Responding to Maine Climate Needs:
A Roundtable Showcasing Available Climate Data and Tools
October 10, 2014
University of Southern Maine
New England Environmental Finance Center
Wishcamper Hall, Lee Auditorium
34 Bedford Street
Portland, ME

Participant Goals:

- ✓ Understand a suite of resources available to help advance Maine’s response to impacts of climate change
- ✓ Build applied knowledge on topics of most concern to Maine agencies
- ✓ Discuss continued climate related needs and opportunities
- ✓ Identify strategies for moving forward and working together
- ✓ Network with Federal, state and regional agencies

Agenda

9:00 **Check-in & Networking**

9:30 **Welcome to University of Southern Maine & New England Environmental Finance Center**
Jack Kartez, Director, New England Environmental Finance Center

9:35 **Goals for the Day**
Deputy Commissioner Heather Parent, Maine Department of Environmental Protection

9:50 **Building on the EPA Climate Summit**
Ken Moraff, US EPA Region 1

10:05 **Introduction to the Sessions**
Ellen Mecray, NOAA

10:10 **Impacts of Precipitation on Infrastructure**
Moderator: Judy Gates, Maine Department of Transportation

Topics and Panelists:

NOAA Tools for Tracking a Changing Climate
David Vallee, NOAA’s Northeast River Forecast Center

USGS Hydrologic Data and Studies Relevant to Infrastructure and Climate Change
Glenn Hodgkins, USGS

Assessing and Addressing Climate Change Impacts: FHWA Resources
Cassie Chase, Federal Highways

11:30 **Lunch:** Food is available for purchase at the Woodbury Food Court. See map.

12:45 **Impacts of Sea Level Rise on Infrastructure**

Moderator: Peter Slovinsky, Maine Geologic Survey

Topics and Panelists:

Impacts of Sea Level Rise on Infrastructure: Statewide Datasets and Highlighted Projects and Efforts
Peter Slovinsky, Maine Geologic Survey

Climate Change Adaptation for Critical Infrastructure
William DeLong, Department of Homeland Security

Advancing Water Sector and Community Resiliency
Jane Downing, US EPA Region 1

Integrating Climate Considerations into Asset Management at Maine DOT
Judy Gates, Maine DOT

2:00 **Impacts on the Natural Environment**

Moderator: James Connolly, Maine Inland Fish and Wildlife

Topics and Panelists:

Maine Wildlife Action Plan
James Connolly, ME Inland Fish & Wildlife

Climate Change and Interacting Stressors: Responding to Coastal Change in Casco Bay
Curtis Bohlen, Casco Bay Estuary Partnership

Regional Planning Tools for Coastal Resource Management
Jamie Carter, NOAA

Decision Support Tools and Forest Lands
David Hollinger, US Forest Service

3:15 **Participants Reactions to the Day & Next Steps**

Moderator: George MacDonald, Maine Department of Environmental Protection

3:30 **"Office Hour"**

Opportunity to ask more specific questions about a tool, resource or project that you heard about during the sessions. Speakers will be available to discuss ideas and opportunities identified throughout the day.

4:30 **End of the meeting**

Speaker Bios

Jack Kartez currently serves as Director of the New England Environmental Finance Center as well as Professor of Community Planning and at the Edmund S. Muskie School of Public Service located at the University of Southern Maine. He has extensive experience in environmental mediation, citizen engagement, and survey design.

Heather Parent is the Acting Deputy Commissioner for the Maine Department of Environmental Protection. She was the Policy Director overseeing legislation, rulemaking, and enforcement activities. Prior to joining the Department she practiced environmental law as partner at the Bangor-based law firm, Eaton Peabody. Heather has a Juris Doctor and Master's in Environmental Law from Vermont Law School. She is a native Mainer having spent her early childhood in Winn before moving to Peru, Oxford County. In 2012, Heather was named a "Forty under 40" winner by Maine Today Media recognizing her valuable contributions to protecting Maine's great outdoors and ensuring a robust economy. When she's not overseeing environmental policy for the State, Heather enjoys being outside and taking advantage of the Kennebec River's Rail Trail.

Ken Moraff is the Director of Office of Ecosystem Protection within US Environmental Protection Agency Region 1 offices. OEP works with New England states to implement national environmental standards including air permits, air toxics, indoor air, air quality, energy, municipal and community grants, water permits, water quality, surface water, wetlands, and drinking water in a way that reflects the connections among different environmental media.

Ellen Mecray is NOAA's Regional Climate Services Director for the Eastern Region, based in Taunton, MA. She joined NOAA in 2005 to serve as the lead for strategic planning for NOAA's Office of Oceanic and Atmospheric Research. In 2008, she moved to be regionally-based in New England in order to facilitate inter-and intra-agency dialog and collaboration on climate science. She is the lead for the New England Federal Partners climate working group, as well as the NOAA representative to multiple interagency efforts on climate in the eastern region.

David Vallee is the Hydrologist-in-Charge at NOAA's Northeast River Forecast Center in Taunton, MA.

Glenn Hodgkins has been working as a Hydrologist with the U.S. Geological Survey (USGS) in Maine and Indiana since 1990. He and collaborators have published extensively on historical trends in water-related variables in New England such as river flows, river ice, lake ice, and snowpack. Other areas of research include river flooding and bridge scour. Glenn received his Bachelor's Degree in Civil Engineering from the University of Maine and Master's Degree in Engineering from Purdue University.

Cassie Chase is an Environmental Engineer with the Federal Highways Administration Maine Division. She has the primary responsibility for coordinating and implementing environmental program activities associated with the development of the Federal-aid projects in Maine. This includes assuring that: (1) all Federal activities are in keeping with the National Environmental Policy Act (NEPA) and FHWA's environmental program policies and guidance; (2) appropriate identification and implementation of MaineDOT responsibilities and procedures for considering social, economic, and environmental impacts associated with proposed and potential Federal-aid projects; (3) utilization of a systematic interdisciplinary approach to the analysis of environmental effects; and (4) involvement of the public, tribal governments, and other State and Federal agencies charged with human and natural resource management activities in the project development/environmental analysis process.

Peter Slovinsky is a Marine Geologist with the Maine Geological Survey in the Department of Agriculture, Conservation and Forestry. His work focuses on coastal hazards, shoreline erosion, and assessing the vulnerability of both natural and built environments to the potential effects of sea-level rise and storms in support of municipal, regional, and state level decision-making. He has an MS from the University of South Carolina, and a BA from Franklin and Marshall College. He lives in Scarborough, is a member of the Town's Conservation Commission, and can be found either in the water or in the mountains at any time of year.

William DeLong is the Protective Security Advisor for Maine at US Department of Homeland Security's Office of Infrastructure Protection.

Jane Downing is the Chief of the Drinking Water Branch at the US Environmental Protection Agency's Region 1 offices. Her current responsibilities include managing the federal drinking water program in New England, with emphasis on implementation of the Safe Drinking Water Act program. Also responsible for policy making on matters affecting drinking water in New England. She holds a MS in Environmental Engineering from Tufts University and a BS in Chemistry from Boston College.

Judy Gates has served as the Director of Maine DOT's Environmental Office since 2006 where she provides advanced management to diverse groups of scientists and specialists who implement policies, programs, projects and practices related to environmental, cultural, functional and regulatory aspects of state transportation systems; advocates for the Department's mission in the interpretation and application by external parties of statutes and regulations; participates in the development of both long-range and triennial work plans; and oversees diverse stakeholder efforts focused on improving resource management and increasing predictability of the regulatory environment. Prior to Maine DOT, Judy worked for seven years with the Maine Department of Environmental Protection coordinating their natural resource licensing program, and three years with the Maine Department of Agriculture. Judy earned a B.S. in Agriculture from West Virginia University, an M.S. in Plant & Soil Science and an M.S. in Forest Biology from the University of Maine Orono, and is ABD in the Ph.D. in Public Policy program at the University of Southern Maine's Muskie School of Public Service.

James Connolly is the Director of the Wildlife Division of the Maine Department of Inland Fish and Wildlife. Previously, he served as a wildlife biologist for 11 years at DIFW.

Dr. **Curtis Bohlen** is the Director of the Casco Bay Estuary Partnership (CBEP). CBEP works collaboratively with nonprofits, municipalities, and state and federal agencies on behalf of Casco Bay and its watershed. Dr. Bohlen previously served on the Environmental Studies faculty at Bates and Colby Colleges, and was a research scientist at the University of Maryland's Chesapeake Biological Laboratory. He also worked for Trout Unlimited and the Chesapeake Bay Foundation as a staff scientist and spent a year working on Capitol Hill as a legislative aide and Congressional Science Fellow. He holds B.S. and M.S. degrees in Biology from Stanford and a Ph.D. in Ecology from Cornell.

Jamie Carter is a geospatial consultant for NOAA's Office for Coastal Management, and is located in Yarmouth, Maine to support coastal decision makers in the northeast. He's worked for the Office for 11 years processing LiDAR and high-resolution imagery, developing decision-support tools, and delivering GIS and remote sensing trainings. His topical interests are in coastal ecology and natural hazards, and today will present some products and services from NOAA that touch on both themes.

David Hollinger is the Climate, Fire and Carbon Cycle Sciences project leader with the US Forest Service in Durham, NH. He also serves as the Director of the USDA Northeast Regional Climate Hub. The mission of the Hub is to develop and deliver science-based, region-specific information and technologies to agricultural and natural resource managers that enable climate-smart decision-making and provide assistance to enable land managers to implement those decisions.

George MacDonald is the Director of the Sustainability Division within Maine's Department of Environmental Protection.

