with renewable generation. The latter should only be considered when renewable sources can be designed to survive the event that interrupts utility power.

Long-Duration Outages: Alternate electrical sources for long-duration outages include standby generators, standby generators augmented with BESS, renewable generation, and portable standby generators. Provisions should be installed to facilitate the connection of portable generators.

4. Fuels and Combustible Gases

Fuels and combustible gases are often needed for heating and, in some facilities, for AC, the production of domestic hot water, cooking, and operating standby power sources. Diesel and fuel oil are common liquid fuels. LP and NG are common combustible gases. Manufactured gas, often called town gas, is another combustible gas provided by utilities.

Because the focus of this Recovery Advisory is reducing risks to critical facilities from the loss of utilities, the risk from a loss of NG or town gas should also be considered.

The transmission and distribution of combustible gases is primarily through underground piping that is not directly affected by environmental hazards such as high winds and winter storms. Consequently, combustible gases are generally considered highly reliable. However, in preparation for natural hazard events, combustible gas service can be preemptively shut down to reduce fire risk during and after an event. Combustible gas lines can be damaged by high-wind events that topple and uproot trees after their roots have grown and are entangled around NG service lines as well as by earthquakes when gas lines can be damaged by ground movement.

The effects of the loss of NG service on a critical facility vary. Although the loss of NG service may prevent the production of domestic water and the operation of gas-fired heating systems, its loss will not immediately impact the function of a critical facility. However, for critical facilities with emergency or standby generators that operate on NG, the loss of NG service will immediately prevent them from functioning if the loss of NG service coincides with the loss of utility power.

For critical facilities that have several systems that operate on NG, compressed natural gas (CNG), which can be stored on site, is an alternative to NG provided by a utility. For critical facilities that only rely on NG for emergency or standby power systems, dual fuel (NG/diesel) generators, which can operate on NG, diesel, or both, are alternatives for improved resiliency.

5. Potable Water

The loss of potable water will severely impact the operational capabilities of critical facilities and prolonged outages can ultimately result in the inability of critical facilities to perform their critical mission/function(s). Potable water is most commonly associated with fulfilling the drinking water requirements for building occupants but has numerous other uses within a building to ensure operation and occupancy. Potable water is also commonly used for the following functions:

- Fire protection/suppression systems (fire flow)*
- HVAC systems and evaporation coolers*
- Steam/boiler makeup*
- Hand washing, showers, and toilet flushing (sanitary)

*A component outage could lead state, health, fire, or other regulatory authorities to require the building be evacuated because of unsafe conditions

Similar to electricity, potable water usage ranges from desired functions to critical needs, such as fire protection. Interruption of the potable water supply can adversely impact or restrict and stop critical operations. As in the case of fire protection, the evacuation of a building can sometimes be required by codes, regulations, or authorities having jurisdiction (AHJ) because of the risk of inhabiting a structure that lacks a fully functioning fire protection system. Additionally, some HVAC equipment, such as evaporative coolers, require water to operate; the loss of water service can limit or prevent their proper operation. The inability to heat or cool a critical facility can result in extreme temperatures and humidity levels, which can degrade equipment and personnel operations and place occupants at unnecessary risk.

The duration of the loss of potable water and the number of building occupants will influence the decisions to determine which building functions are required to remain operational and how much water is required for those building functions. The duration of outages can vary greatly from hours to days and perhaps weeks. Operators of critical facilities generally have two choices, they can either accommodate the loss of water or they can relocate personnel, equipment, and/or responsibilities to another facility that provides those critical services. Appropriate planning and preparedness for a potential outage can minimize the impact to the critical facility, by either having countermeasures in place or being ready for contingencies, until the duration of the outage can be determined. Critical facilities need to identify which potable water–dependent functions need to remain operational in order to enable operations to continue. Additionally, the maximum daily water usage for the facility should be identified for the various facility demands, such as HVAC equipment and water consumed by building occupants. This operational understanding will help in developing a plan to identify what outage duration is to be bridged and how the potable water demand is to be met until potable water distribution from the local utility can be restored. To bridge the gap, potable water needs to be either stored on site or supplied via alternative means, such as an on-site groundwater well.

Prior to an event that can result in a potable water outage, the critical facility owners/operators should perform a vulnerability assessment to determine whether the building plumbing system(s) should be modified to enable alternative or stored water sources to be used or how best to enable these water sources to effectively supply critical building functions. Additionally, FEMA recommends that critical facility owners, operators, and other interested stakeholders discuss and develop a plan and a prioritization system with the local water utility for how they will restore water service faster to the critical facility. Similar meetings could also be held with other local utility providers, such as electricity or wastewater, to help expedite restoration of services.

