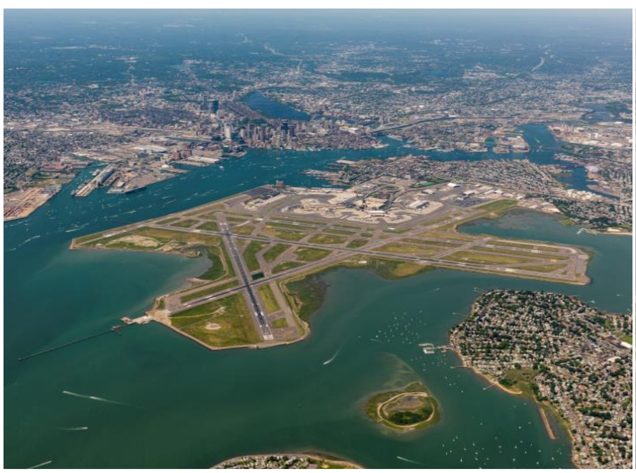
MASSACHUSETTS PORT AUTHORITY

FLOODPROOFING DESIGN GUIDE

November 2014

Revised April 2015



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1. Letter from the Massport Resiliency Program Manager

Massport's Resiliency Program, begun in 2014, is both progressive and adaptive. We base our analyses and recommendations on sound science, emerging technology, and the latest proven best practices. In an effort to keep the Floodproofing Design Guide relevant and up-to-date, we actively seek best available information and, when appropriate, responsibly change our standards. Revisions in this April 2015 Floodproofing Design Guide reflect newer modeling information (generously shared by MassDOT) and the use of a new datum that better aligns our resiliency efforts with those of other transportation agencies. (Please see Appendix C for more detail on the revised approach.) It is our sincere hope that the Floodproofing Design Guide will help enable the built environment to "withstand a major disruption system within acceptable degradation parameters, recover within an acceptable time, and balance composite costs and risks" - our definition of resiliency. Please feel free to contact the Resiliency Program at Massport with questions/comments.

Sincerely,
Robbin Peach
Program Manager of Resiliency
rpeach@massport.com

2. INTRODUCTION

2.1 SCOPE AND INTENT

Massachusetts Port Authority (Massport) facilities, including Logan International Airport and the maritime facilities in South Boston, are increasingly susceptible to flooding hazards caused by extreme storms and rising sea levels as a result of climate change. Massport is incorporating this Floodproofing Design Guide into its capital planning and real estate development processes to make its infrastructure and operations more resilient to these anticipated flooding threats.

2.1.1 Flood Resiliency Objectives

Incorporation of this Floodproofing Design Guide is intended to help Massport achieve the following flood resiliency objectives:

- Protect the safety of passengers, occupants, workers, and first responders.
- Minimize flood damage to critical Massport facilities, whose destruction or loss of service will have a debilitating effect on the security, economy, safety, health and welfare of the public.
- Enhance business resiliency, and expeditiously recover and restart critical services with minimum delay and damage to public safety and health, economy and security.
- Provide for operational continuity to the greatest extent possible.
- Minimize losses of electrical power, communications, security and other critical services facility wide and to individual critical assets.
- Prevent structural and property damage to the maximum extent possible.
- Maintain capacity to support regional emergency response and disaster recovery at Logan Airport and Conley Terminal during, and immediately after, an extreme storm event.

2.1.2 Applicability

This Design Guide shall be used by Massport staff, tenants, third party developers, design professionals and contractors during planning, design and construction of the following projects at Logan Airport, Conley Terminal, Fish Pier, Black Falcon Cruise Terminal, or other Massport properties in South Boston:

(a) New structures and additions, including subsequent work to such structures.

(b) Work classified as substantial repair or substantial improvement[1] of an existing structure.

(c) Retrofit of an existing structure or facility with the explicit objective to make it resilient to flooding.

The provisions of this Design Guide do not apply to routine maintenance and repair projects, unless otherwise directed by the Massport Director of Capital Programs.

The provisions of this Design Guide may only be waived by written authorization from Massport's Director of Capital Programs.

2.2 Background

In 2013, Massport launched a comprehensive resiliency initiative to maximize business continuity in the midst of various human and natural threats. Recent extreme storms, such as Hurricane Sandy (2012), Tropical Storm Irene (2011), and winter storm Nemo (2013), demonstrated the link between climate hazards and the resiliency of the built environment, including air and maritime transportation infrastructure. As part of its broader resiliency initiative, Massport retained Kleinfelder Northeast to perform a *Disaster and Infrastructure Resiliency Planning Study (DIRP)* focused on the risks associated with climate change, primarily coastal flooding from extreme storms and sea level rise. DIRP included climate hazard analyses, vulnerability assessments for critical infrastructure, and resiliency intent recommendations for capital improvements and programming. One of the high priority recommendations was for Massport to develop and adopt design guidelines for flood resiliency, including establishing design flood elevations possibly more stringent than required by current building codes for future flood scenarios.

2.2.1 Extreme Storms and Coastal Flooding Hazards at Massport

Flood modeling, utilizing the <u>S</u>ea, <u>L</u>ake, and <u>O</u>verland <u>S</u>urge from <u>H</u>urricanes (SLOSH) model developed by the National Weather Service, was carried out as part of the DIRP climate hazards analysis to predict the worst-case flooding conditions that might occur at Massport facilities under a wide range of hurricane scenarios. The resulting flood maps were analyzed to determine the maximum possible extent and depth of coastal flooding across Logan Airport and

[1] Substantial repair and substantial improvement are defined as any repair, reconstruction, rehabilitation, addition, or other improvement to a structure, the cost of which equals or exceeds 50% of its pre-improvement market value, or equals or exceeds a smaller percentage established by the Massport Capital Planning Department.

the Maritime facilities in South Boston. The modeling methodology used for the DIRP study, including the underlying scenario parameters (i.e., hurricane intensity, tidal condition), were developed through a consultative process between Massport Capital Programs leadership and Kleinfelder. As noted in Appendix C, results from MassDOT's new Boston Harbor Flood Risk Model (BH-FRM) were later reviewed and compared with SLOSH results from DIRP.

The latest flood modeling results for Logan Airport and the Maritime facilities in South Boston based on the BH-FRM model are included in Tables B-1 and B-2, in Appendix B. These tables report the estimated maximum flood elevations (NAVD88) for existing critical infrastructure at Logan Airport and the Maritime facilities in South Boston under the different scenarios modeled. These tables indicate at what elevations interior flooding is likely to occur (red cells), based on the BH-FRM flood modeling results. First floor elevations were derived from sources that were readily available at the time of the DIRP study (e.g., from engineering plans or the Massport Survey Department). However, detailed surveys were not conducted under DIRP, and therefore, first floor elevations may need to be re-verified during final design. More details on sources of data and methods used are provided in the DIRP final draft report.