NOAA Tools for Tracking A Changing Climate in Maine

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

Fort Kent, Maine at the confluence of the Fish and Saint John Rivers, April 30, 2008

Outline

- A very brief look at changing temperature and precipitation in Maine
- Tools to assist communities

We've been a little busy these past 10 years!
The face of changing flood behavior...

Record flooding along the Fish and Saint John Rivers – northeast Maine, 4/30/2008

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

Providence Street – West Warwick, RI at 1030 am Wednesday 3/31/10

Damage along Schoharie Creek, Prattsville, NY – T.S. Irene, Photo: J. Vielkind / Times Union

The Changing Climate

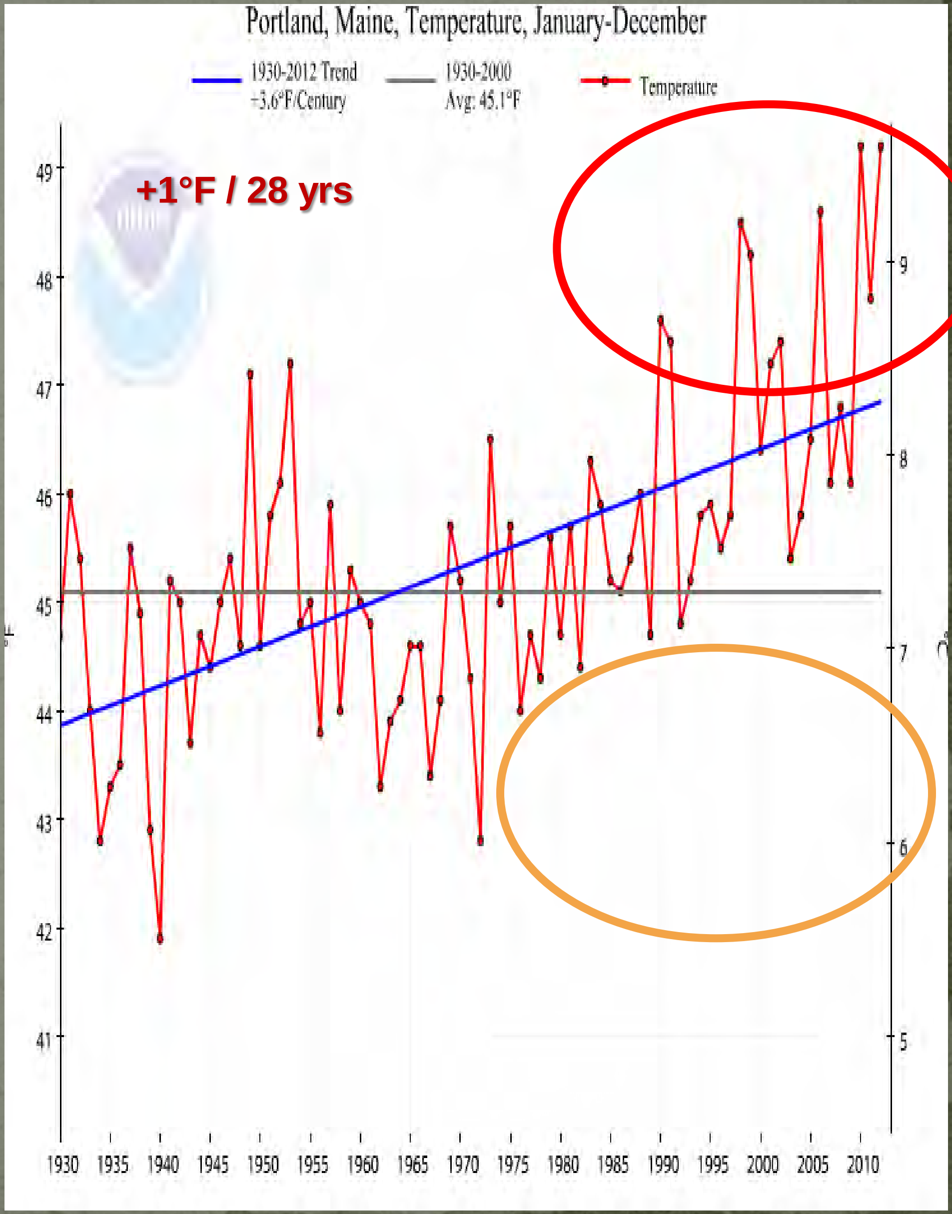
- Common themes across New England and Maine:
  - Increasing annual precipitation
  - Increasing frequency of heavy rains
  - Warming annual temperatures
  - Earlier "ice out" and peak spring flows
  - Shift in precipitation frequency
- For smaller (<800 sq. mi) basins in southern and western Maine
  - Trend toward increased flood magnitude and/or frequency
    - Most pronounced where significant land use change and/or urbanization has occurred
- For northern & eastern Maine
  - Not as discernable a signal at this point

Ice Jam Flooding in Farmington, ME, January 2006. (Photo: D. Roy)


Flash Flooding causes road washouts in Calais, ME, July 26th, 2013. (Photo: R. Posick, Bangor Daily News.com)

