C Checklist for Vulnerability of Flood-Prone Sites and Buildings

The Checklist for Vulnerability of Flood-Prone Sites and Building can be used to assess site-specific flood hazards and building vulnerability. The checklist presented here is an amended version of the checklist that was developed for FEMA P-424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds* (FEMA 2010a). The checklist is organized by specialty area, and each section can be assigned to a subject matter expert in that specialty for greater accuracy and completeness of the assessment. The results should be integrated into a master vulnerability assessment to guide the design process and choice of appropriate mitigation measures.

Checklist for Vulnerability of Flood-Prone Sites and Buildings

Vulnerability Considerations	Guidance	Observations
Siting Conditions		
Is the site near a body of water (with or without a mapped flood hazard area)? Is the site in a flood hazard area shown on the community's map (FIRM or other adopted map)? If so, what is the flood zone? Is the site affected by a regulatory floodway?	All bodies of water are subject to flooding, but not all have been designated as a floodplain on FIRMs. Flood hazard maps are usually available for review in local planning and permit offices. Electronic versions of the FIRMs may be available online at http://www.fema.gov. Paper maps can be ordered by calling (800) 358-9616. Development in floodways, where floodwaters are typically faster and deeper, must be supported by engineering analyses that demonstrate no rise in flood levels. Floodwalls and levees are not permitted in floodways per NFIP regulations.	
Is the site in a storm surge inundation zone (or tsunami inundation area)?	In coastal communities, even sites at some distance inland from the shoreline can be exposed to extreme storm surge flooding. Storm surge maps may be available at State or local emergency management offices. ASCE 24, *Flood Resistant Design and Construction*, and NFIP regulations do not allow dry floodproofing in Coastal High Hazard Areas. Further, ASCE 24 does not allow dry floodproofing in Coastal A Zones or in High Risk Flood Hazard Areas.	

Checklist for Vulnerability of Flood-Prone Sites and Buildings (continued)

Vulnerability Considerations	Guidance	Observations
What is the DFE (or does an analysis have to be done to determine the DFE)? What is the minimum protection level required by regulatory authorities? Does the FIS or other study have information about the 500-year flood hazard area? Has FEMA issued post-disaster advisory flood elevations and maps? What are the expected depths of flooding at the site (determined using flood elevations and ground elevations)?	Refer to the FIS for flood profiles and data tables. Site-specific analyses should be performed by qualified engineers. Check with regulatory authorities to determine the required level of protection. If a major flood event has affected the community, FEMA may have issued new flood hazard information, especially if areas not shown on the FIRMs have been affected. Sometimes these maps are adopted and replace the FIRMs; sometimes the new data are advisory only.	
Has the site been affected by past flood events? What is the flood of record?	Records of actual flooding augment studies that predict flooding, especially if historical events resulted in deeper or more widespread flooding. Information may be available from local planning, emergency management, and public works agencies, State agencies, the U.S. Army Corps of Engineers, or the Natural Resources Conservation Service. The flood of record is often a lower probability event (with higher flood elevations) than the 100-year flood.	
What is the expected velocity of floodwaters on the site?	Velocity is a factor in computing loads associated with hydrodynamic forces, including drag on building surfaces. Approximations of velocity may be interpolated from data in the FIS Floodway Data Table if the waterway was studied using detailed methods, application of approximation methods based on continuity, local observations and sources, or site-specific studies. ASCE 24 limits dry floodproofing to areas where flood velocities are less than or equal to 5 feet per second.	
Are waves expected to affect the site?	Waves can exert considerable dynamic forces on buildings and contribute to erosion and scour. Wind-driven waves occur in areas subject to coastal flooding and where unobstructed winds affect wide floodplains (large lakes and major rivers). In riverine floodplains with high velocities, standing waves may occur. ASCE 24 and NFIP regulations do not allow floodproofing in Coastal High Hazard Areas. ASCE 24 also does not allow dry floodproofing in Coastal A Zones.	

Checklist for Vulnerability of Flood-Prone Sites and Buildings (continued)