For short-duration outages, critical facilities should prioritize the building functions that need to remain operational and ensure that drinking water is available on site for occupants. Drinking water can be provided by bottled and canned water or can be stored in portable tanks, which typically range from 50 to 500 gallons.

One of the most critical building functions supplied by potable water is the fire suppression system. If the fire suppression system is offline, the AHJ or local codes and regulations may require a fire watch to be staffed. If a fire watch cannot be staffed or the potable water outage is anticipated to be more than a few hours, the AHJ or local codes and regulations may require the critical facility to be evacuated. Although the International Fire Code (IFC) and NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, establish criteria for when a fire watch is to be staffed and when a building needs to be evacuated, the local AHJ or facility stakeholders often have more stringent requirements. To provide redundancy for the fire suppression system, an on-site potable water storage tank can be installed that is sized in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, and NFPA 22, *Standard for Water Tanks for Private Fire Protection*, with a corresponding supply pump.

For other potable water needs, such as water to flush toilets, clean, use in kitchens, and address various other building needs, potable water trucks can be prepositioned at the critical facility. If potable water trucks are to be used, consider having multiple/redundant contracts for potable water trucks, as they may be scarce or have long travel times in the event a truck needs to be refilled.

Manually Flushing of Toilets

Many occupied critical facilities in Southwest Florida lost potable water during Hurricane Ian. Occupants continued to use the restroom, causing a sanitary crisis. Critical facility operators used the syphon effect to manually flush toilets by filling the toilet bowl with water. Because water service was interrupted, critical facility operators used 5-gallon buckets filled with stormwater collected from on-site stormwater ponds or potable water from pre-positioned water trucks to fill the toilet bowl.

One method to bridge the gap of a multi-day outage is to size and construct a flow-through tank. With a flow-through tank, the water main feeding the critical facility would first fill/enter the tank. Once the water is inside the tank, a pump will pull water from the tank and distribute the water to the critical facility under the required pressure. During periods of normal water supply, water is allowed to continually flow through, eliminating the concern of the water diminishing in quality. When water supply from the utility is interrupted, the backflow preventor prevents water in the flow-through tank from leaving the tank via the inlet pipe. The flow-through tank would need to be sized for the total water demand of critical functions (e.g., drinking water consumption, HVAC systems, boiler systems, sanitary) for the anticipated outage. If fire suppression systems utilize the same flow-through tank, the capacity of the tank will need to include the necessary storage volume for the fire suppression system. To prevent water required for the fire suppression system from being used by other building functions, two separate outlet pipes at different elevations can be used, as shown in Figure 2. The outlet pipe for building functions would be at an elevation that is above the necessary volume of water required for fire suppression while the outlet pipe for the fire suppression system would be located on the floor of the tank.

