welcome
Weston & Sampson

transform your environment
Implementation of Climate Adaptation Measures

Massachusetts Municipal Association
January 19, 2018

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Introduction

**Weston & Sampson Recent Resiliency Projects**

- MBTA Resiliency GEC – Ongoing services, Massachusetts
- MBTA Blue Line Flood Vulnerability Assessment (Aquarium to Maverick Portal) – Ongoing, Massachusetts
- Division of Capital Asset Management and Maintenance (DCAMM) Statewide Resilience Master Plan - Massachusetts
- Climate Change Vulnerability Assessment & Adaptation Plan – Lynn, MA
- Church Creek Drainage Study – South Carolina
- Chelsea Flood Resiliency Improvements – Chelsea, MA
Municipal Resilience Process

PHASE 1 – CLIMATE SCENARIO SELECTION

TASK 1
Map climate conditions under future conditions

PHASE 2 – VULNERABILITY AND RISK ANALYSIS

TASK 2
Identify critical assets located in vulnerable areas

TASK 3
Identify the tipping point that would damage each critical asset

TASK 4
Evaluate risk given probability of climate scenario and consequence

PHASE 3 – ADAPTATION STRATEGIES

TASK 5
Identify and select adaptation strategies (criteria comparison)

TASK 6
Implement adaptation and preparedness plan and monitor progress
PHASE 1 – CLIMATE SCENARIO SELECTION

Source: EOEEA
PHASE 2 – VULNERABILITY AND RISK ANALYSIS

INFRASTRUCTURE

CLIMATE HAZARDS

CRITICAL ASSETS

RISK RANKING

INCREASING RISK

PROBABILITY

Low
Medium
High
Very High
Criticality

- Portfolio Review
- Pre-selected Assets
- Stakeholder Feedback
- Exposure
- Consequences
Lynn EDIC – Pump Station Example

Legend
- Lynn City Floodplain
- Zones of Potential Flood Inundation 2008
- Northeast Flooded Level in Flood
- Northeast Flooded Level in Base
- Southeast Flooded Level in Flood
- Southeast Flooded Level in Base
- Reed Street Sewer Lift Station

Predicted Flood Elevations
Threshold Elevation is EL 8.85

Criteria Describing Consequence

<table>
<thead>
<tr>
<th>Score</th>
<th>Consequence</th>
<th>Public Safety, Emergency Services</th>
<th>Public Health, Environment</th>
<th>Repair Cost</th>
<th>Reduced Economic Activity</th>
<th>Public Services; Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Regional Emergency</td>
<td>Regional Emergency</td>
<td>&gt;$20 MM</td>
<td>Regional Emergency</td>
<td>&gt;1 Month</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>City Emergency</td>
<td>City Emergency</td>
<td>$2 MM - $20 MM</td>
<td>City Emergency</td>
<td>15-30 Days</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>High</td>
<td>High</td>
<td>$200K - $2 MM</td>
<td>High</td>
<td>7-14 days</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Moderate</td>
<td>Moderate</td>
<td>$20K - $200K</td>
<td>Moderate</td>
<td>1-6 days</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Low</td>
<td>Low</td>
<td>&lt;$20K</td>
<td>Low</td>
<td>&lt;1 day</td>
<td></td>
</tr>
</tbody>
</table>

Facility | Consequence Score | Probability 2016 | Probability 2041 | Probability 2066 | Weighted Risk Score
--- | --- | --- | --- | --- | ---
Reed Street Sewer Lift Station | 0.04 | 0.01 | 0.01 | 0.1 | 2.37 |
### EXTERIOR

