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Climate Change: From Theory to Stormwater Practice

Thursday April 23, 2020
1:00 – 3:00 PM ET

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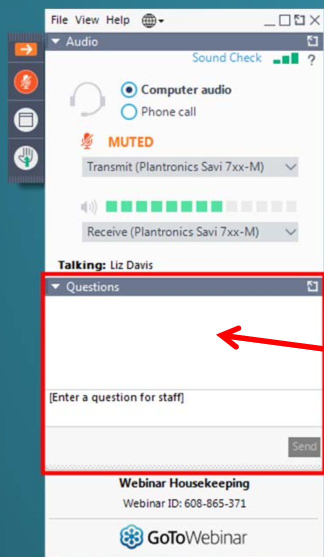
How to Participate Today



- **Audio Modes**
  - Listen using Mic & Speakers
  - Or, select "Use Telephone" and dial the conference (please remember long distance phone charges apply).
- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this webcast.**

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Today's Moderator

Kari Mackenbach

Director of Sustainability

MS Consultants

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Today's Presenters

- David Vallee
  - Examining Our Changing Climate in New England and Its Impacts on River and Coastal Flooding
- Julia Rockwell
  - Creating Actionable Climate Science to Inform Infrastructure Planning & Design
- Keren Bolter
  - Sea Level Rise and Stormwater Flooding: Miami is Shifting from Reactive Solutions to Cost Effective and Equitable Prevention via Future-Proofing

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David R. Vallee

Hydrologist-in-Charge

NOAA/NWS Northeast River Forecast Center

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Examining Our Changing Climate in New England and Its Impacts on River and Coastal Flooding

David R. Vallee
Hydrologist-in-Charge
NOAA/NWS Northeast River Forecast Center




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Religious Experience:

Record floods in my hometown of West Warwick – March 2010

Record flooding on the Pawtuxet River, West Warwick, RI – 10 am March 31st, 2010. Photo: D. Vallee/NWS

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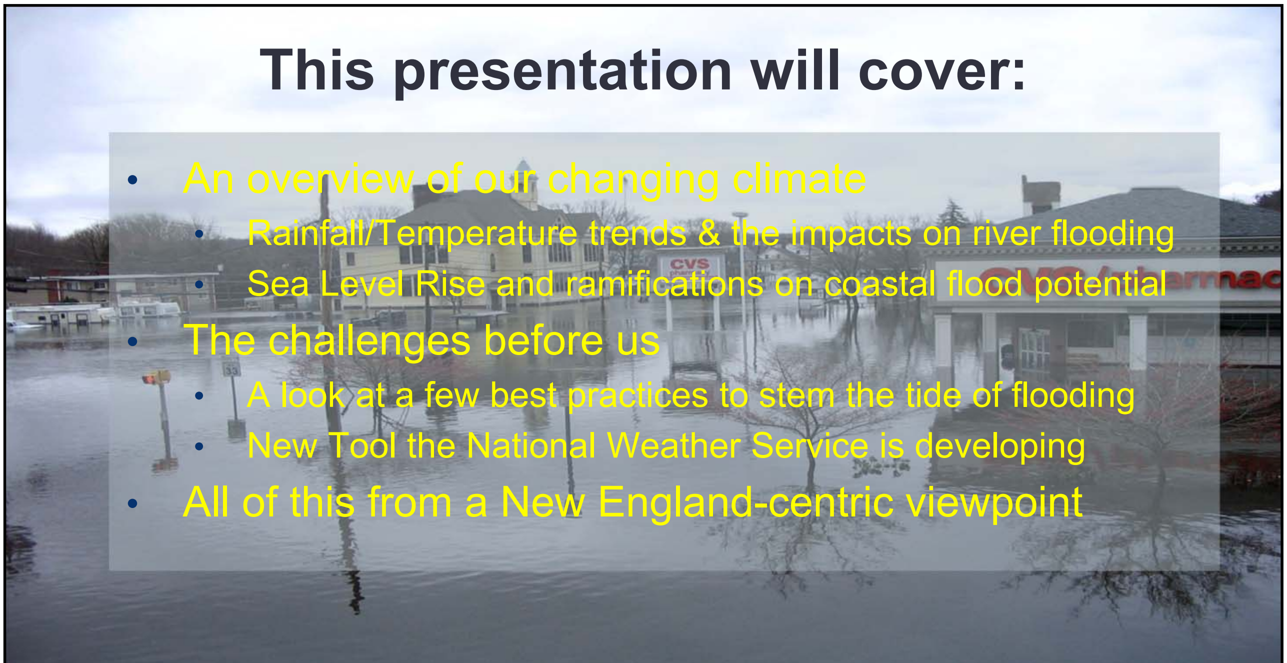

This presentation will cover:

- An overview of our changing climate
  - Rainfall/Temperature trends & the impacts on river flooding
  - Sea Level Rise and ramifications on coastal flood potential
- The challenges before us
  - A look at a few best practices to stem the tide of flooding
  - New Tool the National Weather Service is developing
- All of this from a New England-centric viewpoint

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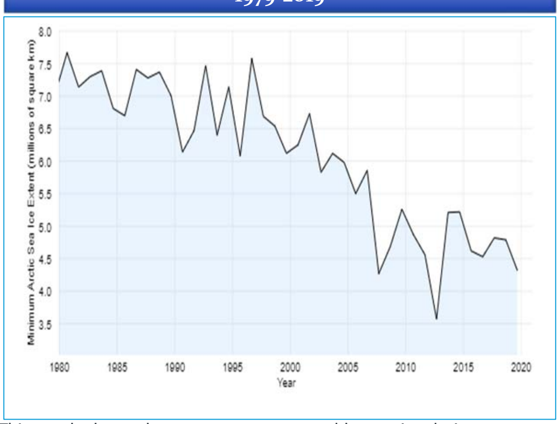
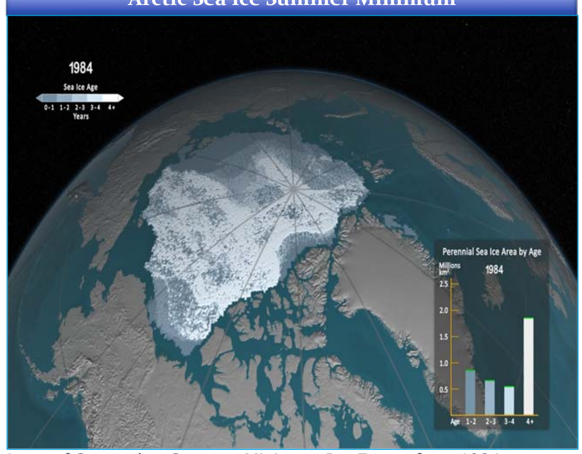
The latest Science:
A warming planet and shrinking Arctic Sea ice

September Minimum Sea Ice Cover 1979-2019



This graph shows the average area covered by sea ice during September each year. Minimum sea ice extent has decreased 12% per decade since 1979. Reference: Fourth National Climate Assessment https://nca2018.globalchange.gov/chapter/1/#fig-1-2

Arctic Sea Ice Summer Minimum



Loop of September Summer Minimum Ice Extent from 1984 through 2016. Note the steady decrease in coverage. Reference: Fourth National Climate Assessment. https://nca2018.globalchange.gov/chapter/2/#key-message-7

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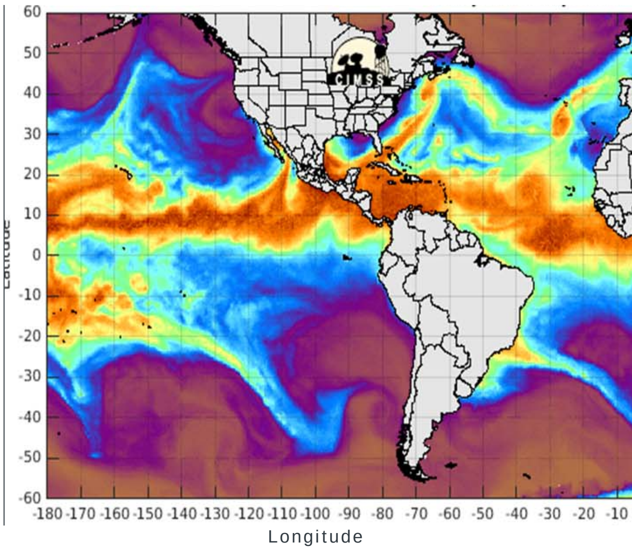
Is there a common theme to recent floods?

Composite loop of Atmospheric Water Vapor – 10/12/2018



Several:

- Slow moving weather systems – a blocked up atmosphere
  - Multiple events in close succession
  - One big slow moving storm
- Results in saturated antecedent conditions before the "main event"
- Each fed by a "tropical connection"
  - Plumes of deep moisture
  - High moisture values are reaching our latitude more frequently
  - Storm tracks that impact the Northeast are interacting with these plumes

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The Changing Climate

- Common themes across New England:
  - Increasing annual precipitation
  - Increasing frequency of heavy rains
  - Warming annual temperatures
  - Wildly varying seasonal snowfall
- Shift in precipitation frequency (50, 100 yr – 24 hr rain)
- For smaller (<800 sq mi) basins:
  - Trend toward increased flood magnitude and/or frequency
  - Most pronounced where significant land use change and/or urbanization has occurred

Infrastructure damage from flooding in Patten, ME. June 26, 2012. (Photo: NWS)

The Spicket River floods Lawrence, MA, May 16, 2006. (Photo: The Eagle Tribune)

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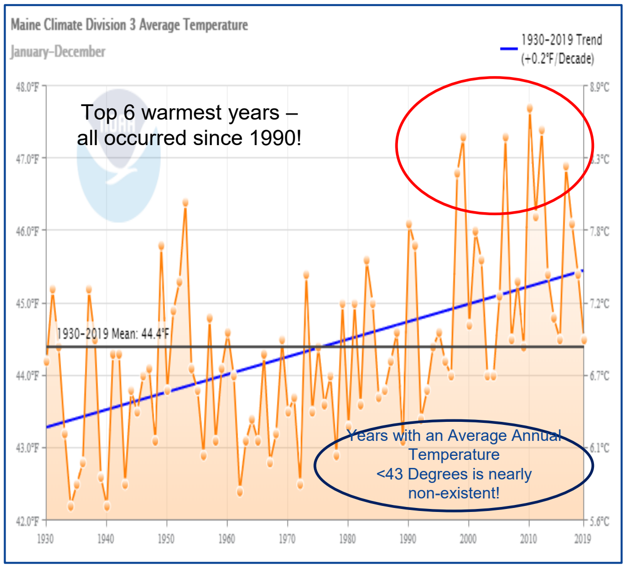
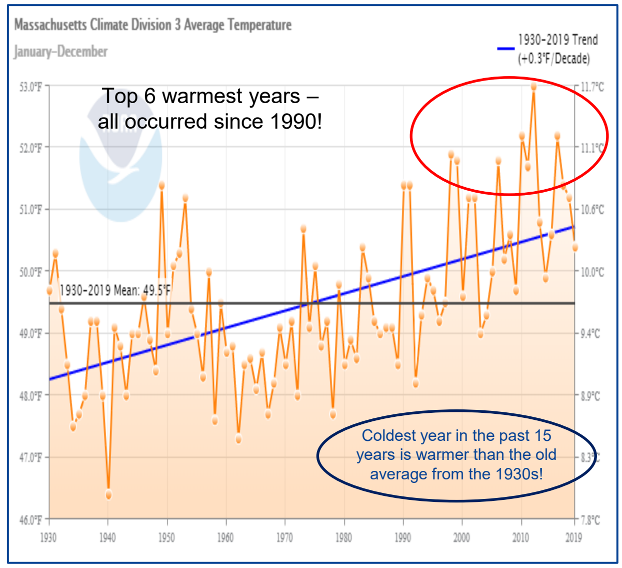
Temperature Trends – A Sample in the Northeast





http://www.ncdc.noaa.gov/cag

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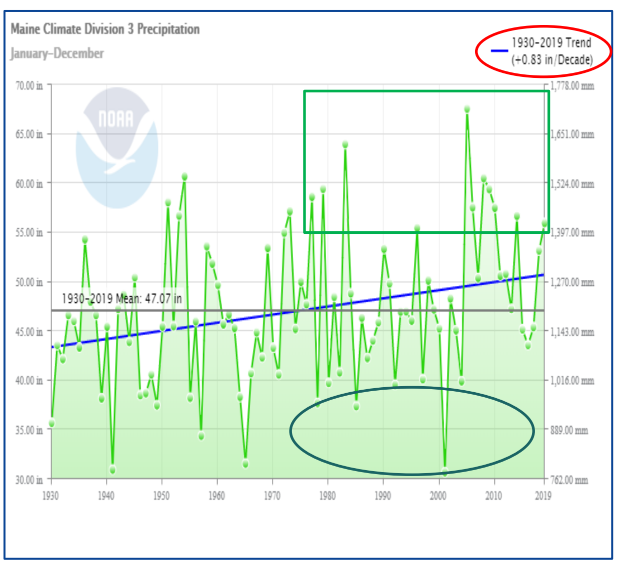
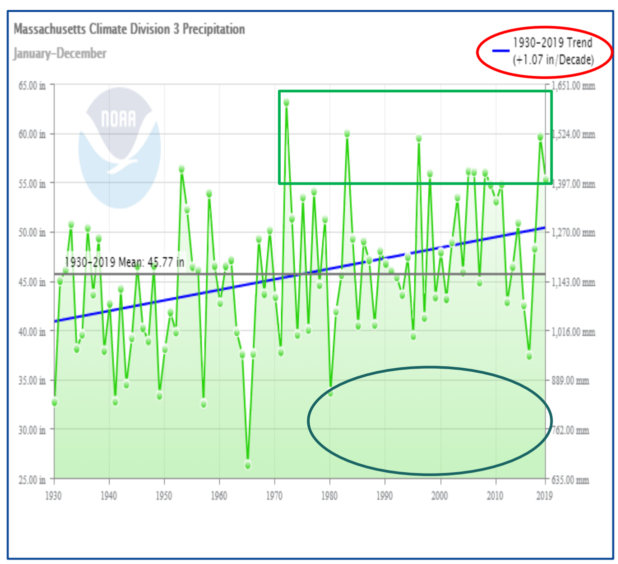
Precipitation Trends – Gulf of Maine Region





