Reducing Flood Effects in Critical Facilities

FEMA

HURRICANE SANDY RECOVERY ADVISORY *RA2, April 2013*

Purpose and Intended Audience

In the hours and days after Hurricane Sandy struck, damage to essential equipment, including mechanical, electrical, and plumbing systems prevented many critical facilities in New York and New Jersey from serving their communities when those communities needed them most. In numerous instances, critical facilities could not function because essential equipment was placed in basements, sub-basements, or ground floor levels that flooded. In some cases, components of essential systems were elevated well above the floodwaters, while other critical system elements (transformers, transfer switches, fuel tanks, pumps, etc.) were placed at lower levels and therefore were vulnerable to flooding. When those vulnerable critical elements failed, the systems were rendered inoperative and the functionality of the critical facilities suffered as a result.

This Recovery Advisory provides information and recommendations to improve the functionality of critical facilities by reducing the vulnerability of essential systems and equipment to flooding. Critical facilities include hospitals and other health care facilities; fire and police stations; emergency operations centers; communication and data centers; essential government buildings; and other critical facilities and their contents, machinery, and equipment therein, that serve the community or affect the safety, health, or welfare of the surrounding population. In some cases, the community may determine that wastewater treatment plants, water treatment plants, electrical substations, transportation facilities, and buildings such as schools or community centers are critical or essential for their community. In these situations, the recommendations in this advisory should be applied to those buildings. This Recovery Advisory describes how essential equipment must be protected from flooding to allow a critical facility to perform its primary function during and after a flood event. To accomplish this, facility owners and operators should work with a design professional, emergency manager, and their facility manager to help identify vulnerabilities in essential facility systems and equipment using a holistic approach well in advance of an event so that identified vulnerabilities can be reduced.

> For more information on category classification requirements, see Occupancy Category Table 1-1 ASCE 7-05 and Risk Category Table 1.5-1 in ASCE 7-10 as well as the guidance in FEMA 543; *Design Guide for Improving Critical Facility Safety from Flooding and High Winds*, January 2007. Note: ASCE 7-05 and ASCE 7-10 have differences in category classifications; also, check for any modifications made by your State or local jurisdictions.

The information in this Recovery Advisory is most useful for new construction, although the same concepts can be applied to retrofits of existing construction. Although the focus of this advisory is on critical facilities, many of the recommendations can also be applied to other types of facilities. The intended audience for this Recovery Advisory includes facility owners and operators and other individuals involved in making decisions for critical facilities. If reconstructing a critical facility, FEMA recommends relocating the facility outside of the floodplain in addition to applying the other mitigation options described in this advisory.

Key Issues:

1. Major components of essential systems and equipment are frequently placed on the lowest floors or subgrade (basement) levels potentially well below the base flood elevation (BFE). Equipment located on lower floors and basements is often vulnerable to flood damage even when the building is located outside of mapped Special Flood Hazard Areas (SFHA) or is above the BFE.

2. Although critical facility managers typically understand which systems and equipment are essential to the functionality of their facility, they may not have a complete understanding of all the different system components and the vulnerabilities to flooding that may be present in their facility.

This Recovery Advisory Addresses:

- The importance of maintaining critical facility functionality for community resilience
- Protecting components of essential systems and equipment
- Code requirements and FEMA recommendations
- Mitigation measures to help protect essential systems and equipment
- Design considerations for protecting essential systems and equipment
- Vulnerability assessments
- Conclusions and recommendations

Definitions

Special Flood Hazard Area (SFHA): Land areas subject to a 1 percent or greater chance of flooding in any given year. These areas are indicated on Flood Insurance Rate Maps (FIRMs) as Zone AE, A1-A30, A99, AR, AO, AH, V, VO, VE, or V1-30.

Base Flood Elevation (BFE): Elevation of flooding, including wave height, having a 1 percent or greater chance of being equaled or exceeded in any given year.

Design Flood Elevation (DFE): Regulatory flood elevation adopted by a local community. If a community regulates to minimum NFIP requirements, the DFE is identical to the BFE. Typically, the DFE is the BFE plus any freeboard adopted by the community.

Importance of Maintaining Critical Facility Functionality to Community Resilience

The services and functions provided by critical facilities are essential to a community, especially during and after a disaster. For a critical facility to function, it must be supplied with essential utilities (typically power, water, waste disposal, and communications, but occasionally also natural gas and steam). Furthermore, building systems and equipment needed for the facility to function must remain operational.

