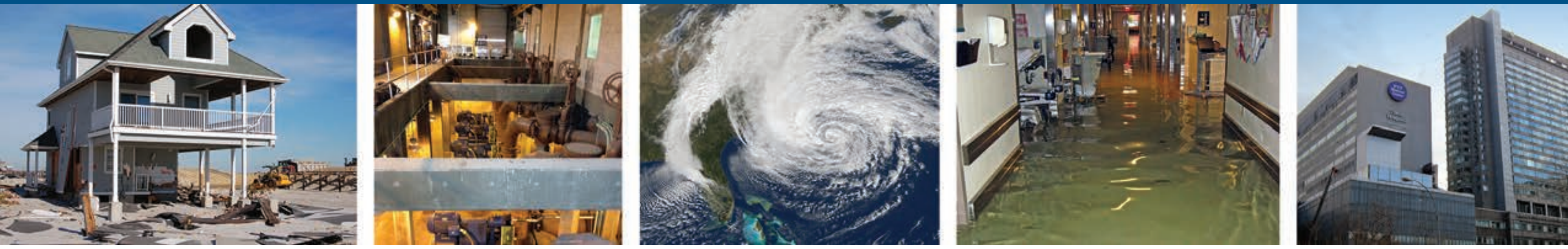

HURRICANE
SANDY
IN NEW JERSEY
AND NEW YORK

7 Conclusions and Recommendations

This chapter presents the MAT's conclusions and recommendations related to their observations of various buildings in the aftermath of Hurricane Sandy.

In contrast to Chapters 2 through 6, the conclusions and recommendations are organized by function rather than structure type. As such, this chapter starts by providing general conclusions and recommendations that are applicable to all facility types, followed by recommendations related to codes and standards, and lastly, building functional aspects: siting, structural, building systems and continuity of operations. Continuity of operations is organized by facility type. The last section provides conclusions and recommendations specific to historic structures.

7.1 Summary of Building Performance

According to preliminary analyses, 53 percent of the areas flooded by Hurricane Sandy in New York City had water levels that exceeded the BFEs (New York City 2013b). Flood effects extended beyond the inland extent of the mapped SFHAs in most communities the MAT visited, and many buildings both inside and outside the SFHAs were heavily damaged or destroyed by floodwater. In contrast, there was minimal wind damage from Hurricane Sandy. Although Hurricane Sandy's pressure at landfall was typical of a Category 3 hurricane, the observed wind speed was on the lower end of Category 1 hurricane intensity, per the Saffir-Simpson Hurricane Wind Scale.[1]

In New Jersey, the storm surge inundated barrier islands, forced its way into back bay areas, and drove sea water up into Newark Bay, the Passaic and Hackensack Rivers, Kill Van Kull, and Arthur Kill (NHC 2013b).

Areas in New York State experienced higher than expected storm surge that pushed up the Hudson River and caused flooding as far north as Albany. In New York City, a storm tide (the combination of the storm surge and astronomical tide) of over 14 feet above the Mean Lower Low Water was measured at the Battery Park, breaking the previous record of 10 feet that was set when Hurricane Donna hit New York in 1960 (New York City 2013b). In Queens and Brooklyn, the area flooded by Sandy was almost twice as large as the floodplain area on FEMA's Effective FIRMs. Long Island flooded 3 to 6 feet above ground level along the Atlantic Coast, with a HWM of 4.6 feet above ground level recorded at Freeport and a storm surge elevation of 5.6 feet above normal tide levels recorded by a gauge in Montauk (NHC 2013b). See Appendix D for examples of inundation levels observed in New Jersey and New York.

Inundation of building systems was the most prevalent form of building damage from Hurricane Sandy. This damage was observed primarily in buildings with unprotected systems located below the Sandy flood levels, especially in subgrade enclosures. Floodwater rendered building systems inoperable, which slowed recovery considerably. Other types of damage varied by building type.

Low-Rise Buildings. Inundation of basements in low-rise buildings caused system damage as well as isolated basement wall failures in some buildings. Recently constructed low-rise buildings generally suffered less flood damage because they complied with modern building codes and floodplain ordinances. The MAT observed both new and older construction that lacked adequate load path connections to resist simultaneous uplift from flood sources and lateral forces from wind.

Mid- and High-Rise Buildings. The majority of mid- and high-rise buildings suffered no structural damage from floodwater inundation. When equipment was located on the upper floors of the structure, building systems incurred no damage.

Healthcare Facilities. Healthcare facilities were mainly affected by disrupted functionality of building systems, including emergency power systems with components located below grade. Interruption of elevator service limited the ability to transport patients between floors, while loss of communications undermined the ability to coordinate transportation to and from the facilities.

BUILDING SYSTEMS

Building systems include components such as the MEP systems, gas installations, communications systems, and fire suppression systems.

1 http://www.nhc.noaa.gov/aboutsshws.php.

Other Critical Facilities. Damage to first responder facilities and schools was primarily to building systems and not structural. Facilities outside the areas flooded by Sandy or that had equipment elevated above flood levels were successful at maintaining continuity of operations after Sandy.

Damage to other facilities visited by the MAT (data centers, WWTPs, transportation facilities, and gas stations) was commensurate with that of similar building types. Damage to building systems was the primary effect of the flooding:

- Both data centers the MAT visited were in high-rise buildings with building systems located in basements. Failure of the building systems caused significant disruption to service.

- WWTPs were shut down when building systems and emergency power equipment located in subgrade areas and tunnels below the plants were flooded and damaged. WWTPs were closed for days to weeks while the facilities were drained and building systems were cleaned, repaired, or replaced.

- Transportation facilities, mainly transit facilities, most were below ground, and were inundated by floodwater and had varying degrees of damage to facility building systems. Facilities with emergency power systems located above flood elevations were operable shortly after the event, but those with flood-damaged systems required extensive repairs before they were operational again.

Historic Structures. Damage to historic structures was largely a function of their location and whether or not the buildings had subgrade or basement areas. Damage to historic structures was similar to that observed for other building types. Isolated wind damage was observed in historic buildings.

7.2 General Conclusions and Recommendations

Conclusion 1. Vulnerability Assessment: The quality of planning and preparedness for Hurricane Sandy at the many buildings visited by the MAT varied greatly. This variance of planning may have been due to the information sources used to identify the risks, as well as local government recommendations about whether to close the facilities during the flood event. Many building managers and owners may not have been aware of their risks from a severe flood event.

> ***Recommendation 1a. Perform vulnerability assessments:*** Facility owners should have vulnerability assessments conducted by a team of knowledgeable professionals to help determine options available to mitigate hazards and risks for high-rise and mid-rise buildings, critical facilities and key assets, and other structures that may be heavily impacted by a flooding event. Facility owners and operators should work with key internal staff and design professionals to analyze their facilities, key systems and components, operational assumptions, and operations plans to determine a path forward for developing project priorities and funding capital improvements that maximize facility and operational resiliency. See Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the BFE After Hurricane Sandy* (FEMA 2013e) for selecting the appropriate flood elevation for design.

Recommendation 1b. Perform vulnerability assessments for all critical facilities: The vulnerability assessments conducted for facility owners and operators (Federal, State, and local governments and the private sector) should identify all critical and essential facilities that are subject to flooding and recommend mitigation goals that address current building code compliance, local floodplain ordinances, preparedness and mitigation, continuity of operation, and measures to minimize damage and recovery efforts. Further guidance can be found in FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds* (FEMA 2007b) and FEMA 577, *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and Winds* (FEMA 2007c).

7.3 Codes and Standards

This section presents conclusions and recommendations based on the MAT review of floodplain management and building code programs and regulations in the State of New Jersey, New York State, and New York City that are summarized in Appendix G. It also presents conclusions and recommendations based on the MAT review of guidelines and a standard pertaining to healthcare facilities, which are summarized in Appendix F, Section F.5.

7.3.1 New Jersey

Conclusion 2. Flood Hazard Area Control Act: In January 2013, the NJDEP issued emergency amendments and concurrent proposed amendments to the Flood Hazard Area Control Act Rules. The emergency rules were adopted in May 2013 without change. The rules contain a number of requirements specific to the design and construction of buildings that are inconsistent with minimum requirements of the NFIP and inconsistent with the flood provisions of the New Jersey UCC. For background, see Appendix G, Section G.1.1.

Recommendation 2. NJDEP, NJDCA, and FEMA should coordinate review: The NJDEP, in coordination with the NJDCA and FEMA, should review the Flood Hazard Area Control Act rules that apply specifically to buildings and other structures to identify and resolve inconsistencies, except those where the NJDEP is intentionally requiring a higher standard than required by the UCC and NFIP. Instead of establishing requirements for buildings and other structures, the NJDEP rules should refer to the requirements of the UCC.

Conclusion 3. Model Flood Damage Prevention Ordinance: The NJDEP Community Assistance Program Unit provides a model flood damage prevention ordinance that contains complete requirements for regulating development in flood hazard areas, including requirements that are, for the most part, duplicative with the flood provisions of the UCC. Local officials in New Jersey and the regulated public are expected to resolve the differences between three sets of rules: the Flood Hazard Area Control Act rules, the flood provisions of the UCC, and locally adopted flood damage prevention ordinances. For background, see Appendix G, Section G.1.1.

Recommendation 3. NJDEP should evaluate FEMA model floodplain management ordinance: The NJDEP should evaluate the model floodplain management ordinance that is being developed by FEMA that is specifically written to coordinate with building codes and consider its merits related to reducing duplicative and potentially conflicting requirements. Adopting a coordinated ordinance will enhance local enforcement.

Conclusion 4. Code Officials and Continuing Education: Code officials and inspectors are required to be licensed and to maintain qualifications through continuing education. Having flood provisions incorporated into the UCC generates a need for training that specifically addresses those provisions. For background, see Appendix G, Sections G.1.1 and G.1.2.

Recommendation 4. Develop training on flood provisions of New Jersey building code: The NJDCA and NJDEP, in cooperation with FEMA, should develop one or more courses specifically addressing the flood provisions of the NJDEP rules and the UCC. The training should include inspection of SFHA development, with particular attention to the Substantial Improvement and Substantial Damage requirements and how the local floodplain administrator and code enforcement officers work together to fulfill these requirements. This recommendation is similar to one put forth by the Passaic River Basin Flood Advisory Commission's 2011 report to the Governor. Excerpts of the flood provisions of the UCC should be prepared and made available to local floodplain administrators and local code officials.

Conclusion 5. State Review of Buildings in Flood Hazard Areas: The NJDCA performs plan reviews for State-owned buildings and many other buildings, including certain healthcare facilities and public school facilities. Although communities use the "prior approval" process (see Chapter 2, Section 2.1.5 of this report) to coordinate specification of the flood elevation to be enforced in the building code as well as Substantial Damage and Substantial Improvement determinations, NJDCA does not have an equivalent relationship with the NJDEP. For background, see Appendix G, Section G.1.2.

Recommendation 5. Establish formal consultation process: The NJDCA and NJDEP should establish a formal consultation process for identifying flood elevations and flood zones and for making Substantial Damage and Substantial Improvement determinations so that buildings in SFHAs for which the NJDCA performs plan reviews will meet the flood-resistant requirements of the UCC and the NFIP.

Conclusion 6. Building Code Amendments to the New Jersey UCC: The MAT review of the flood provisions of the New Jersey UCC identified a number of opportunities to improve consistency with the NFIP, while also increasing resiliency of construction in flood hazard areas. For background, see Appendix G, Section G.1.3.