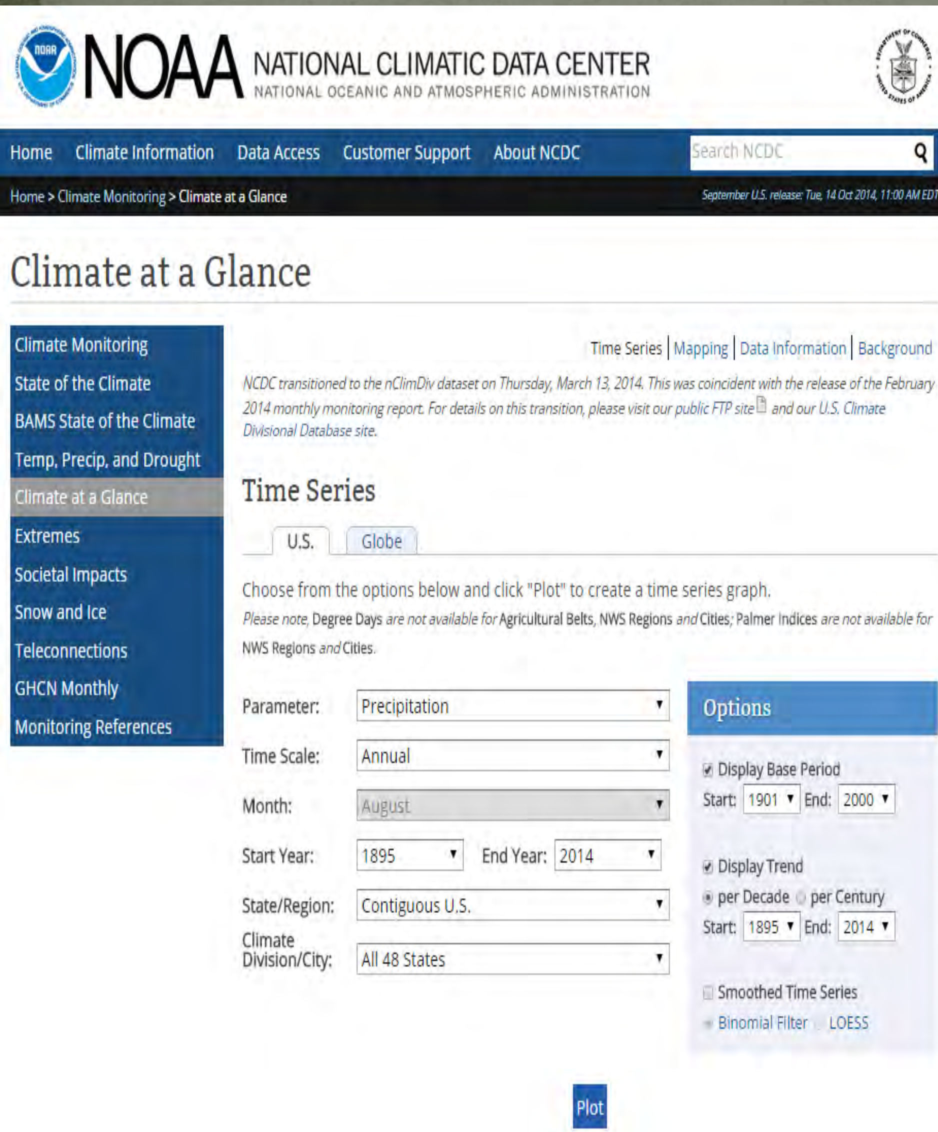
A Look at Temperature Trends

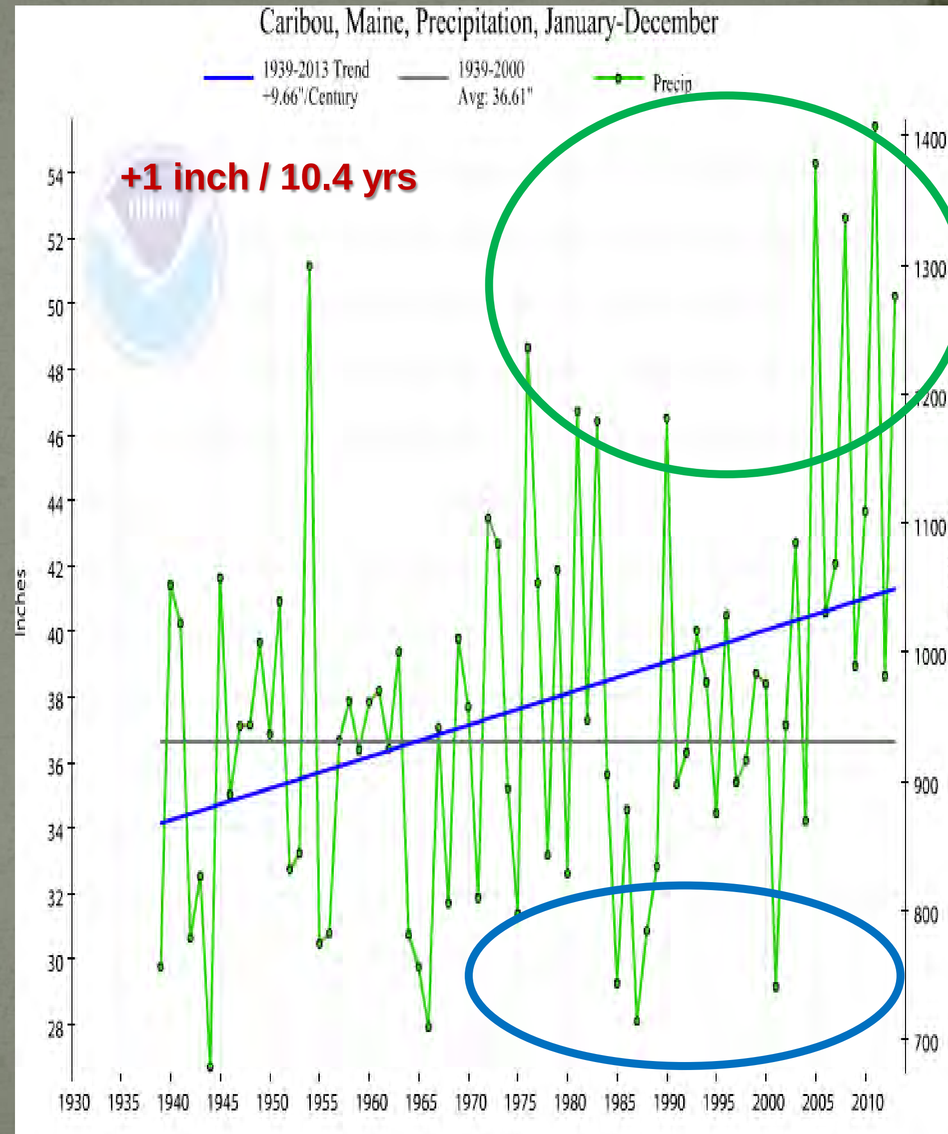
http://www.ncdc.noaa.gov/cag



A Look at Precipitation Trends

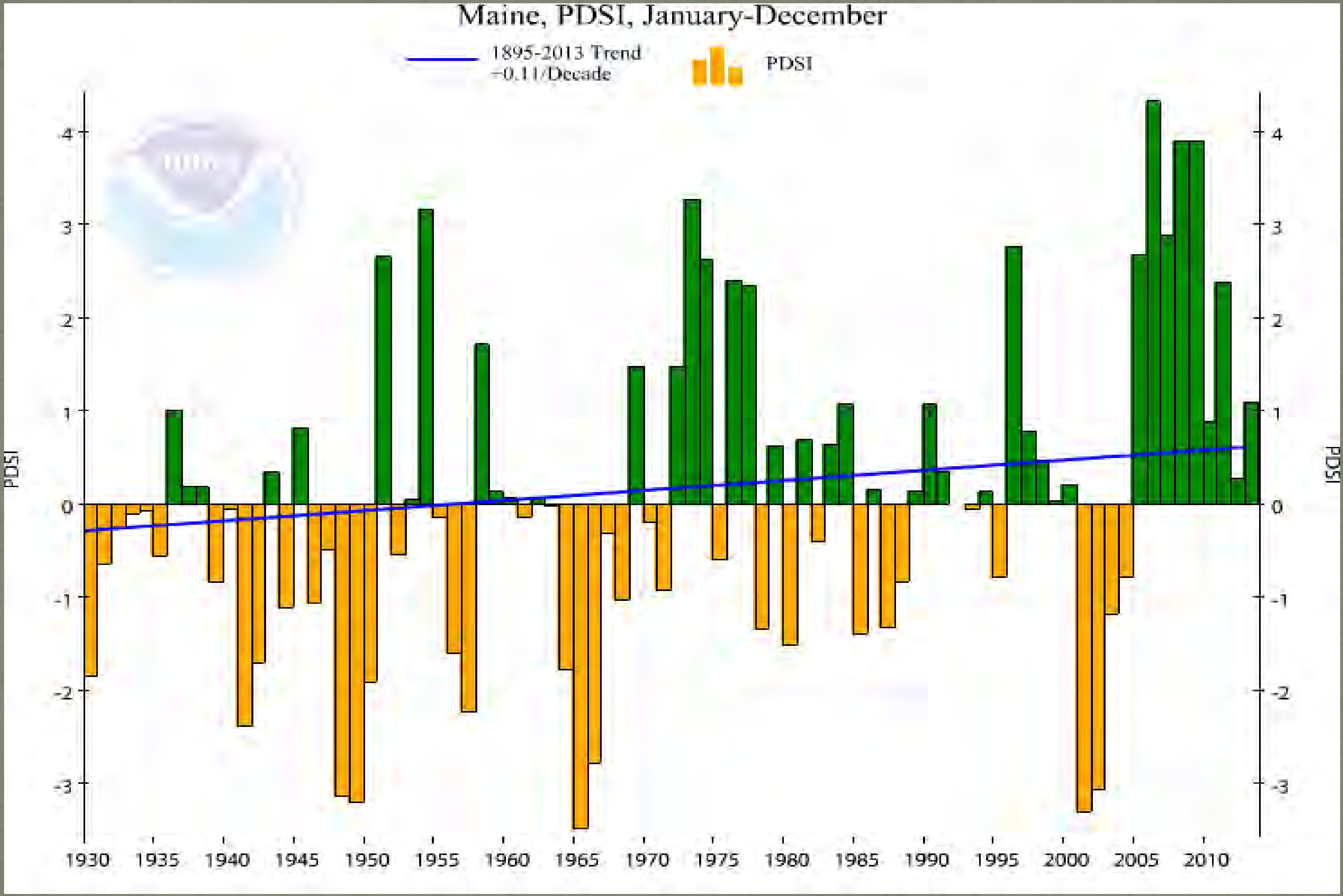
http://www.ncdc.noaa.gov/cag