Vulnerability Considerations	Guidance	Observations
Is there information on how quickly floodwaters may affect the site? What is the expected duration of flooding?	Warning time is a key factor in the safe and orderly evacuation of critical facilities. Certain protective measures may require adequate warning so that actions can be taken by skilled personnel. For dry floodproofing, ASCE 24 specifies minimum warning times when human intervention is necessary based on whether the community has a warning system and emergency plan. Duration has bearing on the stability of earthen fills, access to a site and emergency response, and durability of materials that come into contact with water. Records of actual flooding are the best indicator of duration because most floodplain analyses do not include an examination of duration.	
Is there a history of flood-related debris problems or erosion on the site?	Floodproofing design should account for deposition of debris and sediment, as well as the potential for erosion-related movement of the shoreline or waterway as appropriate. Buildings exposed to debris impact or undermining by scour and erosion should be designed to account for these conditions.	
Is the site in an area predicted to flood if a levee or floodwall fails or is overtopped? Is the site in an area predicted to be inundated if an upstream dam failed?	Flood protection works may be distant from the sites being assessed and not readily observable. Although, failure or overtopping is a low-probability event, it can cause unexpected and catastrophic damage because the protected lands are not regulated as flood hazard areas. The effects of an upstream dam failure are not shown on the FIRMs or most flood hazard maps prepared locally. Although dam failure is generally considered an unlikely event, the potential threat should be evaluated because of the catastrophic consequences. (Owners of certain dams should have emergency action plans for notifying and evacuating vulnerable populations and critical facilities.)	
Does the surrounding topography contribute to the flooding at the site? Is there a history of local surface drainage problems due to inadequate site drainage?	If areas with poor local drainage and frequent flooding cannot be avoided, filling, re-grading, and installation of storm drainage facilities may be required.	
Given the nature of anticipated flooding and soils, is scour around and under the foundation likely?	Scour-prone sites should be avoided, in part because of likely long-term maintenance requirements. Flooding that is high velocity or accompanied by waves is more likely to cause scour, especially on fills, or where local soils are unconsolidated and subject to erosion.	

Checklist for Vulnerability of Flood-Prone Sites and Buildings (continued)

Vulnerability Considerations	Guidance	Observations
Has water from other sources entered the building (e.g., high groundwater, water main breaks, sewer backup)? Is there a history of water intrusion through floor slabs or wall-floor connections? Are there underground utility systems or areaways that can contribute to basement flooding? Are there stormwater sewer manholes upslope of window areas or openings that allow local drainage to enter the basement/ lower floor areas?	These questions pertain to existing facilities that may be impaired by water from sources other than the primary source of flooding. The entire building envelope, including below-grade areas, should be examined to identify potential water damage.	
Is at least one access road to the site/building passable during flood events? Are at-grade parking lots located in flood-prone areas? Are below-grade parking areas susceptible to flooding?	The longer the duration of the flood, the more important access is. For the safety of occupants, most critical facilities should not be occupied during flood events. Areas where vehicles could be affected should have signage to warn users, including bus drivers, of the flooding risk. Emergency response plans should include instructions on notifying car owners.	
Architectural		
Are any critical building functions occupying space below the elevation of the 500-year flood or the DFE? Can critical functions be relocated to upper levels that are above predicted flood elevations? If critical functions cannot be relocated, is floodproofing feasible? If critical functions must continue during a flood event, have power, supplies, and access issues been addressed?	New critical facilities in flood hazard areas should not have any functions occupying flood-prone spaces other than parking, building access, and limited storage. Existing facilities in floodplains should be examined carefully to identify the best options for protecting functionality and the structure itself.	
Are any critical contents (files, computers, servers, equipment, or data) on levels of the facility below the flood elevations? Are critical records maintained offsite?	Existing facilities that are located in flood hazard areas may require continued use of flood-prone space. However, the potential for flooding should be recognized and steps taken to minimize loss of expensive equipment and irreplaceable data. If critical contents cannot be permanently located on higher floors, a flood response plan should take into account the time and attention needed to move such contents safely.	

Checklist for Vulnerability of Flood-Prone Sites and Buildings (continued)

Vulnerability Considerations	Guidance	Observations
Structural Systems		
What is the construction type and foundation type and what is the load-bearing capacity? Has the foundation been designed to resist hydrostatic and hydrodynamic flood loads?	If siting in a floodplain is unavoidable, new facilities should be designed to account for all loads and load combinations, including flood loads. Building components may need to be strengthened to withstand flood forces and the loads imposed by dry floodproofing components.	
If the building has below-grade areas (basements), are the lower floor slabs subject to cracking and uplift?	Below-grade spaces and their contents are the most vulnerable to flooding and local drainage problems. Rapid pump-out of below-grade spaces can unbalance forces if the surrounding soil is saturated, leading to structural failure. If below-grade spaces are intended to be dry floodproofed, the design must account for buoyant forces. Building spaces below the design flood level can be dry floodproofed, but higher flood levels can overtop the protection measures and result in severe damage. Dry floodproofing creates large unbalanced forces that can jeopardize walls and foundations that are not designed to resist the hydrostatic and hydrodynamic loads.	
Are any portions of the building below the DFE? Has the building been damaged in previous floods?	For existing buildings, it is important to determine which portions are vulnerable in order to evaluate floodproofing options. If flood depths are expected to exceed 2 or 3 feet, dry floodproofing may not be feasible. Alternatives include modifying the use of flood-prone areas.	
If the building is elevated on a crawlspace or on an open foundation, are there any enclosed areas?	New buildings may have enclosures below the DFE if the use of the enclosures is limited to crawlspace, parking, building access, and limited storage. In addition, the enclosures must have flood openings to allow inflow and outflow of floodwaters to minimize differential hydrostatic pressure. Existing buildings that are elevated and have enclosures below the flood elevation can be retrofit with flood openings.	
For an existing building with high-value uses below the flood elevation, is the building suitable for elevation in-place, or could it be relocated to higher ground?	Elevating a building provides better protection than dry floodproofing. Depending on the type and soundness of the foundation, even large buildings can be elevated on a new foundation or moved to a site outside the floodplain.	