Recommendation 6. Amend the UCC: FEMA recommends that the NJDCA amend the UCC to:

- Explicitly link the rehabilitation subcode to the prior approval process under which local floodplain administrators make Substantial Damage and Substantial Improvement determinations

- Specifically refer to local floodplain management regulations where FISs and FIRMs are adopted

- Modify UCC Section R322.3 (coastal high hazard area) to refer to ASCE 24, *Flood Resistant Design and Construction*

7.3.2 New York State

Conclusion 7. Model Local Law for Flood Damage Prevention: The NYSDEC Floodplain Management Section provides a model local law for flood damage prevention that contains complete requirements for regulating development in flood hazard areas, although some requirements use language that differs from the flood provisions in the New York State Uniform Code. Local officials in New York and the regulated public are expected to resolve the differences between the local laws and the flood provisions of the building code. For background, see Appendix G, Section G.2.1.

> ***Recommendation 7. NYSDEC should evaluate FEMA model floodplain management ordinance:*** The NYSDEC should evaluate the model floodplain management ordinance that is being developed by FEMA that is specifically written to coordinate with building codes and consider its merits related to reducing duplicative and potentially conflicting requirements. Adopting a coordinated ordinance will enhance local enforcement.

Conclusion 8. Model Local Law for Administration of the Building Codes: The New York State Uniform Code does not include the administrative chapters of the model I-Codes. The Division of Code Enforcement and Administration (DCEA) promulgates rules for administration and enforcement that are used by all entities that enforce the code. DCEA provides a model local law with provisions for administration of the codes. Currently, neither the rules nor the model local law include administrative provisions for flood hazard areas. For background, see Appendix G, Section G.2.2.

> ***Recommendation 8. Develop optional provisions for model local law:*** The DCEA should, in coordination with NYSDEC, develop optional provisions based on the flood provisions of the I-Codes for inclusion in the model local law for administration and enforcement to facilitate compliance and enforcement of the flood provisions.

Conclusion 9. Site Requirements of the New York State Hospital Code: Hospitals in New York State were heavily damaged by flooding. Some facilities remained inoperative months after the event. Section 711.3, *Site Requirements*, of the New York State Hospital Code authorizes the State Health Commissioner to require specific additional flood-resistant provisions when healthcare facilities are considered for construction in flood hazard areas. Although not specifically stated, those provisions could allow hospitals to continue to function during and after a design flood event. However, the regulations only allow, but do not require, the State Health Commissioner to require the additional specific flood provisions. For background, see Chapter 2, Section 2.4 of this report.

> ***Recommendation 9. Modify the hospital code to make flood provisions mandatory:*** Revise Section 711.3, Site Requirements, of the New York State Hospital Code so that the additional specific flood provisions contained in Section 711.3 are mandatory for all hospitals located in flood hazard areas except those explicitly exempted by the State Health Commissioner.

Conclusion 10. Code Officials and Continuing Education: Local code enforcement officials are required to complete basic training requirements and complete 24 continuing education credits each year. Having flood provisions incorporated into the State building code generates a need for training for code officials that specifically addresses those provisions. For background, see Appendix G, Section G.2.2.

Recommendation 10. Develop training on flood provisions of New York building code: The DCEA and NYSDEC, in cooperation with FEMA, should develop one or more courses specifically addressing the flood provisions of the State building code and inspection of SFHA development. Excerpts of the flood provisions of the building code should be prepared and made available to local floodplain administrators and local code enforcement officials.

Conclusion 11. Technical Bulletin on "Flood Venting": The DCEA 2003 technical bulletin on "flood venting" is out of date and inconsistent with FEMA's guidance in the 2008 edition of FEMA NFIP Technical Bulletin 1, *Openings in Foundation Walls and Walls of Enclosures,* and inconsistent with ASCE 24. For background, see Appendix G, Section G.2.2.

Recommendation 11. Update DCEA technical bulletin on flood venting: The DCEA and NYSDEC should determine whether FEMA's guidance is adequate. If New York-specific guidance is necessary, the DCEA should update its technical bulletin on flood venting.

Conclusion 12. Building Code Amendments to the New York State Uniform Code: The MAT review of the flood provisions of the New York State Uniform Code identified a number of opportunities to improve consistency with the NFIP, while also increasing resiliency of construction in flood hazard areas. For background, see Appendix G, Section G.2.3.

Recommendation 12. Amend New York State code: The DCEA should consider code amendments to:

- Modify the building code to require Risk Category II buildings (primarily non-residential buildings) to be elevated or protected to or above the BFE plus 2 feet (equivalent to on New York State amendment to residential code)
- Specifically refer to local laws for flood damage prevention where FISs and FIRMs are specifically adopted by title and date
- Modify R324.3 (coastal high hazard area) to refer to ASCE 24
- Restore the I-Code language for historic buildings in flood hazard areas to ensure they are treated as required by the NFIP

7.3.3 New York City

Conclusion 13. Building Code Amendments to the New York City Building Code: The MAT review of the flood provisions of the New York City Building Code, including amendments proposed in bill Int. No. 1056 that was pending before City Council in July 2013, identified a number of opportunities to improve consistency with the NFIP, clarity, and enforceability. For background, see Appendix G, Section G.3.1.

Recommendation 13. Modify proposed New York City code amendments: The NYC DOB should modify the proposed code amendments to:

- Improve consistency with the NFIP requirements for enclosed areas below elevated buildings
- Restore the ASCE 24 definitions for "residential" and "nonresidential," or clarify the New York City definitions to be consistent with FEMA guidance specifically for institutional facilities where people are cared for or live on a 24-hour basis in a supervised environment

Conclusion 14. Substantial Damage and Substantial Improvement Determinations: The NFIP expects communities to determine whether alterations, additions, repairs, and other improvements meet the definitions for Substantial Damage and Substantial Improvement (the same definitions are in the building code). For existing buildings in SFHAs, New York City requires applicants to provide documentation of costs and market value and to state whether the work is or is not Substantial Improvement. For background, see Appendix G, Section G.3.1.

Recommendation 14. The DOB should establish protocol to verify data: Guidance in FEMA P-758, *Substantial Improvement/Substantial Damage Desk Reference* (FEMA 2008e), recommends that communities carefully evaluate submitted data when the comparison of costs to market values yields a ratio that is close to 50 percent. The DOB should establish a protocol so that applicant-submitted data and statements are verified when the indicated ratio is between 40 and 50 percent.

Conclusion 15. Inspection of Construction in Flood Hazard Areas: With more than 80,000 buildings affected by Hurricane Sandy, the DOB's resources for inspection of issued permits may be strained. The building code has provisions for special inspections to be conducted by special inspectors and special inspection agencies. For background, see Appendix G, Section G.3.2.

Recommendation 15. Establish mechanism for special inspections: Given the number of buildings damaged by Hurricane Sandy and the extent of SFHAs in all five boroughs, the DOB should establish a mechanism to supplement inspections with a "flood zone compliance special inspection" to be conducted and certified by special inspectors or special inspection agencies, as proposed in pending legislation.

Conclusion 16. Dry-Floodproofed Buildings: Buildings that are designed to be dry floodproofed, with measures that require action by building managers or occupants in order to function as intended, are not protected if those actions are not carried out properly. New York City Building Code, Appendix G, Section G105.4 requires a "flood shield inspection" during construction. For background, see Appendix G, Section G.3.1 of this report.

Recommendation 16. Amend Appendix G of New York City Building Code: The DOB should consider amending Appendix G of the New York City Building Code to require owners of buildings that rely on human intervention to implement dry floodproofing measures to submit periodic inspection reports (e.g., every 3 years) to document:

- Installation and maintenance of flood shields or flood control devices

- Posting of the emergency plan required by ASCE 24, Section 6.2.3
- Performance of periodic practice of shield installation
- That other permit requirements are satisfied

Conclusion 17. New York City School Construction Authority Design Standards: The New York City School Construction Authority Design Standards that are used for planning, design, and construction of public schools contain narrative descriptions of building code requirements that are not consistent with the New York City Building Code Appendix G and the requirements of the NFIP. In addition, the description of work that triggers compliance is described as only applying to repairs for which the cost is “more than 50% of the cost of replacement of the building.” For background, see Appendix G, Section G.3.1 of this report.

> ***Recommendation 17. Revise New York City School Construction Authority Design Standards:*** The New York City School Construction Authority should revise the narrative in Design Requirements 1.3.1.11 to be consistent with the New York City Building Code Appendix G. The description of work for which compliance is required should be expanded to include improvements and additions, and should be consistent with the building code definitions for market value, Substantial Damage, and Substantial Improvement.

7.3.4 Healthcare Facility-Specific Standards

Conclusion 18. NFPA 99: NFPA 99, *Standard for Health Care Facilities,* contains flood provisions for protecting emergency power systems and communication systems. However, NFPA 99 is only referenced in IBC Section 407.10 “Hyperbaric Facilities.” For background, see Appendix F, Section F.5.2.

> ***Recommendation 18. Revise IBC to reference NFPA:*** Revise the IBC to reference NFPA 99 for other portions of hospitals that serve or support critical functions.

Conclusion 19. NFPA 99 and ASCE 24 Consistency: The flood provisions of NFPA 99 are not consistent with ASCE 24, and ASCE 24 is not listed in NFPA 99 Chapter 2, “Referenced Publications.” For background, see Appendix F, Section F.5.2.

> ***Recommendation 19. Revise NFPA to reference ASCE 24:*** Revise NFPA 99 to include ASCE 24 as a referenced publication and revise the flood criteria to be consistent with or more restrictive than ASCE 24.

Conclusion 20. Facility Guidelines Institute: Floodwaters damaged several healthcare facilities in New Jersey and New York. Some facilities remained inoperative months after the event. The FGI Guidelines (FGI 2010) are referenced by both New Jersey and New York as a requirement for hospitals. The FGI Guidelines contain numerous references to flood risk but most of the flood references are qualitative and non-enforceable. Section 1.1 – 4.3, “Flood Protection,” references Executive Order 11988, *Floodplain Management,* but lacks specific language that describes how and when Federal agencies apply the Executive Order to healthcare facilities. Section 1.1 – 4.3, “Flood

Protection" and Section 1.1 – 5.5, "Referenced Codes and Standards" both lack reference to ASCE 24. For background, see Appendix F, Section F.5.1.

> ***Recommendation 20. Revise FGI to reference ASCE 24:*** The FGI should revise Section 1.1 – 4.3, "Flood Protection" and Section 1.1 – 5.5, "Referenced Codes and Standards" of the FGI Guidelines to reference the most recent edition of ASCE 24 and properly characterize the role of Executive Order 11988.

Conclusion 21. Building System Damage and FGI: Floodwaters damaged utilities and interrupted services (such as power, steam, and water) to several hospitals. The interruption of these utilities prevented the hospitals from functioning.

Requirements for utilities and systems are contained in Section A1.2 – 6.5, "Provisions for Disasters" in the FGI Guidelines. Those guidelines state that special design is required for facilities that "must remain operational in the aftermath of a disaster." Essential services are defined as: "power, water, medical gas systems, and, in certain areas, air conditioning." The guidelines further state that special consideration "be given to the likelihood of temporary loss of externally supplied services like power, gas, water, and communications." The guidelines do not list criteria for determining which facilities must remain operational or what systems and utilities are needed for functionality. For background, see Appendix F, Section F.5.1.

> ***Recommendation 21. Revise FGI to provide specific guidance:*** The FGI should revise the FGI Guidelines to provide specific guidance on determining which facilities must remain operational in the aftermath of a disaster and what services must be provided by those facilities. The MAT acknowledges that many factors need to go into such a determination, including proximity to other hospitals, services provided by the hospital, size of the facility, presence (or absence) of redundant utilities supplying the facility, and the reliability of utilities serving the facility.

