Flooding Terminology

- What are we really talking about?

**Nuisance Flooding** - flooding that causes public inconveniences such as frequent road closures (NOAA)

**Chronic Flooding** - flooding that occurs more than 24 times per year or every 2 weeks on average (Union of Concerned Scientists)

**King Tide** – a colloquial term for especially high astronomical tides such as a perigean spring tide (e.g., Night in Venice High Tide)

Note: Not a scientific term
Introduction

My Background:

Graduate of Ocean City HS
Ph.D. in Ocean Engineering
NJ Coastal Research Program Director
OE Program Director at Stevens

Urban Coast Institute Assoc. Director
NJ Sea Grant Community Resilience Specialist
Introduction

• Work with OCFLooding
  • Science Partnership
    • AGU Thriving Earth Exchange
    • Flood Forum USA
    • Volunteer Scientist
    • NJ Sea Grant

• Objective
  • Transfer of knowledge to inform science-based decisions on local issues
Assessing Flooding & Hydrodynamics for Flood Prevention & Mitigation

Challenge: Sea level rise and land subsidence along the Mid-Atlantic coast is increasing the frequency of rainfall, high tide nuisance flood events and the magnitude of storm inundation. Aging infrastructure and low topography require science-based decision making for long term community resilience to flooding.

Leads: Suzanne Hornick, Chair, Ocean City Flooding Committee; Dr. Tom Herrington, Associate Director, Urban Coast Institute, Monmouth University.

Action: Empower the community to formulate science-based decisions that support long-term flood mitigation and the creation of a resilient coastal community.

Impact: Community engagement in short and long term planning for island-wide flood mitigation.
The Issue: Changes in Rainfall Frequency and Intensity
The Issue: Relative Sea Level Rise

8534720 Atlantic City, New Jersey

4.08 +/- 0.15 mm/yr

- Linear Relative Sea Level Trend
- Upper 95% Confidence Interval
- Lower 95% Confidence Interval
- Monthly mean sea level with the average seasonal cycle removed
Result: More Days Like This
This Evenings Talk

**Stormwater Management**
- Requirements
- Challenges
- Options

**Tidal Flood Frequency**
- Present Conditions
- Future SLR Scenarios
- Impacts

**MITIGATION OPTIONS**

**Combined Impacts**
Stormwater Management

• Objective
  • Convey stormwater through drainage system to bay or ocean
  • Storage of stormwater in detention basins to reduce runoff
  • Percolation of stormwater into ground through detention basins/rain gardens
Challenges on Barrier Islands

• Low topographic elevations
• High water table
• Limited location for underground utilities and piping
• Lack of storage areas
Solution: Storage and Pumping

**Pump it up**

Miami Beach plans to spend between $400-$500 million during the next five years to install about 60 pumps like this throughout the city. From Sunset Harbour down to the MacArthur Causeway, four pumps have already been installed to push the water into Biscayne Bay.

1. Rainwater accumulates at the drainage structure and first makes it way to the detention box.

2. The detention box collects the stormwater and filters it before discharging to the pump.

3. The water then goes into the pump, which pressurizes and moves the water through a valve box, into the vortex that separates any remaining solids from water and pushes it to the closest open body of water.

Source: City of Miami Beach
Ocean City is Leader in NJ

• Michael Baker Flood mitigation study for 250 acres between 26th and 34th Streets and West and Bay Avenues
• Focus: mitigate the more common rainfall events that cause routine or nuisance flooding throughout the study area.

• Goals
  • quantify the amount of rainfall throughout the study area
  • determine the amount of rainfall entering the storm sewers
  • understand the performance of the existing system
Drainage Areas Modeled
Model
## MB Simulated Rainfall Events

<table>
<thead>
<tr>
<th>Event</th>
<th>Rainfall Amount</th>
<th>Runoff Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Year Event</td>
<td>2.68 Inches</td>
<td>14.67 Million Gallons</td>
</tr>
<tr>
<td>2 Year Event</td>
<td>3.27 Inches</td>
<td>18.04 Million Gallons</td>
</tr>
<tr>
<td>5 Year Event</td>
<td>4.24 Inches</td>
<td>23.53 Million Gallons</td>
</tr>
<tr>
<td>10 Year Event</td>
<td>5.08 Inches</td>
<td>33.79 Million Gallons</td>
</tr>
</tbody>
</table>
Model Simulation Output
Tidal Flooding
The Issue: Relative Sea Level Rise

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Meters

How do we know this?

