Resilience Standards: Emerging Best Practices and Definitions

DESIGN FLOOD ELEVATION (DFE)

Design Flood Elevations (DFEs) are requred minimum floor heights based on existing and future flood conditions. In The District, there are two DFEs: DFE-1 pertains to the ground floor height; DFE-2 pertains to the second floor and critical infrastructure.

NAVD88

The North American Vertical Datum of 1988 (NAVD 88) is the vertical control datum leveling network that denotes the fixed the height of the primary tidal bench marks in North America.

WET FLOODPROOFING

Wet floodproofing allows water to enter and exit non-habitable portions of a building through engineered flood vents. This strategy minimizes structural damage from flood waters by equalizing hydrostatic pressure on the walls of the building, and prevents damage from bouyancy or uplift foces. In The District, wet floodproofing is allowed in low-occupancy service spaces such as loading and parking.

DRY FLOODPROOFING

Dry floodproofing is a system of multiple components aimed at inhibiting water from entering a structure. This technique is appropriate for low flood elevations and non-residential portions of structures that can withstand hydrostatic and hydrodynamic loads imposed by flooding. Dry floodproofing strategies may include watertight enclosures for openings, including barriers that might requre human intervention in advance of a storm event; membranes and sealants to reduce seepage; structural reinforcement to wall assemblies and foundations; drainage and pumping systems with backup power to control water intrusion; check valves to prevent the entrance of water or waste through plumbing systems; and flood doors and egress requirements. In The District, dry floodproofing may be allowed for lobbies or entries below DFE-1.

CRITICAL INFRASTRUCTURE

Building utility systems, including electrical and mechanical equipment that would create costly damage, safety risks, and loss of habitability and other critical building functions during a flood event are considered critical infrastructure. Critical mechanical systems include: Boilers and furnaces; Air-handlers, condenser units, and heat pumps; Ductwork and piping; Fuel storage tanks; Water heaters; Fire-suppression sprinkler controls; and, Elevator machine rooms. Critical electrical systems include: Electrical panels and switchgear; Backup generators; Alarm controls and components; Service wiring and receptacles; Building management systems; Telecommunications equipment; Electric and gas meters; and, Utility shut-off switches.

Engineered flood vents are part of a wet floodproofing strategy.

Deployable flood barriers are part of a dry floodproofing strategy.

FLOOD-RESISTANT MATERIALS

Flood damage-resistant materials are any building materials, components or systems capable of withstanding direct and prolonged contact with floodwaters without sustaining significant damage. They include materials such as concrete, stone, masonry block, ceramic and clay tile, pressure-treated and naturally decay-resistant lumber, epoxy paints, and metal. In addition to resisting damage from flood waters, these materials are relatively easy to clean after flood waters have receded.

Additional Resources:
- FEMA Technical Bulletin 2: Flood Damage Resistant Materials Requirements
- Building Science Corporation, BSD-111: Flood and Hurricane Resistant Buildings

LANDSCAPE INTERVENTIONS

There are many landscape intervention strategies to improve site and district-level resilience. At a minimum, landscapes should be designed to maximize stormwater absorbtion, require minimal irrigation or fertilizer, and be salt-tolerant where applicable. Plant species with robust root systems will hold soil and land best, preventing severe erosion damage. Care should be taken to utilize native plant species that contribute to the greater ecosystem that The District is part of.

ON-SITE ENERGY PRODUCTION

In the event of a blackout, providing reliable on-site backup power for continued operation of critical services can greatly increase a building's resilience. A backup power system includes generation equipment, dedicated circuitry, and associated components.

Examples of power generation include: Fuel-fired generator, with stored fuel supply; Piped natural gas generator; Bi-modal solar-electric system with battery storage; Combined Heat and Power, sometimes referred to as cogeneration, or "cogen," which generates on-site electricity and utilizes waste thermal energy for heating end-uses. Each of the above systems vary in terms of energy or fuel storage, quantity of emissions, fuel cost, and safety and maintenance. Because emergency generators sit idle 99% of the time, they may not be as reliable in the event of interrupted power as systems that are designed for continued use, such as solar-electric with storage and cogen.

Additional Resources:
- Enterprise Community Partners, Inc., Ready to Respond: Strategies for Multifamily Building Resilience
- LEED Resilient Design Pilot Credit: Passive Survivability and Back-up Power During Disruptions

Landscape interventions designed to maximize stormwater absorbtion contribute to site, district, and watershed resilience.

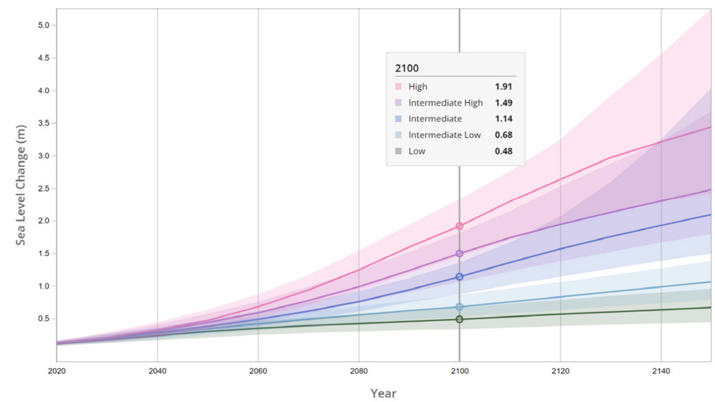
- FEMA Recovery Advisory 2: Reducing Flood Effects in Critical Facilities

BACKUP WATER MANAGEMENT

Backup water management systems, including sump pumps and backflow preventers, protect buildings from unintended flood water entry in conjunction with floodproofing strategies. Sump pumps remove water from below-grade spaces that may have made its way through gaps in sealed openings or walls. They also remove water from an underdrain system at the perimeter of below-grade walls or under a slab on grade. Sewage Backflow Prevention options include check, gate, and dual backflow valves.