7.3.5 FEMA

Conclusion 22. International Code Series Amendments: FEMA participates in the triennial code development process to propose changes to the codes based on experience gained through post-flood investigations that are documented in MAT reports. The nature of damage observed after Hurricane Sandy and documented in this MAT report, combined with similar observations after other flood disasters, reinforces the benefits that can be gained by additional changes to the I-Codes.

> ***Recommendation 22. Propose changes to I-Codes:*** FEMA should propose changes to the I-Codes:
>
> ***IRC:***
>
> - Incorporate additional height (freeboard) of 1 foot above BFE for dwellings in all flood hazard areas.
> - Require Coastal A Zones, where a LiMWA is delineated on a FIRM or if otherwise designated by a community, to be regulated using the same requirements for Zone V, with

an exception for filled stemwall foundations that that are designed to account for wave action, debris impact, erosion, and local scour.

- Include specific requirements for underground and above-ground tanks.
- Clarify that in Zone V, where stairs are enclosed by walls designed to break away under flood loads, a door that meets the requirements for exterior doors is installed at the top of the stairs.
- Remove prescriptive provisions allowing unreinforced masonry foundation walls for new construction in Zone A.

IBC:

- Add a definition of Coastal A Zone to clarify such areas are present if the LiMWA is delineated on a FIRM or if otherwise designated by a community. This change would achieve consistency with the next edition of ASCE 24.

7.4 Siting

Several of the waterfront communities affected by Hurricane Sandy are more than 100 years old. Shoreline erosion has been ongoing during this time, and many shoreline protection structures (e.g., seawalls, bulkheads, revetments) have been built to combat erosion. In other cases, land was created by filling former marsh or shallow water areas and stabilized with erosion control structures. As a result, many low-rise buildings in these communities are situated within 10 to 20 feet of an erosion control structure.

Long-term changes, such as sea level rise, can magnify the risks faced by waterfront communities. Existing FEMA guidance, such as FEMA P-55, *Coastal Construction Manual* (2011a), and Hurricane Sandy Recovery Advisory 5, *Designing for Flood Levels Above the BFE After Hurricane Sandy* (FEMA 2013e), address some mitigation options and consideration for future sea level rise. However, FEMA's FIRMs and other mapping products depict only today's flood risk. Addressing flood risk based on current conditions does not account for the increased flood risk that may result from sea level rise.

Conclusion 23. Siting of Buildings Relative to Erosion Control Structures: The effectiveness of erosion control structures (e.g., bulkheads, seawalls, revetments) varied widely during Hurricane Sandy, depending on the height, age, construction, and condition of the structure; the beach/shoreline condition seaward of the structure; and the proximity of an upland building to the erosion control structure. Many erosion control structures failed and subjected nearby buildings to undermining and flood damage. Other erosion control structures remained intact but were overtopped by storm waves and/or surge, and many buildings near the overtopped structures sustained flood damage. In a few instances, the erosion control structures remained intact and were high enough or strong enough to prevent or reduce landward erosion and flood damage.

FEMA's guidance for mapping flood hazards landward of erosion control structures (e.g., area of wave overtopping [splash zone], Zone VE) is based, in large part, on studies and analytical tools dating to the 1980s. No systematic review of these mapping procedures has been undertaken. The existing mapping guidance would benefit from a review of data and photographs documenting Hurricane Sandy building damage landward of these structures. Also, newer simulation techniques may be useful in evaluating the existing guidance and developing new guidance.

Recommendation 23a. Document performance of erosion control structures: FEMA should document the successes and failures of erosion control structures (e.g., bulkheads, seawalls, revetments) and damages to buildings situated landward of these structures. Use this information to develop educational materials related to building siting and design near erosion control structures.

Recommendation 23b. Review mapping procedures: FEMA should review the mapping procedures used to identify flood hazards (including Zone VE splash zones) landward of erosion control structures, such as bulkheads, seawalls, and revetments, and revise the procedures where Hurricane Sandy data and application of new simulation techniques indicate better guidance can be developed.

Recommendation 23c. Conduct detailed evaluation of damage behind erosion control structures: FEMA should conduct a detailed evaluation of building damage behind erosion control structures. This would allow FEMA to validate or revise its Zone VE overtopping splash zone criteria contained in the *Atlantic Ocean and Gulf of Mexico Coastal Mapping Guidelines Update* (FEMA 2007d).

Conclusion 24. Protection Afforded by Beaches and Dunes: Low and narrow beaches and dunes were completely eroded in many areas, and buildings and infrastructure landward of the dunes were subject to damaging wave action and/or high-velocity flow. By comparison, the MAT observed that the presence of wide beaches and tall, wide dune fields reduced damage to buildings and infrastructure situated landward of the dunes. Cuts across or through dunes (e.g., for pedestrian access) appeared to have provided pathways for high-velocity flow in some cases. FEMA flood mapping regulations have recognized this general fact since the mid-1980s, and use a particular criterion to predict dune loss during base flood events (< 540 square feet of dune cross-section above 100-year stillwater level and seaward of dune peak).

Recommendation 24a. Review dune loss criterion: FEMA should review the 540-square-foot criterion used in coastal FISs to predict base flood dune loss, and should validate or revise this criterion based on data collected during Sandy and other recent storm events.

Recommendation 24b. Develop siting and design guidance for Sandy-affected coastal areas: FEMA should review available data and any forthcoming studies of dune loss or breaching, or overwash and high-velocity flow across coastal landforms. Using information from these studies, FEMA should develop specific siting and design guidance for coastal areas affected by Hurricane Sandy. The effects of pedestrian and vehicular access paths on dune breaching should be included in the review. Guidance for dune walkovers and beach access structures should be distributed by New Jersey and New York and their communities.

Recommendation 24c. Identify barrier islands with history of breaching: States and communities should identify those barrier islands and barrier spit areas with a history of breaching or high velocity flow during Sandy or other severe coastal storms. This information should be distributed to designers and others involved in planning, siting, and designing coastal buildings and infrastructure.

7.5 Structural

Although Hurricane Sandy did not result in widespread damage to building foundation and below-grade areas, flooding events similar to Hurricane Sandy have done so. Damage to foundations can result in cascading damage to buildings and infrastructure. Hurricane Sandy affected a very dense, urban population, and these communities face unique challenges as they rebuild. The following section presents conclusions and recommendations based on the MAT's observations and review of structural issues encountered in New Jersey, New York, and New York City areas visited by the MAT.

Conclusion 25. Effect of Foundation on Building Survival: One- and two-family houses and other low-rise buildings on foundations elevated above Sandy's flood level performed well. Many undermined, shallow building foundations collapsed while deep foundations typically survived. Few older structures (some as old as 100 years) along the New Jersey and New York coast were constructed to accommodate scour and erosion and the MAT observed many of these structures collapsed. Those that survived had very robust foundations or deep pile foundations, but these significant foundations are not common.

Recommendation 25a. Reference FEMA guidance regarding foundations for new construction: Design professionals and builders should consult FEMA guidance, such as FEMA P-55, *Coastal Construction Manual* (2011) and FEMA P-550, *Recommended Residential Construction for Coastal Areas: Building on Strong and Safe Foundations* (2009), to specify foundations for new one-and two-family houses and other new low-rise buildings in coastal areas. The information in FEMA P-55 on determining site-specific loads will help design professionals develop foundations that are sufficiently deep to withstand flood loads despite scour and erosion and will also help designers determine the appropriate elevation for a building located in an area subject to flooding.

Recommendation 25b. Elevate existing low-rise buildings where possible: Local communities should ensure that existing low-rise buildings are elevated where possible and the foundations are replaced where needed. Although numerous buildings were determined to have incurred Substantial Damage or were destroyed, many buildings sustained only minor structural damage. Even those buildings that do not meet the Substantial Damage threshold should be mitigated. At a minimum, these buildings should be brought to the current codes and standards for new construction adopted by the community. Where possible, a design professional may be able to assess an existing foundation and provide a design capable of withstanding future flood loads. The Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the BFE After Hurricane Sandy* (FEMA 2013e), provides guidance to help design professionals and homeowners understand NFIP and building code requirements and how design and construction practices can minimize damage to buildings.

Recommendation 25c. Fill below-grade areas of buildings in the SFHA: Below-grade garages or basements are common in older construction in New Jersey and New York. For residences in the SFHA, owners should consider filling these below-grade areas and installing flood openings in any remaining enclosure that is at or above grade, but below the lowest floor. Communities, States, and FEMA should help educate owners on the benefits of these measures that can reduce damage to equipment and reduce flood insurance premiums. Information provided to communities should discourage the improper use of space below the BFE. Additionally, the Hurricane Sandy Recovery Fact Sheet No. 2, *Foundation Requirements and Recommendations for Elevated Homes* (FEMA 2013e), describes options for elevating houses on small lots where deep foundations are required, where it is not possible to move houses to implement mitigation actions.

Recommendation 25d. Develop mitigation guidance for existing residential buildings: FEMA should develop guidance on mitigation solutions for existing residential buildings in order to minimize damage to buildings and reduce flood insurance premiums, taking into consideration the unique challenges faced when rebuilding in dense urban settings. The Hurricane Sandy Recovery Advisory No. 7, *Reducing Flood Risk and Flood Insurance Premiums for Existing Residential Buildings in Zone A* (FEMA 2013e), provides information on potential mitigation measures for existing residential buildings.

Conclusion 26. Insufficient Load Path Continuity: A large portion of the coastal residential and other low-rise light-frame building stock in the area affected by Hurricane Sandy is many decades old. Many failures occurred as a result of a lack of a continuous load path, a lack of maintenance on the load path, or a load path that was not sized to address the loads applied to the building during the storm event. Many continuous load paths were further altered on buildings because repairs and additions were made over time.

Many one- and two-family houses and other low-rise light-frame buildings failed at the floor-to-pile foundation connection as a result of insufficient connectors. Load path failures observed were primarily due to buildings having first-floor framing at or below the floodwater elevation and the combined flood and wind loads exceeding the capacity of the load path connections. The floor-joist-to-foundation load paths typically consisted of either a simple nailed connection or a system of load path connectors or blocking. In several instances, where a system of load path connectors was used, the strap connectors utilized were those more commonly used to make a truss-to-top-plate connection; this type of strap does not have sufficient capacity to resist both the shear and uplift forces encountered during flood inundation. In other instances, whether connectors may have provided sufficient uplift and shear resistance is unknown because connectors were corroded, which significantly reduced the capacity of the connectors.

Existing construction with a first floor system at or below the BFE is at significant risk of being severely damaged or destroyed by future events unless it is elevated or load path improvements are made to resist the combined flood and wind loads. New construction should be elevated high enough to prevent floodwater from entering the building envelope during future events.

Recommendation 26a. Retrofit existing homes to improve load paths: To address both the uplift and shear loads associated with combined flood and wind loads, existing homes with first-floor framing at or below the BFE should be retrofitted with either additional elevation or stronger, continuous load paths. The foundations of existing homes within the SFHA should be evaluated by local building officials to verify they maintain sufficient load path continuity.

Hurricane Sandy Recovery Advisory No. 1, *Improving Connections in Elevated Coastal Residential Buildings* (FEMA 2013e), provides details on suggested improvements for both existing and new construction for strengthening elevated floor-to-pile foundation connections and protecting metal connectors and brackets from corrosion.