Checklist for Vulnerability of Flood-Prone Sites and Buildings (continued)

Vulnerability Considerations	Guidance	Observations
Building Envelope		
Are there existing floodproofing measures below the expected flood elevation? What is the nature of the measures and what condition are they in? Is there an annual inspection and maintenance plan? Is there an action plan to implement floodproofing measures when flooding is predicted? Do the building operators/occupants know what to do when a flood warning is issued?	Floodproofing measures are only as good as their design and condition, especially if many years have passed since initial installation. Floodproofing measures that require human intervention are entirely dependent on the adequacy of advance warning and the availability and ability of personnel to install the measures properly.	
For existing buildings, what types of openings penetrate the building envelope below the 500-year flood elevation or the DFE (e.g., doors, windows, cracks, vent openings, plumbing fixtures, floor drains)?	For dry floodproofing to be effective, every opening must be identified and either permanently seal or covered with special barriers to resist infiltration. Sewage backflow can enter through unprotected plumbing fixtures.	
Are flood-resistant materials used for structural and nonstructural components and finishes below the 500-year elevation or DFE?	Flood-resistant materials are capable of withstanding direct and prolonged contact with floodwaters without sustaining damage that requires more than cosmetic repair. Contact is considered to be prolonged if it is 72 hours or longer in freshwater flooding areas, or 12 hours or longer in areas subject to coastal flooding.	
Utility Systems		
Is the potable water supply for the facility protected from flooding? If served by a well, is the wellhead protected?	Operators of critical facilities that depend on freshwater for continued functionality should learn about the vulnerability of the local water supply system and the utility owner's plans for recovery of service in the event of a flood.	
Is the wastewater service for the building protected from flooding? Are any manholes below the DFE? Is infiltration of floodwaters into sewer lines a problem? If the site is served by an onsite system that is located in a flood-prone area, have backflow valves been installed?	Most waste lines exit buildings at the lowest elevation. Even buildings that are outside the floodplain can be affected by sewage backups during floods.	

Checklist for Vulnerability of Flood-Prone Sites and Buildings (continued)

Vulnerability Considerations	Guidance	Observations
Are there any aboveground or underground tanks on the site in flood hazard areas? Are they installed and anchored to resist flotation during the design flood? Are tank openings and vents elevated above the 500-year elevation or DFE, or are they otherwise protected to prevent entry of floodwater or release of product during a flood event?	Dislodged tanks become floating debris that poses special hazards during recovery. Lost product causes environmental damage. Functionality may be impaired if tanks for heating fuel, propane, or fuel for emergency generators are lost or damaged.	
Mechanical Systems		
Are air handlers, HVAC systems, ductwork, and other mechanical equipment and systems located above the 500-year elevation or DFE? Are the vents and inlets located above the flood level or sealed to prevent entry of floodwater?	In existing buildings, utility equipment that is critical for functionality should be relocated to higher floors or elevated additions.	
Plumbing and Gas Systems		
Are plumbing fixtures and gas-fired equipment (e.g., meters, pilot-light devices/burners) located above the 500-year elevation or DFE?	In existing buildings, utility equipment that is critical for functionality should be relocated to higher floors or elevated additions.	
Is plumbing and gas piping that extends below flood levels installed to minimize damage?	Piping that is exposed could be affected by debris.	
Electrical Systems		
Are electrical systems, including backup power generators, panels, and primary service equipment, located above the 500-year elevation or DFE? Are electrical stand-by equipment and generators equipped with circuits to turn off power? Are the switches and wiring required for safety (minimal lighting, door openers) below the flood level designed for use in damp locations?	In existing buildings, utility equipment that is critical for functionality should be relocated to higher floors or elevated additions.	

Checklist for Vulnerability of Flood-Prone Sites and Buildings (continued)

Vulnerability Considerations	Guidance	Observations
Fire Alarm Systems		
Is the fire alarm system located above the 500-year elevation or DFE?	In existing buildings, utility equipment that is critical for functionality should be relocated to higher floors or elevated additions.	
Communications and IT Systems		
Are the communication/IT systems located above the 500-year elevation or DFE?	In existing buildings, communications and IT systems critical for functionality should be relocated to higher floors or elevated additions.	

ASCE American Society of Civil Engineers

DFE design flood elevation

FEMA Federal Emergency Management Agency

FIRM Flood Insurance Rate Map

HVAC heating, ventilation, and air conditioning

IT information technology

NFIP National Flood Insurance Program