Additional Resources:
- FEMA P-348, Edition 2: Protecting Utility Systems from Flood Damage.

Resilience Standards: Context and Approach



2022 NOAA SLR projections for the year 2100 in Providence.

GOALS FOR THE GUIDELINES

The goal of flood resilience standards in The District is to balance best practices for long term flood protection with reasonable development feasibility and public realm benefit. Flood resilience standards are specific to The District's unique geography and hydrology, and include measures to protect new structures from both the immediate threats of riverine and tidal flooding, as well as longer-term risk associated with storm surges. The District sits in a FEMA X zone and is not subject to FEMA flood requirements, as it is protected by a hurricane barrier. Requirements set forth in this document reflect risk from existing riverine flooding events and future sea level rise, neither of which are currently accounted for in FEMA regulations.

LIFESPAN & TIMESPAN

Development in The District requires design considerations for long-lifespan commercial and residential buildings. It is more efficient to elevate buildings and critical infrastructure before buildings are built. For this reason, our methodology looks out to 2100.

DATA SOURCES

SEA LEVEL RISE

Due to the complex and dynamic variables that contribute to sea level rise, projections beyond 2050 are more uncertain than near-term projections. The latest NOAA sea level scenarios for Providence, RI in the year 2100 range between 1.6 feet and 6.3 feet of SLR above mean higher highwater. Our methodology designs for the Intermediate Curve of 3.74 feet of SLR, using Providence data.

RIVERINE FLOOD DATA

The highest recorded high water from a precipitation event in the Providence River was an elevation of 9.29 feet NAVD88 during the 2010 Great Floods—a series of rainstorms between February and March of that year that inundated the state with stormwater. Source: Flood Insurance Study: Providence County, Rhode Island (All Jurisdictions). FIS Number 444007CV001C:Federal Emergency Management Agency, 2015. https://tinyurl.com/4v9rfz5k

STORM SURGE

CRMC STORMTOOLS is a method to map storm inundation for varying return period storms across all of Rhode Island's coastal waters. Predictions show water extent and depth at any given point for nuisance floods (1, 3, 5, and 10 year intervals) and 25, 50, 100, and 500 year storm scenarios at a 95% confidence interval. Sea level rise of 1, 2, 3, 5, and 7 feet on their own as well as combined with each

STORMTOOLS inundation mapping for 3'SLR and 100yr storm.

storm scenario are also modeled. Inundation levels in The District vary depending on topography and other factors, but averages 23' for District parcels. Source: STORMTOOLS https://stormtools-mainpage-crc-uri.hub.arcgis.com/

SPECIAL CONSIDERATION: HURRICANE BARRIER

Currently, the Fox Point Dam hurricane barrier closes to protect downtown Providence from storm surge events. During a storm event in which the barrier is deployed, large pumps pull water from the Providence River that would otherwise accumulate upstream of the barrier. The pumps are operated to keep the upstream water levels at or below 8.87' NAVD88.

The barrier was built to protect from storm surges up to 20', but was not built to withstand the level of sea level rise that we may see in 50 or more years, and the barrier does not close for regular tidal flooding events. The City of Providence/State of RI is due to make a decision by 2050 about redesigning the barrier to accommodate for both aging infrastructure and increased sea level rise that could overwhelm the barrier.

Because of the severity of worst-case scenarios identified by STORMTOOLS modeling (in the event of barrier failure during a major storm event) our methodology does include designing for this rare scenario.

DESIGN FLOOD ELEVATIONS

DFE-1

Flood events at ground level will be due to tidal and riverine flooding, both of which are not currently mitigated by the hurricane barrier. Of these risks, river flooding is more immediate, higher in elevation, and less predictable.

Accordingly, the ground floor DFE is set at 9.3' NAVD88, just above the historic high river mark recorded in the Providence River due to heavy rainfall over the course of several months in 2010. This elevation provides protection for near-term worst case scenarios, as well as long-term protection from tidal flooding exacerbated by sea level rise.

DFE-2

While the hurricane barrier is anticipated to provide protection from storm surges for the near term, there remains some measure of risk associated with extreme weather events. If the barrier gates are not operable, or sea level rise in conjunction with a storm surge causes the barrier to be overtopped, flooding could be extensive. While the risk of these is either low or far in the future, it is nonetheless prudent to take measures to ensure that buildings in the district are at least resilient, if not protected, in the event of a barrier breach.

This approach allows the development parcels to assume a measure of protection by the barrier for storm surges, but encourages an additional layer of long-term resilience by requiring that critical infrastructure and building mechanical systems be placed out of harm's way. The objective is to ensure that while some damage to the ground level may occur, the overall building and its occupancy are not completely compromised.