Recommendation 26b. Perform regular inspections for compromised connections: Load path connections should be periodically inspected by owners or their designees to verify that the load path has not been compromised by the coastal environment. Repairs and reconstruction should use flood damage-resistant materials per NFIP Technical Bulletin 2, *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas* (FEMA 2008b), and Technical Bulletin 8, *Corrosion Protection for Metal Connectors in Coastal Areas for Structures Located in Special Flood Hazard Areas* (FEMA 1996).

Recommendation 26c. New home designs should adequately address flood risk: Designers of new homes should consider the likelihood and consequences of flood levels exceeding the BFE, and designs should address this risk. This risk is commonly addressed by either incorporating additional elevation above the minimum requirements or meeting the minimum elevation requirements and incorporating a sufficient continuous load path to resist the combined uplift and shear loads associated with flood and wind loads.

Hurricane Sandy Recovery Advisory No. 5, *Designing for Flood Levels Above the BFE After Hurricane Sandy* (FEMA 2013e), should be used by design professionals to determine an appropriate elevation for design purposes for both existing homes and new homes. Proper elevation can reduce the potential for flood loads to impact the first-floor framing and can reduce the required size of the load path connectors.

Recommendation 26d. Publish prescriptive load path details: Prescriptive load path details and connections suitable for the Hurricane Sandy-affected area should be compiled and published for use by designers, building officials, and contractors. Although building codes indicate the requirement for a load path, the codes do not prescriptively address the connections. Load path details specifically addressing foundation-to-floor framing connections should be developed by manufacturers and trade organizations related to wood framing.

Recommendation 26e. Require plans and specifications to show load path connections: Local building departments should require that load path connections be clearly shown and described in building plans and specifications. A design professional should evaluate the number, size, corrosion protection, and type of load path connectors necessary to resist all the applicable building loads. Identifying load path connectors on the plans and specifications will improve incorporation of sufficient load path connectors and improve verification of their presence. Describing and identifying load path connections in building plans and specifications should apply to both new construction and existing construction that is either being repaired or renovated. The Hurricane Sandy Recovery Advisory No. 1, *Improving Connections in Elevated Coastal Residential Buildings* (FEMA 2013e), provides details of elevated floor-to-pile connections using a variety of methods and materials and includes a list of FEMA documents that have important information related to load path connections in residential buildings.

Conclusion 27. Insufficient Siding Installation: In many instances, exterior siding was not sufficiently connected to the building. Multiple layers of siding were most commonly observed on older buildings (one- and two-family houses and other low-rise buildings). Rather than removing all of the existing siding, new siding appeared to have been installed over older siding and insulation layers. The fasteners for the outermost siding typically did not have sufficient embedment into an appropriate material, such as wood studs, to resist the wind loads. In contrast, there was little damage to buildings with properly installed siding.

Recommendation 27. Install siding properly: To withstand wind loads, siding should be installed and attached in accordance with the manufacturer's guidelines using appropriate fasteners attached to the appropriate substrate material to achieve the design wind pressures. Additionally:

- All existing exterior siding should be removed before installing new siding
- The fasteners should be corrosion resistant, have sufficient length to resist withdrawal from wind pressures, and be attached to the appropriate substrate materials. Installers should ensure proper fastener size, length, spacing, and depth of embedment in the substrate material
- Local building departments should require contractors/builders to certify that siding was installed according the manufacturer's instructions

7.5.1 Flood Protection

Conclusion 28. Flood Protection of Critical and Essential Facilities: Facilities such as WWTPs, transit facilities, and data centers that provide data and communication capabilities are not identified as "essential" or "critical" (Risk Category IV) by building codes and therefore may not be required to meet higher standards than typical non-residential buildings. However, the failure of these facilities can cripple recovery from a disaster event by incapacitating the critical infrastructure systems they support.

Recommendation 28. Local jurisdictions should determine what facilities are critical and essential: In addition to those facilities identified by the building code, the local jurisdiction should determine which facilities are critical or essential and should meet flood resistance design criteria, performance goals, and governing standards for Risk Category IV buildings. Occupied critical facilities should meet criteria recommended in ASCE 24 for Risk Category IV facilities and be coordinated with design criteria and performance goals for other system components or key assets with the respective critical infrastructure system. This includes associated siting mitigation measures, such as flood barriers, and supporting functional operations assets/facilities that are not listed as examples in ASCE 24-05, but require consideration as critical facilities; such facilities include data centers, WWTPs, and public transportation facilities, and their critical supporting substations or emergency power facilities.

Conclusion 29. Flooding in Subgrade Areas between Buildings: Subgrade areas shared between buildings are convenient for locating shared utilities. Some buildings that experienced no surface water flooding during Sandy had subgrade areas and basements that flooded as a result of water entering through slab or wall penetrations, tunnels, vaults, or connections to basements or subgrade areas in adjacent buildings. A strict reading of FIRMs will not pick up these vulnerabilities unless a designer knows what spaces and components are underground.

In general, the MAT did not observe preventive measures in place to prevent floodwater from entering shared subgrade spaces. Inter-building flooding occurred because either preparation had not been made to prevent floodwater transmission, or installed preventive measures failed. In locations where flood doors were installed, either the doors failed or the walls surrounding the doors failed. Subgrade flooding was observed at hospital complexes with shared access tunnels and/or basements, in two high-rise residential buildings that shared a below-ground parking garage and basement, and in two WWTPs.

> ***Recommendation 29a. Develop educational materials on below-grade flooding vulnerabilities:*** FEMA should develop educational materials to emphasize below-grade building vulnerabilities to flooding. Designers and building operators should understand how to identify such vulnerabilities and how to mitigate flood damage in basements and subgrade areas. A discussion of dry- and wet-floodproofing techniques should be included in the educational materials, including cautions about potential structural failures if dry-floodproofed areas cannot withstand the flood loads that will result from dry floodproofing (particularly in existing buildings).

> ***Recommendation 29b. Protect against flooding across subgrade connections:*** Owners of buildings that share subgrade connections (e.g., access tunnels, basements, or underground parking) should implement flood protection measures to ensure that flooding from one area does not damage other areas or other buildings. Protection could be accomplished by implementing a dry floodproofing system, where structurally feasible, that includes barriers or watertight doors and is augmented by sump pumps with emergency power to remove any floodwater where seepage occurs. Alternatively, wet floodproofing techniques can be used if the connected spaces would not be damaged by inundation and could be cleaned up and placed back in service after flooding. FEMA P-936, *Floodproofing Non-Residential Buildings* (2013d), contains guidance on floodproofing.

7.5.2 Elevating Structures and Freeboard

Conclusion 30. Poor Performance of Buildings and Building Systems: Many non-elevated or low elevation buildings and building systems sustained flood damage due to inundation and/or wave damage. Buildings elevated above the Hurricane Sandy flood level on strong foundations sustained no such damage. Systems elevated above the flood level or protected by floodproofing measures also performed well.

TERMINOLOGY

Preliminary Work Maps: FEMA is in the process of releasing updated maps showing coastal flood hazard data in certain communities in New Jersey and New York. The updated maps (called Preliminary Work Maps) are an interim product created as part of the process of developing new FIRMs. The information on these Preliminary Work Maps is made available to applicable communities to use as the best available data for rebuilding and recovery efforts in the aftermath of Hurricane Sandy.

Recommendation 30a. Elevate new and Substantially Damaged/Improved structures to protect from flooding: Local communities should require new buildings, those determined to have Substantial Damage, and those that will undergo Substantial Improvement be elevated in accordance with Table 7-1, and associated building systems in accordance with Table 7-2. The recommendations differ from the next edition of ASCE 24 in two ways: 1) one additional foot of freeboard is added for Risk Category II structures, and 2) some Risk Category III structures are treated like Risk Category IV. All structures should have at least 2 feet of freeboard relative to detailed flood study results (not including ABFEs), and some Risk Category III structures warrant treatment like Risk Category IV for flood resistance purposes.

Table 7-1: Recommended Elevations for New and Substantially Damaged or Substantially Improved Buildings

New and Substantially Damaged or Improved Construction, Building Type[a]	Minimum Recommended Elevation and Floodproofing Level (select highest)
• One- and two-family structures • Other Risk Category II residential structures • Risk Category II non-residential structures	• Effective BFE + 2 feet, or Preliminary BFE + 2 feet,[b] or State/local DFE
• Risk Category III structures housing occupants or residents with limited mobility • Risk Category III structures that a community considers essential	• Risk Category IV elevation, see below
• Risk Category III structures not included above	• Effective BFE + 2 feet, or Preliminary BFE + 2 feet,[b] or State/local DFE
• Risk Category IV structures	• Effective BFE + 2 feet, or Preliminary BFE + 2 feet,[b] or State/local DFE, or 0.2-percent-annual-chance (500-year) flood level • Where the design flood is associated with coastal flooding, add 1 additional foot of freeboard to account for future sea level rise

a. See ASCE 7 (2010 Edition), Table 1.5-1 for Building Category explanation.

b. Use ABFE where Preliminary Work Maps have not been released, but where ABFE is more than 2 feet above the Effective BFE.

ABFE = Advisory Base Flood Elevation

BFE = base flood elevation

DFE = design flood elevation

Table 7-2: Recommended Elevations for Building Systems

Risk Category[a]	Minimum Recommended Elevation and Floodproofing Level (select highest)
Risk Category II structures, and Risk Category III not treated like Risk Category IV	At structure elevation
Risk Category IV structures, and certain Risk Category III structures (see Table 7-1)	1 foot above the structure elevation from Table 7-1
Existing structures (where practicable)	Corresponding elevation for new construction; if not practicable, elevate/floodproof as high as practical

a. See ASCE 7 (2010 Edition), Table 1.5-1 for Building Category explanation.

Recommendation 30b. Elevate existing structures to protect from flooding: The elevation recommendations in Tables 7-1 and 7-2 should also be applied, to the extent practical, to existing buildings that are undergoing repair or retrofit, and that do not meet substantial damage/substantial improvement criteria.

Recommendation 30c. Building designs should account for flood conditions: In addition to the freeboard recommendations in Recommendations 30a and 30b, building designs should be based on flood conditions that will accompany floods associated with freeboard elevations (see Figure 7-1). Specifically:

- Enforce Zone A design and construction standards in the area between the Effective/ SFHA landward limit, and a ground elevation equal to the adjacent Zone A BFE plus freeboard. This will mandate flood-resistant design and construction in some areas shown as Zone X on the Effective/ FIRMs.
- Enforce Coastal A Zone design and construction requirements in the area between the LiMWA and the LiMWA associated with the recommended freeboard.
- Enforce Zone V design and construction standards in the area between the Effective Zone V limit and the Zone V limit associated with the recommended freeboard.

Recommendation 30d. Improve protection of subgrade areas outside the SFHA: In addition to expanding the area over which freeboard is required as described in Recommendation 31 communities and States should address the vulnerability of basements and subgrade spaces in buildings outside the SFHA. To adequately protect these spaces from flooding, designers need to consider more than just location relative to the SFHA limit. NFIP Technical Bulletin 10-01, *Ensuring That Structures Built on Fill In or Near Special Flood Hazard Areas Are Reasonably Safe From Flooding* (FIA-TB-10) (2001), contains guidance that can be applied. Although it was written for buildings on fill, its content relating to measures that will mitigate buildings to be "reasonably safe from flooding" applies outside the SFHA as well.