http://www.ncdc.noaa.gov/cag

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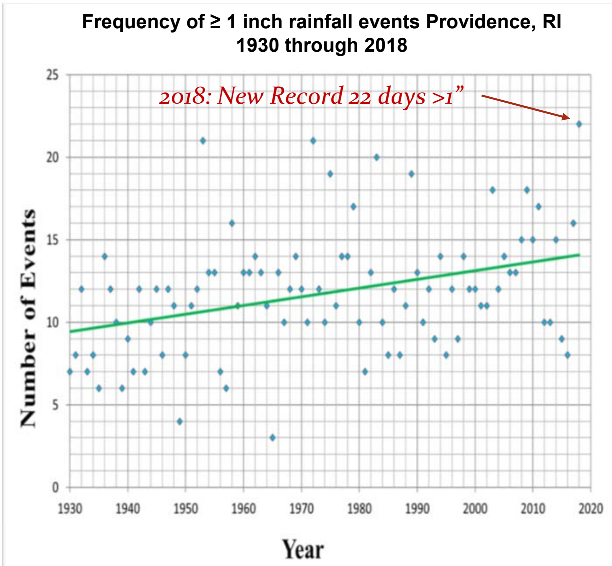
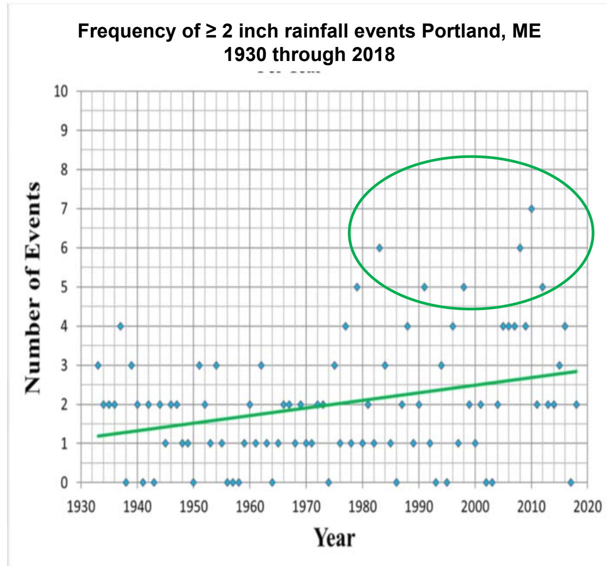
Intense Precipitation Trends





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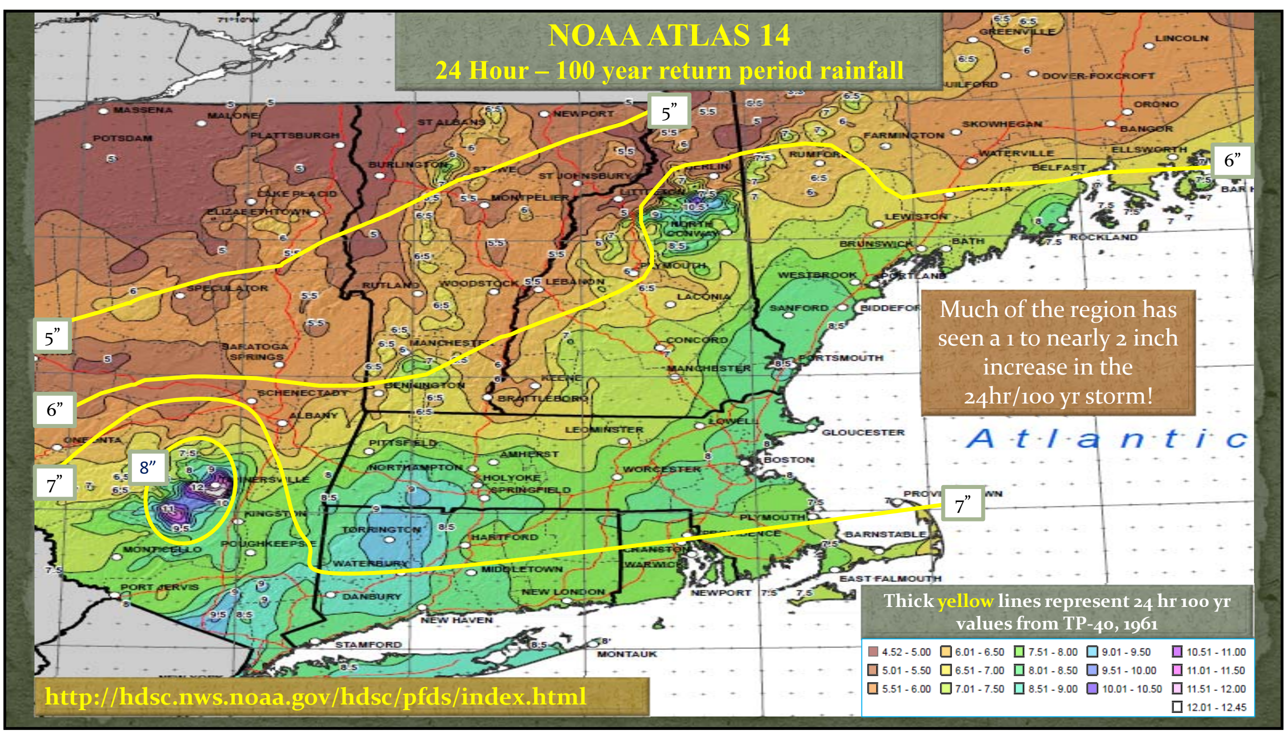

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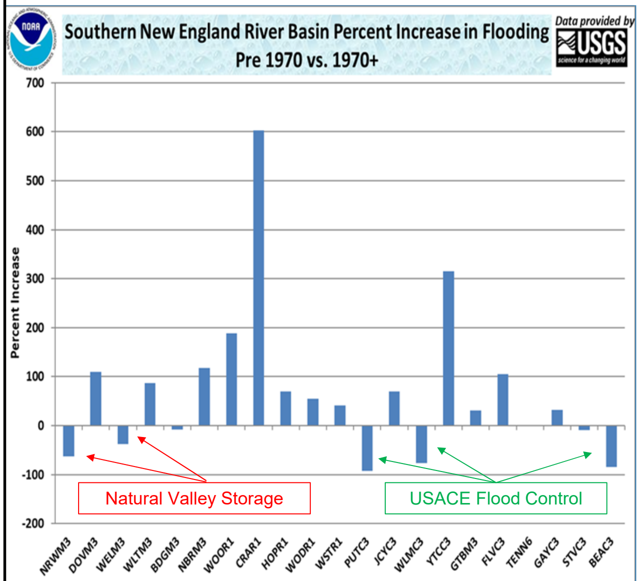
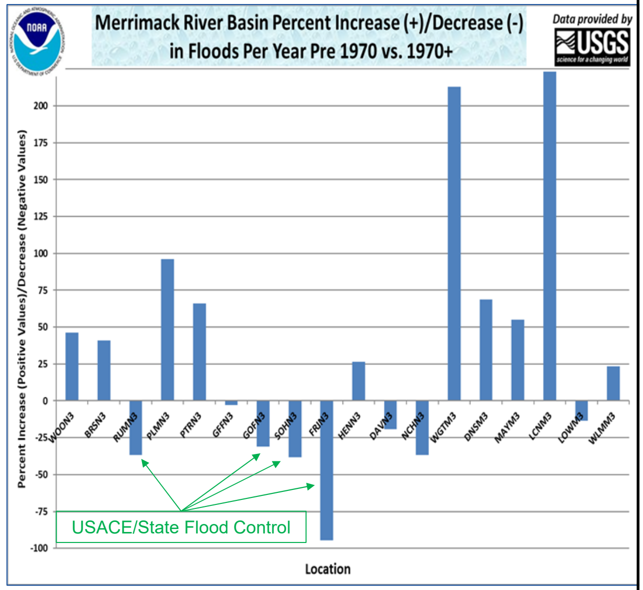
The Riverine Response: Increased Flooding





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Record Flash Flooding from 5-7 inches of rain. Westport, CT September 25th, 2018. Photo: Westport Fire Department

St-Jean-sur-Richelieu, Quebec, Canada, 5/6/11 Photo: AP//Canadian Press, R. Remoirz

Warwick Mall overtaken by the Pawtuxet River - Warwick, RI at 1030 am Wednesday 3/31/10. Photo: RI ANG

Record flooding in Dolgeville, NY on West Canada Creek, November 1st, 2019. Source: D. McGee, Office of the Governor

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Moving to the coast: Sea Level Rise

Increasing high tide flood events

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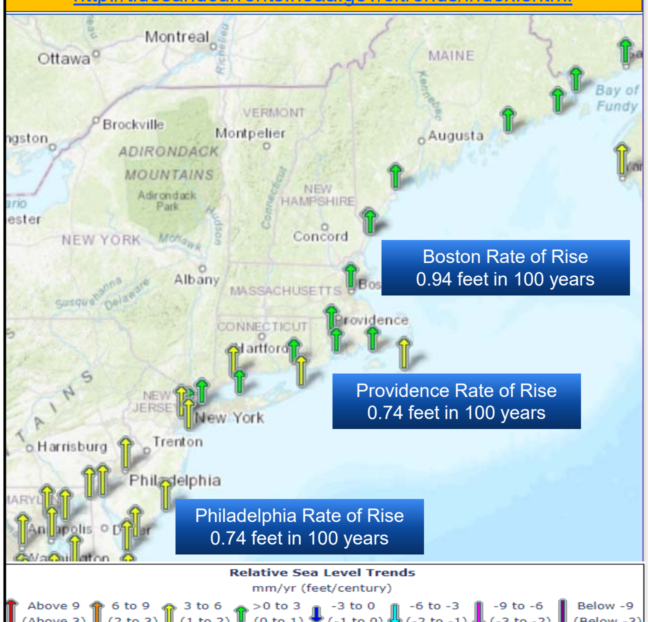
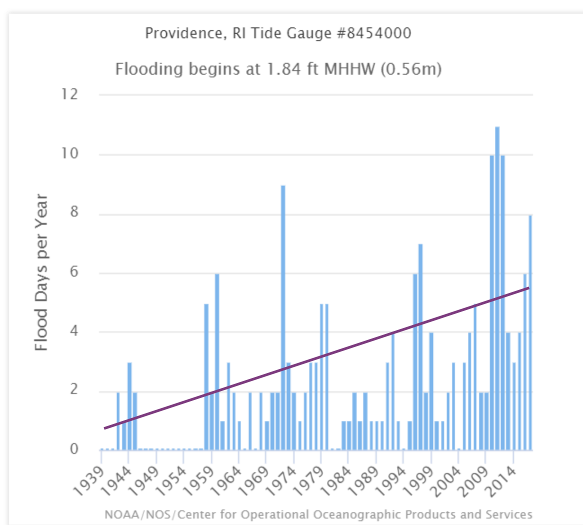
http://tidesandcurrents.noaa.gov/sltrends/index.shtml



High Tide Flooding

Historical Yearly Inundation Events



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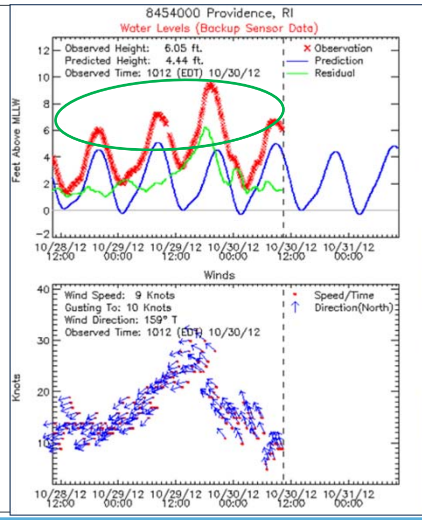
Sandy's Setup:

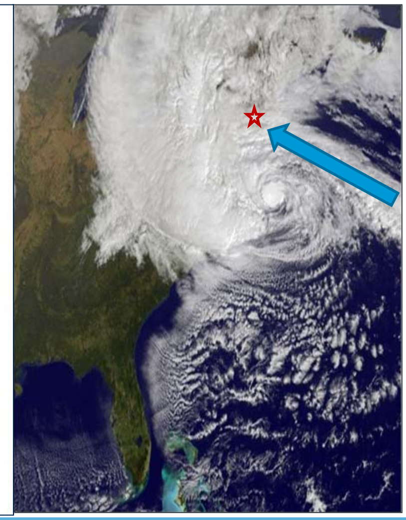
Long Duration Southeast Fetch

Damaging Waves, Multiple Tide Cycles & a 4-5 ft Storm Surge

Swells built on 2 days of southeast winds were driven right into the south coast of RI

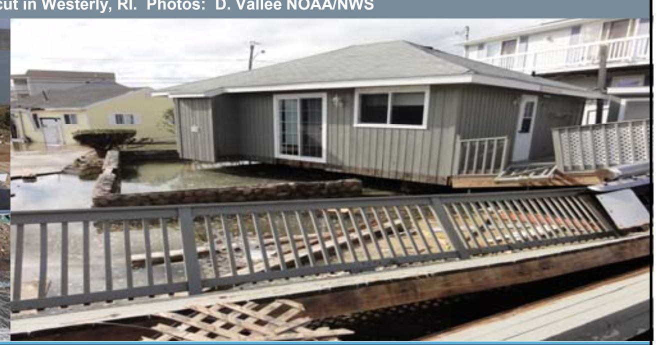
- Impacted Multiple Tide Cycles – worst of which was Monday night
- 15-30 foot seas resulted in relentless pounding surf which first weakened then obliterated the 6-10 foot dunes along parts of the coast
- Storm surge of 4-5 feet atop a “middle-of-the-road” astronomical tide produce a total water level (storm tide) of 9.6 feet; One foot shy of Hurricane Bob in ’91
- What she lacked in intensity she made up for in duration!