<table>
<thead>
<tr>
<th>SITE FEATURE</th>
<th>OBSERVATIONS</th>
<th>CLIMATE PARAMETERS</th>
<th>SENSITIVITY</th>
<th>ADAPTIVE CAPACITY RATING</th>
<th>CONSEQUENCE RATING</th>
<th>RISK RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PRE-EXISTING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing problems and/or concerns?</td>
<td>X</td>
<td>Drainage by loading dock reportedly inadequate, increased size (1)</td>
<td>FLOOD/EXT. PRECIP</td>
<td>1</td>
<td>3</td>
<td>High</td>
</tr>
<tr>
<td>Water staining/mold/growth as flooding evidence?</td>
<td>X</td>
<td></td>
<td>FLOOD/EXT. PRECIP</td>
<td>1</td>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td><strong>GRADING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Located down gradient of surrounding areas?</td>
<td>X</td>
<td>Surrounding grades higher at Federal street, lower at bridge street</td>
<td>FLOOD/EXT. PRECIP</td>
<td>1</td>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td>Grades slope towards building?</td>
<td>X</td>
<td>Yes</td>
<td>FLOOD/EXT. PRECIP</td>
<td>1</td>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td>Slopes steeper than 2:1:1V present?</td>
<td>X</td>
<td>Footpath connecting Bridge to Federal eroded</td>
<td>LANDSLIDE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DRAINAGE</strong></td>
<td></td>
<td>Drainage pipe on canopy becomes disconnected and drips (2)</td>
<td>FLOOD/EXT. PRECIP</td>
<td>1</td>
<td>2</td>
<td>Low</td>
</tr>
<tr>
<td>Stormwater retention on site?</td>
<td>X</td>
<td>2 tanks, in unknown condition</td>
<td>FLOOD/EXT. PRECIP</td>
<td>1</td>
<td>3</td>
<td>High</td>
</tr>
<tr>
<td>10% or more of site impervious surfaces?</td>
<td>X</td>
<td></td>
<td>FLOOD/EXT. PRECIP</td>
<td>1</td>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td>Bioswales or rain gardens present?</td>
<td>X</td>
<td></td>
<td>FLOOD/EXT. PRECIP</td>
<td>1</td>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td><strong>VEGETATION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiple trees on site (&gt;3)?</td>
<td>X</td>
<td>Landscapers maintain branches regularly</td>
<td>WIND/FLOOD</td>
<td>1</td>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td>Visible signs of erosion?</td>
<td>X</td>
<td>Footpath connecting Bridge to Federal eroded</td>
<td>EX. PRECIP/LANDSLIDE</td>
<td>0</td>
<td>3</td>
<td>Low</td>
</tr>
<tr>
<td>Vegetation providing shade?</td>
<td>X</td>
<td>Not much shade provided on site</td>
<td>HEAT</td>
<td>1</td>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td><strong>OPEN SPACE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area to store snow onsite?</td>
<td>X</td>
<td>Snow removal agency takes offline</td>
<td>WINTER STORM</td>
<td>1</td>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td>Objects on site that could become debris?</td>
<td>X</td>
<td>Cars</td>
<td>WIND/FLOOD</td>
<td>1</td>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td>Below ground parking?</td>
<td>X</td>
<td></td>
<td>FLOOD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shaded parking lot?</td>
<td>X</td>
<td></td>
<td>HEAT</td>
<td>1</td>
<td>1</td>
<td>Low</td>
</tr>
</tbody>
</table>

**NOTE:** REFER TO STRUCTURAL SECTION FOR EXTERIOR BUILDING WALLS AND FOUNDATIONS

**ADDITIONAL COMMENTS:**

1. no longer problem with flooding
2. puddles observed along bridge street (historically) and tidal flooding near the F. Webb building further down bridge street. The META parking lot has tidal flooding too.

The generator and transformers are located along bridge street.
PHASE 3 – ADAPTATION STRATEGIES
Adaptation Planning

**BEFORE**

- **PREPARE** for chronic and acute climate impacts

**DURING**

- **RESIST** climate event (heatwave, storm)

**AFTER**

- **RECOVER** from climate event (flooding, damages)
Adaptation/Resiliency Strategies: Grouped by Type of Action

**Policy**
- Programmatic
- Deferred Maintenance Request
- O&M
- Master Plan

**Retreat**
- Remove CC sensitivity
- Relocate on site
- Relocate off-site
- Elevate above PFE

**Protect**
- Prevent CC impact
- Flood Barriers
- Backflow preventers/flood gates
- Reinforce Windows/Wall

**Accommodate**
- Allow CC impact, reduce damage
- Increase drainage capacity
- Green infrastructure
- Wet floodproofing
CRITERIA FROM CLIMATE READY BOSTON

• **Effectiveness** (risk reduction)
• **Feasibility** (cost/constructability)
• **Design Life & Adaptability** (flexibility/time to implement)
• **Social Impact** (recreational/aesthetic)
• **Equity** (benefits for vulnerable populations)
• **Value Creation** (new value)
• **Environmental Impact** (mitigation/health)

Source: Climate Ready Boston Report (2017)
EXAMPLES

Example Adaptation Strategy for Transformer – Elevate Transformer

- Planning Horizon: Before
- Strategy: Retreat
- Cost – $$$
- Effectiveness – Max
- Feasibility – Yes.
- Adaptability – No.
- Co-benefits – Yes, ease of maintenance and access.