Conclusion 31. Accounting for Future Conditions: Coastal erosion has occurred for many years throughout much of the area affected by Sandy, and is likely to continue into the future. Records also indicate that sea levels have been rising relative to the land across the area; future projections of sea level rise range from simple extrapolation of historical trends, to accelerated rates of rise. While future erosion rates and rates of relative sea level rise are subject to debate, both processes can increase flood hazards at a site, and it is prudent to incorporate these future conditions into planning, design, construction, and mitigation projects. Some regions are already responding to changing conditions. New York City recently released revised evacuation maps that extended the evacuation area to account for greater hazard risks.

Recommendation 31. Designers should consider the potential impacts of sea level rise: Sources for information on this topic include:

- Hurricane Sandy Recovery Advisory 5, *Designing for Flood Levels Above the BFE After Hurricane Sandy* (FEMA 2013e)
- Chapter 3 of FEMA P-55, *Coastal Construction Manual* (2011a)
- Technical Factsheet 1.6 in FEMA P-499, *Home Builder's Guide to Coastal Construction* (2010d)

- FEMA study titled *The Impact of Climate Change and Population Growth on the National Flood Insurance Program Through 2100* (AECOM 2013)

Information regarding potential increases in BFEs resulting from sea level rise in New Jersey and New York can be found at the U.S. Global Change Research Program Web site.[2] This Web site contains interactive maps that display the projected future areal extent of SFHAs. Calculators on the Web page allow the user to project an estimated future BFE resulting from sea level rise.

Taking sea level rise into account is similar to how freeboard affects flood zones (pushes the zones landward). Figure 7-1 illustrates how higher flood levels shift flood zones landward. Element A-1 shows a cross-section of an existing ABFE, Preliminary, or Effective FIRM. Element A-2 shows how recommended flood hazard zones shift as flood levels increase or higher freeboard is considered.

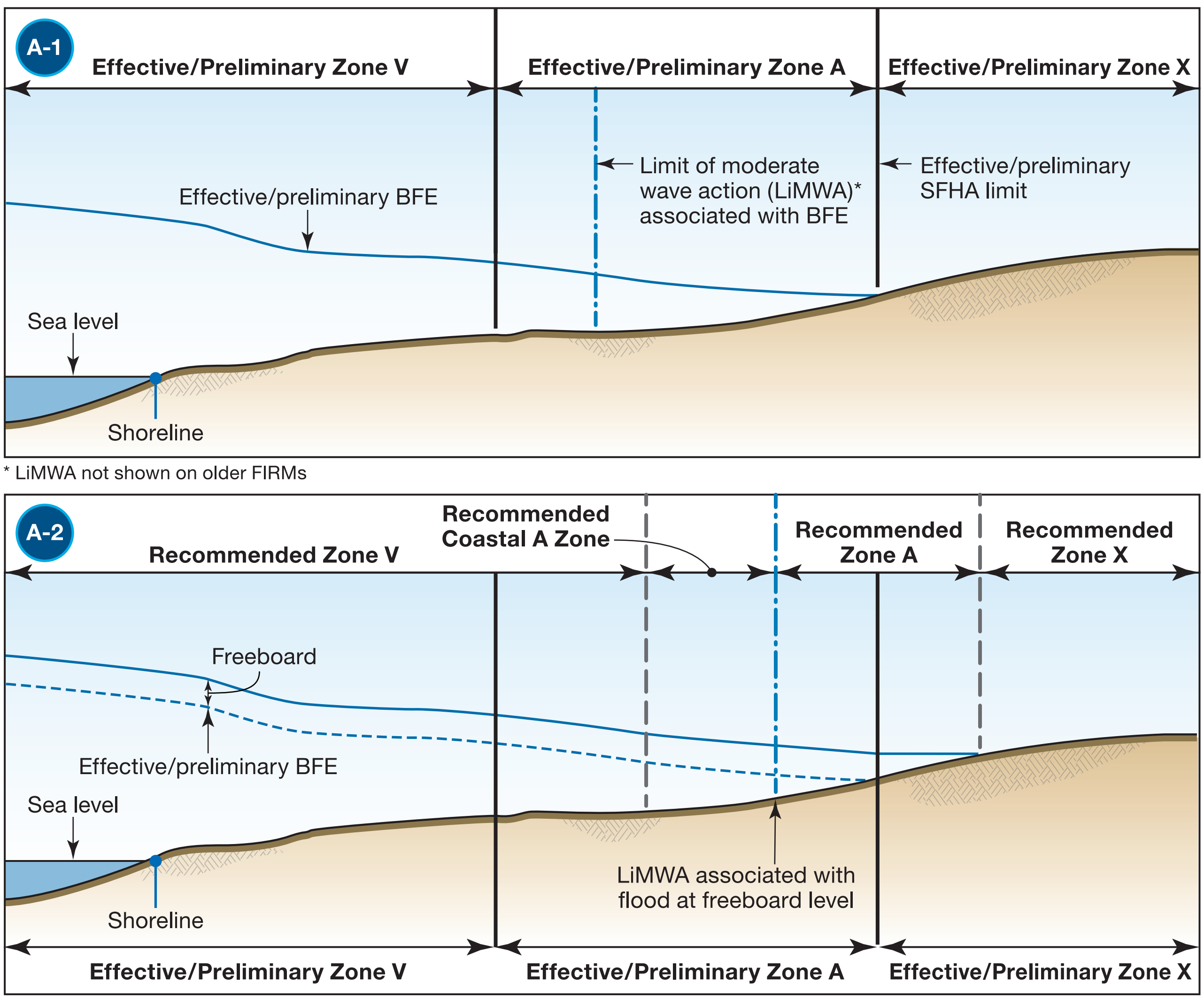

Figure 7-1: Higher flood levels shift flood zones landward

2 http://www.globalchange.gov/component/content/article/87-assessment/902-coastal-resilience-resources.

7.6 Building Systems

Building systems are essential to the functionality of all facility types. Even when flooding does not cause structural damage to a building, the inundation of building systems can cause the building to be uninhabitable or to have limited functionality for weeks or months. Building systems include MEP systems, as well as elevators, emergency power systems, fuel tanks, sump pumps, and other related equipment.

7.6.1 General Protection

Conclusion 32. Protection of Building Systems: Building systems such as the MEP systems were often insufficiently protected to prevent damage from floodwater. Most buildings did not incur Substantial Damage, but many of their critical building systems such as furnaces, boilers, water heaters, and electrical panels were located on floors at or below grade and were inundated and damaged. For basements and below-grade garages, sump pumps, that under normal conditions would keep these areas from flooding, were overwhelmed by the severe rain or storm surge entering through doorways, windows, and vents. Other equipment such as air conditioners were elevated, but damaged by flood-borne debris knocking out support piles.

IMPORTANCE OF CRITICAL BUILDING SYSTEMS

Critical building systems, those deemed essential by a community or the building code, are important for community resilience.

Recommendation 32. Building owners should elevate, relocate, or protect building systems above the BFE: Systems such as air conditioning compressors, which are often located on exterior platforms, should be elevated above the BFE and either cantilevered off the building or on a foundation designed to resist flood loads, including debris impact. Any exterior mounted equipment should be properly anchored to resist wind loads (and seismic loads, if necessary) using corrosion resistant anchorage straps. Additional information is available from several FEMA publications:

- Hurricane Sandy Recovery Advisory No. 3, *Restoring Mechanical, Electrical, and Plumbing Systems in Non-Substantially Damaged Residential Building* (FEMA 2013e)
- FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings* (FEMA 2007b)
- FEMA 577, *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds: Providing Protection to People and Buildings* (FEMA 2007c)
- FEMA P-424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds* (FEMA 2010a)

Conclusion 33. Emergency Power Systems: Flood protection systems that rely on electrical power were rendered ineffective when power was lost. Emergency power systems protected from flood damage would have allowed the flood protection systems to remain functional.

Recommendation 33a. Submit a proposal to modify ASCE 24, Section 7.1 commentary: A proposal should be submitted to the ASCE 24 *(Flood Resistant Design and Construction)* Standard Committee to modify the commentary of Section 7.1 to state it is the intent of standard Section 7.1 to include emergency power systems.

Recommendation 33b. Determine minimum required emergency power duration and capacity: Facility owners should conduct a critical review of existing and future conditions that could impact a building during a storm event. The minimum required emergency power duration and capacity should be determined.

Conclusion 34. Protection of Building System Components: Some components of building systems are required by New York City building code to be located on the lowest level of the building, which generally equates to a basement or subgrade area. However, high-rise residential buildings and critical and essential facilities had building systems located in basements or subgrade areas in both New Jersey and New York City. The location of building systems is important in maintaining building operations: facilities with elevated building systems resulted in a functioning building, post-event.

Recommendation 34. Protect critical building systems in subgrade areas: Building owners with building systems in basement or subgrade areas susceptible to flooding should protect these systems from coming into contact with floodwater. These systems can be protected by a variety of methods used singly or to greater effect, in conjunction with one another. Recommendations for general building systems are described in the Hurricane Sandy Recovery Advisories Nos. 2, 3, and 4. The following recommended actions apply to critical systems, those determined to be essential to the function of the building:

1) Relocate

- Relocate building systems and/or components in accordance with the recommendations in Table 7-2
- Relocate utility equipment to a higher floor or build an elevated addition to use as a utility room
- Relocate systems to a higher elevation per ASCE 24

2) Elevate

- Elevate critical building systems components in accordance with the recommendations in Table 7-2
- Elevate damaged building systems during repair or replacement
- Elevate to the BFE or higher even if it is not required; if elevating to the BFE or relocating the equipment is not feasible, raise the equipment as high as possible in place
- Pay attention to specific vulnerabilities, characteristics, and restrictions on equipment placement that can affect the ability to elevate or relocate it

- Install platforms on the floor to elevate equipment in place

3) Dry Floodproof

- Seal building systems penetrations
- Install backflow prevention devices on plumbing equipment
- Require emergency power for floodproofing system components (e.g., sump pumps)
- Protect building systems through integrated floodproofing by using a combination of wet and dry floodproofing techniques

4) Install System and Component Redundancy

- Require emergency power to support critical facility functions
- Establish redundancies

Conclusion 35. Facilitate the Connection of Temporary Building Systems: Many buildings had temporary equipment installed in flooded areas to replace damaged connections and restore function to building systems. After other flood disasters, the MAT has observed buildings where temporary connections in floodprone areas were converted to permanent connections. In many instances these converted temporary connections were not protected by being relocated above the BFE or being dry floodproofed before their conversion to permanent connections and thus were vulnerable to damage by flooding.

Recommendation 35. Establish points for temporary power connection: In order to reduce service outages, building owners should establish and maintain points of temporary power connection for mechanical and electrical service components. Building owners should consider long-term recovery when selecting the locations for temporary power, heat, and other building systems connections since the temporary connection may become permanent. New permanent connections for critical building systems should be located as indicated according to the Risk Category shown on Table 7-2 or otherwise protected from floodwater through dry floodproofing.

7.6.2 Elevators

Loss of elevator service created hardship for many building tenants in both critical facilities and non-critical facilities.

Conclusion 36. Protect Below-Grade Elevator Equipment: Below-grade sections of elevators (i.e., elevator pits) are extremely vulnerable to inundation. Many elevator shaft walls collapsed and related equipment was destroyed.

Recommendation 36a. Emergency plans should address the possibility of elevator failure: Building owners and operators should recognize the impact of elevator failure on evacuation, emergency operations, and normal operations and plan accordingly. Elevate and/or floodproof elevator system components to minimize flood damage in accordance with FEMA Technical Bulletin 4, *Elevator Installation for Buildings Located in Special Flood Hazard Areas in accordance with the National Flood Insurance Program* (FEMA 2010b).