SANDY'S DESTRUCTIVE POWER

Pictures from the coastal village of Misquamicut in Westerly, RI. Photos: D. Vallee NOAA/NWS



Can’t overlook the Nor’easter Threat

Boston Fire Fighters in flood waters on State Street and Atlantic Avenue, during the record setting Floods of January 4th, 2018. Photo: Reuters

State Street and Atlantic Avenue flooded by the March 2, 2018 Nor’easter. Photo: WBZ-TV

Peggotty Beach and Kent Street Marshes overrun by March 4th, 2018 floods. Photo: Karl Swenson/SKYWARN Spotter)

Homes on Lighthouse Road, Scituate, MA flooded by the March 2, 2018 Nor’easter. Photo: Channel3000.com

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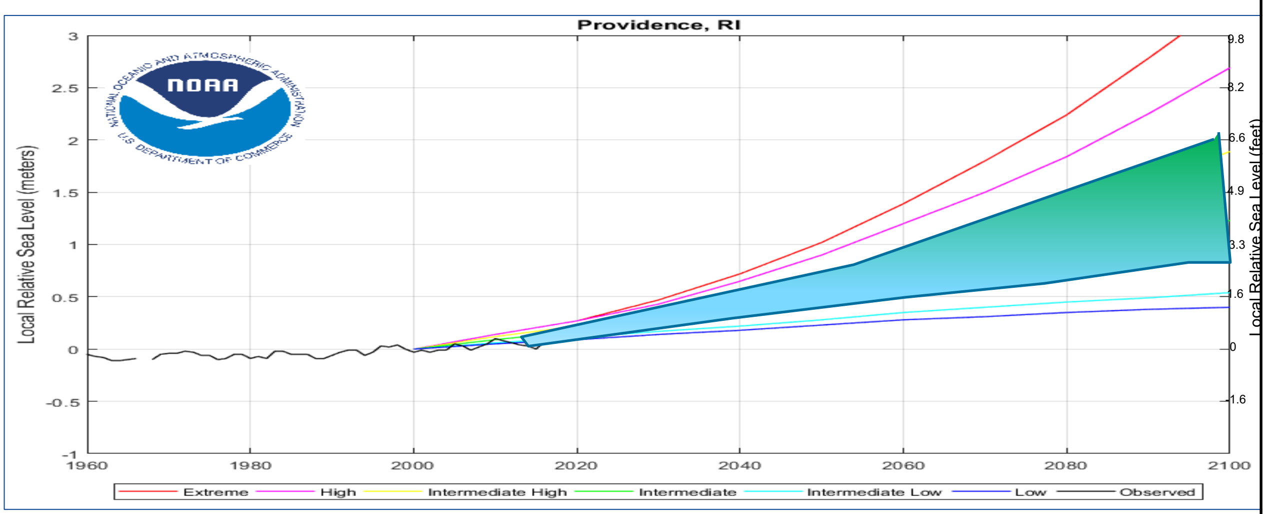
Annual Mean Relative Sea Level since 1960

with various regional emissions scenarios



https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?plot=scenario&id=8454000

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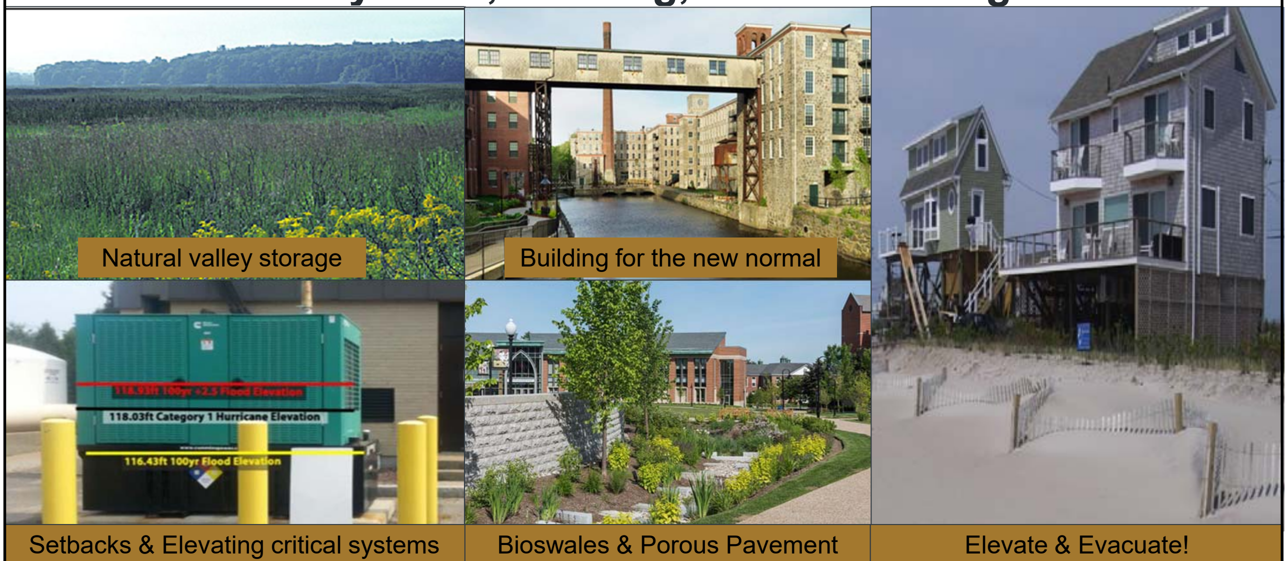
Practices that are working to mitigate losses due to heavy rains, flooding, and storm surge



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A Look At The Future of Water Prediction:
Toward A Weather & Water-Ready Nation

- Provide consistent, high resolution ("street level") analyses, predictions and data to address critical unmet information and service gaps
- Transform information into actionable intelligence by linking hydrologic, infrastructural, economic, demographic, environmental, and political data

Actionable Water Intelligence

High Resolution, Integrated Water Analyses, Predictions and Data

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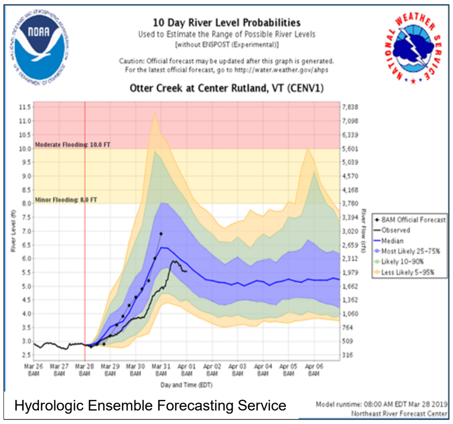
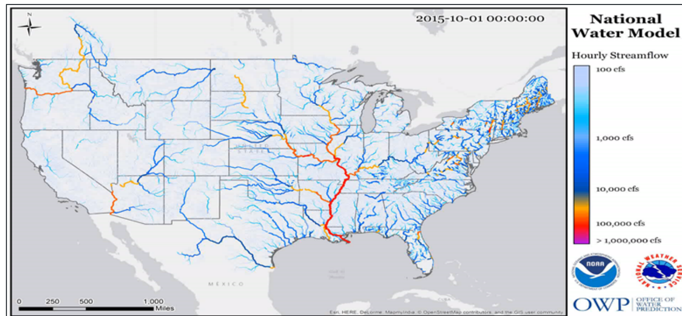
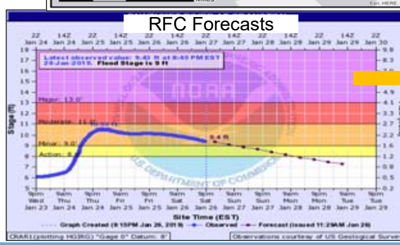
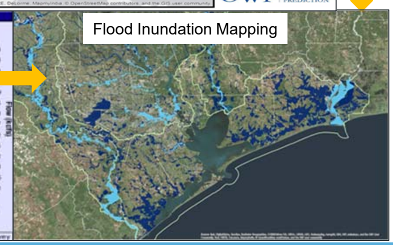
Key Investments to Becoming a Water-Ready Nation









Upgrades in 2020-2021 to include:
- 2-4 times daily runs for 0-10 day
- Updated to use version 12 of the Global Ensemble Forecast System

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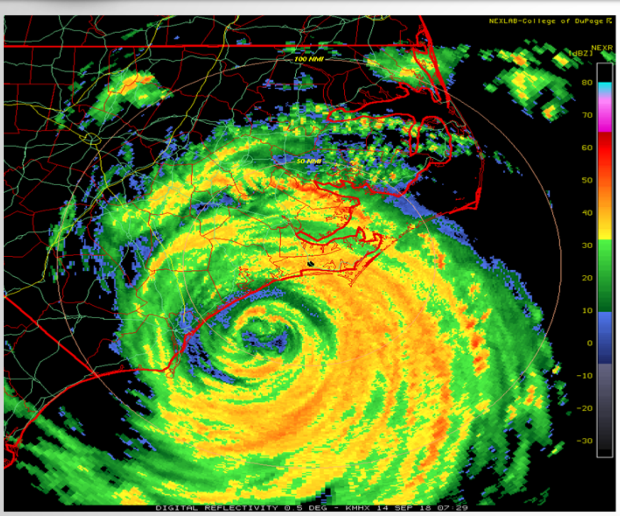
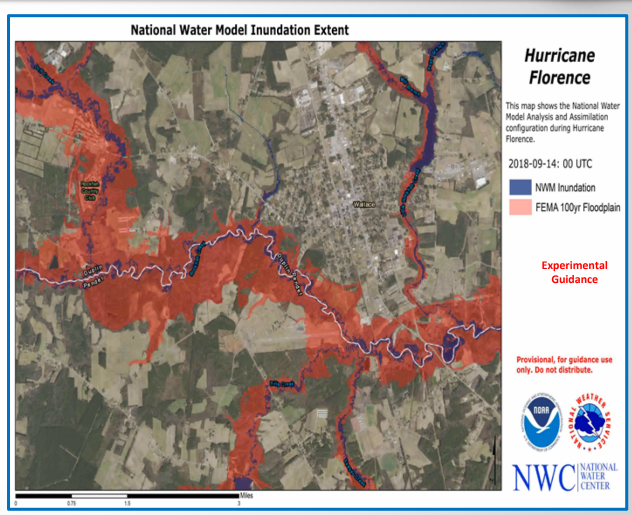
New Graphics Services:

Flood Inundation Areal Extent Predictions



Hurricane Florence Approaching North Carolina



Flood Inundation Areal Extent Prediction

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Examining Our Changing Climate in New England and Its Impacts on River and Coastal Flooding

David R. Vallee
Hydrologist-in-Charge
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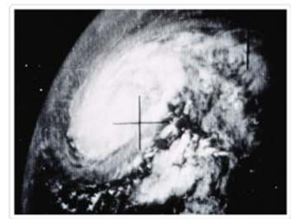

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Julia Rockwell

Manager, Climate Change Adaptation Program

PHILADELPHIA WATER DEPARTMENT

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Creating Actionable Climate Science to Inform Infrastructure Planning & Design

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Overview

- Background & Context: Climate Adaptation Planning at PWD
- Creating Actionable Science: Precipitation and Sea Level Rise Projections
- Adaptation in Action: Mainstreaming the use of Climate Information

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Philadelphia Water Department

Drinking Water

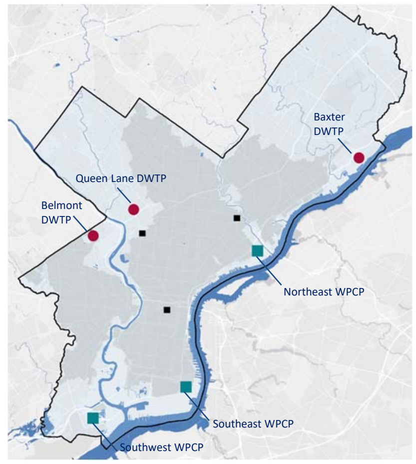
- Source: Delaware and Schuylkill Rivers
- 1.7 million drinking water customers
- Three Water Treatment Facilities
- Over 300 million gallons treated per day
- 3,000 miles of water mains, 25+ pumping stations

Wastewater

- 2.2 million wastewater customers
- 3 Water Pollution Control Plants
- Over 522 million gallons treated per day
- 3,716 miles of sewers, 19 pumping stations
- Biosolids handling facility