The flood modeling results and subsequent vulnerability assessments revealed that a number of existing critical infrastructure assets are at risk of coastal flooding from storm surge, particularly under more severe scenarios which may become more likely in the future due to climate change and sea level rise. The costs of infrastructure damage and business interruption, if such an event were to occur, represent a strategic risk that must be managed by increasing current levels of flood protection and preparedness.

3. DESIGN FLOOD ELEVATIONS

3.1 GENERAL

Design flood elevations are indispensable tools for managing the risks of flooding in flood hazard areas and are already widely incorporated in building codes, zoning regulations, and engineering standards. The design flood elevation (DFE) corresponds to the maximum level of water that an engineered structure has been designed to resist, being a foundational input for the calculation of design flood loads, which then set the parameters for structural design. DFEs are also used as a vertical threshold above which the lowest floor of the lowest enclosed area, important utilities, life safety systems, and other critical equipment must be elevated.

If elevation above the DFE is not feasible, floodproofing critical areas below the DFE may be permitted. **Floodproofing** is any combination of structural or nonstructural adjustments, changes, or actions that reduce or eliminate flood damage to a structure, contents, and attendant utilities and equipment. **Dry floodproofing** renders a structure envelope substantially impermeable to the entrance of floodwater, resulting in a space free of through cracks, openings, or other channels that permit unobstructed passage of water and seepage during flooding, and prevents accumulation of more than 4 in. of water depth in such a space during a period of 24 hours (see Section 5.1). **Wet floodproofing** relies on the use of flood-damage-resistant materials and design/construction techniques to minimize flood damages to areas below the DFE of a structure that are intentionally allowed to flood (see Section 5.2). Through these applications, DFEs can help limit the exposure of occupants and property to the damaging effects of flooding and ensure that basic functions can be maintained during a flooding event or quickly restored thereafter.

Existing codes and regulations generally set the DFE for a facility based on the latest approved version of the FEMA Flood Insurance Rate Map (FIRM) for the area in which the facility is located. The FIRM indicates the boundaries of flood hazard zones and the base flood elevations (BFEs) within those zones that have a 1% annual probability of being exceeded. It also indicates areas that may be exposed to wave action. The BFE at the location of the facility, plus any additional “freeboard” height required as a safety factor against additional wave action or higher-than-anticipated flooding, is typically set as the DFE for the facility. However, a property owner may set the DFE higher than the minimum code requirement.

The methodologies used to create FEMA FIRMs and determine FEMA BFEs are based on historical data and do not incorporate sea level rise or other projected climate change impacts. They are therefore likely to underestimate the risk of future flooding, particularly over longer time horizons.

Through a deliberative process involving scientists, engineers, and institutional leadership, Massport has developed Design Flood Elevations (DFEs) that go above and beyond existing code requirements. The initial choice of DFEs was informed by the results of historical analysis, storm surge modeling, projections of future sea level rise, and review of the latest academic research on climate change's influence on storm frequency and intensity. Subsequently, MassDOT completed the development of the Boston Harbor Flood Risk Model (BH-FRM), which takes these considerations into account probabilistically. BH-FRM results were used as the basis for the revised DFEs set forth in this section. Figure C-1, in Appendix C, summarizes the change in DFEs from those published in November 2014 to those in the April 2015 revision.

The DFEs set forth in this section, along with the floodproofing performance standards that follow, are necessary tools to programmatically address current and future risk from coastal flooding at Logan Airport and the Maritime facilities in South Boston. Their institutionalization will ensure that new facilities on Massport property minimize exposure to flood damage and that existing facilities become more resilient over time through incremental improvements implemented through targeted resiliency investments and as part of other substantial upgrades, renovations, and additions.

Recognizing that future risks of flooding are greater than at present and that existing facilities face greater constraints, such as limited space to modify facility siting and layout arrangements and higher costs and complexities of retroactive floodproofing up to high flood depths, the DFEs for existing facilities are less stringent and the performance standards more flexible, than for new facilities. The DFEs for both new and existing facilities demonstrate Massport's stewardship of their assets. Their implementation is an ambitious policy development supported at the highest levels of Massport leadership.

3.2 DFE FOR EXISTING FACILITIES

For existing facilities, the DFE will be defined by the maximum water elevation with a 0.2% annual probability of exceedance in 2030 (as modeled by BH-FRM) plus 3 ft. of freeboard. This translates to an elevation of 13.7 ft (NAVD88) for facilities at Logan Airport and in South Boston (Table 1).

For projects at existing facilities, the DFE shall be used to determine the following design elements:

- Design loads and structural calculations for evaluating and designing dry and wet floodproofing options
- Minimum effective level of protection provided by dry and wet floodproofing designs
- Elevation below which Floodproofing Performance Standards in Section 6.2 shall be applied.

3.3 DFE FOR NEW FACILITIES AND ADDITIONS

For new facilities, the DFE will be defined by the maximum water elevation with a 0.2% annual probability of exceedance in 2070 (as modeled by BH-FRM) plus 3 ft. of freeboard. This translates to an elevation of 17.0 ft (NAVD88) for facilities at Logan Airport and in South Boston (Table 1).

For new facilities, the DFE shall be used to determine the following design elements:

- Design loads and structural calculations
- Elevation of the lowest floor of the lowest enclosed space
    - Excludes certain access, storage spaces, and areas used solely for parking vehicles which may be wet floodproofed
- Minimum effective level of protection provided by dry and wet floodproofing designs
- Elevation below which Floodproofing Performance Standards in Section 6.1 shall be applied.

Table 1 – Design Flood Elevations for New and Existing Massport Facilities

Location	Existing Facilities	New Facilities
Logan International Airport; South Boston Maritime Facilities	13.7 ft. (NAVD88)	17.0 ft. (NAVD88)

*****Add 0.81 ft. to NAVD88 elevations to convert to NGVD29 elevations.
*Add 6.46 ft. to NAVD88 elevations to convert to BCB elevations.

4. CRITICAL INFRASTRUCTURE SUBJECT TO FLOODPROOFING PERFORMANCE STANDARDS

The equipment and systems listed in Table 2 are considered critical and shall be considered for floodproofing in accordance with Section 6 – Floodproofing Performance Standards.