Changes in the Palmer Drought Index

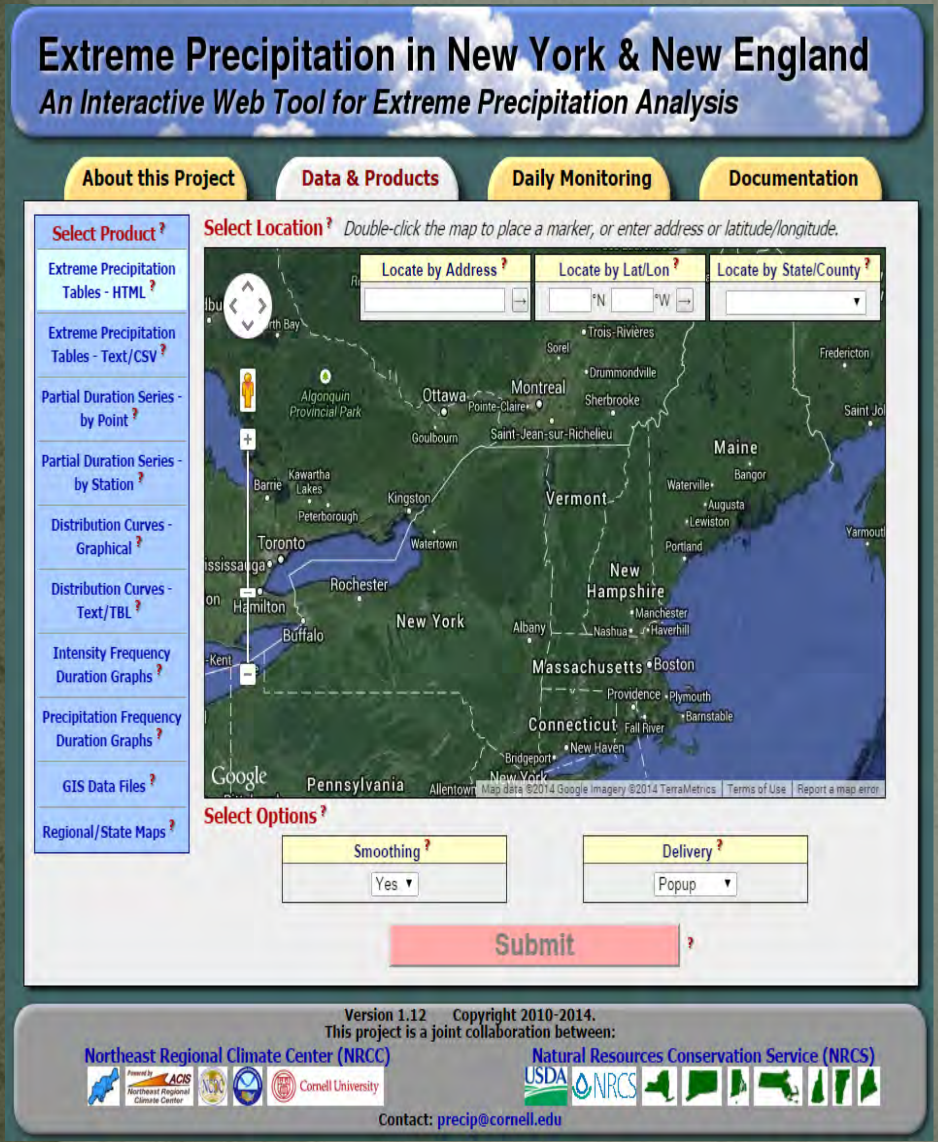
http://www.ncdc.noaa.gov/cag

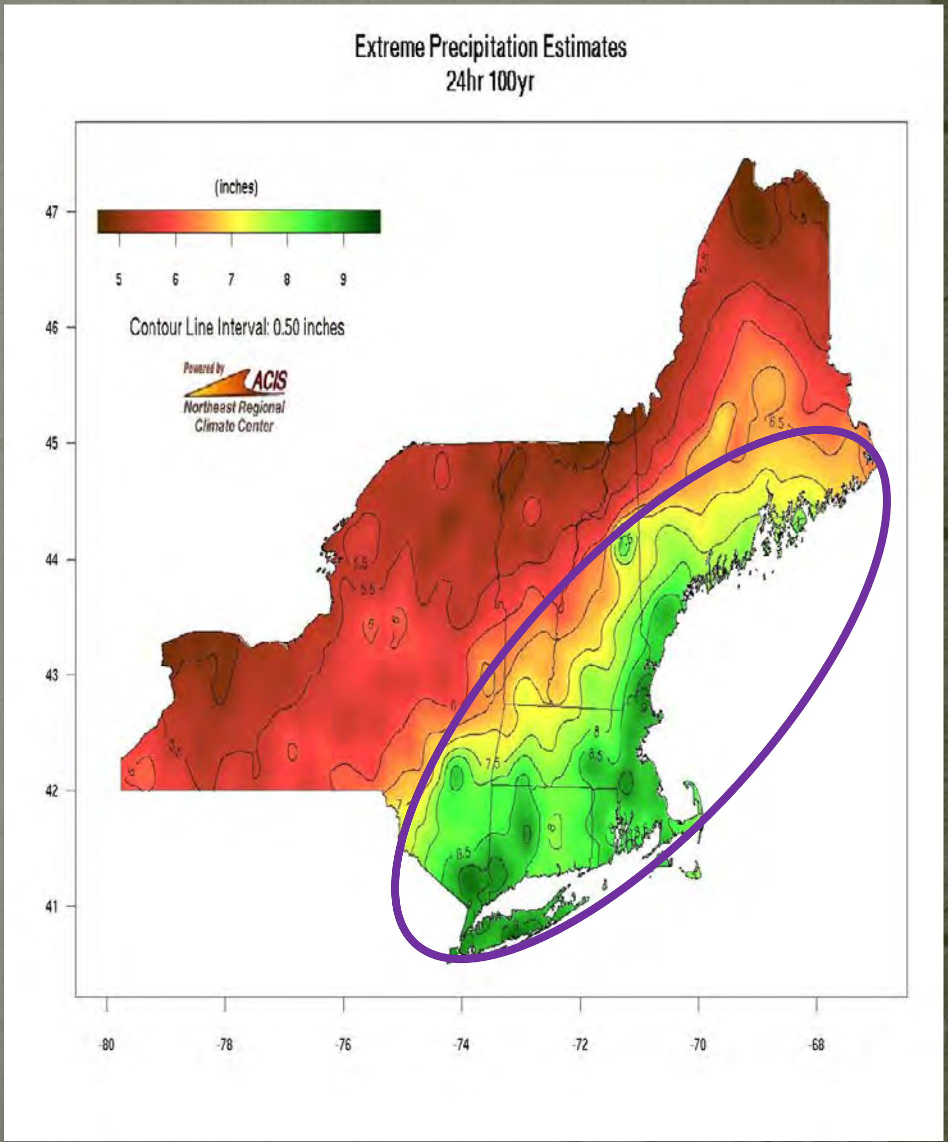


Since the late 60s, signature of less frequent & shorter dry periods and longer, more frequent and intense wet periods