Stormwater

- Roughly 60% Combined Sewer, 40% Separate Sewer
- Green City, Clean Waters - Large-scale green stormwater infrastructure program to reduce CSOs



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Mill Creek Sewer Construction
47th and Haverford, 1883
Source: Philadelphia Water Department Archives

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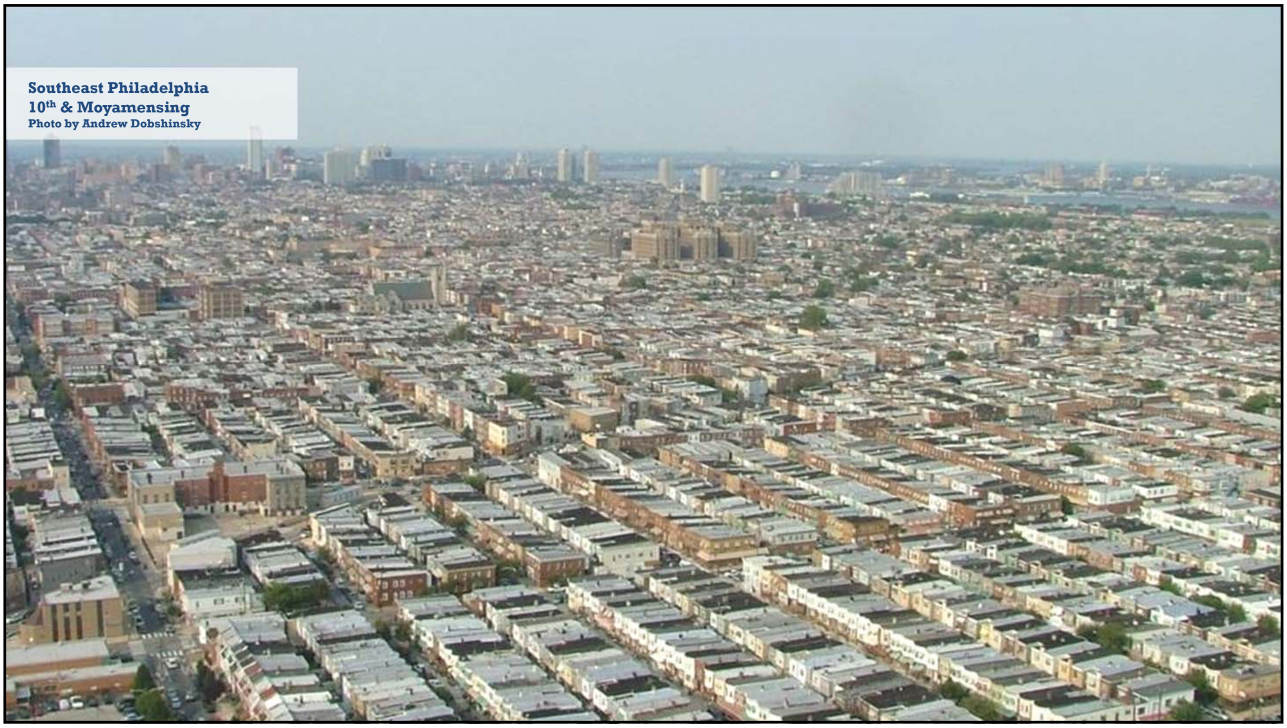

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The work we do to achieve our mission is…

- **DRIVEN BY <u>DATA AND BEST AVAILABLE SCIENCE</u>**
  - Understand existing conditions and potential future conditions
- **BASED ON <u>SOPHISTICATED TOOLS</u>**
  - Analyze how our systems and infrastructure perform under a range of conditions
- **FOUNDED ON <u>COMPREHENSIVE, WATERSHED-WIDE PLANNING</u>**
  - Evaluate risks and develop short and long-term strategies to reduce risks
- **IMPLEMENTED USING <u>INNOVATIVE APPROACHES</u>**
  - Adaptive management, policy changes, advanced technologies, bilateral and multilateral networks and partnerships

UNDERSTAND → ANALYZE → PLAN → IMPLEMENT

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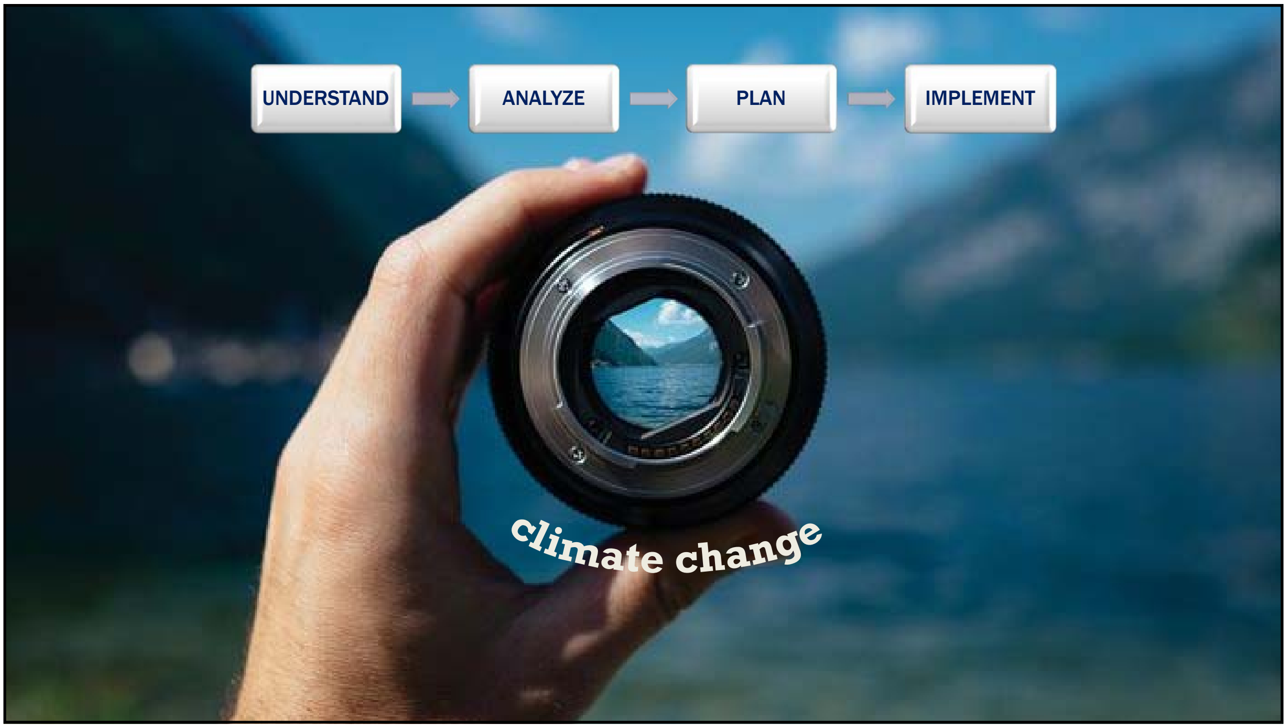

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Climate Change Adaptation Program (CCAP)
Est. 2014

PHILADELPHIA WATER DEPARTMENT

Program Goal
Reduce the risks and associated expenses PWD will face from the impacts of climate change by identifying and implementing effective and feasible adaptation strategies

- Precipitation ↑
- Sea level ↑
- Air temperature ↑
- Extreme storm events* ↑
- Droughts ↑ ↓ —

*the **number of heavy & extremely heavy precipitation events per year** only

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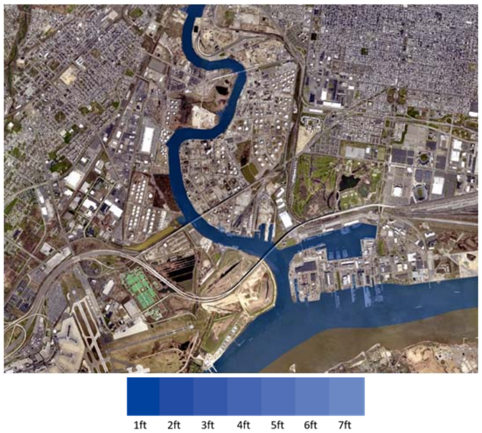
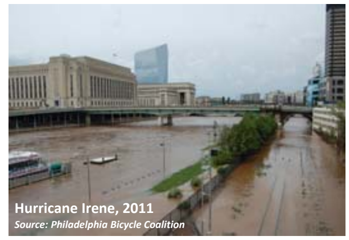
Priority Risks to Address Include…

Coastal, riverine and infrastructure-based flooding





Water quality impacts

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UNDERSTAND → ANALYZE → PLAN → IMPLEMENT

How and when will these impacts affect the operations and management of our systems?

What strategies can we employ to reduce risks and maintain current levels of service?

ACTIONABLE SCIENCE IS REQUIRED

"…data, analyses, projections, or tools that can support decisions regarding the management of the risks and impacts of climate change." (ACCCNRS, 2015)

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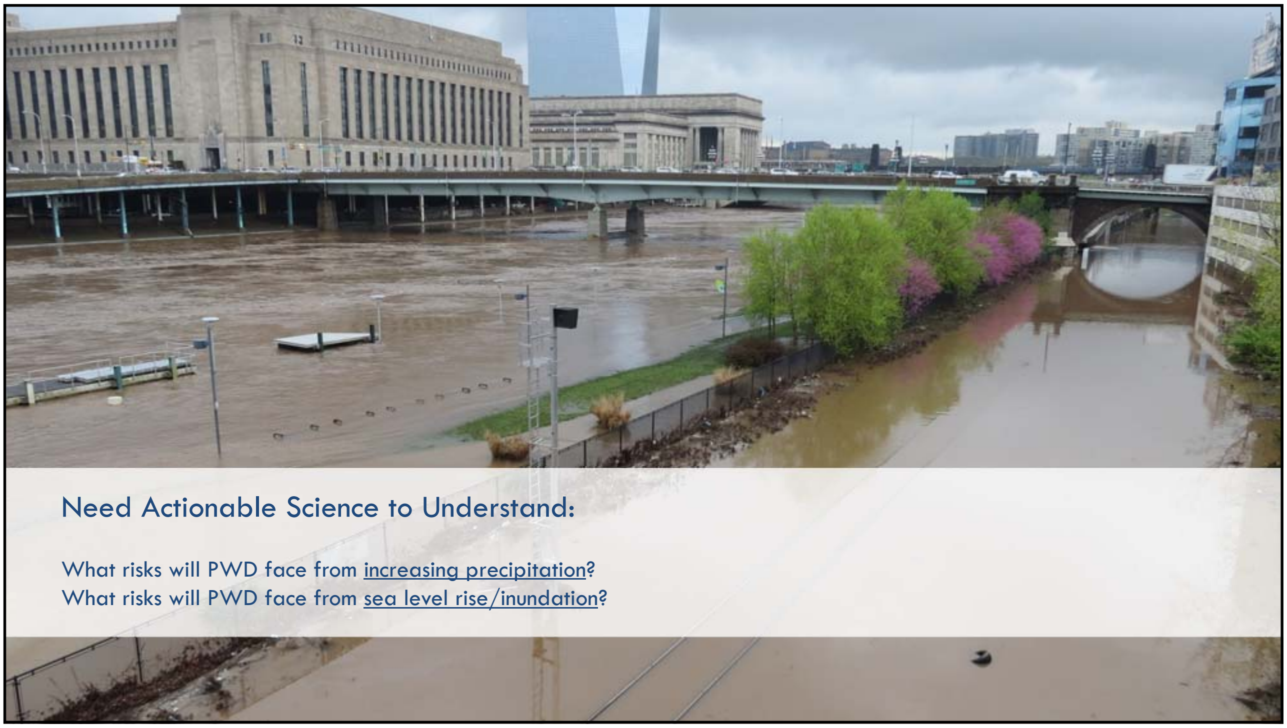

Need Actionable Science to Understand:

What risks will PWD face from <u>increasing precipitation</u>?
What risks will PWD face from <u>sea level rise/inundation</u>?

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Creating Actionable Precipitation Projections

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Precipitation Analysis

What risk does increasing precipitation pose to PWD?

Potential risks include:

- More frequent combined sewer overflows (CSOs)
- Increased erosion and sediment transport
- Increased riverine flooding
- Increased infrastructure-based flooding (basement/sewer back-ups)

Actionable science developed includes:

- High resolution precipitation projections for use in modeling applications
- Future design storm events
- Stochastic rainfall generator to evaluate current and future precipitation variability

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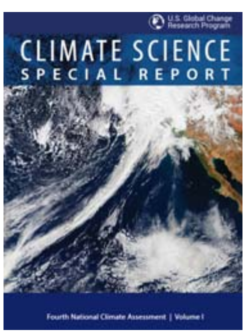
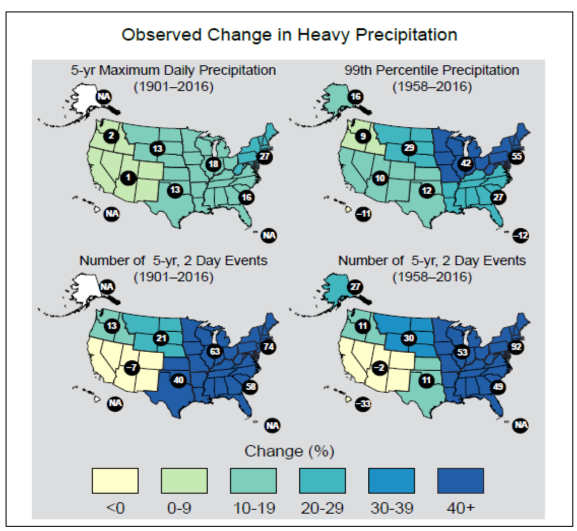
Observed increases in precipitation

Variety of statistical parameters from the National Climate Assessment show **heavy rainfall is increasing in the Northeast U.S.**



Source: *science2017.globalchange.gov*



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How do we use precipitation data?