Tide Gauge Data. Atlantic City, NJ Station operating from 1912 – 2018!
Impacts: March 2018 Nor’Easters

Influence of Sea Level Rise on Water Elevation at Atlantic City

Observed 2018
Predicted 1962

Minor Flood
Moderate Flood
Future Impact: 2074

Influence of Sea Level Rise on Water Elevation at Atlantic City

Elevation in Feet NAVD88

Date and Time (m/dd/yyyy h:mm)
Concerns/Questions

1. How frequently will low-lying roadways and infrastructure experience flooding in the future?
2. Is Sea Level continuing to rise linearly or is the rate of rise increasing?
Ocean City Case Study

Elavation Map of New Jersey, USA

http://elevation.maplogs.com/poi/new_jersey_usa.14971.html

Roosevelt Bld. has an elevation of approx. 3 ft NAVD88
**NOS Tide Datum at Atlantic City**

<table>
<thead>
<tr>
<th>Datum</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MHHW</td>
<td>9.56</td>
<td>Mean Higher-High Water</td>
</tr>
<tr>
<td>MHW</td>
<td>9.14</td>
<td>Mean High Water</td>
</tr>
<tr>
<td>MTL</td>
<td>7.14</td>
<td>Mean Tide Level</td>
</tr>
<tr>
<td>MSL</td>
<td>7.17</td>
<td>Mean Sea Level</td>
</tr>
<tr>
<td>DTL</td>
<td>7.26</td>
<td>Mean Diurnal Tide Level</td>
</tr>
<tr>
<td>MLW</td>
<td>5.13</td>
<td>Mean Low Water</td>
</tr>
<tr>
<td>MLLW</td>
<td>4.96</td>
<td>Mean Lower-Low Water</td>
</tr>
<tr>
<td>NAVD88</td>
<td>7.57</td>
<td>North American Vertical Datum of 1988</td>
</tr>
<tr>
<td>STND</td>
<td>0.00</td>
<td>Station Datum</td>
</tr>
</tbody>
</table>

- MSL is 0.4 ft below NAVD88
- Roosevelt Blvd. is 3.4 ft above Mean Sea Level
Roosevelt Blvd was flooded on 12 consecutive high tides between March 2-8, 2018.
What about the Future?

https://tidesandcurrents.noaa.gov/waterlevels.html?id=8534720
Processing

- Start with hourly water levels from Atlantic City
- Use 20 years of observations to identify high tide peaks and elevations in data set
- 1997 - 2017
Processing

- Develop probability distribution of high tide amplitudes relative to Mean Sea Level
- Analyze data for exceedance probability of High Tides relative to Mean Sea Level
- Provides % time that High Tides were at or above specific elevations
- Assume same distribution will occur with sea level rise
50% of high tides are 1.8 ft above MSL.
High Tide Elevation Above MSL at Atlantic City (1997 - 2017)

Exceedance Probability

Amplitude of High Tide Peak, Feet from MSL

Tidal Range

Roosevelt Blvd Elevation
Convert to # of High Tides per year

- Easier to think in terms of how many high tides per year exceed a specific elevation
  - Assume the high tides will continue to follow the 20-year distribution of high tides
  - Two high tides per day
  - 730 total high tides per year
Annual High Tide Elevations at Atlantic City

Amplitude of High Tide Peak, Feet from MSL

Annual Number of High Tide Events

Roosevelt Blvd Elevation

24
Global Mean Sea Level Projections

From Kriebel 2017
Future Sea Level Rise Projections for the year 2100

Annual High Tide Elevations at Atlantic City

- Low
- Medium
- High
- Highest

MSL

Present SLR Rate

Amplitude of High Tide Peak, Feet from MSL

Annual Number of High Tide Events
Future Number of Floods by Year

Day of Water Elevations above Roosevelt Blvd.

Year

Low SLR

Medium SLR

High SLR

Existing Trend

Annual Flood Events > 3.4 feet MSL
Is Sea Level Rising Linearly?
Sea Level is not Rising Equally Everywhere
Rain and Tidal Flooding
Real Issue moving forward:

Joint Probability Analysis of Extreme Precipitation and Storm Tide in a Coastal City under Changing Environment

Kui Xu, Chao Ma, Jijian Lian, Lingling Bin

Published: October 13, 2014 • https://doi.org/10.1371/journal.pone.0109341
Future Joint Probabilities are Difficult to Determine
Conclusions

• Number of flood events changes significantly with small changes in sea level
• There will be a large increase in future flood events with current sea level rise trend
• Daily flooding is likely if sea level rise accelerates over the next few decades
• Joint probability of increased rainfall and high tide flood events is not well understood at this time
  • Increased frequency and intensity of rain events will increase frequency of high tide flood events
What can we do about this?