Examining Extreme Precipitation

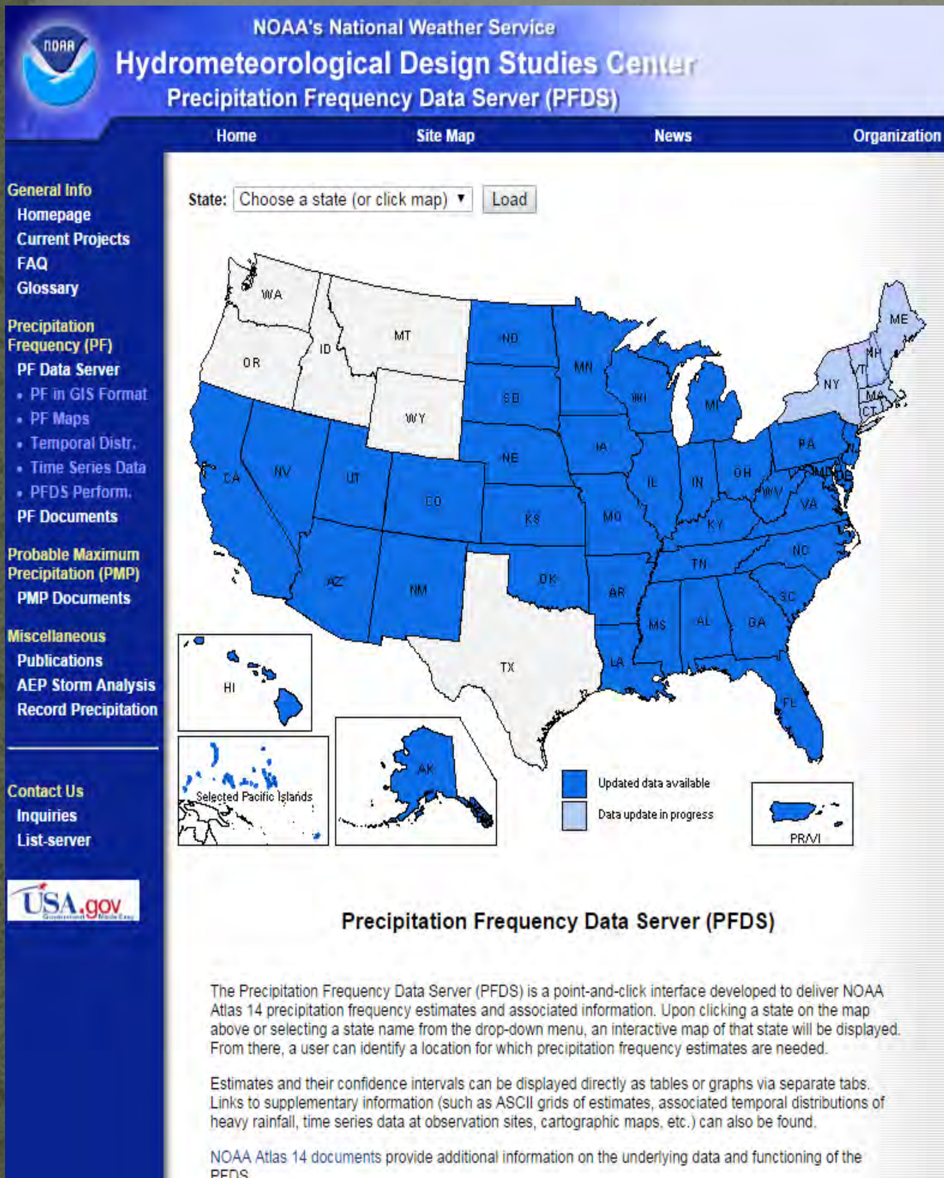
http://precip.eas.cornell.edu

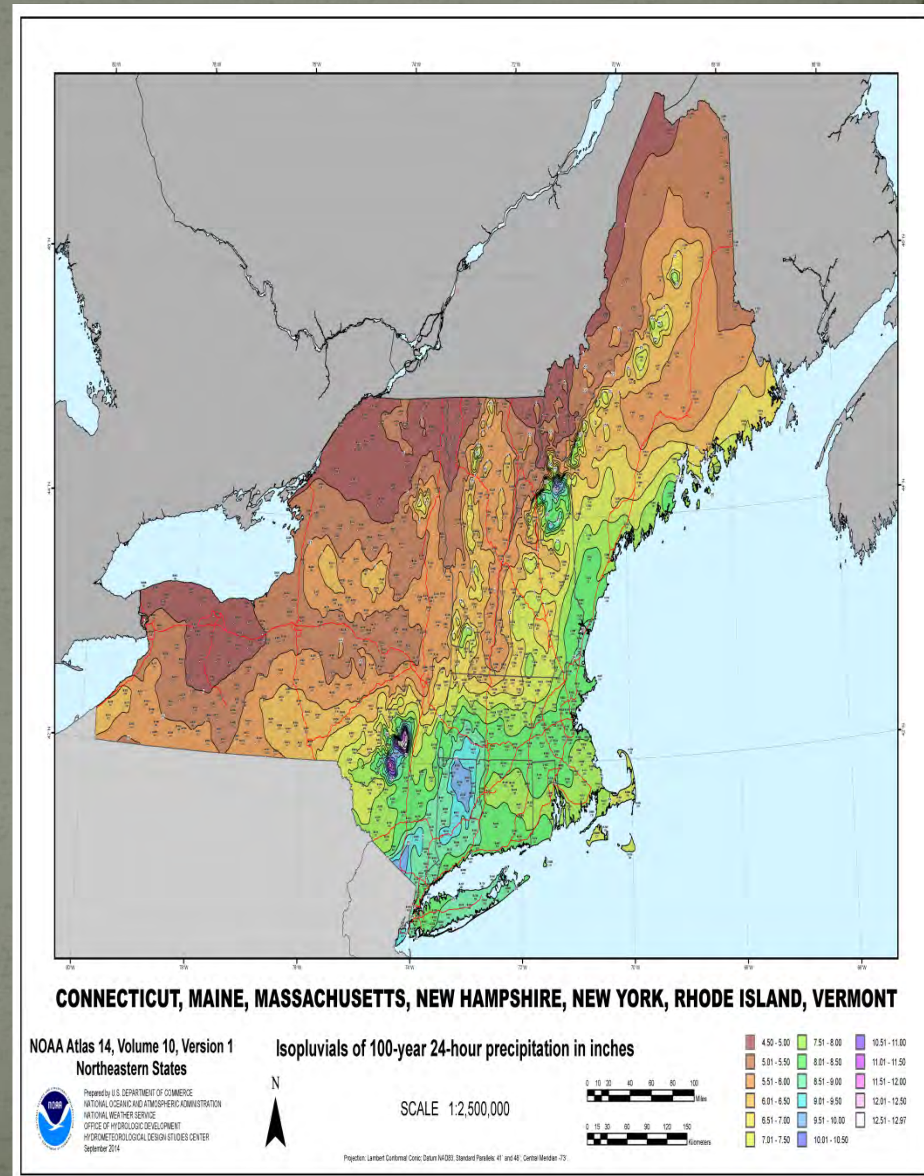




NOAA Atlas Update for New England

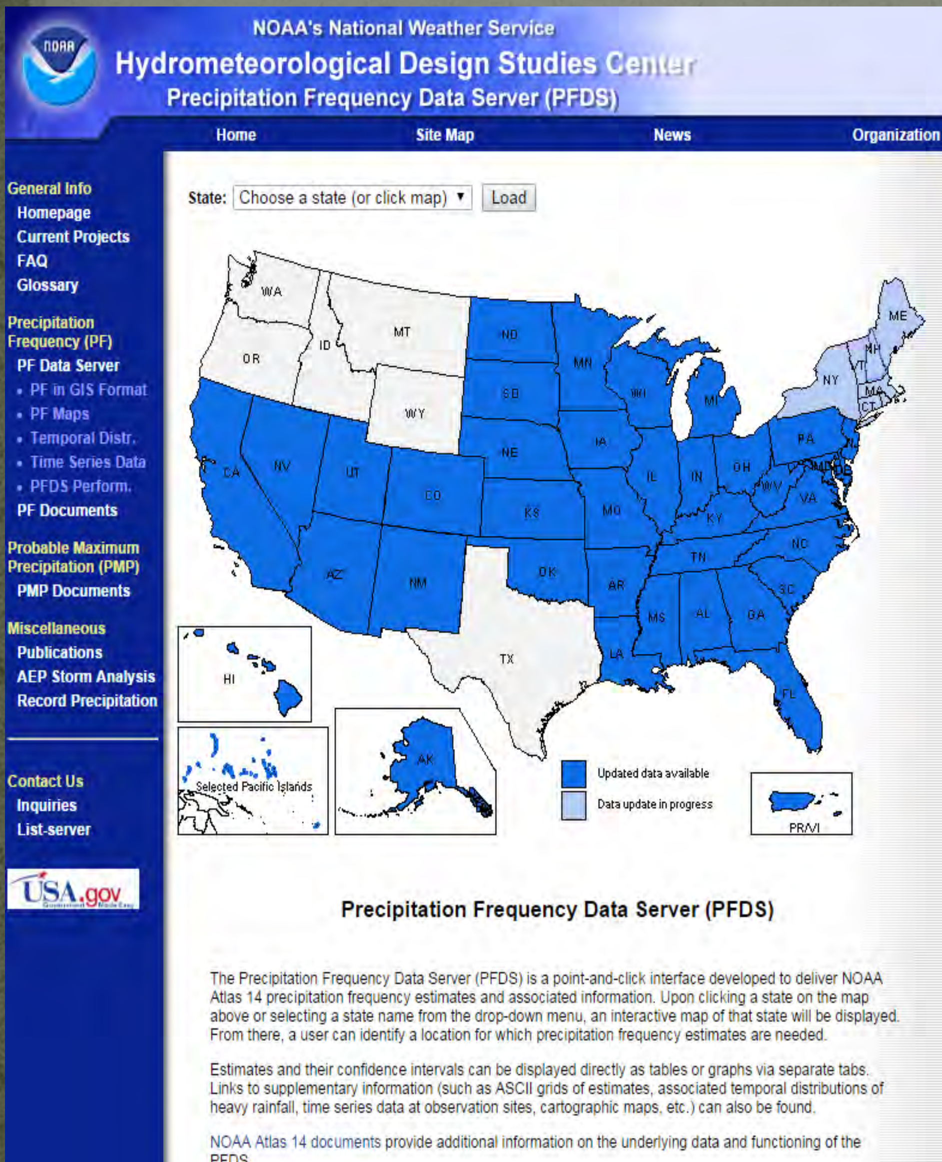
http://hdsc.nws.noaa.gov/hdsc/pfds/index.html

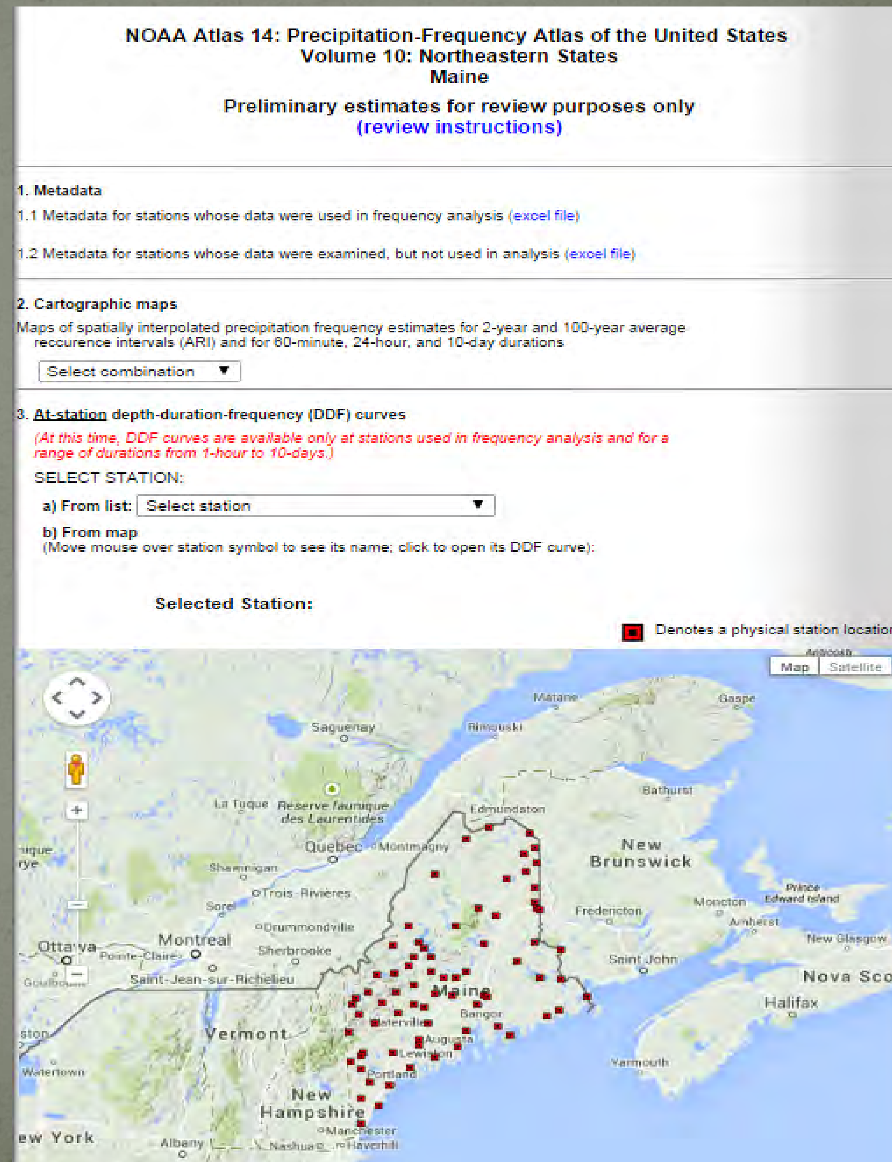




Preliminary Peer Review in Progress

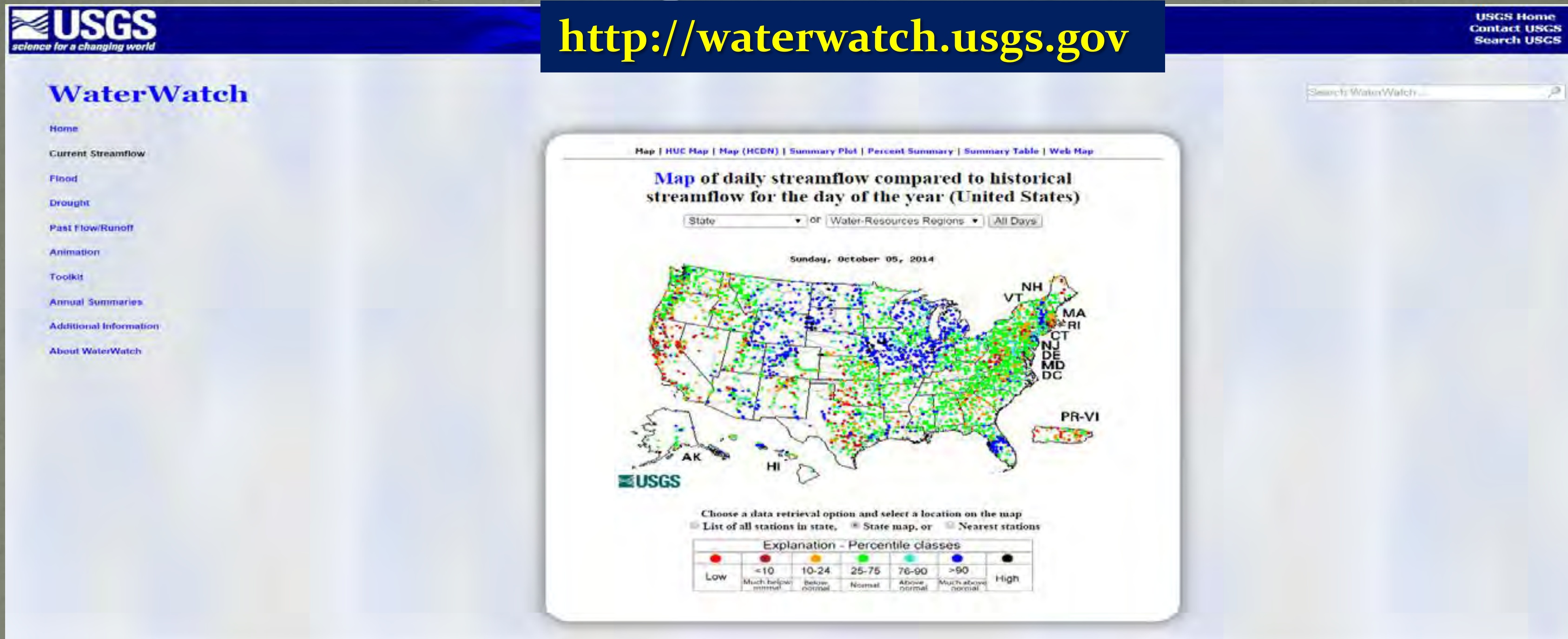
http://hdsc.nws.noaa.gov/hdsc/pfds/peer_review/