System Performance

- Hydrologic & hydraulic (H&H) models use precipitation time series to simulate system performance (combined & separate systems)

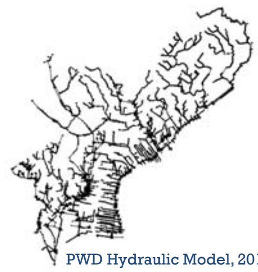
Planning Assessments

- Flood management planning and flood risk analyses rely on up-to-date precipitation information

Infrastructure Design

- Sewer system design and green stormwater infrastructure (GSI) design are directly informed by precipitation data

High resolution precipitation inputs needed



PWD Hydraulic Model, 2019

Source: www.phillywatersheds.org

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GCM Precipitation Output Analysis

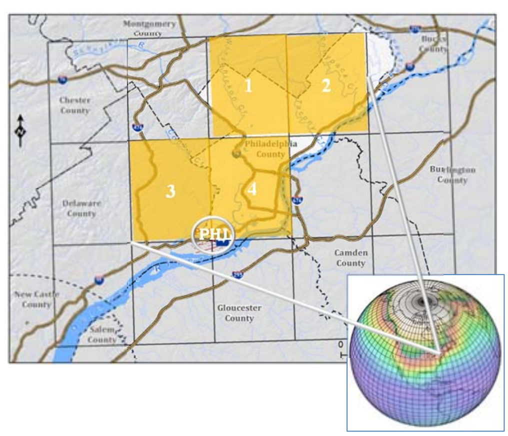
Global Climate Model (GCM) Output:

- 9 GCMs for different climate scenarios
- Statistically downscaled
- Available period: 1950-2099
- Daily precipitation totals: mm/day
- Spatial resolution: 1/8° grid cells (~7.5mi x 7.5mi)

RECLAMATION NCAR USGS Santa Clara University CIRES CLIMATE CENTRAL SCRIPPS INSTITUTION OF OCEANOGRAPHY

Observed Long-term Record:

- Philadelphia International Airport (PHL) rain gauge
- 117 years of hourly totals



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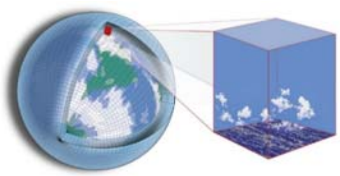
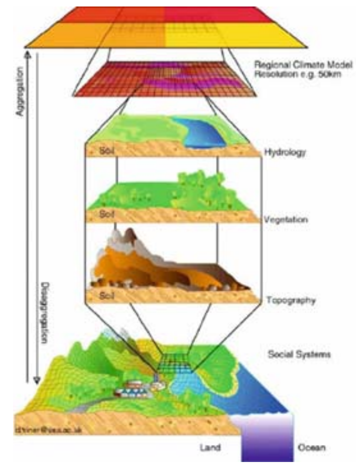
GCM Precipitation Projections: Issue #1

Inadequate Resolution

The resolution of statistically downscaled GCM output is not sufficient for urban stormwater applications because **high temporal resolutions are required**

- GCM output: daily
- Stormwater applications: hourly or sub-hourly





Source: David Viner, Climatic Research Unit, University of East Anglia, UK

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GCM Precipitation Projections: Issue #2

Unrealistic Rainfall Patterns

'GCM Philly'

Real Philly

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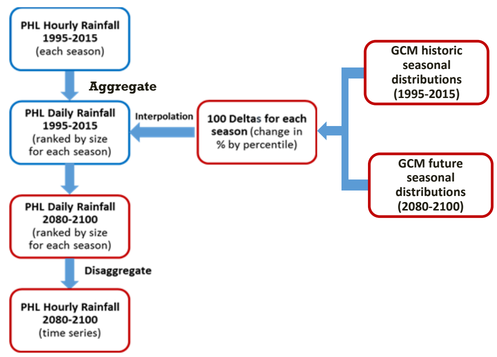
Precipitation Analysis:
Time Series Adjustment Method

Goal: Develop method to bridge mismatch between GCM output resolution and PWD end-user requirements while preserving local precipitation patterns

Method:

- Involves no direct downscaling of GCM output from daily to hourly
- Uses observed hourly data, aggregates it to daily, and then transfers GCM projected increases (1995-2015 to 2080-2100) onto daily data
- GCM projected increases (delta change factors) are calculated by season and storm size
- The 'inflated' time series can be disaggregated back to an hourly (or higher) temporal resolution



Time Series Adjustment Method: Results

Findings Include:

- Precipitation averages and extremes will increase
- Projected increases in precipitation differ by season
- Projected increases are not uniform across storm size; in general, larger storms will increase in volume more than smaller storms
- GCM output suggests the number of wet days per year does not increase (i.e. future increases are the result of more intense rainfall)

PHL observed (1995-2015) compared to adjusted PHL time series (2080-2100) for RCP8.5

Time Period	Average Annual Total (inches/year)	Maximum Annual Total (inches)	Minimum Annual Total (inches)	Mean Event Depth (inches)	Maximum Event Size (inches)	Maximum Intensity (inches/hour)
1995-2015	43.24	64.33	30.41	0.41	8.27	1.36
2080-2100	47.99	70.89	33.82	0.46	8.63	1.5
% Change	11.00%	10.20%	11.20%	11.00%	4.40%	10.40%

GCM Output Source (BCCA) : https://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html

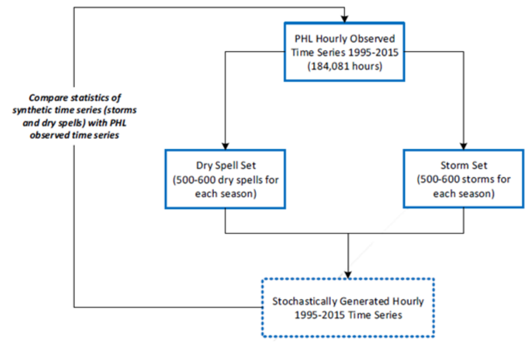
Precipitation Analysis: Stochastic Rainfall Generator

Why not stop with the time series adjustment method?

- The observed precipitation time series (1995 -2015) is not the only realization of current conditions that is possible
- Want to understand potential variability of current and future time series and provide flexibility for a range of future applications

Stochastic rainfall generator

- Non-parametric, event-based generator that uses resampling approach
- Stochastic sampler picks randomly from storm set and dry spell set
- Observed frequencies of storms and dry spells automatically creates an accurate probability profile



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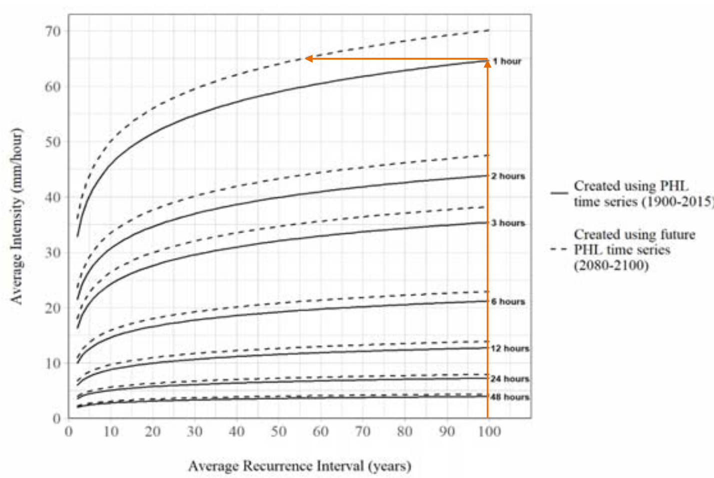
Precipitation Products: IDF Curves



Comparison of IDF curves generated by fitting GEV Type II distribution on AMS using PHL data (1900-2015) with future PHL time series based on the 2080-2100 storm set for RCP8.5

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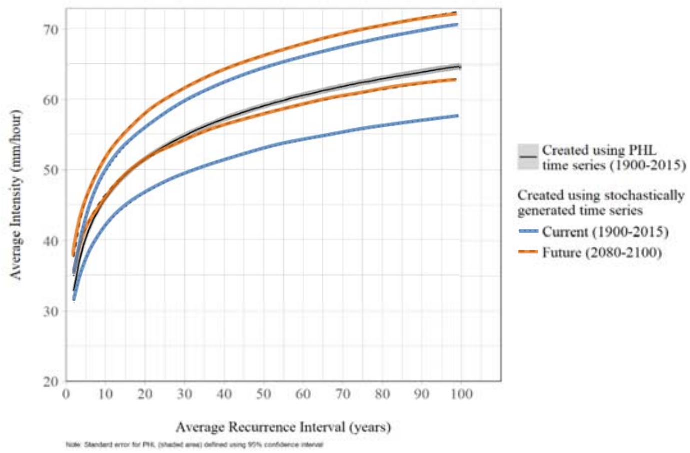
Precipitation Products: IDF Curves



Comparison of IDF curve generated by fitting GEV Type II distribution on AMS using PHL data (1900-2015) for a 1-hour duration storm event with IDF curves based on stochastically generated time series for 1900-2015 PHL conditions and 2080-2100 conditions under RCP8.5.

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Transforming Global Climate Model Precipitation Output for Use in Urban Stormwater Applications

M. Maimone, Ph.D., P.E., D.WRE, M.ASCE; S. Malter; J. Rockwell; and V. Raj

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Photo by Joseph Kaczmarek

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Creating Actionable
Sea Level Rise Projections

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Inundation Analysis

What risk does sea level rise and storm surge pose to PWD?

Potential risks include:

- Flooding of PWD assets
  - Surface and below-grade
  - Treatment plants & pump stations
- Degraded source water quality (salinity)
- Impacts to source water quantity
- Increased energy demand (pumping)

Actionable science developed includes:

- Analysis of sea level rise projections and storm surge elevations on Delaware River
- Customized GIS screening tool for PWD assets
- Proposed design flood elevation (DFE) based on flooding risks

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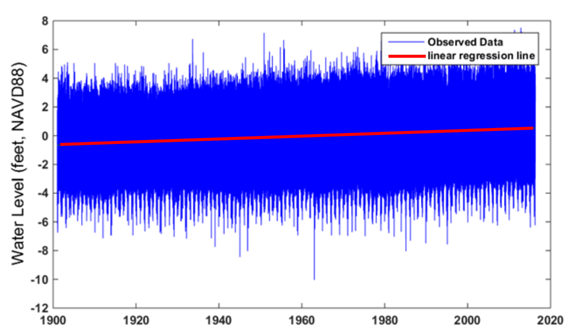
Observed Sea Level Rise

The rate of sea level rise in Philadelphia is almost **50% higher** than the global average over the period of record!



1901-2016 continuous hourly data from Philadelphia's NOAA tide gauge 8545240

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Inundation Analysis: Risk-Based Approach

Likelihood
- Sea Level Rise (permanent inundation)
- Sea Level Rise + Storm Surge (temporary inundation)

Future Water Elevations

Consequence
- Mapping (asset exposure)
- Bottom-up Analysis (asset flooding thresholds)
- Site Visits and Staff Interviews (asset sensitivity & adaptive capacity)

Asset/System Vulnerability

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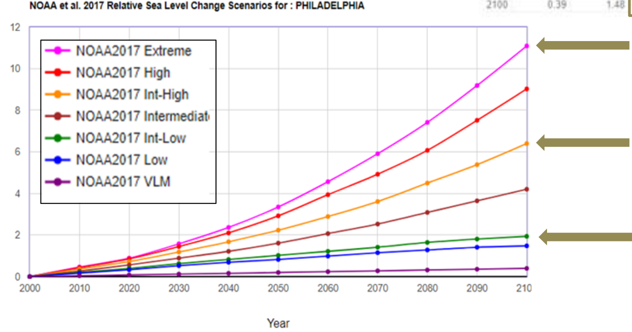
Sea Level Rise Projections

Year	NOAA2017 VLM	NOAA2017 Low	NOAA2017 Int-Low	NOAA2017 Intermediate	NOAA2017 Int-High	NOAA2017 High	NOAA2017 Extreme
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	0.04	0.16	0.20	0.26	0.36	0.43	0.46
2020	0.08	0.33	0.39	0.56	0.72	0.85	0.89
2030	0.12	0.52	0.62	0.89	1.18	1.44	1.57
2040	0.16	0.69	0.82	1.21	1.67	2.10	2.36
2050	0.20	0.82	1.02	1.61	2.23	2.92	3.35
2060	0.24	0.98	1.21	2.07	2.89	3.94	4.56
2070	0.28	1.15	1.41	2.53	3.61	4.92	5.91
2080	0.31	1.28	1.64	3.08	4.49	6.07	7.41
2090	0.35	1.41	1.80	3.64	5.38	7.51	9.19
2100	0.39	1.48	1.94	4.20	6.40	9.02	11.09

NOAA et al. 2017 Relative Sea Level Change Scenarios for : PHILADELPHIA



Which future path will we take? Can we curb our carbon emissions?