Recommendation 36b. Facilities should protect elevator service, especially when it is essential to function: Building owners should know that power outages occur and make preparations for them. There should be a clear understanding of what to expect and how to prepare. Protecting elevator service may include:

- Relocating essential controls above the DFE
- Dry floodproofing essential elevator systems
- Providing a water sensor in the elevator pit to recall elevator to DFE

Additional guidance can be found FEMA Technical Bulletin 4, *Elevator Installation for Buildings Located in Special Flood Hazard Areas* (2010b).

7.6.3 Fuel Tanks and Emergency Pumps

Conclusion 37. Protection of Fuel Storage Tanks: The MAT observed numerous fuel storage tanks used to supply emergency generators and other equipment that were not designed to be protected against flood hazards. Large fuel storage tanks in New York City are located at the lowest occupied grade, often at basement level, in accordance with the building code and because of concerns related to fire risk and efficient use of available space. During the flood event, some tanks broke their anchorage and damaged other building systems within the compartment, while other tanks were crushed and released fuel oil into the floodwater.

Recommendation 37a. Design installation of large fuel storage tanks to resist flotation and implosion: Building owners and operators, including WWTPs, should install large fuel storage tanks that are designed to resist flotation forces and implosion for the design flood level. To meet business continuity requirements, redundant emergency power systems should be considered. Facility owners should understand that full tanks or those that are nearly full are inherently less buoyant, better resist uplift, and are less susceptible to crushing. Therefore, facility owners should considering filling tanks prior to a flooding event (depending on advance warning). See Hurricane Sandy Recovery Advisory No. 6, *Protecting Building Fuel Systems from Flood Damage* (FEMA 2013e) for more information on protecting building fuel systems.

Recommendation 37b. Protect tanks in subgrade areas from flood damage: Building owners with fuel tanks located in below-grade spaces should locate tanks in dry-floodproofed enclosures per ASCE 24 or ensure that tanks are able to resist buoyance and crushing pressures. When possible, move mechanical and electrical systems associated with the tanks to above the elevation specified by ASCE 24. When elevation is not possible, protect these critical building systems with wet or dry floodproofing. Any electrical or mechanical equipment required to operate a dry floodproofing enclosure should have emergency power. Guidance can be found in Hurricane Sandy Recovery Advisory No. 4, *Reducing Interruptions to Mid- and High-Rise Buildings during Floods* (FEMA 2013e). Some recommendations from the Hurricane Sandy Recovery Advisories Nos. 4 and 6 include:

- Elevate the tank above flood levels
- Use tanks that can withstand pressure
- Anchor tanks to resist buoyancy
- Dry floodproof the tank room and use normal (not high-pressure resistant) tanks
- Do not use oil as a fuel source in below-grade areas, use natural gas boiler instead
- Filling the tank is a failsafe/emergency measure to be done pre-event

Conclusion 38. Protection of Associated Utilities Equipment: Many of the utilities and building systems observed by the MAT were not designed and protected against flood hazards. Utilities and equipment located in the basement levels, including electric switchgears, pumps, and chillers, as well as copper cables and elevators, were completely submerged and heavily damaged.

Recommendation 38. Install fuel pumps in large storage tanks to maintain operations: Facility owners should install fuel pumps for large storage tanks that are designed to operate during flood conditions. Depending on the relative location of the large storage tank and the generators, submersible pumps, elevated pumps, and/or flood protection measures may be required to maintain operation.

Facility owners should also elevate electric power systems and cooling systems 1 foot above the structure elevation shown in Table 7-1. This also applies to switchgear and transformer vaults often hosted by the local electrical utility.

Conclusion 39. Sump Pumps: Water continued to seep into basements for several weeks after the flood event as the groundwater level slowly receded. Inadequate groundwater protection systems and emergency pumping of subgrade levels resulted in ongoing seepage that slowed cleanup and recovery efforts throughout the affected area.

Recommendation 39. Install sump pumps to remove seepage from subgrade areas: To address ground saturation and increased seepage into basements during and following a flood event, facility owners should install sump pumps that are tied to emergency power systems to remove seepage and/or floodwater.

7.7 Continuity of Operations in Critical Facilities and Other Key Assets

Protecting critical infrastructure from natural hazards is vital not only to minimizing damage, but also to minimizing down-time. Prolonged down-times place a heavy burden on the community.

Continuity of operations is particularly important for critical facilities and other key community assets. The following conclusions and recommendations are primarily for critical and essential facilities, though owners and operators of other facilities may also find them useful.

7.7.1 Planning for Continuity of Operations

Conclusion 40. Need for Holistic Approach to Building Systems and Planning: Many of the emergency preparedness plans for critical and essential facilities visited by the MAT did not consider damage from a hazard in combination with system failures and similarly, building systems were not designed with this consideration. For example, many facilities were not prepared for concurrent flooding and power loss. This lack of detailed planning had a large effect on those facilities that decided to "defend in place." For instance, some facilities had to unexpectedly evacuate when emergency power was lost and access to the lower floors was made difficult by the presence of floodwater.

Some examples of the types of damage that occurred because of the combined failures of building systems include:

- The MAT found that most of the damage observed was related to the placement of **mechanical and electrical systems in basements and first stories**. When systems were directly inundated or intentionally shut down to reduce damages, a wide range of building services was interrupted. Electrical switchgear and mechanical systems were destroyed and boilers inundated. The MAT observed that transformer vaults and unit substations were often placed on lower levels; when this equipment flooded, it prevented the facility from receiving utility power until the vault transformers or the unit substations were replaced, typically after the utility company energized its distribution lines.

- **Fuel supplies** for emergency power systems (i.e., main fuel tanks, pumping systems, day tanks, and tank vents) and electrical supplies for emergency power (generator and distribution equipment, supplies to vulnerable equipment, and power configuration) were not considered holistically. The result was that floodwater entered many buildings via the numerous entry points where floors and walls were penetrated by mechanical piping and electrical conduits.

- In data centers, older style **communication cables** consisted of multi-pair copper conductors with paper insulation. Outside of the facility, the cables were pressurized to prevent water entry. However, floodwater disrupted power to the compressors that supplied the cables. The loss of pressurization allowed floodwater to enter the communication cables, destroying the paper insulation and damaging the cables beyond repair. Newer style fiber optic cable, on the other hand, was mostly undamaged.

Recommendation 40a. Building owners should provide emergency power systems for facilities: This is particularly important for healthcare and other critical facilities. Specifically, facility owners should:

- Examine emergency power systems holistically to evaluate not only the emergency power system, but other systems that rely on emergency power such as the electrical system and mechanical system. Mutually dependent systems should be evaluated together to design a resilient system that includes redundancies. Facility owners should evaluate combinations of hazards, such as fire and flood.

- Elevate or dry floodproof critical emergency power equipment.

- Protect fuel supplies for emergency power systems. The focus should be on protecting liquid fuels (i.e., diesel and oil) and system components (i.e., day tanks, pumping systems, main fuel tanks, and tank vents). Refer to Hurricane Sandy Recovery Advisory No. 6, *Protecting Building Fuel Systems from Flood Damage* (FEMA 2013e), for additional details and also see recommendations in Hurricane Sandy Recovery Advisory No. 4, *Reducing Interruptions to Mid- and High-Rise Buildings During Floods* (FEMA 2013e), for general building systems.

- Mitigate electrical systems for emergency power. For instance, elevate generator and distribution equipment and transfer switches, isolate supplies to vulnerable equipment, and reconfigure emergency power systems to be less vulnerable to flooding.

Recommendation 40b. Adhere to Presidential Preparedness Directive 21: As the recent Presidential Preparedness Directive 21 states, critical infrastructure needs to withstand and rapidly recover from all hazards. Lower floors of buildings should be floodproofed, evacuated, and preparedness plans should include a contingency for lack of access to or from the building post-event.

Further guidance can be found in FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds* (FEMA 2007b). See also the Hurricane Sandy Recovery Advisory Numbers 2, 4, and 5 for information on floodproofing and limiting building interruptions.

Recommendation 40c. Facility owners and operators should develop holistic plans to limit disruption of critical functions: New buildings, repairs to existing buildings, and systems that support critical functions should be designed to be more resistant to disruption by flood events. Owners and operators should provide emergency power systems or temporary connections to reduce outages when utilities are disrupted. Recommendations described in other parts of this chapter should be applied to protect such systems, specifically by:

- Establishing and maintaining connection points for temporary facilities (refer to Recommendation 35)

- Establishing and maintaining redundancies (refer to Recommendations 21, 34, 37a, 40a, 41, and 45c)

- Prioritizing which electrical systems will use back-up power or emergency generators (refer to Recommendation 33b)

- Protecting elevator service (refer to Recommendation 36b)

- Using flood damage-resistant materials (refer to Recommendation 26b)

- Limiting use of lower floors (refer to Recommendations 25c and 30d)

- Elevating temporary equipment (refer to Recommendation 35)

7.7.2 Healthcare Facilities

Conclusion 41. Prepare for Emergency Evacuation: Emergency evacuation of a healthcare facility either during or immediately after an event is difficult and dangerous. Complete loss of power, including back-up systems, is common following these events. Healthcare facilities struggled after Hurricane Sandy to provide care or evacuate in the dark.

Recommendation 41. Healthcare facilities should develop a comprehensive plan for complete power loss: Healthcare facilities should take steps to prepare for disaster events, such as:

- Include in preparedness plans the details of an emergency evacuation during or immediately after an event; such plans should include internal and external resources and agreements
- Elevate or dry floodproof mechanical and electrical service components per ASCE 24
- Elevate electrical systems for utility power (elevate main switchgear, utility transformers, and distribution equipment; isolate supplies to vulnerable equipment)
- Install and maintain redundancies in building systems to speed post-disaster recovery
- Install or maintain quick connects for temporary power and other systems (i.e., power, potable water, heat) for use in future storm events if needed and appropriate measures to protect the backup emergency equipment should be taken

Conclusion 42. Loss of Power: Most of the hospitals observed by the MAT experienced complete loss of power, including back-up systems, during Hurricane Sandy. Hospitals struggled to provide care, perform evacuations in the dark, and start up quickly after the event. Hospitals and long-term healthcare facilities were forced to transfer patients and long-term residents to other facilities with few or no accompanying records. Emergency evacuation of a hospital either during or immediately after a flood event is difficult and potentially dangerous.

Recommendation 42. Develop emergency plans that cover complete power loss for extended periods: Healthcare facilities should plan for extended complete power loss and associated loss of other utilities by developing emergency plans that include emergency operations, training exercises, and procurement of emergency systems and supplies. Appropriate supplies may include provision of headlamps for staff, back-up communication systems with batteries, and battery-powered lighting.

Conclusion 43. Vulnerable Healthcare Equipment: Key equipment on lower floors is vulnerable to flooding. Key equipment includes hospital equipment (i.e., CT scanner, MRI machines, refrigeration equipment for blood banks, etc.), communications equipment, and vital records.

Recommendation 43a. Prepare key records before a significant storm event: Healthcare facilities should prepare key records in advance of a storm to aid continuity of patient care in the event of power loss or evacuation. For example, NYU Langone Medical Center pre-printed patient summaries that greatly aided the receiving hospitals when patients were evacuated.

Recommendation 43b. Protect critical function areas from flooding: Facility owners should dry floodproof and/or place critical functions (i.e., emergency room and radiology) on upper floors, and wet floodproof or place non-critical functions (i.e., laundry and food service) on lower floors more prone to flooding. Facilities should identify back-up spaces for critical functions that cannot be moved, such as their Emergency Department. They may also want to consider subcontracting non-critical functions, such as laundry and food service, as part of their planning process. Some medical imaging equipment is located on subgrade floors due to shielding requirements and may not be moveable.