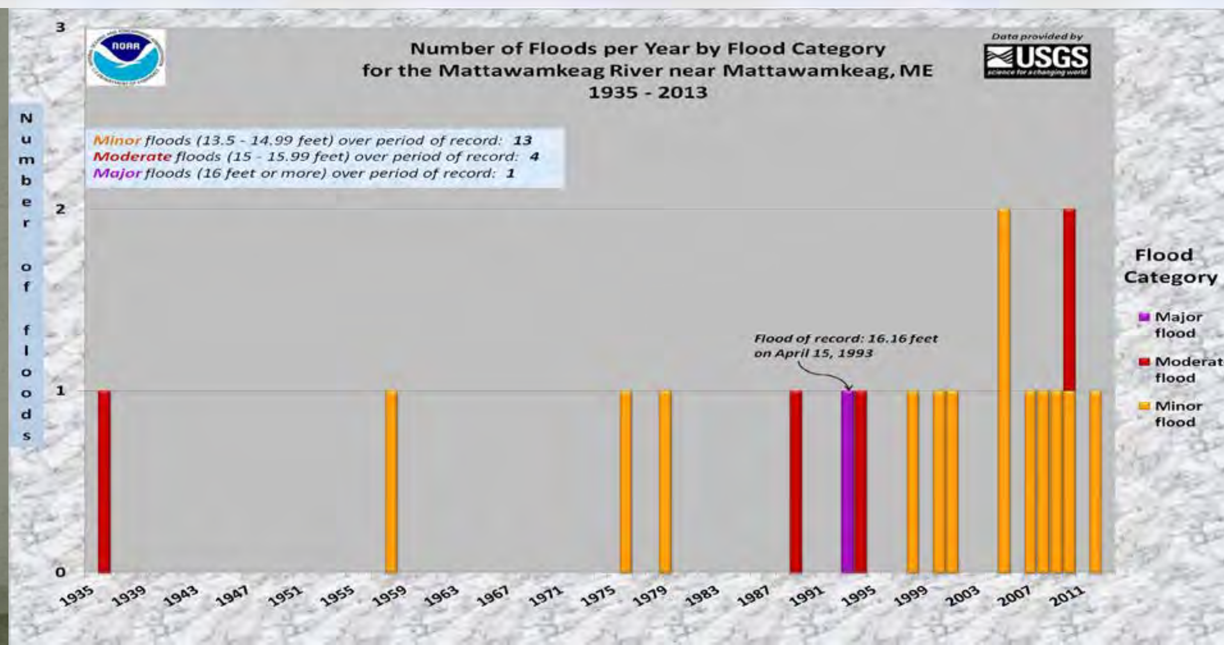




Flood History at Gaged Locations: USGS Source

http://waterwatch.usgs.gov





NOAA Tools for Tracking A Changing Climate in Maine

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

Fort Kent, Maine at the confluence of the Fish and Saint John Rivers, April 30, 2008

USGS hydrologic data and studies relevant to infrastructure and climate change

Glenn Hodgkins

Robert Dudley

USGS New England Water Science Center

Overview of (brief) presentation

- Climate-sensitive hydrologic data relevant to Maine and New England
- Historical hydrologic trends (for climate sensitive stations)
- Potential future streamflows in Maine

Climate-sensitive hydrologic data

- All historical USGS streamflow data available online
  - http://waterdata.usgs.gov/nwis/sw
- Need long-term data minimally influenced by human alterations to see climate signals in the data
  - Avoid watershed alterations such as urbanization and reservoir regulation
  - Difficult to distinguish climate signal if data is affected by watershed alterations
- USGS GAGES-II dataset (Lins, 2012) defines minimally altered watersheds nationwide with long-term streamflow data.

USGS
science for a changing world

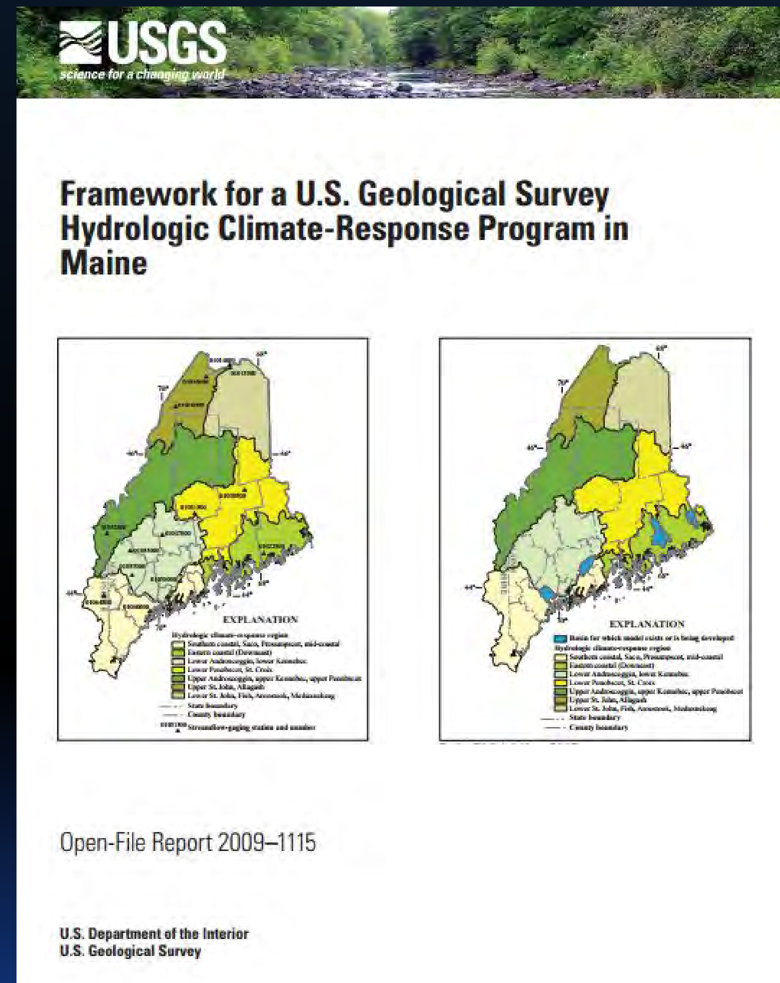
How best to collect and analyze climate-related hydrologic data in Maine?

- 2009 goals for USGS Maine hydrologic climate response network
  - Provide systematic information to resource managers
    - Streamflows, groundwater, lake ice, etc.
  - Provide an early warning of hydrologic response to climate change
  - Maintain important long-term data collection stations and identify gaps
  - Provide locations for process-level research

USGS science for a changing world

Framework for a hydrologic climate response network in Maine

- Identified key hydrologic variables that respond to climate change
  - Including appropriate stations
- Identified relatively homogeneous climate response regions