Any interruption to essential utilities or damage to essential systems and equipment can jeopardize the ability of the critical facility to function. The loss of municipal utilities prevented some critical facilities from functioning during and immediately after Hurricane Sandy and in some cases, loss of municipal water and waste disposal prevented facilities from being able to operate weeks after the event. However, damage to essential systems and equipment within those facilities had a much greater impact on their ability to function than loss of utilities.

To prevent interruptions in critical services, it is important for facility operators to identify and mitigate vulnerabilities in utilities, essential systems, and essential equipment. Mitigation can reduce vulnerabilities in one of two ways: (1) ***improve equipment to reduce risk*** or (2) ***establish redundancies***. Elevating equipment is an example of improving equipment to reduce risk, and providing alternate methods of supplying critical services is an example of redundancy. Redundancies can either be internal or external. For example, redundant patient care can be provided using alternative sites within a facility (internal redundancy) or establishing memorandums of understanding with other facilities to provide services when a critical facility is unable to do so (external redundancy). Creating redundancies requires emergency planning and explicit documentation in a disaster plan based on a comprehensive understanding of system capacity.

Disaster Plans

Traditional disaster plans often center on how a facility will mitigate a single event. The events of Hurricane Sandy illustrate the importance of expanding disaster planning to account for simultaneous events like flooding and loss of power.

Protecting Components of Essential Systems and Equipment

For a critical facility to function during and after a flood event, essential utility systems and essential equipment within the facility must be protected from flooding. ***Electrical systems*** are needed for lighting, life-safety equipment (emergency evacuation, recovery, and response equipment), fire alarms and fire pumps, elevators, and mechanical systems. ***Mechanical systems*** are needed to provide heating, ventilation, and air conditioning (HVAC); distribute hot and cold potable water; discharge waste; and control groundwater and floodwater infiltration. ***Essential equipment*** is any equipment required for the facility to serve its critical function. The following may be considered essential, depending on the specific services offered by the facility:

- Electrical systems (e.g., primary/utility power, power from emergency generators, communications, information technology [IT] equipment, switchgear, and transformers)
- Mechanical systems (domestic water, sanitary sewer, sump pumps, drainage systems, and HVAC equipment)
- Conveyance systems (elevators and escalators)
- Fuel systems (fuel pumps, lines, and tanks)
- Data systems (IT servers, networks, and wiring)
- Communication systems (land-based phone, cellular communication, radio transmitters, and receivers)
- Specialized equipment (medical diagnostic equipment, oxygen, nitrous oxide, medical air systems, critical equipment that is costly or is difficult to replace)
- Life-safety equipment (fire alarm systems, fire pumps, and smoke control systems)

Facility operators and owners should consider not only the essential systems and equipment, but also all ancillary elements required for each system to function. For example, for an HVAC system to function, individual pieces of HVAC equipment must be protected from damage and all supplies to that equipment (like hot water from boilers, chilled water from chillers, and power from the electrical system) must be also protected.

Major components of essential systems and equipment are often placed on the lowest floors or subgrade (basement) levels in buildings (Figures 1 and 2). In some cases, equipment is installed on lower floors because of physical requirements or policy mandates.

Figure 1: Hospital fuel oil pump (red circle) was flooded, resulting in failure of the emergency generator (Manhattan, NY)

Figure 2: Unelevated fuel pumps and controls were flooded when floodwater reached the high water mark shown by the red line, causing the emergency power generator to fail (top). New pumps, located on the back side of the unit, were installed but not elevated to reduce venerability to flooding (bottom). (Long Beach, NY)

For example, the main storage tanks that supply fuel oil to buildings are often required to be placed on the lowest floor to reduce fire hazards. Another example is when large, heavy components of mechanical and electrical equipment are placed at low elevations to facilitate maintenance and replacement. More often, mechanical and electrical equipment is placed on the lowest floor because the upper floors are more valuable for other uses.

Equipment located on lower floors is more vulnerable to flood damage, particularly when the facility is located in or near a mapped SFHA. Critical facility owners should be aware that essential utility systems and equipment installed below grade can be vulnerable to flooding even when the building is outside of the SFHA. Properties outside of high-risk flood areas account for over 20 percent of NFIP claims and one-third of disaster assistance for flooding.[1] People often mistakenly believe a building located outside of a mapped flood hazard area has no risk of flooding. Hurricane Sandy demonstrated the fallacy of this assumption. Many of the buildings damaged or destroyed by flooding, including numerous critical facilities, were located outside the SFHA. Figure 3 shows a fire station that was outside the SFHA, but was still inundated with 2.3 feet of floodwater. Incorrect conclusions about flood risk can lead to design decisions similar to those that made facilities vulnerable to the extraordinary flooding during Sandy in 2012. Actions taken now can help to reduce damage from future flood events.