For additional details in reducing flood effects, including guidance in regard to medical and compressed gas storage tanks, refer to Hurricane Sandy Recovery Advisory No. 2, *Reducing Flood Effects in Critical Facilities* (FEMA 2013e).

7.7.3 Gas Stations

Conclusion 44. Fuel Shortages: The availability of fuel for generators and vehicles, as well as the ability to deliver it, was sharply reduced in the affected areas after Hurricane Sandy (New York City 2013b). The fuel shortage affected hospitals, fire and police stations, and other critical facilities, as well as recovery efforts and employees of businesses not directly affected by the power outage.

Recommendation 44a. Prepare a plan for maintaining fuel supplies: Critical facilities or those that must be functional during and immediately after a disaster event should develop plans for maintaining fuel supplies during emergency situations. The plans should include fuel for generators, emergency employees, and work vehicles and should specify coordination with a fuel supplier.

Recommendation 44b. Protect subgrade fuel pumps from flooding: To remain operational during and immediately after a flood event, gas stations in SFHAs should protect subgrade fuel pumps from flood damage and make arrangements for emergency power, particularly for stations that require IT and telecom systems to dispense fuel. If emergency generators are not installed, a dedicated circuit to rapidly connect portable generators may be useful.

7.7.4 Transit Facilities (Maintenance Facilities, Entry Stations)

Conclusion 45. Insufficient Flood Protection of Transit and Maintenance Facilities: The transit facilities and their related maintenance facilities were inadequately protected from flood hazards. Floodwaters flooded system tunnels where access points to the subways and rail systems, such as elevator kiosks at street level and stairway entrances, were inadequately protected from flood inundation.

Recommendation 45a. Protect key utilities and ventilation equipment to the level applicable for critical facilities: Facility owners should consider elevating or protecting key utilities and ventilation equipment at maintenance facilities and the associated transit facilities to the 0.2-percent-annual-chance flood level, consistent with design guidance for critical facilities (refer to Recommendation 34). The potential for seepage after the flood event may continue for several weeks and protection from this seepage should be considered for facilities. Facility and transit protection should consider the potential for multiple subsurface seepage penetration points from adjacent buildings, utility system entry points, and proximate remnant or relic urban underground systems and should also be coordinated with protection and recovery plans along the transit alignments.

Recommendation 45b. Prepare a plan to protect critical assets: Transit facility owners and operators should develop and execute a more robust plan for moving critical assets such as rail cars and subway cars out of high hazard areas in advance of a hazard event.

Recommendation 45c. Install barriers to prevent floodwater entering transit stations: Transit facility owners should consider installing barriers and floodgates to prevent floodwater entry into transit stations at key points. Inflatable barriers could be installed as a redundant measure to provide intermediate pressure relief at pumping locations or to prevent or divert surface flow runoff. Where inflatable barriers are used, facility owners should consider filling them with salt water, as opposed to fresh water, to ensure that density is not an issue. If possible, floodproofing measures should protect to the DFE or 0.2-percent-annual-chance flood event elevation, whichever is higher. The design of floodgates and barriers should consider existing structural capacity, interconnectivity of underground tunnels, and the flood resistance of supporting structures.

Conclusion 46. Insufficient Preparedness of Transit Facilities: Many transit facilities in flood zones have systems for pumping street drainage from rainfall and snow melt, but do not have emergency power systems for flood events. One system had submersible pumps that successfully pumped water during the flood event until they were damaged by debris, such as plastic bags and trash, carried by the floodwater from streets and public containers.

Recommendation 46. Install submersible pumps: Transit facility owners should consider installing submersible pumps for flood events with safeguards against debris, such as plastic bags and trash.

7.7.5 Wastewater Treatment Plants

Conclusion 47. Insufficient Below-Grade Flood Protection of Wastewater Treatment Plants: The WWTP observed by the MAT did not have adequate flood protection of their below-grade areas. The lack of effective flood barriers outside of or within the tunnel system allowed floodwater to fill the utility tunnels and connected facility basements. Specifically, flooded utility tunnels resulted in extended downtime while the utility systems were being repaired.

Recommendation 47. Protect utility tunnels from flooding: WWTP owners and operators should consider protecting utility tunnels by installing barriers and/or partitions. Depending on the flood elevation and location, berms and floodgates around the utility tunnel should be considered in conjunction with structural flood barriers within the tunnel system that create partitions. In order for any structural barriers to be effective, however, the original structure must be carefully evaluated before implementing any floodproofing measure to ensure its structural capacity to resist DFE flood loads. To address ground saturation and increased seepage into utility tunnels during and following a flood event, sump pumps tied to emergency power systems that have adequate capacity for removing seepage and/or floodwater should be provided.

7.8 Historic

Protecting historic structures and preserving stored artifacts are in the best interest of our Nation. Therefore, protecting these historic structures and artifacts from natural hazards should be included in community hazard mitigation plans. The following conclusions and recommendations are based on the MAT's observations and review of the historic structures and properties it visited in New Jersey, New York, and New York City.

Conclusion 48. Hazard Planning: The majority of the historic structures visited by the MAT lacked site-specific hazard mitigation plans. While historic structures and other cultural resources are usually included as part of a local jurisdiction's hazard mitigation plan, these plans do not delve into each historic property in detail and instead provide general mitigation strategies.

Recommendation 48a. Develop site-specific multi-hazard mitigation plans for landmark buildings: Whether publically or privately owned, historic property owners should develop a site-specific multi-hazard mitigation plan for landmark buildings and their associated landscape features. While specifically written for State and local governments, FEMA 386-6, *Integrating Historic Property and Cultural Resource Considerations into Hazard Mitigation Planning: State and Local Mitigation Planning How-To Guide* (FEMA 2005), is also useful for building owners, as it describes the four steps of developing a mitigation plan: (1) organize resources, (2) assess risks, (3) develop a mitigation plan, and (4) implement the plan and monitor progress.

Recommendation 48b. Protect historic structures that cannot be elevated: Where elevation is not feasible or would be an adverse effect, floodproofing might be a viable alternative. Floodproofing measures could include:

- Relocating critical building systems components such as electrical systems, HVAC, furnaces, and boilers out of the basement to a higher floor
- Wet floodproofing basement areas
- Using flood-resistant materials below the BFE
- Where structurally feasible, bracing and reinforcing walls to withstand hydrostatic forces
- Where structurally feasible, installing exterior watertight shields for doors and windows or using interior watertight shields over windows and doors where the use of exterior shields may adversely affect the historic designation
- Where structurally feasible, using membranes and other sealants in basement areas to reduce water seepage through walls

- Installing sump pumps or a drainage collection system in basement areas
- Where possible, elevating or relocating appliances to elevated areas

Conclusion 49. Integrate N.J.A.C. 5:23-6 and the NFIP: The New Jersey Rehabilitation subcode (N.J.A.C. 5:23-6, 2013) and the NFIP are not integrated. Both documents provide favorability to historic structure elevation requirements provided by the building code and the NFIP.

Recommendation 49. Develop mitigation guidance for historic structures: FEMA should work with the NJDCA to provide mitigation guidance about a broad range of mitigation options to make historic structures more resilient by retrofitting historic structures with wet floodproofing techniques as opposed to traditional elevation techniques.

Conclusion 50. Retention of Historic Designation: The Federal government encourages the retention of historic designation through incentives such as not having to meet the floodplain management requirements of the NFIP as long as they maintain their historic structure designation, and through tax credits for the rehabilitation of historic structures.

Recommendation 50. Evaluate retrofit options for historic buildings: Owners of historic structures should evaluate if the structure can be retrofitted with flood mitigation measures without loss of historic designation. If retrofitting without loss of historic designation is possible, a registered design professional with experience rehabilitating historic structures should be used when designing and installing flood mitigation retrofits to a historic structure.

Conclusion 51. Protection of Climate-Controlled Artifacts: Museums and historic structures need temporary power to maintain climate-control in locations where artifacts are stored and to protect historic fixtures and finishes. Without a climate-controlled environment, fragile artifacts and building elements are vulnerable to damage by humidity. The MAT observed that critical building systems were damaged and rendered non-functional by storm surge and floodwater, and temporary power systems either did not exist or failed, placing artifacts and interior fixtures/furnishings at risk due to heightened moisture levels.

Recommendation 51. Protect critical building systems of historic structures: The recommendations for protecting critical building systems components and continuity of operations (see Section 7.7) are also applicable to museums and historic structures. However, the design must ensure that protective measures do not compromise the building's historic designation or eligibility for historic designation. Protective measures may include:

- Elevating critical building systems and components
- Dry floodproofing critical building systems and components if unable to elevate them
- Storing artifacts and other fragile items in areas above BFE

If located outside the building, temporary power generators installed at a historic building should be placed so as to not adversely affect character-defining features of the building and surrounding landscapes and view sheds, but should still ensure the equipment is protected from floodwater and high wind.

Conclusion 52. Unshielded Subgrade Windows and Doors: The MAT observed many instances of damage that resulted from unshielded subgrade basement windows and unshielded doors that failed and allowed water to enter the first floor and basement areas of historic structures.

> ***Recommendation 52. Protect subgrade windows and doors:*** Building owners should protect subgrade basement windows and unshielded doors by installing flood shields to cover openings to protect the structure from low-level flooding (less than 3 feet deep). A registered design professional should be consulted to determine whether or not the building will be able to resist the loads imposed by the level of flooding. Any mitigation measures should be incorporated in such a way as not to cause loss of historic designation or obscure existing significant historic features.

7.9 Summary of Conclusions and Recommendations

Table 7-3 is a matrix showing a list of the conclusions and recommendations cross referenced to the sections of the report that describe the supporting observations. Note that while some recommendations may be applicable to all building types, only the buildings for which the recommendations are most applicable are indicated on this table.