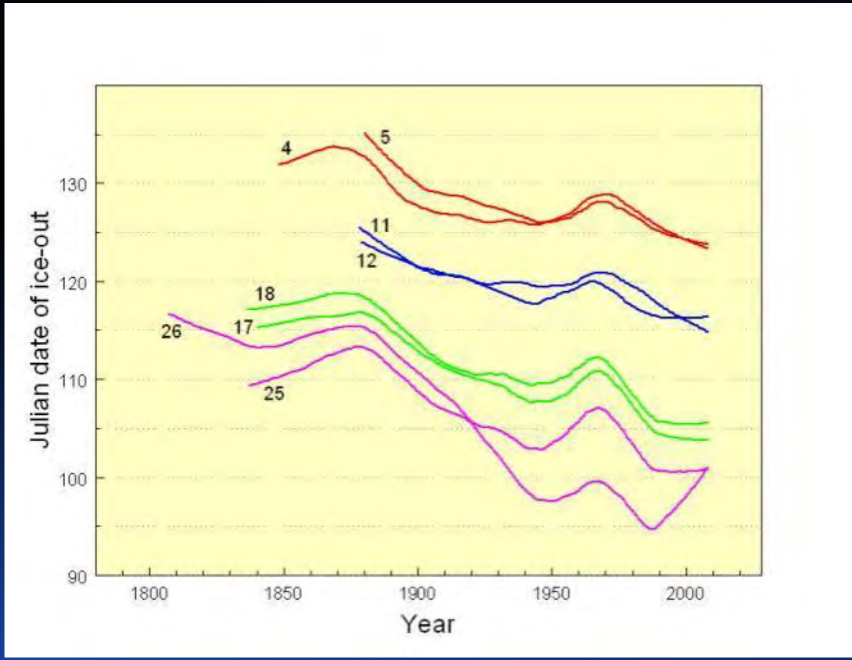


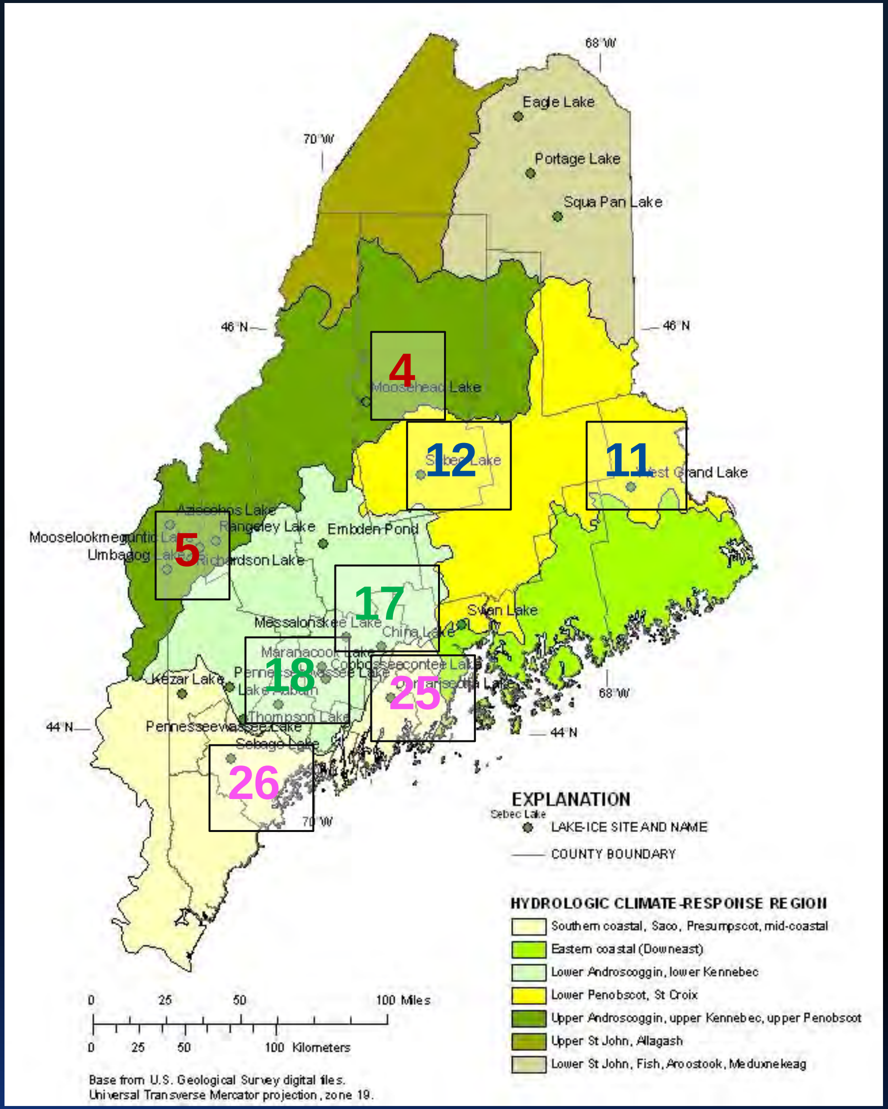
Hodgkins, Lent, Dudley, and Schalk, 2009

USGS science for a changing world

Maine climate response regions

- Historical changes in timing of lake ice-out dates, 1800's-2008

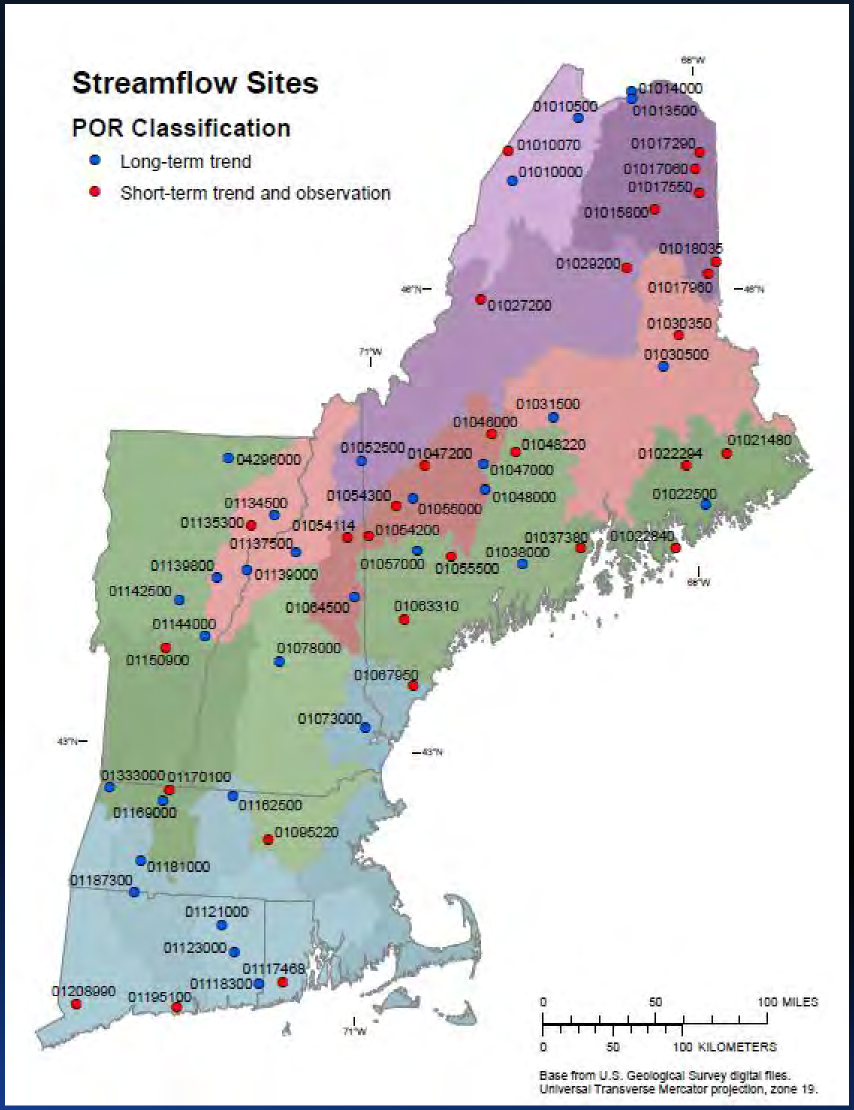




USGS science for a changing world

Framework for a hydrologic climate response network in New England

- Developed framework for Maine
- Currently working on similar framework for New England
- Example
  - Streamflow sites



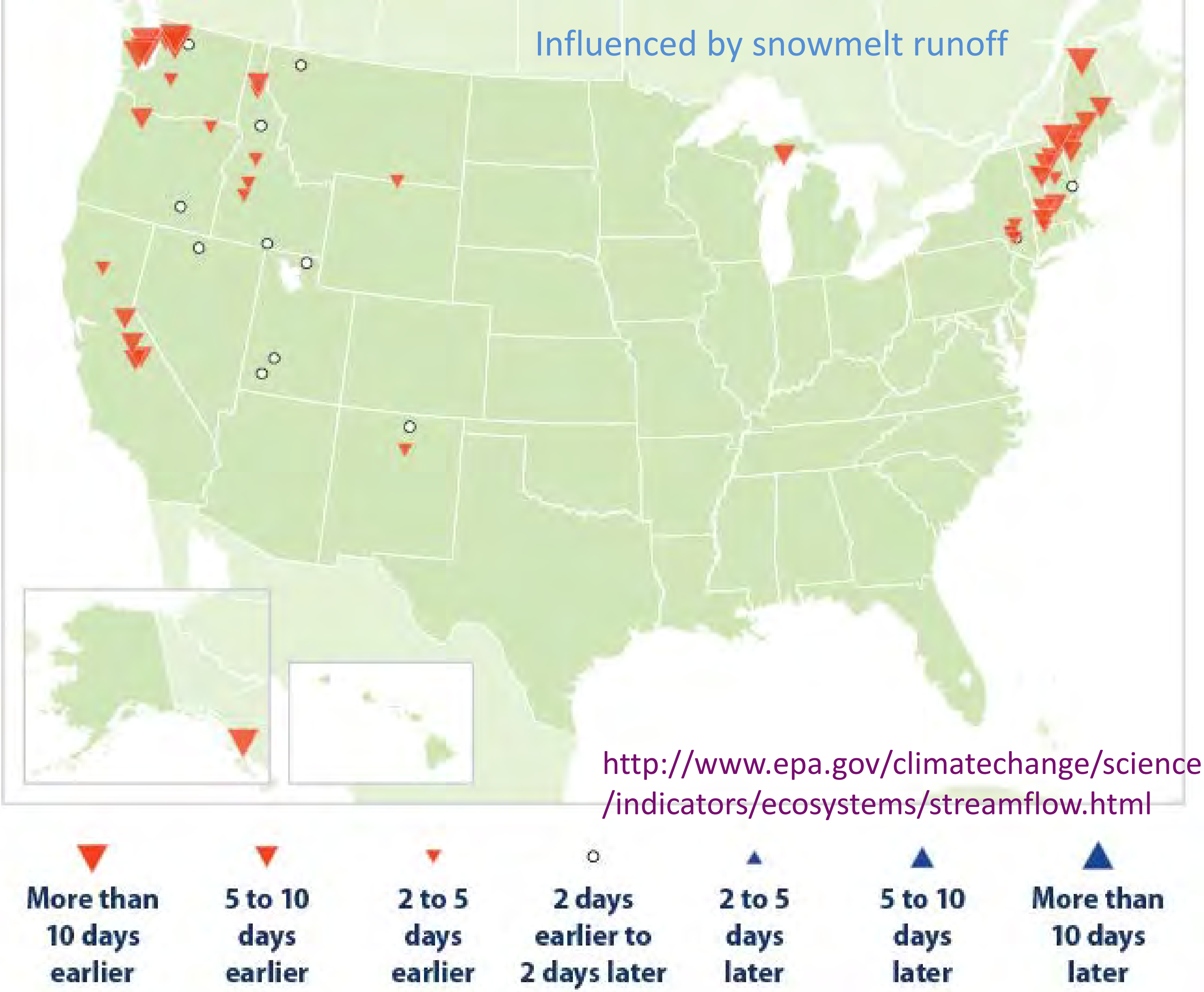
Lent, Hodgkins, Dudley, and Schalk, in review