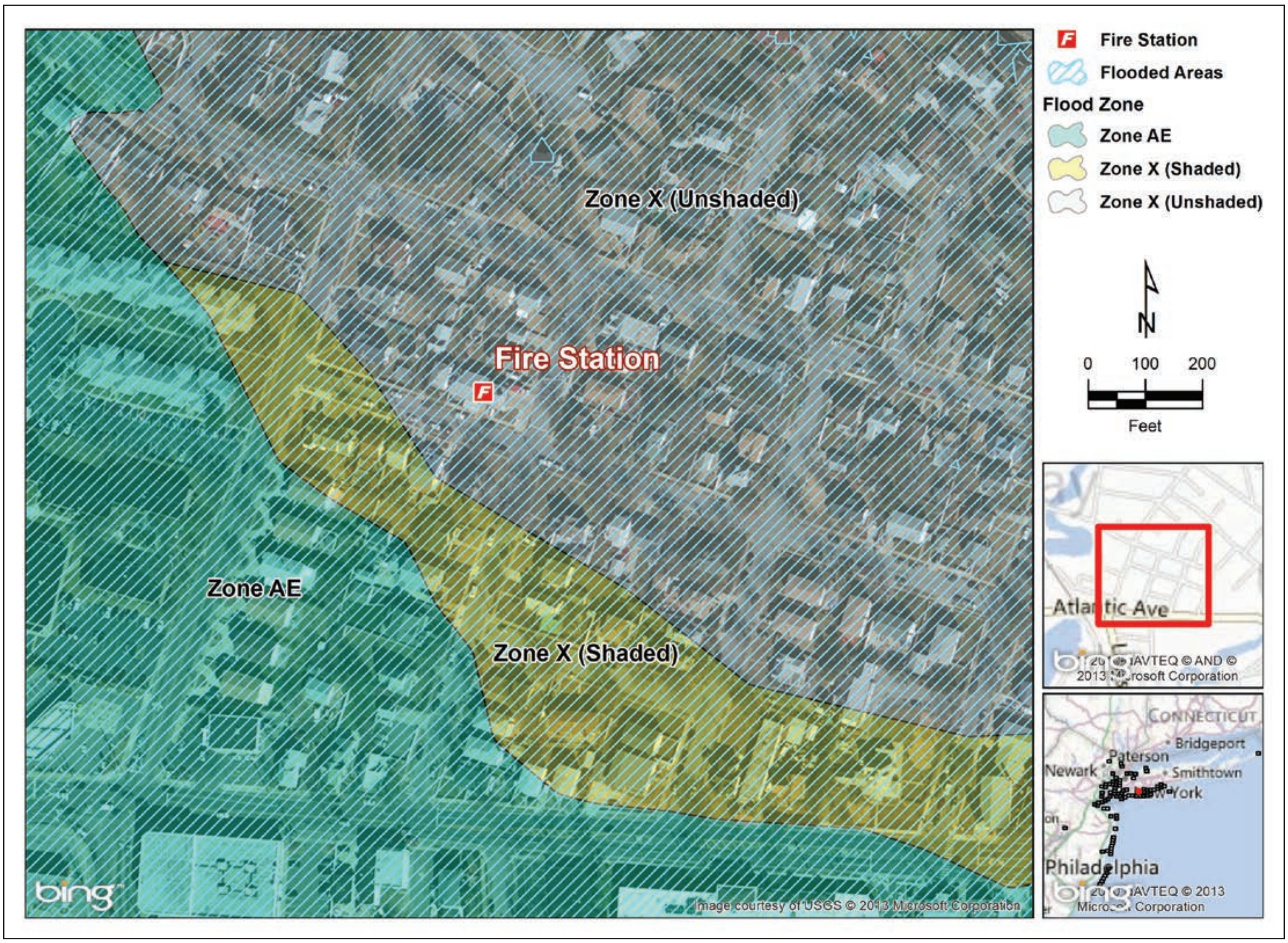

Figure 3. Map showing flood extent of Hurricane Sandy and effective flood zones. The fire station was not located in an SFHA (Zone AE shown on map), but was inundated with 2.3 feet of floodwater.