Table 7-3: Summary of Conclusions and Recommendations

Observations	Conclusions	Recommendations	Low-Rise	Mid- and High-Rise	Healthcare Facilities	First Responders	Schools	Data Centers	Wastewater Treatment Plants	Transportation Facilities	Historic Structures
Sections 4.1.3, 4.1.4, 4.2.3, and 4.2.4	**1:** Vulnerability Assessment	**1a**: Perform vulnerability assessments		✔							
Section 5.2.2, 5.5.2, 5.6.2, and 5.7.2		**1b**: Perform vulnerability assessments for all critical facilities			✔	✔	✔	✔	✔	✔	
Appendix G, Section G.1.1	**2:** Flood Hazard Area Control Act (New Jersey)	**2:** NJDEP, NJDCA, and FEMA should coordinate review	✔	✔	✔	✔	✔	✔	✔	✔	
Appendix G, Section G.1.1	**3:** Model Flood Damage Prevention Ordinance (New Jersey)	**3:** NJDEP should evaluate FEMA model floodplain management ordinance	✔	✔	✔	✔	✔	✔	✔	✔	
Appendix I, Section G.1.1, Section G.1.2	**4:** Code Officials and Continuing Education (New Jersey)	**4:** Develop training on flood provisions of New Jersey building code									
Appendix G, Section G.1.2	**5:** State Review of Buildings in Flood Hazard Areas (New Jersey)	**5:** Establish formal consultation process	✔	✔		✔					

Table 7-3: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Low-Rise	Mid- and High-Rise	Healthcare Facilities	First Responders	Schools	Data Centers	Wastewater Treatment Plants	Transportation Facilities	Historic Structures
Appendix G, Section G.1.3	**6:** Building Code Amendments to the New Jersey UCC (New Jersey)	**6:** Amend the UCC	✔	✔	✔	✔	✔	✔	✔	✔	
Appendix G, Section G.2.1	**7:** Model Local Law for Flood Damage Prevention (New York State)	**7**: NYSDEC should evaluate FEMA model floodplain management ordinance	✔	✔	✔	✔	✔	✔	✔	✔	
Appendix G, Section G.2.2	**8:** Model Local Law for Administration of the Building Codes (New York State)	**8:** Develop optional provisions for model local law	✔	✔	✔	✔	✔	✔	✔	✔	
Section 2.4	**9:** Site Requirements of the New York State Hospital Code (New York State)	**9**: Modify the hospital code to make flood provisions mandatory			✔						
Appendix G, Section G.2.2	**10:** Code Officials and Continuing Education (New York State)	**10**: Develop training on flood provisions of New York building code									
	11: Technical Bulletin on "Flood Venting" (New York State)	**11**: Update DCEA technical bulletin on flood venting	✔	✔	✔	✔	✔	✔	✔	✔	✔
Appendix G, Section G.2.3	**12:** Building Code Amendments to the New York State Uniform Code (New York State)	**12**: Amend New York State Code	✔	✔	✔	✔	✔	✔	✔	✔	
Appendix G, Section G.3.1	**13:** Building Code Amendments to the New York City Building Code (New York City)	**13**: Modify proposed New York City code amendments	✔	✔	✔	✔	✔	✔	✔	✔	
	14: Substantial Damage and Substantial Improvement Determinations (New York City)	**14:** The DOB should establish protocol to verify data	✔	✔	✔	✔	✔	✔	✔	✔	
Appendix G, Section G.3.2	**15:** Inspection of Construction in Flood Hazard Areas (New York City)	**15**: Establish mechanism for special inspections	✔	✔	✔	✔	✔	✔	✔	✔	

Table 7-3: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Low-Rise	Mid- and High-Rise	Healthcare Facilities	First Responders	Schools	Data Centers	Wastewater Treatment Plants	Transportation Facilities	Historic Structures
Appendix G, Section G.3.1	**16:** Dry-Floodproofed Buildings (New York City)	**16:** Amend Appendix G of New York City Building Code		✔	✔	✔	✔	✔	✔	✔	
Appendix G, Section G.3.1	**17:** NYC School Construction Authority Design Standards (New York City)	**17**: Revise NYC School Construction Authority Design Standards					✔				
Appendix F, Section F.5.2	**18:** NFPA 99	**18:** Revise IBC to reference NFPA			✔						
Appendix F, Section F.5.2	**19:** NFPA 99 and ASCE 24 Consistency	**19:** Revise NFPA to reference ASCE 24			✔						
Appendix F, Section F.5.1	**20:** Facility Guidelines Institute	**20**: Revise FGI to reference ASCE 24			✔						
Appendix F, Section F.5.1	**21:** Building System Damage and FGI	**21**: Revise FGI to provide specific guidance			✔						
Sections 3.1, 4.1, 4.2, Chapter 5, and Chapter 6	**22:** International Code Series Amendments	**22:** Propose changes to I-Codes	✔	✔							
Sections 3.1.1 and 6.1	**23:** Siting of Buildings Relative to Erosion Control Structures	**23a:** Document performance of erosion control structures									
Sections 3.1.1		**23b:** Review mapping procedures									
Sections 3.1.1, 4.1.1, 4.2.1, 6.1 Appendix J, Sections J.1.3, J.6.2		**23c:** Conduct detailed evaluation of damage behind erosion control structures	✔	✔							
Sections 3.1.1, 4.1.1, 4.2.1, 6.6, Appendix J, Sections J.1.3, J.6.2	**24:** Protection Afforded by Beaches and Dunes	**24a:** Review dune loss criterion									
Sections 3.1.1, 4.1.1, 4.2.1, 6.6, Appendix J, Sections J.1.3, J.6.2		**24b**: Develop siting and design guidance for Sandy-affected coastal areas	✔	✔	✔	✔	✔	✔	✔	✔	

Table 7-3: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Low-Rise	Mid- and High-Rise	Healthcare Facilities	First Responders	Schools	Data Centers	Wastewater Treatment Plants	Transportation Facilities	Historic Structures
Sections 3.1.1, 4.1.1, 4.2.1, 6.6, Appendix J, Sections J.1.3, J.6.2	**24:** Protection Afforded by Beaches and Dunes	**24c**: Identify barrier islands with history of breaching	✔	✔	✔	✔	✔	✔	✔	✔	
Section 3.1.3	**25:** Effect of Foundation on Building Survival	**25a**: Reference FEMA guidance regarding foundations for new construction	✔								
Section 3.1.3		**25b**: Elevate existing low-rise buildings where possible	✔								
		25c: Fill below-grade areas of buildings in the SFHA	✔								
		25d: Develop mitigation guidance for existing residential buildings	✔								
	26: Insufficient Load Path Continuity	**26a**: Retrofit existing homes to improve load paths	✔								
		26b: Perform regular inspections for compromised connections	✔								
		26c: New home designs should adequately address flood risk	✔								
		26d: Publish prescriptive load path details	✔								
		26e: Require plans and specifications to show load path connections	✔								
Section 3.2	**27:** Insufficient Siding Installation	**27:** Install siding properly	✔								
Chapter 5, Appendix J	**28:** Flood Protection of Critical and Essential Facilities	**28**: Local jurisdictions should determine what facilities are critical and essential			✔	✔	✔	✔	✔	✔	
Sections 4.2.1, 5.2.1, 5.5, 5.6, 5.7	**29:** Flooding in Subgrade Areas Between Buildings	**29a:** Develop educational materials on below-grade flooding vulnerabilities		✔	✔	✔	✔	✔	✔	✔	
		29b: Protect against flooding across subgrade connections		✔	✔	✔			✔	✔	

Table 7-3: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Low-Rise	Mid- and High-Rise	Healthcare Facilities	First Responders	Schools	Data Centers	Wastewater Treatment Plants	Transportation Facilities	Historic Structures
Sections 3.1.6, 4.1.3, 4.2.3, 5.2.3, 5.3.3, 5.4.3, 5.5.3, 5.6.3, 5.7.3	**30:** Poor Performance of Buildings and Building Systems	**30a:** Elevate new and Substantially Damaged/ Improved structures to protect from flooding	✔	✔	✔	✔	✔	✔	✔	✔	
		30b: Elevate existing structures to protect from flooding	✔								
		30c: Building designs should account for flood conditions	✔	✔	✔	✔	✔	✔	✔	✔	
		30d: Improve protection of subgrade areas outside the SFHA	✔	✔	✔	✔	✔	✔	✔	✔	✔
Sections 1.2.2, 1.4	**31:** Accounting for Future Conditions	**31**: Designers should consider the potential impacts of sea level rise	✔	✔	✔	✔	✔	✔	✔	✔	
Sections 3.1.6, 4.1.3, 4.2.3, Chapter 5	**32:** Protection of Building Systems	**32:** Building owners should elevate, relocate, or protect building systems above the BFE	✔	✔	✔	✔	✔	✔	✔	✔	✔
	33: Emergency Power Systems	**33a:** Submit a proposal to modify ASCE 24, Section 7.1 commentary		✔	✔	✔	✔	✔	✔	✔	
		33b: Determine minimum required emergency power duration and capacity		✔	✔	✔	✔	✔	✔	✔	
	34: Protection of Building System Components	**34:** Protect critical building systems in subgrade areas		✔	✔	✔	✔	✔	✔	✔	
	35: Facilitate the Connection of Temporary Building Systems	**35:** Establish points for temporary power connection		✔	✔	✔	✔	✔	✔	✔	
Sections 4.1.4, 4.2.4, 5.2, 5.5, 5.7	**36:** Protect Below-Grade Elevator Equipment	**36a:** Emergency plans should address the possibility of elevator failure		✔	✔	✔	✔	✔	✔	✔	
		36b: Facilities should protect elevator service, especially when it is essential to function		✔	✔	✔	✔	✔	✔	✔	

Table 7-3: Summary of Conclusions and Recommendations (continued)

Observations	Conclusions	Recommendations	Low-Rise	Mid- and High-Rise	Healthcare Facilities	First Responders	Schools	Data Centers	Wastewater Treatment Plants	Transportation Facilities	Historic Structures
Sections 4.1.3, 4.2.3, Chapter 5	**37:** Protection of Fuel Storage Tanks	**37a:** Design installation of large fuel storage tanks to resist flotation and implosion		✔	✔	✔	✔	✔	✔	✔	
		37b: Protect tanks in subgrade areas from flood damage		✔	✔	✔	✔	✔	✔	✔	
Sections 3.1.6, 4.1.3, 4.2.3, Chapter 5	**38:** Protection of Associated Utilities Equipment	**38:** Install fuel pumps in large storage tanks to maintain operations		✔	✔	✔	✔	✔	✔	✔	
	39: Sump Pumps	**39:** Install sump pumps to remove seepage from subgrade areas		✔	✔	✔	✔	✔	✔	✔	
Chapter 5	**40:** Need for Holistic Approach to Building Systems and Planning	**40a:** Building owners should provide emergency power systems for facilities			✔	✔	✔	✔	✔	✔	
		40b: Adhere to Presidential Preparedness Directive 21			✔	✔	✔	✔	✔	✔	
		40c: Facility owners and operators should develop holistic plans to limit disruption of critical functions			✔	✔	✔	✔	✔	✔	
	41: Prepare for Emergency Evacuation	**41:** Healthcare facilities should develop a comprehensive plan for complete power loss			✔						
Section 5.2	**42:** Loss of Power	**42:** Develop emergency plans that cover complete power loss for extended periods			✔						
	43: Vulnerable Healthcare Equipment	**43a:** Prepare key records before a significant storm event			✔						
		43b: Protect critical function areas from flooding			✔						

Table 7-3: Summary of Conclusions and Recommendations (concluded)

Observations	Conclusions	Recommendations	Low-Rise	Mid- and High-Rise	Healthcare Facilities	First Responders	Schools	Data Centers	Wastewater Treatment Plants	Transportation Facilities	Historic Structures
Section 5.7	**44:** Fuel Shortages	**44a:** Prepare a plan for maintaining fuel supplies								✔	
		44b: Protect subgrade fuel pumps from flooding								✔	
	45: Insufficient Flood Protection of Transit and Maintenance Facilities	**45a:** Protect key utilities and ventilation equipment to the level applicable for critical facilities								✔	
		45b: Prepare a plan to protect critical assets								✔	
		45c: Install barriers to prevent floodwater entering transit stations								✔	
	46: Insufficient Preparedness of Transit Facilities	**46**: Install submersible pumps								✔	
Section 5.6	**47:** Insufficient Below-Grade Flood Protection of Wastewater Treatment Plants	**47:** Protect utility tunnels from flooding							✔		
Chapter 6	**48:** Hazard Planning	**48a:** Develop site-specific multi-hazard mitigation plans for landmark buildings									✔
Chapter 6	**48:** Hazard Planning	**48b:** Protect historic structures that cannot be elevated									✔
	49: Integrate N.J.A.C. 5:23-6 and the NFIP	**49:** Develop mitigation guidance for historic structures									✔
	50: Retention of Historic Designation	**50:** Evaluate retrofit options for historic buildings									✔
	51: Protection of Climate-Controlled Artifacts	**51:** Protect critical building systems of historic structures									✔
	52: Unshielded Subgrade Windows and Doors	**52:** Protect subgrade windows and doors									✔