“It’s not going to be a slow, gradual change. It’s already on an accelerating, upward sloping trajectory”

- WILLIAM V. SWEET, NOAA OCEANOGRAPHER
# Tidal Flood Mitigation

<table>
<thead>
<tr>
<th>Structural</th>
<th>Non-Structural</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Levees</td>
<td>• Elevation</td>
</tr>
<tr>
<td>• Berms</td>
<td>• Beach Nourishment</td>
</tr>
<tr>
<td>• Dikes</td>
<td>• Living Shorelines</td>
</tr>
<tr>
<td>• Floodwalls</td>
<td>• Reefs</td>
</tr>
<tr>
<td>• Bulkheads</td>
<td>• Wetlands</td>
</tr>
</tbody>
</table>
MANAGEMENT MEASURES
STRUCTURAL - LEVEES
Floodwall

Port Monmouth, NJ
MANAGEMENT MEASURES
NATURAL AND NATURE-BASED – BEACH NOURISHMENT
MANAGEMENT MEASURES
NATURAL AND NATURE-BASED – LIVING SHORELINES

HIGH-MARSH SHRUBS

WETLAND WATER'S EDGE

SHORELINE EXPOSED TO WAVES
MANAGEMENT MEASURES
NATURAL AND NATURE-BASED – REEFS

WAVES REACH THE SHORELINE

MEAN SEA LEVEL

DEGRADED REEF FLAT
MANAGEMENT MEASURES

NATURAL AND NATURE-BASED – WETLANDS
Who is going to do all this Planning & Construction and who is going to pay?
Overview

- NACCS Focus Area
- NJ Shore Protection Study Authority (December 1987 House Resolution)
- Single purpose CSRM Feasibility Study
- Initiated as 3-year study (3X3 model)
- Coastal flooding and sea level rise risk management
- FCSA Executed April 2016
- Public Release Spring 2019
EXAMPLE PLANS (AMM)
Natural and Nature Based Features (NNBF)

NNBF are defined in the North Atlantic Coastal Comprehensive Study (NACCS) to include elements that are created and evolve over time through the actions of physical, biological, geologic, and chemical properties operating in nature and elements that mimic characteristics of natural features but are created by human design, engineering, and construction to provide specific services such as coastal storm risk management. NNBF measures considered in the NJBB study include Living Shorelines, Reefs, Wetland Restoration, Submerged Aquatic Vegetation (SAV) restoration, and Green Stormwater Management. Improved implementation of NNBF throughout the NJBB CSR] Feasibility Study area presents a significant opportunity to increase resilience and manage coastal storm flooding risk.

Key to Figures:
- Normal conditions, no measure
- Normal conditions, with measure
- Storm conditions, no measure
- Storm conditions, with measure

Beach Restoration

Living Shorelines

Green Stormwater Management

Submerged Aquatic Vegetation (SAV)

Reefs

Wetland Restoration

Map of NJBB Study Area

Legend:
- Major Roads
- NJBB Study Area

Scale: 0-20 miles
WHAT IS THE PROGRAM?

New Jersey was awarded $10 million from HUD through the National Disaster Resilience competition. Administered by NJDEP, Resilient NJ will fund the development and implementation of up to 5 regional resilience and adaptation action plans to address coastal and riverine flood events. NJDEP will provide qualified consultants to lead the planning process and provide technical support to develop community-driven action plans.

WHO QUALIFIES?

Funding will be awarded on a competitive basis to regional teams. Eligible entities include counties, municipalities, regional planning commissions, utility authorities, and community-based organizations (CBO) within Atlantic, Bergen, Cape May, Essex, Hudson, Middlesex, Monmouth, Ocean, and Union Counties. Each team must include at least 3 contiguous municipalities and 1 CBO. This program is open to all communities within these counties.

HOW WILL YOU BENEFIT?

The program will provide grant funding for neighboring communities to develop and implement regional action plans that:

- Assess vulnerability to current and projected flooding, including permanent inundation, chronic and nuisance flooding, riverine and coastal flooding, and coastal storms and storm surge
- Identify locally-significant and regionally-shared critical assets
- Develop strategic and actionable mitigation actions to reduce flooding risk
- Understand and weigh the costs and benefits of specific actions
- Develop a strategic plan that reduces risk and provides a roadmap for implementation

Resilient NJ will also provide funding to implement these actions. Potential actions include planning and concept design of mitigation projects, master plan updates, ordinance development, outreach, and education programs, or other planning-related activities to reduce impacts from flooding.

A Notice of Fund Availability will be released Spring 2018.

Applications will be available in May 2018.

Questions? Contact the NJDEP Office of Coastal and Land Use Planning for more details at ResilientNj@dep.nj.gov
It’s not going to be quick or easy....
Thank you

....but it is all worth it.