1 http://www.fema.gov/pdf/media/factsheets/2011/mit_natl_flood_ins.pdf

Assessing Flood Risks for Locations Outside of SFHAs

Areas outside SFHAs may still be subject to flooding, so a facility may be vulnerable to flooding even when it is located outside of an SFHA. This is particularly true for facilties with below-grade floors. To assess flood risk, facility owners should:

- Examine the FIRM to determine if the facility is located in a shaded Zone X area. The area shown on a FIRM as shaded Zone X is bounded by areas at risk for inundation during a 1-percent- and the 0.2-percent-annual-chance flood event (100-year and 500-year event, respectively). If within a shaded Zone X, compare the critical equipment elevation with the 100-year and 500-year flood elevations.
- Investigate historic flooding. Records of actual flooding can augment studies that predict flooding, especially if historic events caused deep or widespread flooding. Information may be available from local planning, emergency management, and public works agencies; State agencies; the U.S. Army Corps of Engineers; or the U.S. Natural Resources Conservation Service. The most extreme flood, called the flood of record, is typically a lower probability event than the 100-year flood.
- Determine if the facility is located near a body of water (with or without a mapped flood hazard area). All bodies of water are subject to flooding, but not all have been designated as SFHA on FIRMs. It is important to note that FIRMs are only as accurate as the topography, bathymetry, and technical information used, and the technical analyses performed, to create them. While generally accurate when created, FIRMs become less accurate as physical conditions change.

Additional information can be obtained from the NFIP Floodsmart Web site at http://www.floodsmart.gov.

Code Requirements and FEMA Recommendations

New construction must adhere to adopted State and local code requirements; modification or repair to existing structures may also be required to adhere to code requirements as determined by local building officials. The building code requirements for new construction can be met by elevating equipment or installing dry floodproofing to protect equipment (refer to next section for discussion of mitigation measures).

Many of the flood provisions required by building codes are contained in American Society of Civil Engineers (ASCE) 24, *Flood Resistant Design and Construction*. ASCE 24 is referenced by the International Building Code (IBC) for construction in SFHAs and applies to all areas where the IBC has been adopted without local modifications. Table 1 lists the elevation and floodproofing protection requirements specified by ASCE 24 for Category Type IV Structures.

Table 1.
Required Elevation or Floodproofing Level for Utility Systems and Attendant Equipment for ASCE 24 Category Type IV Structures

Location	Required Elevation	Required Floodproofing
Zone A	BFE + 2 feet, or DFE, whichever is higher*	BFE + 2 feet, or DFE, whichever is higher*
Zone V and Coastal A Zone, where orientation is parallel to waves	BFE + 2 feet, or DFE, whichever is higher*	Floodproofing not allowed per ASCE 24-05 Section 6.2.1
Zone V and Coastal A Zone, where orientation is perpendicular to waves	BFE + 3 feet, or DFE, whichever is higher*	Floodproofing not allowed per ASCE 24-05 Section 6.2.1

Source: Adapted from ASCE 24-05 Tables 6-1 and 7-1

Note: ASCE 24 Structure Category Type IV Structures include hospitals, fire and police stations, and emergency operations centers

BFE = base flood elevation; DFE = design flood elevation

* In the upcoming edition of ASCE 24, it is anticipated that buildings in Category IV will be required to be elevated to the BFE + specified freeboard, or DFE, or 500-year elevation, whichever is greater.

As a best practice, FEMA recommends protection that exceeds code minimums. For example, FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds* (2007) recommends protecting critical facilities to withstand at least a 0.2-percent-annual-chance flood event (often called the "500-year flood event"). Flood elevations for the 0.2-percent-annual-chance flood may be greater than the elevation specified by ASCE 24. If federal funding or other Federal action is involved, the requirements of Executive Order 11988 – *Floodplain Management* may necessitate protection of critical actions to the 500-year flood elevation (critical actions may include the construction and repair of critical facilities).

In existing facilities that have not been substantially damaged, it may not be possible to floodproof or elevate to provide protection from the 0.2-percent-annual-chance flood event. In those instances, floodproofing or elevating as high as practical is recommended.

Mitigation Measures to Help Protect Essential Utilities and Equipment

This Recovery Advisory describes two techniques for reducing flood damage to essential utility systems and equipment: elevating and dry floodproofing utility systems and equipment.