Table 2 – Critical Infrastructure Subject to Floodproofing Standards

System	Critical Equipment/Systems
Electrical	Substations, Transformers, Switchgear, Service and Distribution Panels, Emergency Panels, Cable Terminations and Splices, Emergency Generators, Stock and Parts Storage, Meter Centers
Water and Plumbing	Domestic/Fire Water Pumps and Controls, Sump Pump Non-Submersible Motors and Controls, Plumbing Systems (lavatories, showers, toilets), Ejector and Grinder Pumps, Water Heaters, Pipe Insulation
Mechanical	Air Intake and Exhaust Vents/Louvers, Air Conditioning Units and Condensers, Chilled Water Systems, Pumps, Ventilation Units, Boilers, Unit Heaters, Distribution Duct Work
Telecommunications	Telephone Switches, Network Interface Devices, IDF Closets, Data/Computer Centers/Rooms, Dispatch Rooms, Emergency Communications Centers, Public Announcement System Control Rooms, Radio Systems (incl. personal radio storage areas), Surveillance Systems, Access Control Systems
Emergency and Fire	Fire Alarm Master Boxes, Emergency Operations Centers, Emergency Supplies (medical, food/water, cots/blankets), Emergency Vehicles and Specialized Equipment (medical, fire, rescue, law enforcement)
Hazardous Materials	Waste Oil, Fuel Storage Tanks, Chemical Supplies
Other*	Records Storage, Office Space, Parking Garages

* Floodproofing recommended but not required for tenants and third party leases/developments.

5. PERMITTED FLOODPROOFING STRATEGIES

5.1 Dry Floodproofing

Dry floodproofing involves designing or modifying a building, enclosure, or area to render it substantially impermeable to the entrance of floodwaters, thereby lowering the potential for flood damage. Substantially impermeable shall be defined as resulting in a maximum accumulation of 4 in. of water depth in a dry floodproofed space during a 24 hour period.

Applications of dry floodproofing shall not be allowed in the following cases, unless otherwise approved in writing by Massport's Director of Capital Programs:

- When buildings or facilities are located in high risk flood hazard areas (VE-Zones, as identified on FEMA FIRMs).
- Where flood velocities adjacent to the building or facility are expected to exceed 5 ft. /sec. during the design flood.
- When notice of an impending flood is expected to be less than 12 hours, thus allowing insufficient time for human intervention to install temporary protective devices required for dry floodproofing.
- Where flood depths are expected to exceed 3 feet for existing buildings, unless the structural capacity of the building has been assessed by a qualified structural engineer and found to be capable of resisting the anticipated loads.

Dry floodproofed areas of a building or facility shall:

- Be designed and constructed so that any area below the designated DFE, together with attendant utilities and sanitary facilities, is flood resistant with walls or temporary flood barriers that are substantially impermeable to the passage of water.
- Have walls, floors, flood shields and other temporary flood barriers designed and constructed to resist hydrostatic, hydrodynamic, and other flood related loads, including the effects of buoyancy resulting from the DFE.
- Have any soil or fill adjacent to the structure compacted and protected against erosion and scour.
- Have at least one door satisfying building code requirements for an exit door or primary means of escape, above the designated DFE, and capable of providing human ingress and egress during the design flood. This requirement of ASCE/SEI 24 is interpreted to apply to buildings which are normally occupied. For buildings or facilities that are not

normally occupied, provisions shall be made to remotely monitor water levels within the dry floodproofed area and to remove water from such areas as required to maintain water levels below that which will cause damage to critical equipment.

- Have sump pumps (permanent or temporary) to remove water accumulation due to any seepage of water during the flooding event. Sump pumps shall not be relied upon as a means of dry floodproofing, but rather only to control water levels below critical levels to prevent damage to critical equipment. Sump pumps shall be powered by independent emergency electrical systems raised above the DFE to ensure performance during power outages.
- Be evaluated by a structural engineer to verify that the foundation, exterior wall and floor systems can resist the forces generated by the design flood event.

Dry floodproofing measures may include, but are not limited to the following:

- Installing watertight shields on doors, windows, and louvers.
- Replacing doors hatches with special flood-resistant doors and hatches.
- Permanently closing or sealing windows and other openings below the DFE.
- Using exterior and interior membranes and sealants to reduce seepage through walls, slabs and foundations.
- Sealing electrical conduits and other utilities entering below the DFE.
- Using aquarium glass or other specialized glazed storefront systems designed to resist floodwater pressures.
- Reinforcing walls, slabs and foundation systems to resist hydrostatic and hydrodynamic loads induced by floodwater.
- Installing drainage collection systems and sump pumps (permanent or temporary) to control water levels within dry floodproofed spaces.
- Installing early warning devices to monitor water levels in dry floodproofed spaces.
- Installing back-flow preventer valves on drainage and sanitary sewer piping located below the DFE.
- Installing pressure relief valves in floor systems to avoid structural damage due to buoyancy forces.
- Exterior perimeter flood walls and barriers (permanent or temporary).

Where removable shields or any other temporary measures are to be used as part of a dry floodproofing system, a Flood Operations Plan and Inspection and Maintenance Plan shall be prepared for the building or facility. Both the Flood Operations Plan and the Inspection and Maintenance Plan shall be drafted and submitted as part of the final design (100%) package.

5.2 Wet Floodproofing

Wet floodproofing involves designing or modifying a building, enclosure, or area to accommodate the entrance of floodwaters while minimizing the potential for flood damage to critical infrastructure and equipment.

Wet floodproofing involves the following:

- Using flood damage-resistant materials below the DFE throughout the building.
- Raising utilities, life-safety systems, important contents and other critical infrastructure above the DFE.
- Installing and configuring electrical, telecommunications, mechanical, and other systems to allow for easy isolation of system components located below the DFE, facilitate repairs, and minimize disruptions due to flood damage.
- Installing flood openings or using other methods to equalize the hydrostatic pressure exerted by floodwaters to prevent structural damage to walls and floors.
- Providing pumps (permanent or temporary) to gradually remove floodwater from basements and non-draining areas.
- Designing tie-down systems for fuel tanks below the DFE to resist buoyant forces caused by submersion.

Wet floodproofing of enclosed areas below the DFE shall be limited to:

- Category I structures as defined by ASCE/SEI 24 (see Table 3)
- Enclosures used solely for parking, building access or storage.
- Structures that are functionally dependent on close proximity to water
- Structures that are otherwise approved by Massport’s Director of Capital Programs.