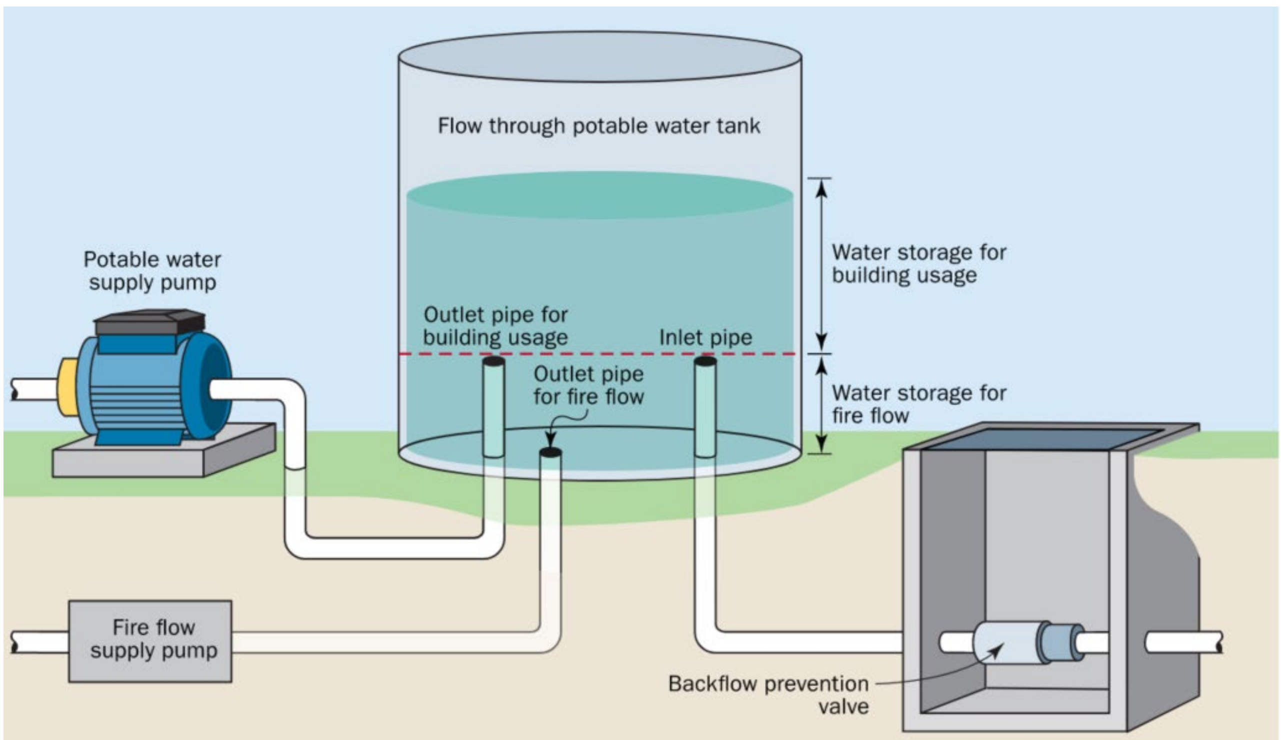

Figure 2: Example of a flow-through tank system to meet water supply needs, with separate fire flow storage capacity

Although sizing a tank to accommodate outages of multiple days is possible, the size of the tank may be too large for the site, be cost prohibitive, or result in water quality issues as chlorine residual decreases. For long-duration outages, drilling a groundwater well or network of groundwater wells may be necessary to fulfill the potable water demand for the critical facility. Depending on the groundwater quality, either a carbon filter or reverse osmosis treatment system may be necessary to treat the water to be used for drinking or in HVAC systems. Alternatively, if certain critical facility functions do not require water to be drinking water quality, the groundwater well can be used for sanitary water needs, as shown in Figure 3.

Figure 3: Example of a groundwater well that was used only to provide water for flushing toilets

The solutions for intermediate and long outages can also be used for shorter-duration events, and these potable water solutions may have components that need to be powered by standby power; therefore, standby power will need to be sized for the increased load.

6. Sanitary Sewer

After potable water is consumed or utilized, it becomes sanitary sewer water, which needs to be disposed of from the facility. Sanitary sewer comprises blackwater (product of toilet flushing, dishwashers, and food preparation sinks), graywater (product of bathtubs/showers, bathroom/nonfood preparation sinks, and laundry), and, in some cases, stormwater discharge (such as rainwater from gutters or basement sump pumps). Stormwater may be discharged to surface water or directly reused within the building; however, blackwater and graywater must be properly treated before being disposed of or reused. Facilities discharge sanitary sewer water either through a system that is operated by a wastewater service provider or through a system that is independent of a utility provider.

6.1. Portable Facilities

A short-term solution to loss of sanitary sewer is deploying portable facilities. Portable water closets (e.g., porta potties, showers, laundry trailers) are classified as a short-term solution (cannot be temporarily isolated for long durations) because they require routine servicing for proper maintenance. Portable water closets should be serviced/pumped weekly at a minimum (VIP Restrooms 2021) but up to three to four times a week in high-traffic areas (Kerkstra 2023). Increasing the quantity of portable water closets will extend the duration between pumping, though routine servicing is recommended for sanitary reasons. As guidance on determining the number of water closets needed, the International Code Council's (ICC's) standard ICC 500, *Standard for the Design and Construction of Storm Shelters,* recommends one water closet for every 50 occupants

(ICC 500, Section 703.3) for use within a storm shelter. Alternatively, Occupational Safety and Health Administration (OSHA) regulations for general industry require up to six water closets for the first 150 occupants and one additional fixture for each additional 40 employees thereafter.[2]

Portable water closets, handwashing stations, showers, or laundry units can be purchased or rented. Figure 4 shows an example of an eight-station shower trailer providing services to a heavily damaged area of Florida following Hurricane Ian. Power for the trailer is supplied by a portable generator, circled within Figure 4, and hot water is provided by an LP on-demand water heater with propane tanks, located on the "tongue" or front of the trailer. The trailer features a mechanical room (not shown in the photo) with a water tank. A waste holding tank stores the graywater. Maintenance of this trailer includes refilling of the propane tanks and water tank, and disposal of the waste holding tank.