Example Adaptation Strategy for Equipment/Mechanical Room – Flood Barriers

- Planning Horizon: Before & During
- Strategy: Protect
- Cost – $ - $5. Customized to openings
- Effectiveness – Max: depends on structural strength of building walls and connections
- Feasibility – Yes: easy to install, use, store and transport
- Adaptability – Flexible: Adjust to water height
- Timing - Short term: <1 hour installation
- Co-benefits - No.

Example Adaptation Strategy for Floor Drains and Under-Slab Drain – Flood Guard

- Planning Horizon: Before & During
- Strategy: Accommodate
- Cost – $, Low, retrofit
- Effectiveness – Moderate, reduces hydrostatic pressure
- Feasibility – Yes: easy to install
- Adaptability – Flexible, taller pipes could be used
- Timing - Short term
- Co-benefits - No.

Example Adaptation Strategy for Temperature Control – Solar control window film

- Planning Horizon: Before & During
- Strategy: Protect
- Cost – $
- Effectiveness: Moderate (priority southern exposure)
- Feasibility: Yes, assuming that installation does not trigger security/safety issues
- Adaptability: No
- Timing – short-term and long-term
- Co-benefits – Reduce the energy demand for the building and contribute to achieve GHG reduction.
### GUIDELINES BY BUILDING SYSTEM

#### Exterior Site Features and Grounds Example

**SITE DRAINAGE**

<table>
<thead>
<tr>
<th>Adaptation: Increase drainage capacity for site drainage systems.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planning Horizon:</strong> Before/During</td>
</tr>
<tr>
<td><strong>Strategy:</strong> Accommodate</td>
</tr>
<tr>
<td><strong>Cost:</strong> $5</td>
</tr>
<tr>
<td><strong>Effectiveness:</strong> Moderate</td>
</tr>
<tr>
<td><strong>Feasibility:</strong> Yes</td>
</tr>
<tr>
<td><strong>Adaptability:</strong> Not Flexible</td>
</tr>
<tr>
<td><strong>Timing:</strong> Mid-term</td>
</tr>
<tr>
<td><strong>Co-benefits:</strong> No</td>
</tr>
</tbody>
</table>

**Discussion:** This adaptation should be considered at low-lying areas of the site. The designer should consider the initial rainfall volumes used for drainage sizing and compare to predicted rainfall volumes. Increasing the capacity of the system is effective as long as the surrounding drainage system is not over capacity, which could result in backflow on the site. A drainage study should be performed.

### GUIDELINES BY BUILDING SYSTEM

#### Architectural Building Example

**DOORWAYS**

<table>
<thead>
<tr>
<th>Adaptation: Install a temporary flood barrier in doorways.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planning Horizon:</strong> During</td>
</tr>
<tr>
<td><strong>Strategy:</strong> Protect (temporary barrier)</td>
</tr>
<tr>
<td><strong>Cost:</strong> $ (500/kiln)</td>
</tr>
<tr>
<td><strong>Effectiveness:</strong> Maximum</td>
</tr>
<tr>
<td><strong>Feasibility:</strong> Yes</td>
</tr>
<tr>
<td><strong>Adaptability:</strong> Flexible</td>
</tr>
<tr>
<td><strong>Timing:</strong> Short-term</td>
</tr>
<tr>
<td><strong>Co-benefits:</strong> No</td>
</tr>
</tbody>
</table>

**Discussion:** This adaptation should be installed immediately before and during a flood event to prevent water from entering the building. The effectiveness depends on the structural strength of the building walls and connections. This strategy is feasible to implement if personnel are on site immediately before, during, and after an event. It is easy to install (1 hour), store, and transport. The solution is flexible to fit different doorway widths. Timing of implementation is short-term.

### GUIDELINES BY BUILDING SYSTEM

#### Exterior Site Features and Grounds Example

**SITE DRAINAGE**

<table>
<thead>
<tr>
<th>Adaptation: Deploy temporary barriers to alter the flow of stormwater runoff away from the site.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planning Horizon:</strong> During</td>
</tr>
<tr>
<td><strong>Strategy:</strong> Protect</td>
</tr>
<tr>
<td><strong>Cost:</strong> $</td>
</tr>
<tr>
<td><strong>Effectiveness:</strong> Moderate</td>
</tr>
<tr>
<td><strong>Feasibility:</strong> Yes</td>
</tr>
<tr>
<td><strong>Adaptability:</strong> Flexible</td>
</tr>
<tr>
<td><strong>Timing:</strong> Short-term</td>
</tr>
<tr>
<td><strong>Co-benefits:</strong> No</td>
</tr>
</tbody>
</table>

**Discussion:** This adaptation should be during climate impacts when stormwater is flowing from another site onto this site. This solution requires personnel on site immediately before, during, and after an event to implement. It will require purchase of the barriers; so timing of implementation is short-term. Barriers can range from sandbags, quick clamps, to NOAA flood deflectors (picted).

