Mapping and Mitigating Future Flood Risks for Boston: A Changing Climate Perspective

Bin Wang, Tianyi Liu, Daniel Stapleton & Chad Cox
OUTLINE

• Background
• Analysis – Storm Surge Simulations using ADCIRC
• Results – Inundation Mapping
• Takeaways
BACKGROUND

- Normal Flow
- Mean Low Tide
- Mean High Tide
- Mean Sea Level
- Storm Tide (Surge + Tide)
- Wave Crest Elevation
- Uplift
- Riverine Flood
- Wave Overtopping

Wave Crest Elevation
BACKGROUND

Boston, MA

Charles River
Cambridge
Back Bay
Boston Harbor

Massachusetts Bay
BACKGROUND
Causes of Coastal Flooding around Boston

- Tropical Cyclones (i.e. hurricanes)
- Extratropical Storms (e.g., nor’easters)
BACKGROUND

Top Elev = 12.2 feet (NAVD) or 12.5 feet (MSL)

BACKGROUND

Source: wikipedia
BACKGROUND

http://www.bc.edu/bc_org/avp/cas/fnart/fa267/boston/bos1641.gif
Astronomical Tides and Storm Tides

Storm Tides (green) - Astronomical Tides (blue) ≈ Storm Surge
Storm Tides at Boston Harbor during Superstorm Sandy

- Predicted (ft)
- Verified (ft)
- Storm Surge
Storm Tides at Boston Harbor during Blizzard 1978

- Water Elevation (feet, NAVD88)
- Storm Surge (feet)

Date & Time:
- 2/6/78 0:00
- 2/7/78 0:00
- 2/8/78 0:00
- 2/9/78 0:00

Legend:
- Predicted (ft)
- Verified (ft)
- Storm Surge
### TABLE 9 – TRANSECT DESCRIPTIONS - continued

<table>
<thead>
<tr>
<th>TRANSECT</th>
<th>LOCATION</th>
<th>ELEVATION (feet NAVD 88)</th>
<th>MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>The transect extends over one of the main steel seawall piers at Charlestown Navy Yard, then terminates in vegetated parkland.</td>
<td>10.0</td>
<td>15.2</td>
</tr>
<tr>
<td>21</td>
<td>This transect crosses a seawall approximately 10 feet high at Lewis Wharf in downtown Boston. Upland development is high density mixed use commercial and residential with parking lots.</td>
<td>10.0</td>
<td>14.7</td>
</tr>
</tbody>
</table>
# ANALYSIS

## TABLE 10 – TRANSECT DATA - continued

<table>
<thead>
<tr>
<th>TRANSECT</th>
<th>STILLWATER ELEVATIONS (FEET NAVD88)</th>
<th>TOTAL WATER LEVEL</th>
<th>BASE FLOOD ELEVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10- PERCENT-ANNUAL CHANCE</td>
<td>2- PERCENT-ANNUAL CHANCE</td>
<td>1- PERCENT-ANNUAL CHANCE</td>
</tr>
<tr>
<td>20</td>
<td>8.5</td>
<td>9.5</td>
<td>10.0</td>
</tr>
<tr>
<td>21</td>
<td>8.5</td>
<td>9.5</td>
<td>10.0</td>
</tr>
</tbody>
</table>

1. Water levels are rounded to the nearest tenth of a foot.
2. Flood elevations rounded to nearest foot.
3. NAVD88 is the National Geodetic Vertical Datum of 1988.
Factors to consider for modeling future floods:

- Extreme precipitation (riverine);
- Sea level change (coastal);
- Sea surface temperature (coastal);
- Urban development (riverine & coastal)
USACE Sea Level Rise Calculator

Relative Sea Level Change Projections - Gauge: 8443970, Boston, MA (05/01/2014)

+5.0 ft SLR

Current MSL
Computer Model: ADCIRC+SWAN
• Unstructured mesh
• High resolution
• Coupled circulation and wind-wave models
• Explicit and implicit solver

Variables and Inputs:
• Topography (land and bathymetry
• Landuse
• Astronomical tides;
• River flow;
• Sea level change;
• Selected hurricane
MODELING

- FEMA Region II ADCIRC Mesh; - Refined for the Boston area
MODELING

- Average grid size ~ 20 to 30 m in River and Boston
**MODELING**

Simulated Hurricane Track in ADCIRC

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing</td>
<td>10°</td>
</tr>
<tr>
<td>$R_{\text{max}}$</td>
<td>35 nm</td>
</tr>
<tr>
<td>$V_f$</td>
<td>20 kt</td>
</tr>
<tr>
<td>$V_{\text{max}}$</td>
<td>105 kt</td>
</tr>
<tr>
<td>$\Delta P$</td>
<td>68 mb</td>
</tr>
</tbody>
</table>
## List of ADCIRC Runs

<table>
<thead>
<tr>
<th>Case #</th>
<th>Sea Level</th>
<th>Charles River Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MSL (present)</td>
<td>Functional</td>
</tr>
<tr>
<td>1a</td>
<td>MSL (present)</td>
<td>No Dam</td>
</tr>
<tr>
<td>2</td>
<td>USACE High SLR Scenario (2100)</td>
<td>Functional</td>
</tr>
<tr>
<td>2a</td>
<td>USACE High SLR Scenario (2100)</td>
<td>No Dam</td>
</tr>
<tr>
<td>3</td>
<td>USACE High SLR Scenario (2100)</td>
<td>Raised 6ft</td>
</tr>
</tbody>
</table>
RESULTS

Inundation Map – Case 1
RESULTS

Inundation Map – Case 1a
RESULTS

Difference: Case 1a - Case 1
RESULTS

Inundation Map – Case 2
RESULTS

Inundation Map – Case 2a
RESULTS

Difference: Case 2a - Case 2
RESULTS

Inundation Map – Case 3
RESULTS

North Atlantic Coast Comprehensive Study

Stillwater Elevation (ft, NAVD88)

- Mean Tide Point 9583 (ft, NAVD88)
- High Tide Point 9583 (ft, NAVD88)
- High Tide + 5’ SLR

12.2’±
RESULTS

Present

12.2’±
11.3’ (500-yr)
10’ (100-yr)

2’± (normal pool)

4.5’±

MSL

Intermediate SLR

13’±(500-yr)
12’ ± (100-yr)

High SLR

17’ ± (500-yr)
15’ ± (100-yr)

Vertical Datum: NAVD88
TAKEAWAYS

- Significant riverine/coastal flood risks in Boston and its neighboring towns;
- Charles River Dam protects Boston under current sea level conditions;
- Larger inundation areas with sea level rise and climate change;
- Integrated analysis / improvements needed;
- Uncertainty needs to be assessed
Thank you!

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