Table 3 – Classification of Structures (ASCE/SEI 24)

Nature of Occupancy	Category
• Certain temporary facilities • Minor storage facilities	**I**
• All buildings and other structures except those listed in Categories 1, 3 and 4	**II**

• Buildings and structures that represent a substantial hazard to human life in the event of failure, including:
  • Buildings where more than 300 people congregate in one area
  • Power generating station and other public utility facilities not included in Category IV
  • Buildings not in Category IV that handle hazardous materials, fuels, etc.
	III

• Buildings and other structures designated as essential facilities including:
  • Fire, rescue, ambulance and police stations and emergency vehicle garages
  • Hurricane emergency shelters
  • Emergency operation and communication centers
  • Power generating stations and other utilities facilities required during an emergency
  • Ancillary structures required for operation of Category IV structures (communication towers, fuel storage tanks, electrical substations, fire water storage tanks or other fire suppression systems, water storage tanks)
  • Aviation control towers and emergency aircraft hangers
  • Water storage facilities and pump structures required to maintain water pressure for fire suppression
  • Buildings having critical national defense functions
  • Facilities handling and storing hazardous fuels
	IV

6. FLOODPROOFING PERFORMANCE STANDARDS

6.1 Substantial Repairs/Improvements to Existing Facilities and Floodproofing Projects

Existing facilities undergoing substantial repairs or improvements or dedicated floodproofing projects on existing facilities shall meet the floodproofing performance standards listed in Table 5. Floodproofing of existing facilities shall meet the requirements of all applicable building codes, standards, and technical guidelines, including those incorporated by reference in this Design Guide.

Table 4 – Floodproofing Performance Standards for Substantial Repairs/Improvements to Existing Facilities and Floodproofing Projects

Critical Equipment	Massport Ownership/Operation			Tenant and Third Party Lease/Development		
	Elevated Above DFE	Dry FP	Wet FP	Elevated Above DFE	Dry FP	Wet FP
Electrical						
Substations	Yes	Yes		Yes	Yes	
Transformers	Yes	Yes		Yes	Yes	
Switchgear	Yes	Yes		Yes	Yes	
Emergency Panels	Yes	Yes		Yes	Yes	
Emergency Generators	Yes	Yes		Yes	Yes	
Meter Centers	Yes	Yes		Yes	Yes	
Service and Distribution Panels	Yes	Yes		Yes	Yes	
Cable Terminations and Splices	Yes	Yes	Yes	Yes	Yes	Yes
Stock and Parts Storage	Yes	Yes		Yes	Yes	
Water and Plumbing						
Domestic/Fire Water Pumps and Controls	Yes	Yes		Yes	Yes	
Sump Pump Non-Submersible Motors and Controls	Yes	Yes		Yes	Yes	
Ejector and Grinder Pumps	Yes	Yes		Yes	Yes	
Water Heaters	Yes	Yes		Yes	Yes	
Plumbing Systems (lavatories, showers, toilets)	Yes	Yes	Yes	Yes	Yes	Yes
Pipe Insulation	Yes	Yes	Yes	Yes	Yes	Yes
Mechanical						
Boilers	Yes	Yes		Yes	Yes	
Air Conditioning Units and Condensers	Yes	Yes		Yes	Yes	

Critical Equipment	Massport Ownership/Operation			Tenant and Third Party Lease/Development		
	Elevated Above DFE	Dry FP	Wet FP	Elevated Above DFE	Dry FP	Wet FP
Chilled Water Systems	Yes	Yes		Yes	Yes	
Pumps	Yes	Yes		Yes	Yes	
Air Intake and Exhaust Vents/Louvers	Yes	Yes	Yes	Yes	Yes	Yes
Ventilation Units	Yes	Yes	Yes	Yes	Yes	Yes
Unit Heaters	Yes	Yes	Yes	Yes	Yes	Yes
Distribution Duct Work	Yes	Yes	Yes	Yes	Yes	Yes
Telecommunications						
Telephone Switches	Yes	Yes		Yes	Yes	
Network Interface Devices	Yes	Yes		Yes	Yes	
Data/Computer Centers/Rooms	Yes	Yes		Yes	Yes	
Dispatch Rooms	Yes			Yes		
Emergency Communications Centers	Yes			Yes		
Public Announcement System Control Rooms	Yes			Yes		
Radio Systems (incl. personal radio storage areas)	Yes			Yes		
Surveillance Systems	Yes	Yes		Yes	Yes	
IDF Closets	Yes	Yes		Yes	Yes	Yes
Access Control Systems	Yes	Yes		Yes	Yes	
Emergency and Fire						
Fire Alarm Master Boxes	Yes	Yes		Yes	Yes	
Emergency Operations Centers	Yes			Yes		
Emergency Supplies (medical, food/water, cots/blankets)	Yes			Yes		
Emergency Vehicles and Specialized Equipment (medical, fire, rescue, law enforcement)	Yes	Yes	Yes	Yes	Yes	Yes
Hazardous Materials						
Waste Oil	Yes	Yes		Yes	Yes	
Fuel Storage Tanks	Yes	Yes	Yes	Yes	Yes	Yes
Chemical Supplies	Yes	Yes		Yes	Yes	
Other*						
Records Storage*	Yes	Yes		Yes*	Yes*	Yes*
Office Space*	Yes	Yes	Yes	Yes*	Yes*	Yes*
Parking Garages*			Yes	*	*	Yes*

* Floodproofing recommended but not required for tenants and third party leases/developments.

6.2 New Construction/Addition Projects

New facilities shall be laid out such that the critical equipment listed in Table 4 is elevated above the applicable DFE, located in areas designed to be dry floodproofed, or protected by an appropriate combination of floodproofing measures. Such designs shall meet the requirements of all applicable building codes, standards, and technical guidelines, including those incorporated by reference in this Design Guide.

Table 5 – Floodproofing Performance Standards for New Facilities

Critical equipment	Massport Ownership/Operation			Tenant and Third Party Lease/Development		
	Elevated Above DFE	Dry FP	Wet FP	Elevate Above DFE	Dry FP	Wet FP
Electrical						
Substations	Yes			Yes		
Transformers	Yes			Yes		
Switchgear	Yes			Yes		
Emergency Panels	Yes			Yes		
Emergency Generators	Yes			Yes		
Meter Centers	Yes			Yes		
Service and Distribution Panels	Yes	Yes		Yes	Yes	
Cable Terminations and Splices	Yes	Yes	Yes	Yes	Yes	Yes
Stock and Parts Storage	Yes	Yes		Yes	Yes	
Water and Plumbing						
Domestic/Fire Water Pumps and Controls	Yes			Yes		
Sump Pump Non-Submersible Motors and Controls	Yes			Yes		
Ejector and Grinder Pumps	Yes	Yes		Yes	Yes	
Water Heaters	Yes	Yes		Yes	Yes	
Plumbing systems (lavatories, showers, toilets)	Yes	Yes		Yes	Yes	Yes
Pipe Insulation	Yes	Yes		Yes	Yes	Yes
Mechanical						
Boilers	Yes	Yes		Yes	Yes	
Air Conditioning Units and Condensers	Yes	Yes		Yes	Yes	
Chilled Water Systems	Yes	Yes		Yes	Yes	
Pumps	Yes	Yes		Yes	Yes	
Air Intake and Exhaust Vents/Louvers	Yes	Yes		Yes	Yes	Yes