Elevating Equipment

The most effective mitigation method is to elevate all essential equipment above the highest anticipated flood elevation as shown in Table 1 or the elevation of the 0.2-percent-annual-chance flood recommended by FEMA, whichever is higher. When essential equipment is located below grade, elevating typically requires relocating the equipment to higher floors in the building. Unless space is already available, moving the equipment to a higher floor will displace other equipment, tenants, or functions. Building owners may need to evaluate all available space, including the attic and second floor, to determine whether a small elevated addition would be an acceptable solution. When elevating equipment is not practical, dry floodproofing may be an option.

Dry Floodproofing

Essential equipment can be protected with dry floodproofing methods. Dry floodproofing involves constructing flood barriers or shields around individual pieces of equipment or areas that contain essential equipment to prevent floodwaters from coming into contact with critical equipment. For dry floodproofing to be effective, the barrier must be high enough to protect equipment from floodwater, strong enough to resist flood forces, and sealed well enough to control leakage and infiltration. Dry floodproofing measures must also satisfy applicable codes and standards. For example, a dry floodproofed room created to protect a fuel tank will need mechanical ventilation to meet code requirements. Additional information is described in Hurricane Sandy Recovery Advisory No. 4, *Reducing Building Interruptions to Mid- and High-Rise Buildings During Floods* (2013).

Protection from floodwater. Dry floodproofing should meet ASCE 24 criteria in all locations, but in areas where ASCE 24 is adopted, dry floodproofing ***must*** meet them. To meet those requirements, any barrier installed to protect equipment must provide protection to the elevations shown in Table 1. FEMA 543 recommends protecting critical equipment to withstand at least the 0.2-percent-annual-chance flood elevation, which may exceed ASCE 24 requirements.

Protection from flood forces. Areas and equipment protected by dry floodproofing must be designed to resist hydrostatic forces that will exist when fully inundated with floodwater. Inundation creates both ***flood pressures*** and ***buoyant forces*** and successful dry floodproofing must be designed to resist both. Flood pressures can crush submerged equipment and must be resisted by making submerged equipment strong enough to prevent crushing. Crushing pressures depend on the depth of flooding—the deeper the flooding, the greater the pressure. Every foot of flood depth creates a crushing pressure of 62 psf (freshwater) or 64 psf (saltwater). Buoyant forces can dislodge submerged equipment and must be resisted by making the equipment heavy enough or anchored enough to resist the buoyancy force. Buoyant forces do not depend on flood depth but depend instead on the weight of the water displaced by the submerged equipment.

Crushing pressures and buoyant forces can be extreme. The two buildings shown in Figure 4 illustrate these effects. Building A has a fuel tank in a basement room located 10 feet, or one level, below grade. Building B has a fuel tank in a sub-basement room located 30 feet, or three levels, below grade. Both buildings are