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Sea Level Rise Projections

Year	NOAA2017 VLM	NOAA2017 Low	NOAA2017 Int-Low	NOAA2017 Intermediate	NOAA2017 Int-High	NOAA2017 High	NOAA2017 Extreme
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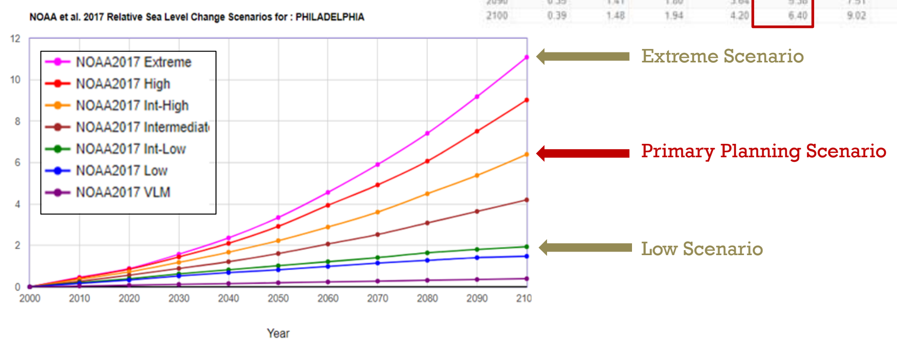

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Storm Surge Analysis

Results from statistical analysis of extreme water elevations at Philadelphia's NOAA tide gauge 8545240

Assumed Surge (feet)	
Recurrence Interval	**Philadelphia Station**
2	2.26
5	2.69
10	3.04
25	3.44
50	3.71
100	3.95

Storm surge amount that has a 50% chance of occurring in any given year (2-year interval)

Storm surge amount that has a 1% chance of occurring in any given year, or a 25% chance of occurring over 30 years (100-year interval)

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Southwest Water Pollution Control Plant
Legend
Southwest Plant
Existing water bodies
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Southwest Water Pollution Control Plant
2060s – Primary Planning SLR Scenario (2.89 ft.)
Mean Higher-High Water
Legend
Southwest Plant
Existing water bodies
MHHW
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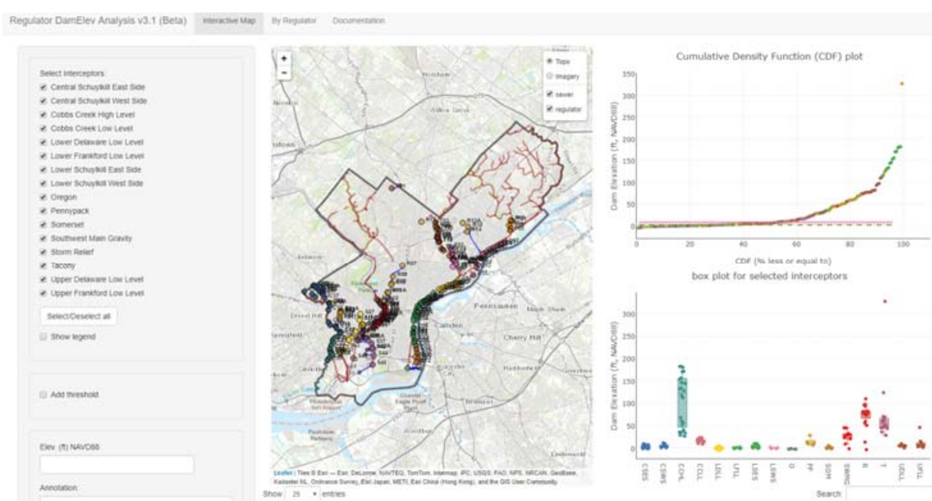
Inundation Analysis:
Regulator Dam Analysis Tool



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How do we use this information to adapt?

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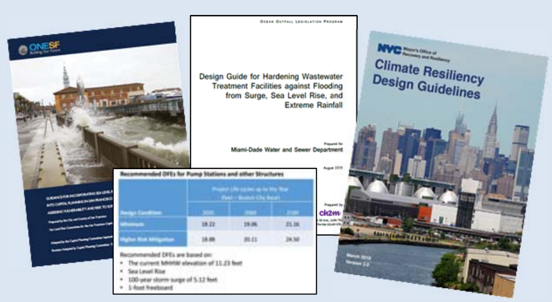
Mainstream the Use of Climate Information

Existing assets: Consider short and long-term strategies to protect existing assets from climate change impacts

New Assets: Ensure the impacts of climate change are being considered during the planning and design of new projects and the process to make capital decisions

- Perform **on-the-ground risk assessments** to identify strategies & investments to protect existing assets
- Inform **long-term infrastructure plans** (Water & Wastewater Master Plans)
- Integrate climate information into the **capital planning** process
- Developing & implement **Climate Change Planning & Design Guidance** for PWD



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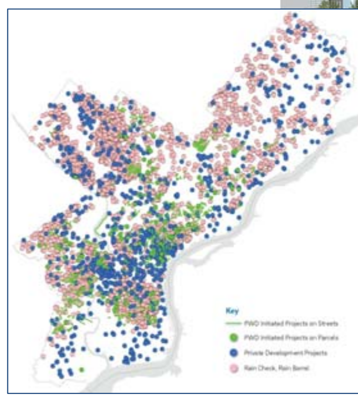
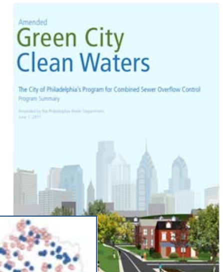
Building Resiliency

Green City, Clean Waters Program

Adaptive Stormwater Management

Columbus Square Planter Trench





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Where We're Headed

- Continue work on priority initiatives that will help mainstream the use of climate information (risk assessments, climate planning & design guidance)
- Continue building internal capacity and engaging with city and regional partners
- Move from planning to implementation of adaptation strategies
- Continue partnering with and leveraging knowledge from peer cities/utilities

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Resources

- PWD Climate Change Adaptation Program website: https://www.phila.gov/water/sustainability/Pages/ClimateChange.aspx
- ASCE Article on PWD Time Series Method: https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29WR.1943-5452.0001071
- Green City, Clean Waters Information: https://www.phila.gov/water/sustainability/greencitycleanwaters/Pages/default.aspx
- Water Utility Climate Alliance (WUCA) website: https://www.wucaonline.org/

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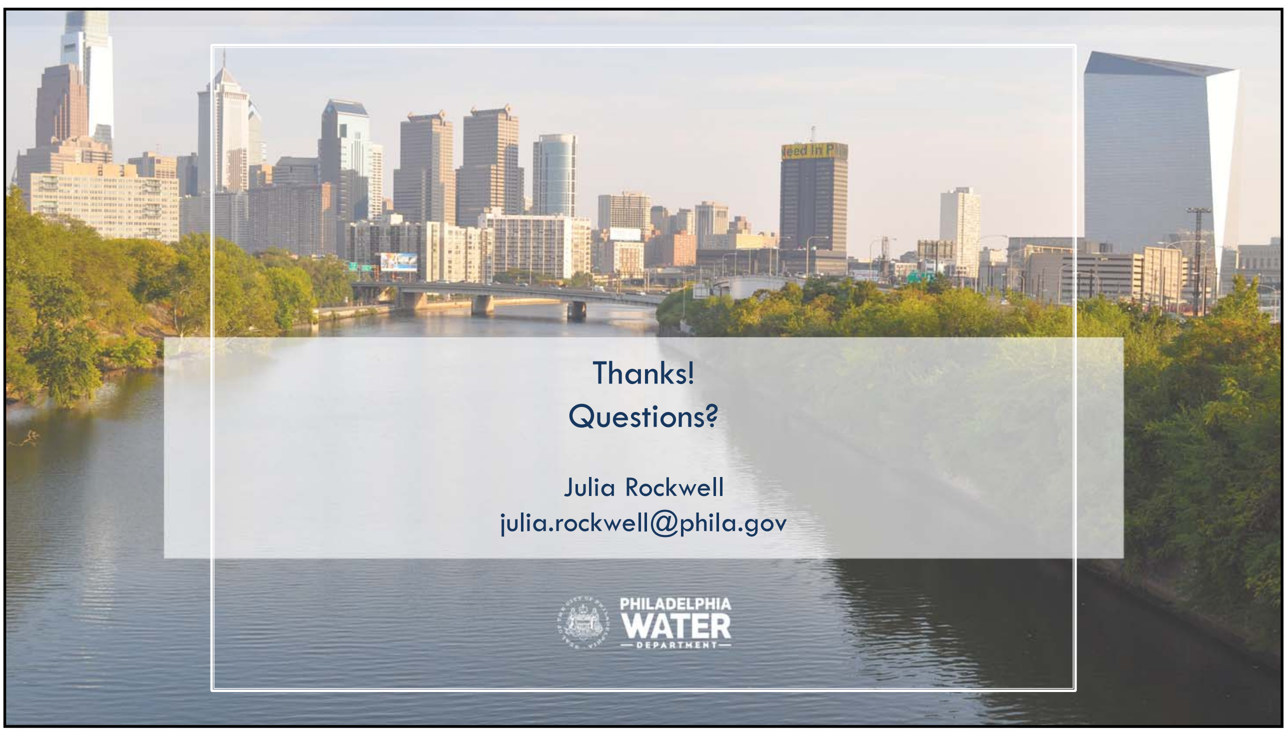

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Keren Bolter, PhD

ARCADIS

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Sea Level Rise and Stormwater Flooding: Miami is Shifting from Reactive Solutions to Cost Effective and Equitable Prevention via Future-Proofing

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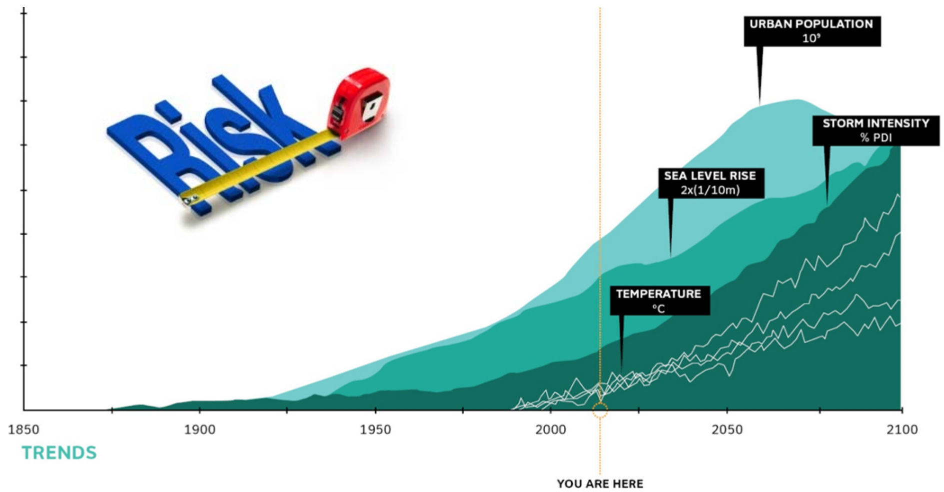
A Changing Risk Context



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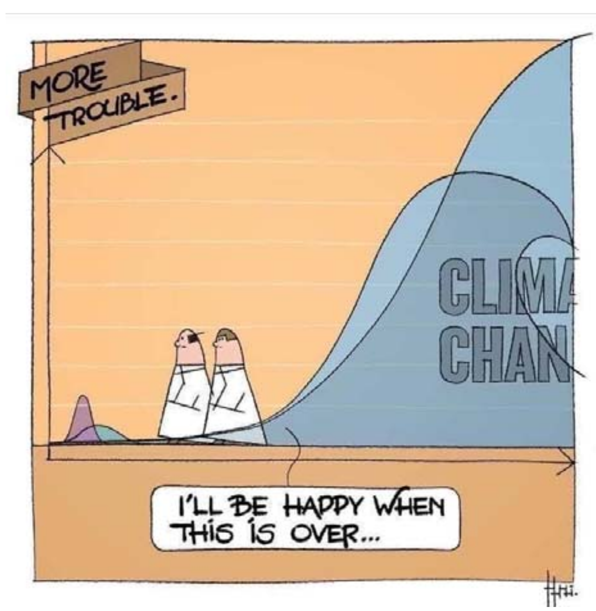

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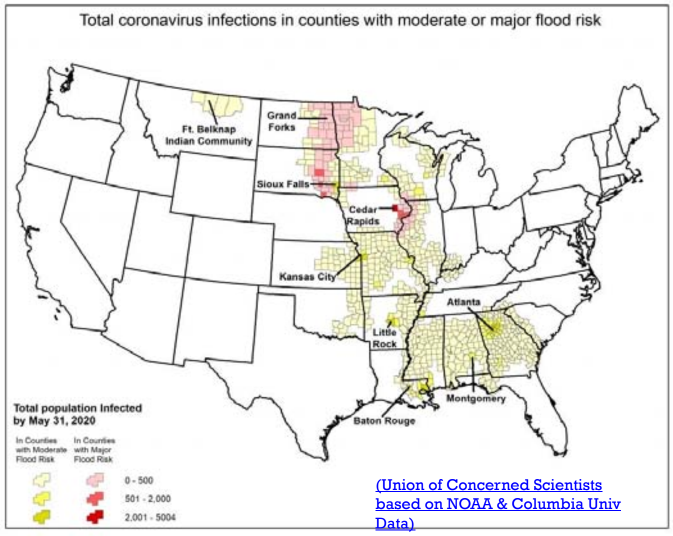
Cascading Catastrophes

- Spring flooding
- Hurricane evacuations
- Tornadoes



[(Union of Concerned Scientists based on NOAA & Columbia Univ Data)]