Critical equipment	Massport Ownership/Operation			Tenant and Third Party Lease/Development		
	Elevated Above DFE	Dry FP	Wet FP	Elevate Above DFE	Dry FP	Wet FP
Ventilation Units	Yes	Yes		Yes	Yes	Yes
Unit Heaters	Yes	Yes		Yes	Yes	Yes
Distribution Duct Work	Yes	Yes	Yes	Yes	Yes	Yes
Telecommunications						
Telephone Switches	Yes			Yes		
Network Interface Devices	Yes			Yes	Yes	
Data/Computer Centers/Rooms	Yes			Yes	Yes	
Dispatch Rooms	Yes			Yes		
Emergency Communications Centers	Yes			Yes		
Public Announcement System Control Rooms	Yes			Yes		
Radio Systems (incl. Personal Radio Storage areas)	Yes			Yes		
Surveillance Systems	Yes			Yes	Yes	
IDF Closets	Yes	Yes		Yes	Yes	Yes
Access Control Systems	Yes	Yes	Yes	Yes	Yes	Yes
Emergency and Fire						
Fire Alarm Master Boxes	Yes			Yes		
Emergency Operations Centers	Yes			Yes		
Emergency Supplies (medical, food/water, cots/blankets)	Yes			Yes		
Emergency Vehicles and Specialized Equipment (medical, fire, rescue, law enforcement)	Yes	Yes	Yes	Yes	Yes	Yes
Hazardous Materials						
Waste Oil	Yes			Yes		
Fuel Storage Tanks	Yes	Yes	Yes	Yes	Yes	Yes
Chemical Supplies	Yes			Yes		
Other*						
Records Storage*	Yes			Yes*	Yes*	*
Office Space*	Yes			Yes*	Yes*	*
Parking Garages*			Yes	*	*	Yes*

* Floodproofing recommended but not required for tenants and third party leases/developments.

7. MASSPORT REVIEWS AND APPROVALS

7.1 Floodproofing Design Implementation Process

Table 6 describes the requirements of the floodproofing design process. This process shall be followed for new construction and additions, substantial repair or improvement projects, or dedicated floodproofing projects. The intent of this process is to identify floodproofing related issues early in the design process to ensure that the proposed floodproofing strategies to be used are adequate and that operational, maintenance and storage requirements are clearly understood by all parties responsible for implementing them.

Table 6 – Floodproofing Design Implementation Process

Design Stage	Design Flood Parameters and Calculations	Floodproofing Design Narrative and Drawings	Floodproofing Calculations	Flood Operations Plan	Floodproofing Inspection and Maintenance Plan
Schematic Design/ Pre-Design	Identify FIRM Map information and Massport DFE.	Identify proposed floodproofing strategies and performance objectives to be achieved by design	Conduct facility condition assessment and/or site assessment	Identify parties responsible for facility flood emergency response	Identify parties responsible for facility inspection and maintenance
30% Design	Preliminary design load assumptions and calculations	Identifies specific measures to achieve performance objectives; Review for code compliance, update narrative	Engineering report with structural calculations demonstrating floodproofed facility can withstand design loads	Outreach to parties responsible for implementing active floodproofing measures; Prepare draft plan	Outreach to parties responsible for inspection and maintenance of floodproofing measures; Prepare draft plan
90% Design	Update	Update narrative and drawings	Update structural calculations	Update draft plan	Update draft plan
Final Design	Finalize	Finalize narrative and drawings. Complete FEMA NFIP floodproofing certificate for non-residential structures signed/ submitted. For new construction with lowest floor elevated above BFE or DFE, complete FEMA NFIP elevation certificate, signed and submitted	Finalize	Final plan and approval memo	Final plan and approval memo

7.2 Floodproofing Design Submittal Form

The Engineer-of-Record for the project shall submit a Floodproofing Design Submittal Form (see Appendix A) to Massport's Capital Programs Department to document that the floodproofing measures and designs for a project conform to the requirements of this Design Guide. Massport's review of the Floodproofing Design Submittal Form does not relieve the Engineer-of-Record from responsibility that the design conforms to applicable building codes, design standards and meets the standard of professional care for similar projects.

8. REFERENCES

8.1 Applicable Floodproofing Standards

The following consensus standards are incorporated into the Massachusetts State Building Code by reference:

- ASCE/SEI 7, *Minimum Design Loads for Buildings and Other Structures*
- ASCE/SEI 24 *Flood Resistant Design and Construction*

Floodproofing for all Massport buildings and facilities shall conform to the requirements of these two consensus standards, except as modified herein.

8.2 Technical Guidance

The following authoritative technical guidance documents are incorporated in the Massport Floodproofing Design Guide by reference:

- FEMA P-936 (2013), *Floodproofing Non-Residential Buildings*
- FEMA 543 (2007), *Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings*
- NFIP Technical Bulletin 1 (2008), *Openings in Foundation Walls and Walls of Enclosures below Elevated Buildings in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program*
- NFIP Technical Bulletin 2 (2008), *Flood Damage-Resistant Materials Requirements for Buildings Located in Special Flood Hazard Areas in Accordance with the National Flood Insurance Program*
- NFIP Technical Bulletin 3 (1993), *Non-Residential Floodproofing – Requirements and Certification*

APPENDIX A

Floodproofing Design Submittal Form

Massport Capital Programs

Floodproofing Design Submittal Form

Project Number: ____

Project Name: ____

Building Name/Number: ____

Submission: __________________________ (Schematic, 30% / 90% / Final)

1. Indicate the applicable DFE for the project from the table below:

Location	Existing Facilities	New Facilities
Logan International Airport; South Boston Maritime Facilities	13.7 ft. (NAVD88)	17.0 ft. (NAVD88)

*****Add 0.81 ft. to NAVD88 elevations to convert to NGVD29 elevations.
*Add 6.46 ft. to NAVD88 elevations to convert to BCB elevations.

2. Enter the existing or proposed elevation of the lowest floor of the lowest enclosed space, whichever is applicable:

Existing elevation (ft NAVD88)	
Proposed elevation (ft NAVD88)	

*****Subtract 0.81 ft. from NGVD29 elevations to convert to NAVD88 elevations.

3. Describe existing/proposed uses, including occupancy, of spaces below the DFE:

4. Provide a narrative summary of the proposed floodproofing performance objectives, and strategies and measures proposed to achieve them:

5. **In the table below, indicate proposed critical equipment protection measures to be in place at project completion**: Indicate whether the following critical equipment will be elevated above the DFE, located in dry floodproofed enclosure (Dry FP), wet floodproofed (Wet FP), protected by other methods, or not protected. Only if the listed equipment will not be present at the existing or proposed facility upon project completion should "not applicable" be selected.