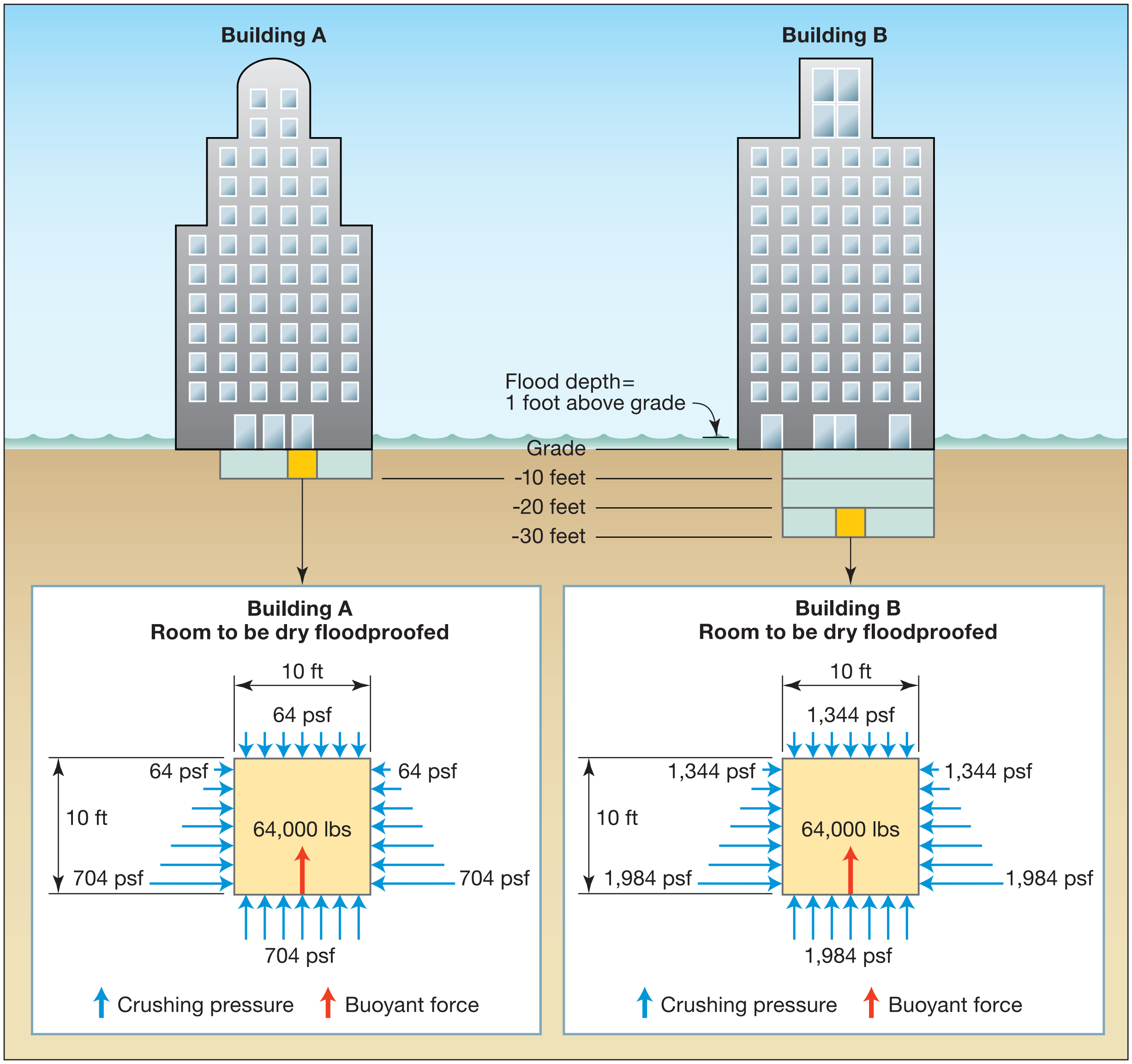

Figure 4. Crushing pressures and buoyancy forces that result when a 10 foot by 10 foot by 10 foot sub-grade dry floodproofed room is inundated with floodwater

located on sites inundated with 1 foot of floodwater, both buildings contain vents at grade level that allow floodwater to fill below-grade areas, and both have fuel tanks in rooms that have been sealed to prevent the entrance of floodwater. Crushing pressures can be calculated as follows:

- *Building A:* The top of the walls and the ceiling of the tank room would be exposed to 1 foot of flooding with a resulting crushing pressure of 64 psf. The base of the walls and floor of the tank room in Building A, however, would be exposed to 11 feet of floodwater with a resulting crushing pressure of 704 psf (11 feet times 64 psf/foot).
- *Building B:* The tank in Building B would be exposed to much deeper floodwaters and much greater crushing pressures than the room in Building A. The top of the walls and the tank room ceiling would be exposed to 21 feet of floodwater (two 10-foot levels plus 1 foot of flooding above grade) with a resulting crushing pressure of 1,344 psf. The base of the walls and the tank room floor would be exposed to 31 feet of floodwater with a resulting crushing pressure of nearly 2,000 psf (31 feet times 64 psf/foot).

The buoyant force experienced by the dry floodproofed room in both Building A and Building B would be the same since the force does not depend on flood depth but instead equals the weight of the displaced water. Both rooms would be subject to a buoyant force of 64,000 pounds (area of 10 cubic feet, subjected to saltwater weight of 64 pounds per cubic foot).

Protection from leakage and infiltration. Few dry floodproofing measures are completely watertight and some leakage and infiltration should be anticipated. Leakage can occur between joints and seams in flood barriers and infiltration can seep through penetrations in the barrier. Even small amounts of leakage or infiltration will eventually cause flooding in protected areas, so provisions to pump water out of dry floodproofed areas are mandatory. Since flooding often disrupts primary electrical power, emergency power should be provided for all pumping equipment serving dry floodproofed areas. To be effective, the entire emergency power system, including its fuel supply, must be protected from flooding.