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OVERVIEW

- Rising Tides, Resilience, and Utilities
  - Sea level rise (SLR): Shocks vs stresses
- Case Studies
  - Miami-Dade County Sea Level Rise Strategy
  - Miami Dade Water and Sewer FEMA grant
- Planning for SLR impacts on Stormwater

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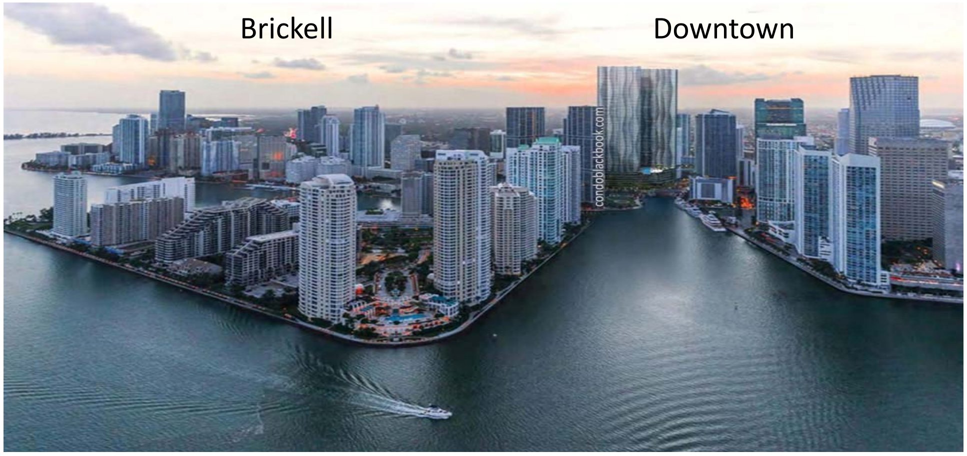

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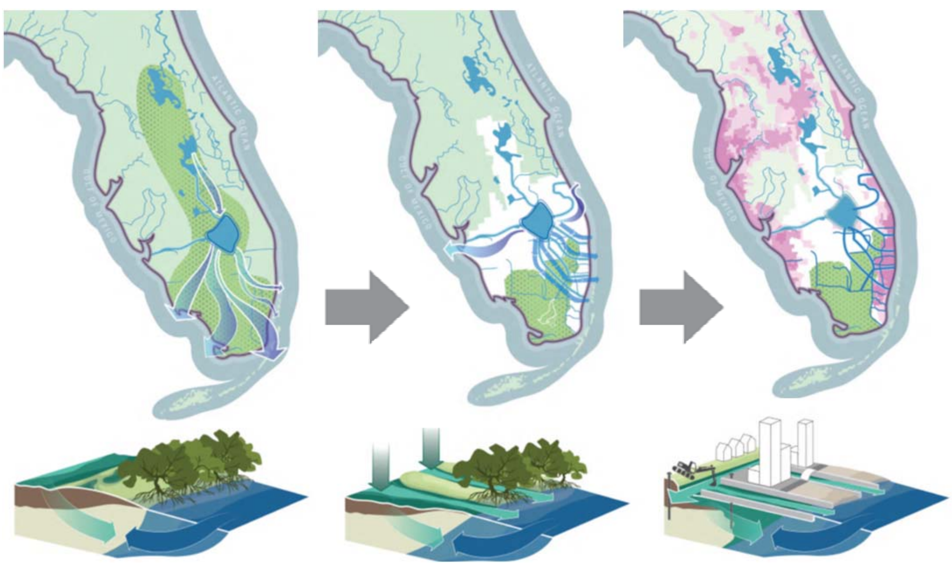
Everglades and Development



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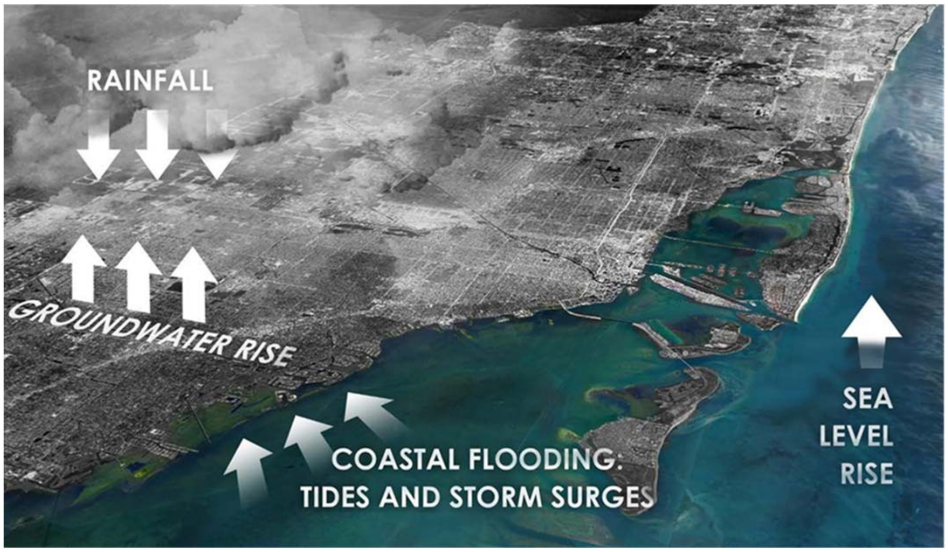
Water from Every Direction



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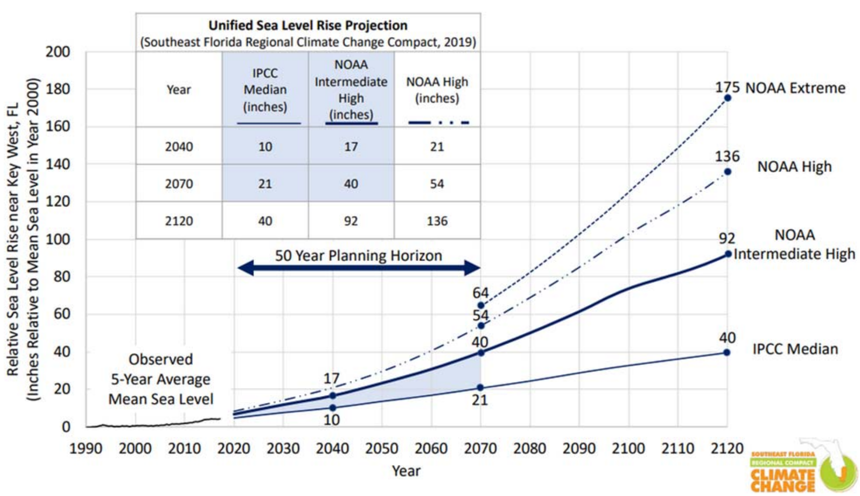
3rd Regional SLR Projection



Unified Sea Level Rise Projection
(Southeast Florida Regional Climate Change Compact, 2019)

Year	IPCC Median (inches)	NOAA Intermediate High (inches)	NOAA High (inches)
2040	10	17	21
2070	21	40	54
2120	40	92	136

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Application to Building Code

		Existing Requirements	Proposed Requirements
1.	**Base Flood Elevation (BFE)**	5.44 Feet NAVD (7 Feet NGVD)	6.44 Feet NAVD (8 Feet NGVD)
2.	**Freeboard**	0 feet above BFE	+1 to +3 feet above BFE
3.	**Seawall Elevation (Private)**	3.2 FT NAVD 4.76 FT NGVD	4 to 5.7 FT NAVD 5.56 to 7.26 FT NGVD
	Seawall Elevation (Public)	3.2 FT NAVD 4.76 FT NGVD	5.7 FT NAVD 7.26 FT NGVD
4.	**Minimum required yard elevation**	No minimum required	5.0 Feet NAVD (6.56 Feet NGVD)

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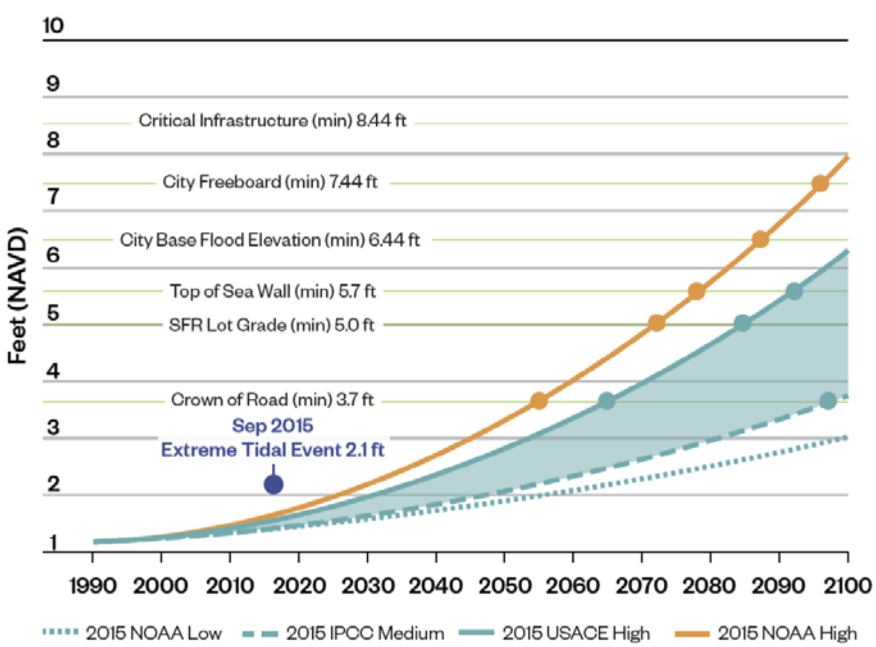

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“Future-proofing”

- anticipating the future and developing methods of minimizing the effects of shocks and stresses of future events
  - ‘Future-proofing’ is how you say climate change in Texas (Kate Yoder, Grist)

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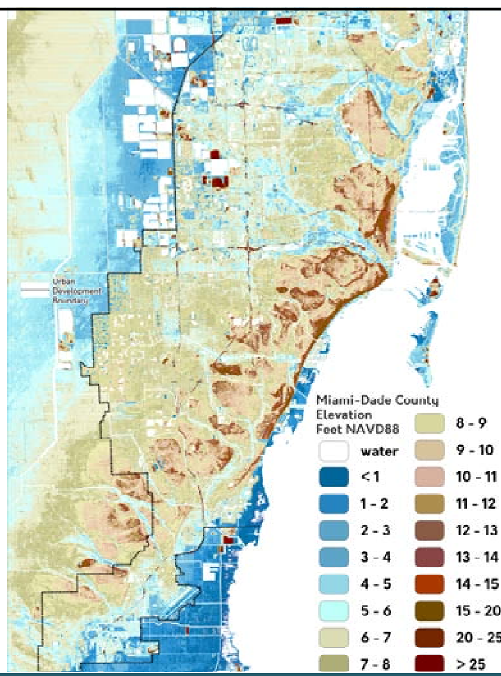

Miami-Dade County Sea Level Rise Strategy

MIAMI-DADE COUNTY

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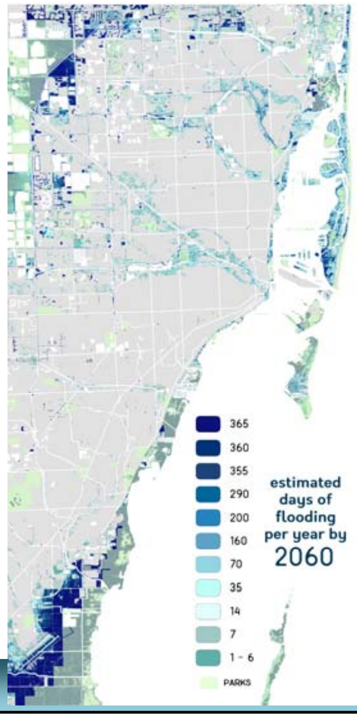
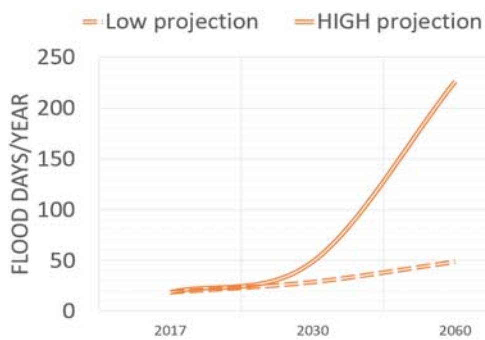
King tide flooding in days per year





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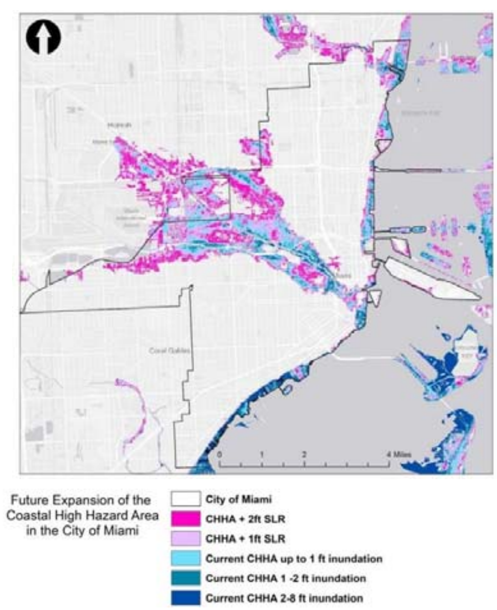

Other Impacts of Chronic Flooding and Sea Level Rise

- Health problems associated with standing water
- Reductions in water quality
- Saltwater intrusion
- Property value impacts
- Socioeconomics
- Vulnerable populations have greater impacts

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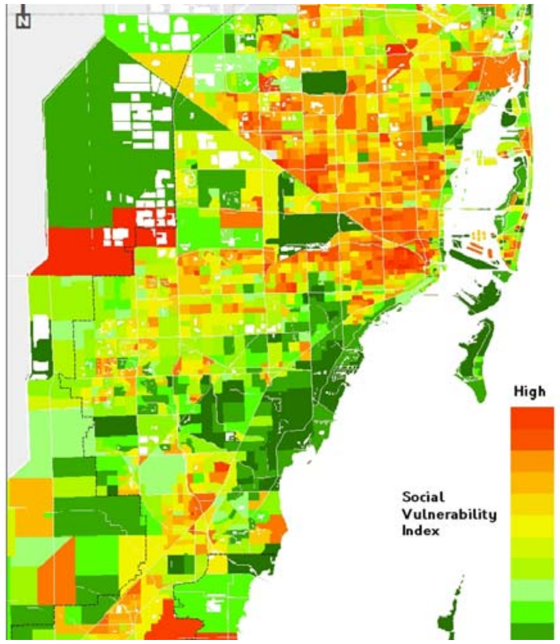
Social Vulnerability Index

LIKELIHOOD	0-.20	.20-.40	.40-.60	.60-.80	.80-1
0-1 ft	M	MH	H	H	H
1-2 ft	ML	M	MH	H	H
2-3 ft	L	ML	M	MH	H
3-4 ft	L	L	ML	M	MH
4-5 ft	L	L	L	ML	M

CONSEQUENCE



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Adaptation Approaches

Where are these applicable?