Critical equipment	Elevated Above DFE	Dry FP	Wet FP	Other	Not Protected	Not Applicable
Electrical						
Substations						
Transformers						
Switchgear						
Emergency panels						
Emergency generators						
Meter centers						
Service and distribution panels						
Cable terminations and splices						
Stock, parts						
Water and Plumbing						
Domestic/fire water pumps and controls						
Sump pump and controls						
Ejector and grinder pumps						
Water heaters						
Plumbing systems (lavatories, showers, toilets)						
Pipe insulation						
Mechanical						
Boilers						
Air conditioning units and condensers						
Chilled water systems						
Pumps						
Air intake and exhaust vents/louvers						

Critical equipment	Elevated Above DFE	Dry FP	Wet FP	Other	Not Protected	Not Applicable
Ventilation units						
Unit heaters						
Distribution duct work						
Telecommunications						
Telephone switches						
Network interface devices						
Data/computer centers/rooms						
Dispatch rooms						
Emergency communications centers						
Public Announcement system controls						
Radio systems (incl. personal radio storage areas)						
Surveillance systems						
IDF closets						
Access control systems						
Emergency and Fire						
Fire alarm master boxes						
Emergency operations centers						
Emergency supplies (medical, food/water, cots/blankets)						
Emergency vehicles and specialized equipment (medical, fire, rescue, law enforcement)						
Other						
Records storage						
Office space						
Hazardous Materials						
Waste oil						
Fuel storage tanks						
Chemical supplies						

6. **For areas proposed to be dry floodproofed in the table in Section 5, describe assumptions, structural analyses conducted, and conclusions regarding the capability of the structure to withstand design flood forces.**

7. **In the table below, list all equipment proposed to be protected by "Other" methods in the table in Section 5, describe the proposed protection measures, and indicate the level of protection the measures are designed to provide:** (if additional space is needed, submit information as an attachment)

Equipment Type	Proposed Protection Measure	Level of Protection (high, medium, low)

8. **In the table below, list all equipment proposed to be "Not Protected" in the table in Section 5, their per unit replacement costs, and their replacement lead time:** (if additional space is needed, submit information as an attachment)

Equipment Type	Units Located Below DFE (number)	Unit Replacement Cost ($)	Replacement Lead Time (days)

9. **Provide additional operational planning information on floodproofing measures requiring human intervention to be effective:** (i.e. temporary installation of protective barriers or relocation of stock/equipment) (if additional space is needed, submit information as an attachment)

Measure	How Much Advanced Time is Needed to Install or Implement (hours)	Staff Requirements Needed to Install or Implement (No. of staff)	Storage Location of Tools and Materials Needed to Install or Implement (e.g., onsite vs. central storage facility)

Submitted by: ______________________________ ______________
Engineer of Record Date

Reviewed by: ______________________________ ______________
Massport Project Manager Date

______________________________ ______________
Facility Manager Date

______________________________ ______________
Massport Resiliency Program Manager Date

CC: Massport Director of Capital Programs
Massport Deputy Director of Capital Programs

APPENDIX B

Maximum Flood Elevations for Individual Buildings and Facilities

Table B-1 – Flood Elevations at Logan Airport Critical Infrastructure Assets

Number	Name	Asset First Floor or Lowest Critical Elevation (ft. NAVD88)	BH-FRM Flood Elevations (ft. NAVD88)					
			2030			2070		
			1% (100-YR)	0.2% (500-YR)	0.1% (1000-	1% (100-YR)	0.2% (500-YR)	0.1% (1000-
79	Fire-Rescue II	10.04	10.1	10.6	10.8	12.9	14	14.1
4	Facilities III	10.05	10.1	10.6	10.8	12.8	14	14.1
11	State Police/TSA Building	10.59	10.1	10.6	10.8	12.8	14	14.1
06A	MPA Pumping Station (New)	10.26	10	10.5	10.8	12.7	14	14.1
85	Marine Fire-Rescure	10.60	9.9	10.4	10.9	12.8	14	14.1
3	Facilities II	10.76	10	10.5	10.8	12.8	14	14.1
41	Porter Street Substation	10.98	10.1	10.6	10.8	12.8	14	14.1
2	Wood Island Substation	11.15	10.1	10.6	10.8	12.8	14	14.1
06B	Electrical/Telecom Building	12.36	NA	10.7	10.8	12.8	14	14.1
15	Large Vehicle Storage Building	11.15	NA	10.5	10.8	12.8	14	14.1
43	Boston EMS Station	11.84	NA	NA	NA	12.7	14	14.1
46	BOSFuel Operations and Control Bldg	12.69	NA	NA	NA	12.8	14	14.1
65	Logan Office Center	13.28	NA	NA	NA	12.8	14	14.1
	Fire Training Facility fuel tanks	14	NA	NA	NA	NA	14	14.1
18	Central Heating Plant/Facilities I	13.68	NA	NA	NA	NA	13.7	13.8
21	Terminal C Pier B	13.39	NA	NA	NA	NA	13.4	13.5
31	Terminal A Main (landside)	13.44	NA	NA	NA	NA	13.9	14
73	West Baggage Room	13.39	NA	NA	NA	12.6	13.9	14
T18E	CHP to Terminal E	12.86	NA	NA	NA	NA	13.7	13.8
T18C	Intersection to Terminal C (door)	13.84	NA	NA	NA	NA	13.7	13.8
T31B	Utility Tunnel between Terminal A and Terminal B (door)	14.01	NA	NA	NA	NA	13.9	14
44	North Gate	15.34	NA	NA	NA	12.3	14	14.1
52	South Gate	15.8	NA	NA	NA	12.2	13.9	14
19	Terminal E	16.17	NA	NA	NA	NA	13.7	13.8
20	Terminal C (Main, Pier B)	13.59-14.63	NA	NA	NA	NA	13.7	13.8
29	Terminal B (Pier B)	14.37-15.62	NA	NA	NA	12.4	13.1	13.2
31	Terminal A Main (airside)	15.41	NA	NA	NA	NA	13.9	14
32	Terminal A Satellite	15.45	NA	NA	NA	NA	14	14.1
32	Harborside Substation	15.5	NA	NA	NA	NA	14	14.1
66	Airfield Lighting Vault	14.61	NA	NA	NA	12.2	13.9	14
67	Bird Island Flats Substation	14.73	NA	NA	NA	12.1	13.8	13.9
78	Fire-Rescue I	14.3	NA	NA	NA	11.5	13.2	13.3
T18A	Intersection to Terminal A (door)	15.16	NA	NA	NA	NA	13.7	13.8
T18B	CHP to Intersection (utility hatch)	15.76	NA	NA	NA	12.4	13.9	14
	Jet Fuel Tank Farm (Containment Wall)	16.4	NA	NA	NA	12.8	14	14.1
23	Terminal C (Pier C)	14.79	NA	NA	NA	NA	NA	NA
25	MPA Administration Building (Boutwell/Pier D)	14.59	NA	NA	NA	NA	NA	NA
25	MPA Administration Building (Old Tower)	15.09	NA	NA	NA	NA	NA	NA
26	Air Traffic Control Tower	11.37	NA	NA	NA	NA	NA	NA
26	Control Tower Substation	12.45	NA	NA	NA	NA	NA	NA
26	MPA Generator - Control Tower	13.30	NA	NA	NA	NA	NA	NA
27	Terminal B (Pier A)	14.66-15.73	NA	NA	NA	NA	NA	NA
T18A	Intersection to Terminal A (utility hatch)	16.35	NA	NA	NA	NA	NA	NA
T18C	Intersection to Terminal C (ventilation and hatch)	13.43	NA	NA	NA	NA	NA	NA
T31A	Termina A Main to Satellite (stair)	15.45	NA	NA	NA	NA	NA	NA