Figure 4: Example of portable shower trailer in Port Carlos Cove, FL

The Hurricane Ian Mitigation Assessment Team (MAT) visited a parking garage at a retirement community that deployed portable water closets for community residents prior to activation of the facility as an HES (Figure 5). The Team also visited several shelters and hospitals that brought in portable water closets, showers, and/or laundry units after the hurricane made landfall, once the facilities were accessible. These portable systems are an option to enable continued facility functionality during utility outages. Contracting with a portable sanitation company well in advance of an event will lessen supply challenges, which are often exacerbated given the high demand for these portable units following an event.

2 See OSHA Standards – 29 CFR, Part 1910 (OSHA Section 1910.141(c)(1)(i) and Table J.1) https://www.osha.gov/laws-regs/regulations/standardnumber.

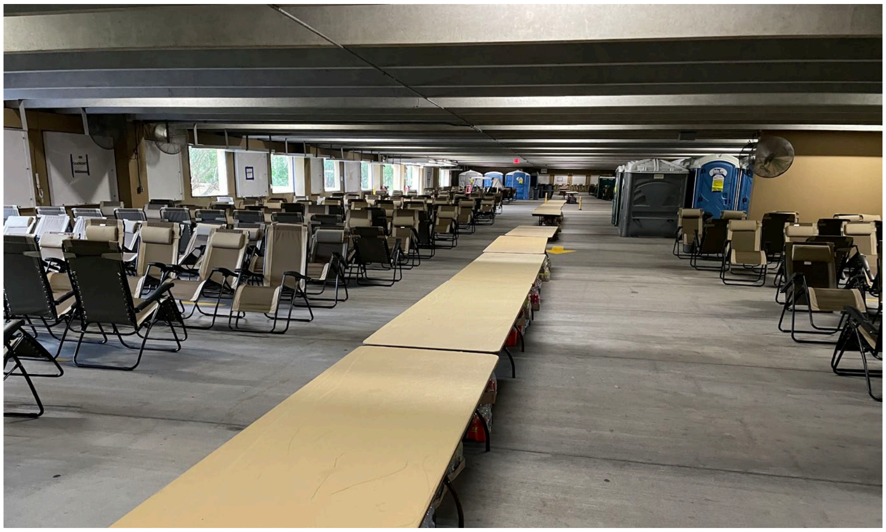

Figure 5: Example of portable water closets for use in a garage that was converted into an HES

When determining whether portable facilities are the appropriate solution, location of the portable facilities and additional utilities needed for their operation must be considered. After an event, portable facilities are used temporarily during the recovery process. These portable facilities are typically placed in a parking lot or grassy area outside of the building. However, for facilities used as an HES that are not specifically designed with hardened/resilient restrooms (e.g., ICC 500 storm shelters) within them, portable water closets should be delivered in advance of the storm event and located within the facility. This will prevent occupants from having to go outside to use the restrooms during the event, which is unsafe. The location of interior portable facilities may be restricted by logistical challenges or may limit shelter space use for other operations. In either case, this reality should be properly planned for in advance for improved shelter operations. Utility hookups are also a consideration. Laundry and shower facilities need to be connected to adequate power and water supply to function properly. Close utility connections to the portable facility are preferred to minimize electrical losses, maximize water pressure, and minimize flow reductions within the system. Some of these facilities, such as laundry and showers, are more commonly used after the event occurs, but before utilities for the given area are functioning again. For heavily damaged areas, it can sometimes take weeks or months for power and/or water to be restored to certain locations.

6.2. On-Site Storage

When a longer isolation period may be required following an event, an on-site sewer storage holding tank may be used as an intermediate solution. Holding tanks are closely related to septic tanks, which are discussed further in the next section. Sizing is an important consideration for holding tanks as capacity dictates the length of time between pumping. Larger critical facilities require larger holding tanks, which the site must be able to accommodate. Facilities with holding tanks may use water conservation techniques to avoid overflow of the tank. The holding tank is pumped by a tanker truck approximately every 2 weeks to a month, or sooner, depending on sewer use and tank capacity (Scherer 2021). This timeframe governs the amount of time the facility can function before access to the holding tank is required. Traditional holding tanks do not require electrical power to operate;

however, if the wastewater disposal piping is discharged via a pump, backup power would be needed in the event of an electrical outage.

6.3. Sewer Lift Stations

Electrical outages will cause loss of function of lift station pumps. Accumulation of sewage in lift stations that lose pumping capabilities can result in overtopping of the lift station if the lift station does not have sufficient capacity. It can also allow sewage levels to rise in wastewater collection systems. Consequently, providing permanent backup power at lift stations without sufficient retention capacity to contain sewage in the event of a power outage is a best practice. Lift stations with adequate retention capacity may be equipped with a quick disconnect to affix a portable generator for temporary backup power following an event.