Design Considerations for Protecting Essential Systems and Equipment

For effective mitigation, ***all*** essential equipment necessary for a critical facility to function should be protected. Mechanical and electrical systems are heavily interconnected, and damage of an individual component will often render the entire system inoperable unless the damaged component can be isolated from the remainder of the system and the system can function without the damaged component. Mitigation measures should be considered even in areas outside of the SFHA, as damaging flooding can still occur in these areas.

Electrical Service and Distribution Systems

Essential electrical systems should be located above flood levels or protected from floodwaters by dry floodproofing to prevent power interruptions during flooding events. Elements of the electrical service and distribution system that should be protected include primary supply lines of the utility company and the transformers they serve, the facility's main electrical service equipment, downstream feeders, and distribution panels. Where possible, the electrical service and distribution equipment should be located on elevated floors, and power should be distributed downward from an elevated floor to serve lower floors. If equipment must remain below the DFE, electrical power can still be supplied to vulnerable equipment provided that: 1) the equipment is fed from designated circuits or feeders that supply no essential equipment; 2) those circuits or feeders can be isolated from the main electrical system; and 3) the loss of the vulnerable equipment does not prevent the facility from functioning or performing its primary service.

Data Systems

The main servers, switches, and network hubs for telephone, data, and communication systems should be installed above flood levels to remain functional. Where communication and data wiring serves areas vulnerable to flooding, flood risks can be minimized by judicious routing of the wiring and placement of outlets. When routing and outlet placement still leave portions of the systems vulnerable to flooding, the vulnerable portions should be able to be readily isolated from the rest of the system. Similarly, power wiring supplying telephone, communication, and data equipment should be installed and routed above flood levels.

Heating, Ventilation, and Air Conditioning Systems

Essential components of HVAC systems should be located above flood levels. Components include boilers, chillers, cooling towers (when water-cooled chillers are used), pumps for circulating heating and chilled water, and associated system controls. Water piping may be routed through vulnerable areas, but the amount of piping exposed to floodwaters should be minimized to reduce cleaning and insulation replacement that will be required after a flood event. Air handling units that serve areas vulnerable to floodwaters should be separate from other portions of the HVAC system to prevent contaminated air from flood-damaged units from migrating to other portions of the building. Units should be installed to facilitate replacement after floodwaters recede.

Water/Wastewater Systems

Domestic water heaters, domestic water booster pumps, and hot water circulating pumps and system controls should be placed above anticipated flood levels. Pressurized piping can be installed in areas vulnerable to flooding, but the amount of piping exposed to floodwaters should be minimized to facilitate cleanup.

If components such as sump pumps, lift pumps, or macerator pumps that discharge effluent must be installed in areas vulnerable to flooding, the components and associated controls should be designed for submersible use.

Emergency Power Systems

Many of the recommendations provided for electrical service and distribution systems apply to emergency power systems. Care should be taken to evaluate each component to ensure the emergency power system will perform during a flood event. Generators, transfer switches (that send power to critical equipment from either the normal power system or the emergency system), pumps for fuel delivery from fuel tanks, electronic controls, and wiring should be located above flood levels whenever possible (Figures 5 and 6).

Flood risks should also be considered when selecting and placing fuel tanks and fuel pumping equipment. Where possible, all portions of the fuel delivery system should be placed above flood levels. If fuel system components (such as main fuel storage tanks and pumps) must remain in areas vulnerable to flooding, the components should be designed for submersible use. Fuel tanks should be designed to withstand the external forces from the weight of the water above and around the tank, anchored to prevent damage from buoyancy, and designed so the fuel tank vents extend above the anticipated flood levels. Designer calculations should assume the fuel tanks are empty. Fuel supply lines required to extend below DFE should be sealed to prevent infiltration of floodwater.

Most critical facilities cannot operate without utility power even for short periods of time. Model building codes are focused on protecting occupants against fire and require only enough emergency power to allow occupants to safely leave a building during a fire. Although the specific needs vary somewhat depending on occupancy and building height, emergency power is typically required to illuminate egress routes and energize exit signs and life safety equipment for 90 minutes after loss of normal power. Code-required emergency power can generally be supplied by stored energy devices such as batteries. For critical facilities that must remain functional during prolonged power outages, on-site power generation is needed.

Figure 5: Emergency generator in a ground-level mechanical room that was inundated by 18–20 inches of water during Hurricane Sandy flooding. The generator was able to continue functioning because it was elevated approximately 20 inches (Ship Bottom, NJ).