Notes:

- Predicted water elevations (ft. NAVD88) are shown for each critical asset (rows) under each modeled scenario (columns).

- White cells with "NA" indicate that no flooding was predicted at the critical asset in the scenario.

- White cells without "NA" indicate that flooding was predicted at the critical asset in the scenario but did not exceed the first floor or lowest critical elevation.

- Red cells indicate that the critical asset was predicted to be flooded above its first floor or lowest critical elevation in the scenario.

Table B-2 – Flood Elevations at Maritime Critical Infrastructure Assets

Facility	Name	Asset First Floor or Lowest Critical Elevation (ft. NAVD88)	BH-FRM Flood Elevations (ft. NAVD88)					
			2030			2070		
			1% (100-YR)	0.2% (500-YR)	0.1% (1000-	1% (100-YR)	0.2% (500-YR)	0.1% (1000-
Haul Rd	Haul Road Sump Pump	8.63	10	10.5	10.8	12.8	14	14.1
FP	Berths	9.01	10.1	10.6	10.9	12.9	14	14.1
FP	Transformer	9.41	10.1	10.6	10.9	12.9	14	14.1
FP	East Building and West Building	9.94	10.1	10.6	10.9	12.9	14	14.1
Conley	Truck Processing Gate (Interchange Facility)	8.79	10	10.5	10.8	12.8	14	14.1
Conley	Reefer yard	9.00	10.1	10.5	10.8	12.8	14	14.1
Conley	Site Switch House	9.63	10	10.5	10.8	12.8	14	14.1
Conley	Rubber Tire Gantry Cranes	10.19	10	10.5	10.8	12.8	14	14.1
Conley	Vessel Cranes 1-6	10.36-10.45	10	10.5	10.8	12.8	14	14.1
Conley	Berths 11 and 12	10.36-10.45	10	10.5	10.8	12.8	14	14.1
Conley	Diesel Underground Storage Tank/ Fuel Island	10.68-10.77	10	10.5	10.8	12.8	14	14.1
Conley	Wharf Switch House No. 1	10.87	10	10.5	10.8	12.8	14	14
Conley	Marine Operations Center	10.94	10	10.5	10.8	12.8	14	14
Conley	Reefer Building	11.44	10.1	10.5	10.8	12.8	14	14.1
Conley	Administration Building	11.45	10	10.5	10.8	12.8	14	14.1
Conley	Wharf Switch House No. 3	11.65	10	10.5	10.8	12.8	14	14
Conley	Reefer substation	11.65	10.1	10.5	10.8	12.8	14	14.1
Conley	Operations Building	11.66	10	10.5	10.8	12.8	14	14.1
Conley	Administration Building substation	11.72	10	10.5	10.8	12.8	14	14.1
Conley	Massport Police Pro Shop Building	11.82	NA	NA	NA	12.8	14	14.1
Conley	Administration Building generator	12.31	10	10.5	10.8	12.8	14	14.1
Conley	Gate Switch House	12.48	NA	NA	NA	12.8	14	14.1
Conley	Massport Police Main Gate Building (Guard House)	12.9	NA	NA	NA	12.8	14	14.1
BF	Berths	11.38	NA	NA	NA	12.8	14	14.1
BF	Gangway / FMT	11.38	NA	NA	NA	12.8	14	14.1
BF	Main Building	12.96	NA	NA	NA	12.8	14	14.1

Notes:

- Predicted water elevations (ft. NAVD88) are shown for each critical asset (rows) under each modeled scenario (columns).
- White cells with "NA" indicate that no flooding was predicted at the critical asset in the scenario.
- White cells without "NA" indicate that flooding was predicted at the critical asset in the scenario but did not exceed the first floor or lowest critical elevation.
- Red cells indicate that the critical asset was predicted to be flooded above its first floor or lowest critical elevation in the scenario.

APPENDIX C

Explanation of April 2015 Revisions

In March 2015, subsequent to Massport's issuance of the Floodproofing Design Guide (November 2014), the Massachusetts Department of Transportation (MassDOT) completed a probabilistic flood model for the Boston Harbor region (Boston Harbor Flood Risk Model, BH-FRM) using a coupled hydrodynamic and wave model. MassDOT's BH-FRM model is comprised of the ADvanced CIRCulation (ADCIRC) model to simulate storm surge flooding and the Simulated WAves Nearshore (SWAN) model to simulate wave generation and transformation. MassDOT invested significant resources into the development of BH-FRM in order to evaluate the vulnerability to flooding of the Central Artery Tunnel system and other MassDOT assets. The model explicitly and quantitatively incorporates climate change influences on sea level rise, tides, waves, river discharge, storm track, and storm intensity for the present (2013), 2030, and 2070 time horizons. It models a statistically-robust sample of storms, including tropical (hurricanes) and extra-tropical (nor'easters), based on the region's existing and evolving climatology, calculates associated water elevations, and runs mathematical and geospatial analyses on the water elevations generated to estimate the probability of different water elevations being exceeded at nodal points within the model boundary. The resulting flood risk maps and probability curves can be interpreted using geographic information systems (GIS) to identify the estimated annual probability, or likelihood, that any nodal point within the model will experience flooding, and if so, up to what elevation.

In an exemplary case of interagency cooperation, MassDOT shared its BH-FRM results with Massport so that Massport could compare them with the results from the Sea, Lake, and Overland Surge from Hurricanes (SLOSH) model, developed by the National Weather Service to assist in hurricane emergency planning and forecasting. SLOSH model results were used to assess the coastal flooding exposure of critical infrastructure assets at Logan Airport and Maritime facilities in South Boston as part of the Disaster and Infrastructure Resiliency Planning (DIRP) study, and were the basis for the Design Flood Elevations (DFEs) published in the November 2014 version of the Massport Floodproofing Design Guide. The results of this comparison showed that DFEs initially selected for Logan Airport and Maritime facilities as part of the DIRP study were higher and more conservative than the maximum water elevations generated by the BH-FRM.