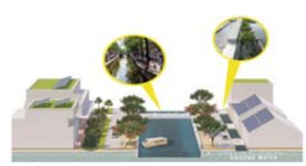
Build on fill

Build like the keys

Build around transit

Build on high ground

Blue & greenways



Green & blue neighborhoods

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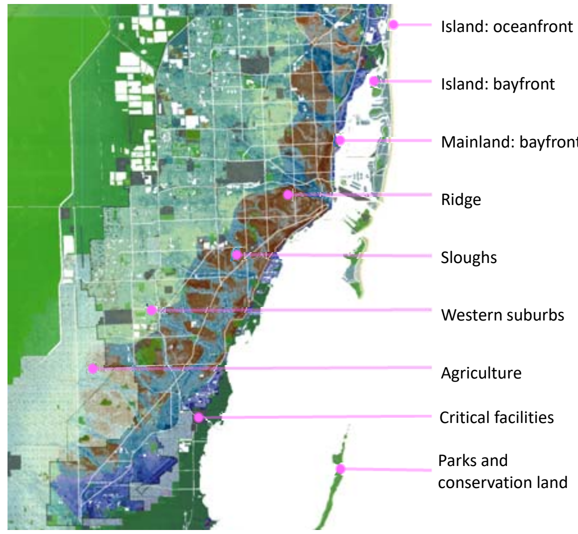
Adaptation approaches and strategies paired with

Land Typologies



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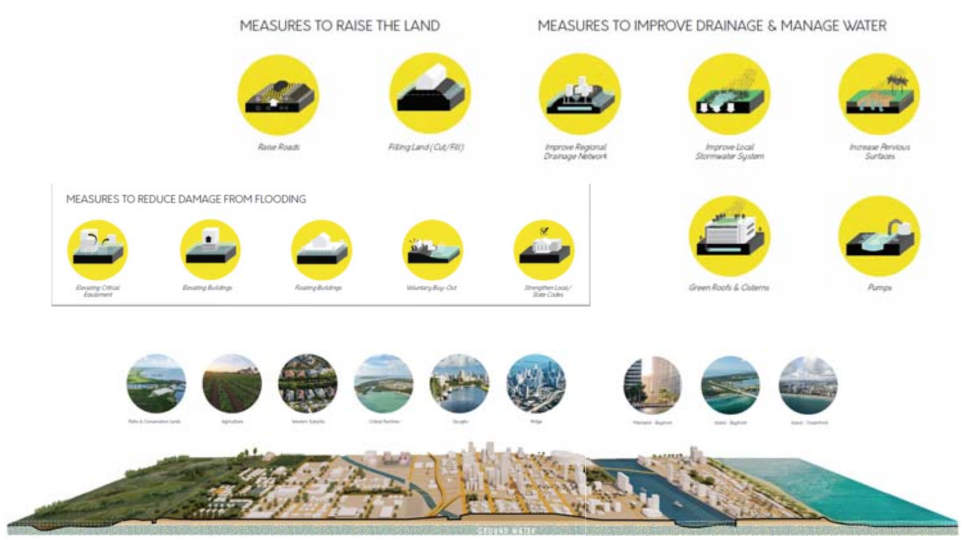
Adaptation Tools



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Stakeholder engagement

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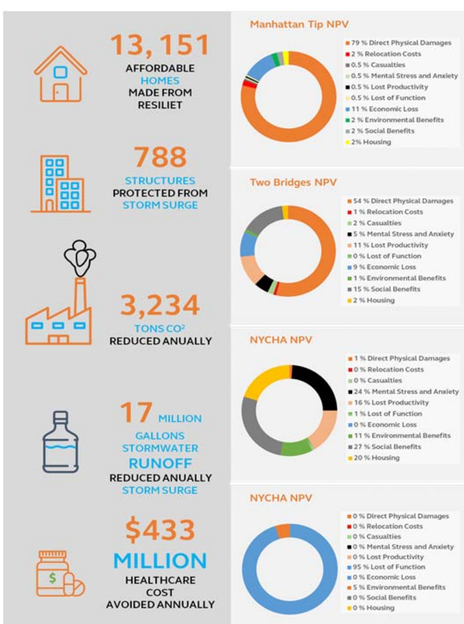
Value of Resilience



National Institute of BUILDING SCIENCES

FEMA

*Natural Hazard **Mitigation** Saves: 2017 Interim Report*
www.nibs.org/page/mitigationsaves

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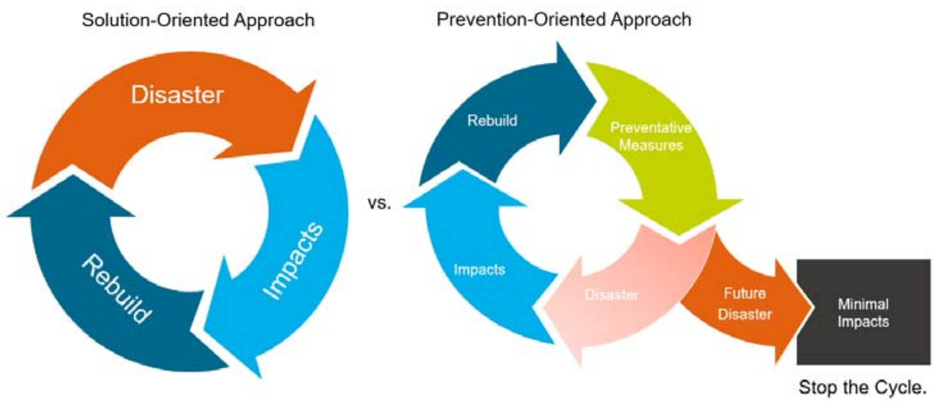
Investments in Utilities Can Provide Significant Returns



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FEMA funding opportunities

Potential Projects

Green Infrastructure Projects

Stormwater Management Projects

Aquifer Storage and Recovery

Power Resiliency (Generators)

Erosion Control

Floodplain Restoration

Stream Restoration

Infrastructure Retrofits

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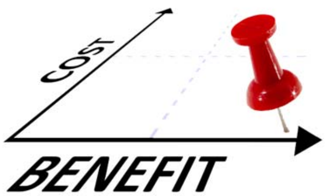
Application Components



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- Scope of Work and Maps
- Cost estimates/Budget
- Benefit Cost Analysis
- Env Review & Historic
- Preservation Compliance
- Supporting documents
- Alternatives
- Tips for wording

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P ldp l#G dgh#Z dwhu#dqg#Vhz hu

- **Challenge**
  - Flood risk to 12 facilities consists of surge, stormwater, and subsurface intrusion into the wastewater collection system – Clean Water Act violations - PSIP $1.6 billion in repairs over the next 15 years
- **Approach**
  - Hurricane Irma (DR-4377) HMGP – 2 applications
  - Phased Project
- **Results**
  - Applied and awarded $36.6M (federal share)

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- Level of protection base **flood** elevation (BFE) + 3 ft freeboard
- **Wind** retrofit to mitigate wind speeds of 190MPH (minimum)
- Emergency **power** generation
- **SCADA** system improvements
- HVAC Improvements for **ventilation** and safety

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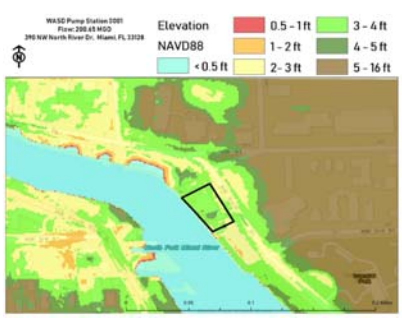
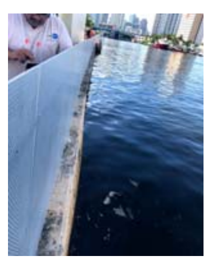
Pump Station 1 >200MGD





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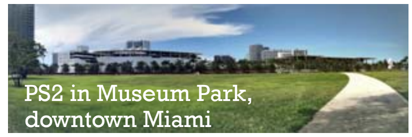
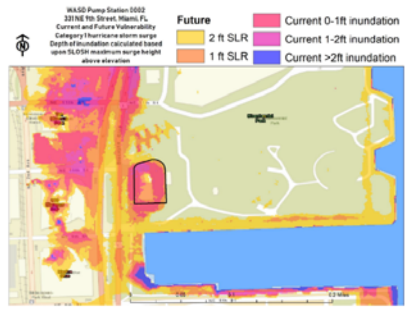
Pump Station 2 >80MGD

- Berm or Floodwall Around Site
- Bulkhead Shutters for Windows and Doors
- Impact and Flood Proof Door to Main Switchgear Room
- Communication Connection to MDC EOC and other Facilities
- **Elevate All Electric Motors and Electrical Equipment**
- Impact and Flood Proof Windows
- Discharge Valve Redundancy (hydropneumatics system)
- **Screen Channel Isolation/Bypass**
- HVAC Redundancy/Ventilation
- Structural and Equipment Reinforcement for wind loading
- Flood Wall for Backflow Preventer
- Emergency Response Safe Room
- Floodproof Electrical Room (pump motor room level)
- Louver upgrades to hurricane grade
- Berm or Floodwall Around Site





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Considerations

PS 0536

Photograph 31: PS 536 Front façade of building and manhole

Photograph 32: PS 536 Side with discharge suction piping

Table 1:

Pump station Number	Hurricane Shelter Count	Fire Dept Count	Police Dept Count	Health Center Count	Health Service Count	City Hall Count	Correctional Rehab Count	Water Treatment Plant
0348	3	5	3	8	4	1	1	2

2075 SLR only (3.1ft)	2075 SLR only (4.0ft)	25yr Modeled Flood Inundation depth (ft)	25yr SLR 1.5ft Modeled Flood Inundation depth (ft)	25yr SLR 4ft Modeled Flood Inundation depth (ft)	100yr Modeled Flood Inundation depth (ft)	100yr SLR 1.5ft Modeled Flood Inundation depth (ft)	100yr SLR 3.1ft Modeled Flood Inundation depth (ft)	100yr SLR 4ft Modeled Flood Inundation depth (ft)
0	0	0.62	0.86	1.61	1.58	1.95	2.52	3.61

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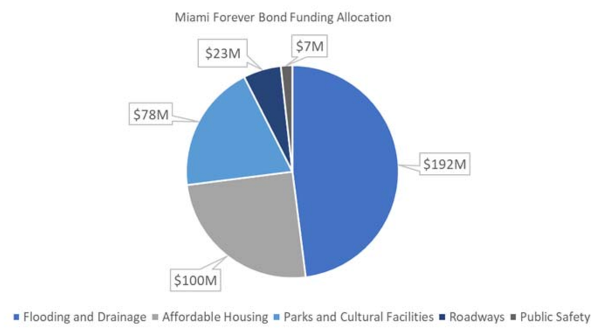
Stormwater Master Plan Update

- Protection of Biscayne Bay and other natural features
- Resilient natural and built coastal features and infrastructure
- Current and future regulatory environments
- Climatic patterns
- Ground water levels
- Rainfall
- Sea level rise projections
- Water quality
- Saltwater intrusion
- Storm surge
- Land use
- Desired levels of service



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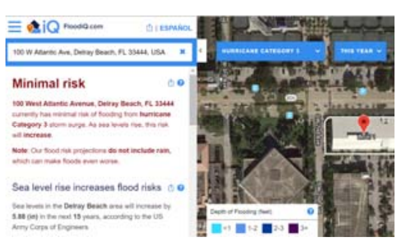
Tools to Learn more

Flood IQ
https://floodiq.com/

Surging Seas
sealevel.climatecentral.org/



NOAA SLR Viewer
https://coast.noaa.gov/digitalcoast/tools/slr

and another great NOAA tool
https://coast.noaa.gov/digitalcoast/tools/flood-exposure.html

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Thank you!

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**We have caveman emotions;
medieval institutions;
and god-like technology**
-E. O. Wilson

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Questions?

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