### GUIDELINES BY BUILDING SYSTEM

#### Architectural Building Example

**DOORWAYS**

<table>
<thead>
<tr>
<th>Adaptation: Install flood plain barrier system around entrances.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planning Horizon:</strong> Before/During</td>
</tr>
<tr>
<td><strong>Strategy:</strong> Protect (temporary barrier)</td>
</tr>
<tr>
<td><strong>Cost:</strong> $ - $5</td>
</tr>
<tr>
<td><strong>Effectiveness:</strong> Maximum</td>
</tr>
<tr>
<td><strong>Feasibility:</strong> Yes</td>
</tr>
<tr>
<td><strong>Adaptability:</strong> Flexible</td>
</tr>
<tr>
<td><strong>Timing:</strong> Short to Mid-term</td>
</tr>
<tr>
<td><strong>Co-benefits:</strong> No</td>
</tr>
</tbody>
</table>

**Discussion:** This adaptation should be constructed before and implemented immediately during a flood event to prevent water from entering the building. The effectiveness depends on the structural strength of the building walls and connections. This strategy is feasible to implement if personnel are on site immediately before, during, and after an event. It is easy to install (1 hour), store, and transport. The solution is customizable and additional plants can be added. Timing of implementation is short to mid-term.

### GUIDELINES BY BUILDING SYSTEM

#### Exterior Site Features and Grounds Example

**SITE DRAINAGE**

<table>
<thead>
<tr>
<th>Adaptation: Install pedestrian flood doors.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planning Horizon:</strong> Before/During</td>
</tr>
<tr>
<td><strong>Strategy:</strong> Protect</td>
</tr>
<tr>
<td><strong>Cost:</strong> $ - $5</td>
</tr>
<tr>
<td><strong>Effectiveness:</strong> Moderate</td>
</tr>
<tr>
<td><strong>Feasibility:</strong> Yes</td>
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<td><strong>Adaptability:</strong> Not Flexible</td>
</tr>
<tr>
<td><strong>Timing:</strong> Short to Mid-term</td>
</tr>
<tr>
<td><strong>Co-benefits:</strong> No</td>
</tr>
</tbody>
</table>

**Discussion:** This adaptation should be implemented before climate impacts. This strategy would replace pedestrian doors with flood doors. Effectiveness depends on the structural strength of the building walls and frame connections. These doors are designed for hydraulic pressures, and can be installed by a subcontractor. Timing of implementation is short to mid-term, and this measure does not require action to display before a storm event.
Next steps: translating recommendations into design

Existing Products

![Existing Products Diagram]

Leverage Opportunities

RCC Solar Canopy – Heat Adaptation Strategy with co-benefits

![RCC Solar Canopy Image]

FIGURE 1 | A FloodBreak barrier gate diagram

Courtesy of A Better City
Chelsea Pump Station Example: Resilience tied into existing project

Weston & Sampson provided design, permitting, and bidding services. The scope of work included:

• Approx. 1,400 feet of new stormwater force main and abandonment of existing force main
• A new discharge structure at a culvert

• **Flood resiliency improvements at the Carter Street Pump Station**
  • A wall around the perimeter of the pump station and a surface drain system to remove water captured within the enclosed perimeter
Design Considerations

- Base-flood Elevation
- Hydrostatic Pressure and Uplift
- Geotechnical
- Structural
- Interior drainage
- Systems upgrades
- Emergency Power
- Access
thank you

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Focus on Implementation

- Leverage Existing Information and Models
- Access to Public and Unpublished Data
- Model coastal and inland flooding, as well as extreme precipitation, heat, snow, and wind.
- Look at regional and site specific implications
VAST TOOL

Facility Checklist Developed for Site Specific Risk and Vulnerability Assessment (W&S)
PHASE 1 – CLIMATE SCENARIO SELECTION

- Synthesis of available relevant technical analyses and reports
  - Coastal Geomorphology
  - Watershed Characteristics
  - Municipal Asset Locations and Information
- Compilation of data into a Geographic Information System (GIS)
- Development of Study Scenarios

- Preliminary review of relevant regulations
Evaluation Criteria Used for Resiliency Strategies

**PRIMARY:**
- Cost
- Effectiveness
- Feasibility

**SECONDARY:**
- Adaptability
- Timing of Implementation
- Co-benefits

- Cost
- Effectiveness
- Feasibility
- Adaptability
- Timing of Implementation
- Co-benefits