Failures Due to Backflow

Stormwater and sewer failures can have disastrous consequences outside of loss of wastewater service. Backflow from sanitary sewers and stormwater conveyance systems can cause significant damage to building interiors. During Hurricane Ian, an assisted living community in Orlando, FL, experienced flooding due to the failure of a nearby lift station. This water intrusion from the lift station failure contributed to the flooding of the facility and caused the evacuation of all 122 residents.

To prevent raw sewage from flowing into a building, some type of check valve or backflow preventer (**Figure 6**) can often be installed to prevent floodwaters from pressurizing the system and entering the building. To mitigate the potential pressurization in the sanitary sewer system from floodwaters, an ejector pump can be installed to force the raw sewage past the backflow prevention device.

Figure 6: Example Backflow Preventor for sewer lateral

For more information, refer to FEMA P-2022, *Hurricane Harvey in Texas Mitigation Assessment Team Report* (2019b) and Hurricane Harvey in Texas Recovery Advisory 1, *Dry Floodproofing: Planning and Design Considerations* (FEMA 2019b).

6.4. On-Site Wastewater Treatment Systems

On-site wastewater treatment systems are an alternative for facilities served by municipal utilities or other wastewater service providers. On-site systems typically include septic tanks, in which solids and liquids collect, and methods to dispose of the liquid effluent that flows beyond the septic tanks. Effluent disposal can range from discharging effluent to drainage fields, often called leach fields, where effluent slowly drains/leaches into the soils below, to packaged treatment systems that provide secondary treatment that reduces organic materials in the effluent or tertiary treatment that removes harmful contaminants from wastewater. Packaged plants can also disinfect wastewater.

Packaged wastewater treatment plants should be provided with on-site standby power systems or the ability to connect portable generators for critical facilities that must remain operational when utility power is lost. For smaller critical facilities, with low daily water-usage rates, septic systems with drainage fields can be a viable alternative. When drainage fields are at higher elevations than the septic tanks, pumps are needed to pump effluent from the tanks to the drain fields and those pumps should include provisions for connecting standby power.

Reducing Wastewater Discharge

Because septic systems have a finite capacity, reducing the load to the system may be warranted. The wastewater discharge load may be reduced in several ways:

- Separation: Separating stormwater, blackwater, and graywater. As previously mentioned, stormwater may be discharged without treatment. Blackwater and graywater may be reused or recycled in different ways after treatment.
- Wastewater reuse: Collecting and treating wastewater for other uses, such as recycling graywater, originally used for example in handwashing, for toilet flushing.
- Wastewater recycling: Collecting and treating wastewater for reuse for the same function, such as recycling toilet water, where the toilet water is treated and reused, for toilet flushing (EPA 2002).

Numerous alternative on-site wastewater treatment systems are available that either enhance or replace waste disposal systems. Filtrations systems can either replace a septic tank or be installed downstream of a septic tank. These systems use sand, peat, or a synthetic or artificial material to filter and treat effluent, much in the same way as typical municipal wastewater treatment systems (Scherer 2021). Other package systems utilize aerobic reactors, which use microorganisms and oxygen, pumped into the wastewater, to treat the water. After the water passes through the reactor and solids have been removed, sodium hypochlorite is often added to disinfect the water before discharge.

When determining whether an on-site wastewater treatment system is the right solution, or which on-site wastewater treatments system is the right solution, consider the following:

- The system must be designed for the characteristics of the wastewater produced by the facility (i.e., daily volumes, rates of flow, pollutant load). This is most notable for nonresidential structures where wastewater produced by the facility may be highly variable and dependent on the facility type. Depending on the wastewater composition, advanced treatment or accommodation for elevated organic loads may need to be considered (EPA 2002).
- When locating the on-site wastewater treatment system, the site must have sufficient space for the required treatment system. This may limit the type of system that can be used. Caution should be taken in siting the system so it does not interfere with other on-site utilities, such as drinking wells (Scherer 2021).
- Similar to holding tanks, septic systems do not require electrical power to function unless a pump is used. However, alternative on-site wastewater systems almost always require electrical power to function. On-site standby power systems or provisions to connect portable generators should be installed for critical facilities whose waste disposal systems require power to operate for those facilities that must remain functional when utility power is lost.
- Operations and maintenance are critical for the success of the system. Routine maintenance will extend the lifespan of the system. However, negligence of routine maintenance may lead to malfunctioning of the system, clogging of pipes and drain fields, nuisance odors, public health issues, and contamination of surface water and/or groundwater.

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