Figure 6: Emergency generator in a basement that was completely inundated during flooding from Hurricane Sandy (Long Beach, NY)

Elevators

Even when not part of the code-required egress routes, elevators are essential for many critical facilities to function. During Hurricane Sandy, many facilities were unable to function because of the loss of their elevators. Like many other critical systems, their vulnerability to flood damage can be reduced by elevating components above the flood level or by using flood-resistant materials for components that must be located in areas exposed to floodwaters. Also, adding controls that prevent elevator cabs from descending into floodwaters can significantly reduce flood damage and long-term loss of function. FEMA's Technical Bulletin TB-4, *Elevator Installation for Buildings Located in Special Flood Hazard Areas in Accordance with the NFIP* (November 2010), contains additional recommendations on elevators and their installation.

Vulnerability Assessments

Unless flood provisions were incorporated into their design, existing critical facilities may be vulnerable to flooding particularly if they are located within or near a SFHA. Flooding can result in damage ranging from minor inconvenience to complete closure of the facility. In some cases, facilities may be closed for several days or possibly weeks. To help facility operators plan for flood events, a vulnerability assessment can be conducted to identify equipment and systems vulnerable to flooding. The assessments are often conducted by a team of architects and engineers working closely with facility managers, operators, and maintenance staff. Findings from such an assessment can lay the groundwork for planning and budgeting capital improvements, identifying mitigation opportunities, and developing contingency plans that address flood risks.

As part of the planning process for new facilities, all possible natural hazards (flood, wind, seismic, and wildfire) should be considered. If the building design does not ensure continuity of operations, contingency plans that address facility disruption should be developed. FEMA's Risk Management Series provides guidance on conducting vulnerability assessments (see Resources and Useful Links).

Conclusions and Recommendations

Flood effects on essential systems and equipment can destroy a facility's ability to function and can prevent the facility from serving its community when it is needed most. Building professionals, building owners, building operators, and key decisionmakers should seek information for implementing a variety of mitigation measures to reduce the vulnerability to damage and disruption of operations during severe flood events. To improve building performance, vulnerability assessments that take a holistic view of critical equipment, critical systems, and critical functions should be completed to identify vulnerabilities and identify possible hazard mitigation measures. Those mitigation measures should be incorporated whenever damaged facilities are repaired or reconstructed. By building or creating robust critical facilities that remain operational during and after a major disaster, people's lives and the community's vitality can be better preserved and protected.

Resources and Useful Links

- American Society of Civil Engineers (ASCE). 2010. *Minimum Design Loads of Buildings and Other Structures.* ASCE Standard ASCE 7-10.
- ASCE. 2005. *Minimum Design Loads of Buildings and Other Structures.* ASCE Standard ASCE 7-05.

Risk Management Series: Publications listed below are available at http://www.fema.gov/mitigation/security-risk-management-series-publications

- FEMA P-424. *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds* (December 2010).
- FEMA 543. *Design Guide for Improving Critical Facility Safety from Flooding and High Winds* (January 2007).
- FEMA 577. *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds* (July 2007).
- FEMA P-936. Unpublished. *Floodproofing Non-Residential Structures* (due to be published in 2013).

The FEMA Region II Web page provides useful information and links for disaster survivors and recovering communities including available FEMA assistance and recovery initiatives. Please refer to http://www.region2coastal.com.

Building Science Publications and Resources: Publications listed below are available at http://www.fema.gov/building-science

- FEMA P-765. *Midwest Floods of 2008 in Iowa and Wisconsin* (October 2009).
- Hurricane Sandy Recovery Advisories and Fact Sheet (2013):
  - RA 1: *Improving Connections in Elevated Coastal Residential Buildings*
  - RA 2: *Reducing Flood Effects in Critical Facilities*
  - RA 3: *Restoring Mechanical, Electrical, and Plumbing Systems in Non-Substantially Damaged Residential Buildings*
  - RA 4: *Reducing Operational Interruptions to Mid- and High-Rise Buildings During Floods*
  - RA 5: *Designing for Flood Levels Above the Base Flood Elevation After Hurricane Sandy*
  - RA 6: *Protecting Building Fuel Supplies from Flood Damage*
  - RA 7: *Reducing Flood Risk and Flood Insurance Premiums for Existing Buildings*
  - Fact Sheet: *Cleaning Flooded Buildings*

For more information, see the FEMA Building Science Frequently Asked Questions website at http://www.fema.gov/frequently-asked-questions.

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