This was expected, as the models differ in key aspects which predispose SLOSH to produce more conservative results. Unlike SLOSH, BH-FRM's maximum predicted water elevations do not correspond to a particular storm intensity (e.g., Category 2 hurricane), storm type (BH-FRM also includes nor'easters), landfall (e.g., direct hit to Boston) or tide-surge scenario (e.g., coincidence of peak storm surge and high tide), but rather incorporates these variables probabilistically. For example, the likelihood of a Category 2 hurricane striking at high tide and low tide are technically equal, with drastically different impacts on flooding (Boston Harbor's tidal range is roughly 10 ft.). BH-FRM takes these probabilities into account when determining what flood levels are likely to be experienced, while SLOSH assumes the worst without considering probability. The maximum water elevations from BH-FRM therefore represent worst-likely scenarios, whereas SLOSH results represent worst-possible scenarios.

Because it was understood that the SLOSH-based DFEs were based on conservative assumptions and therefore encompassed a comfortable safety factor, no freeboard was added to the SLOSH outputs when determining the DFEs. The BH-FRM water elevations do not incorporate any explicit safety factors other than the inclusion of the effects of climate change.

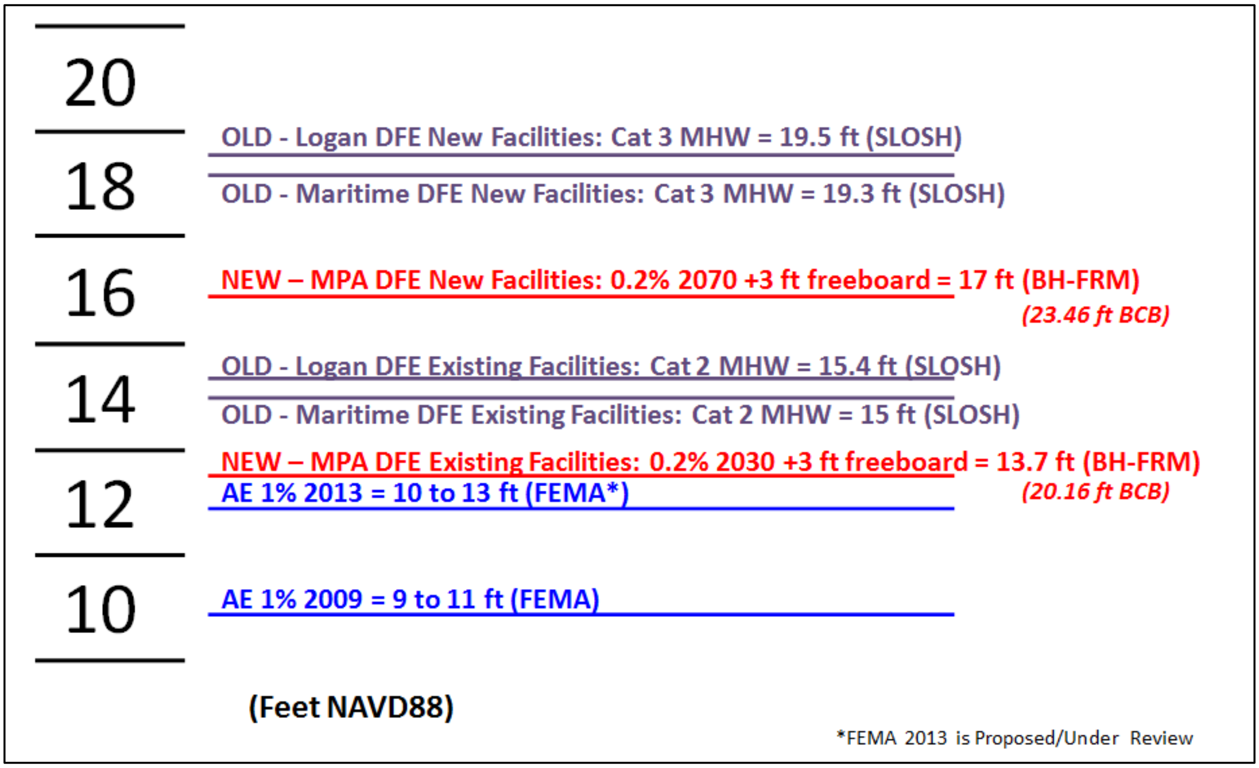
Bearing in mind the BH-FRM results and the underlying reasons for differences between BH-FRM and SLOSH results, Massport decided to adjust the DFEs set in the November 2014 version of the Floodproofing Design Guide. The revised Design Flood Elevations are equal to the maximum water elevation with a 0.2% annual probability of exceedance (1-in-500 years water elevation) predicted by BH-FRM, plus 3 ft. of freeboard as a safety factor. For existing facilities, the revised DFE is based on the 2030 BH-FRM results, and the revised DFE for new facilities is based on the 2070 BH-FRM results.

The revised DFEs for Logan Airport and Maritime facilities in South Boston are:

- Revised DFE for Existing Facilities: 13.7 ft. NAVD88 (14.5 ft. NGVD29, 23.46 ft. BCB)
- Revised DFE for New Facilities: 17 ft. NAVD88 (17.8 ft. NGVD29, 20.16 BCB)

The 3 ft. freeboard safety factor is in line with existing ASCE/SEI 24 (Flood Resistant Design and Construction) guidance for floodproofing highly critical facilities, as well as Federal Executive Order 11988 (amended on January 30, 2015) establishing a Federal Flood Risk Management Standard, which requires critical facilities be designed with 3 ft. of freeboard when receiving federal assistance.

Figure C-1 – Comparison of Old (November 2014) and New (April 2015) DFEs



Use of the BH-FRM results will align Massport and MassDOT's respective resiliency efforts by ensuring a shared foundation for vulnerability assessments and resiliency planning and design. Such coordination will help promote consistency among the region's critical transportation infrastructure owners and operators. It is expected that the BH-FRM will be the coastal flood risk model for the region for the foreseeable future, as MassDOT seeks to expand the model boundaries to the entire Massachusetts coast over the coming years.

In addition, to conform with Massport's policy to transition from NGVD29 to NAVD88 vertical datum, all elevations noted in the Massport Floodproofing Design Guide Revision 1, including DFEs, have all been standardized to NAVD88. This aligns Massport's elevation datum with others, including FAA, FEMA, NOAA, and MassDOT. Elevations in NAVD88 can be converted back to NGVD29 using a simple conversion factor of NAVD88 +0.81 ft. Elevations in NAVD88 can also be converted to Boston City Base (BCB) using a conversion factor of NAVD88+6.46 ft.