Historical hydrologic trends

- Many trend studies completed by USGS New England Water Science Center (and others) at different scales and for different flow variables
- Example: National hydrologic indicators of climate change
  - Cooperative study with USEPA
    - Part of EPA Climate Change Indicators in the U.S.
  - Developed streamflow climate change indicators across United States
    - Dudley, Hodgkins, McHale
  - Used minimally impacted streamflow stations

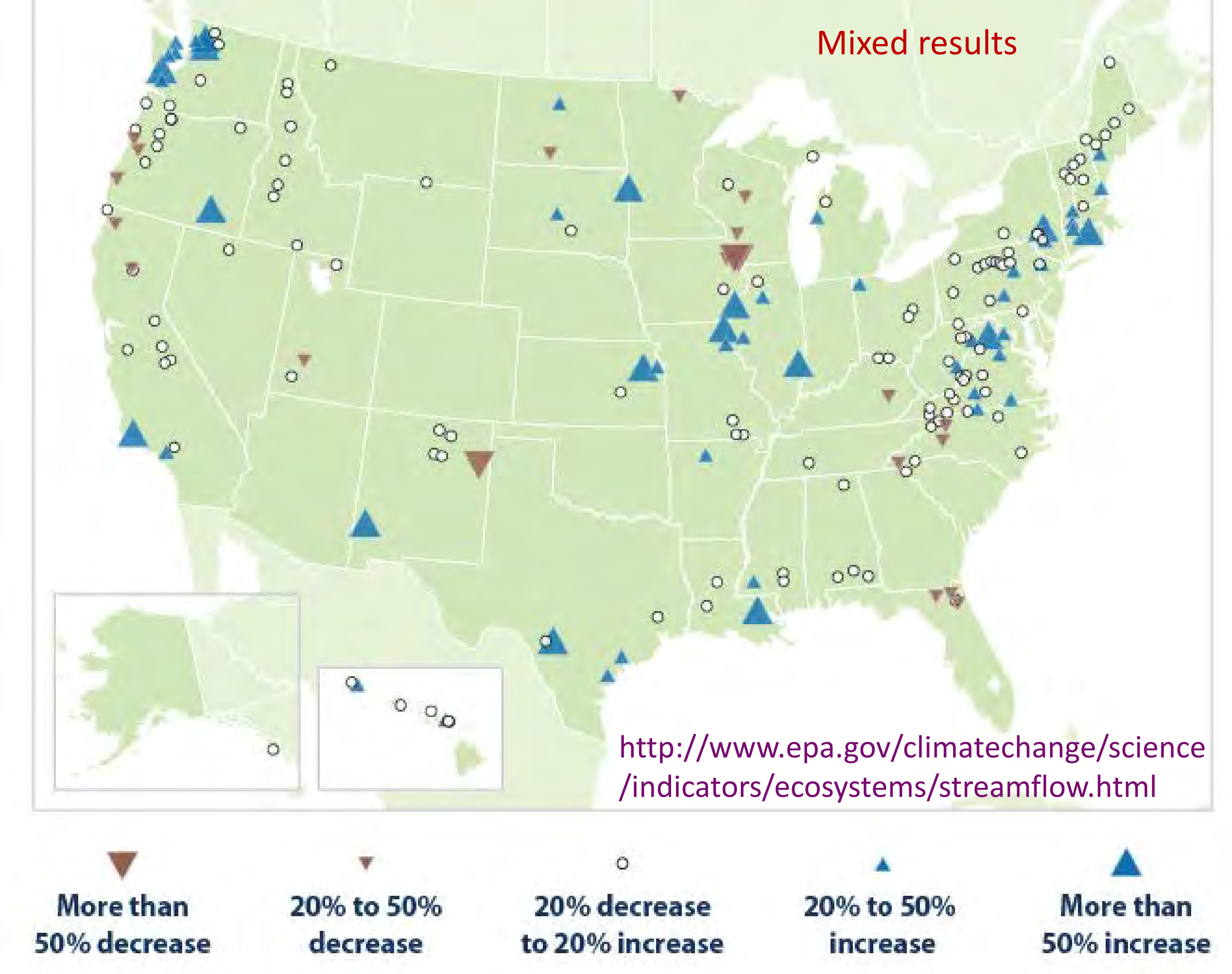
USGS science for a changing world

Timing of winter-spring runoff in the U.S., 1940-2012



http://www.epa.gov/climatechange/science/indicators/ecosystems/streamflow.html

Three-day high streamflows in the U.S., 1940-2012



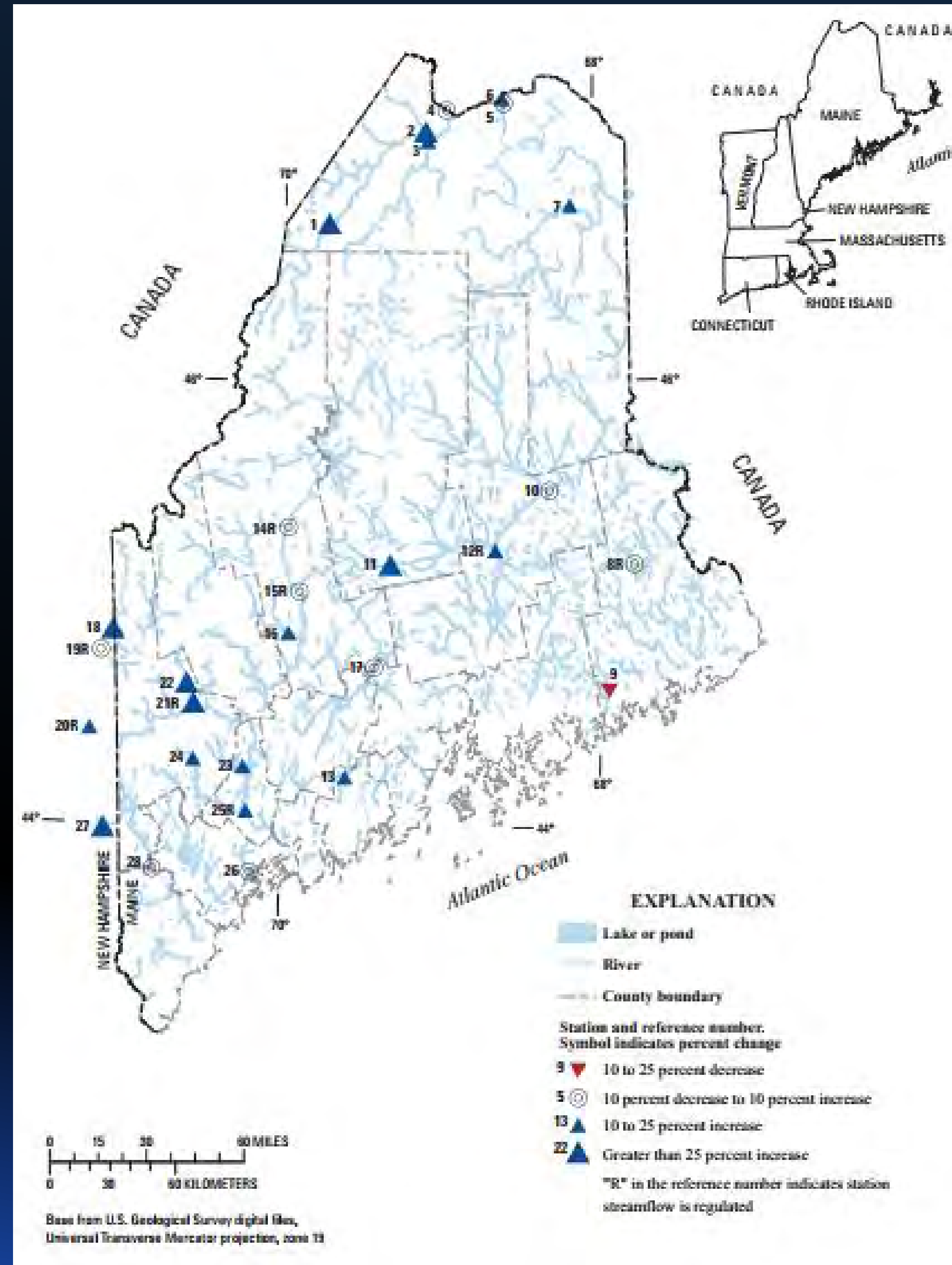
Historical changes in annual peak flows in Maine and implications for flood-frequency analyses

- Cooperative study with MaineDOT
  - USGS/MaineDOT cooperative studies related to peak flows started in 1960s
- Computed annual peak-flow trends over time in Maine using historical data
- Compared design peak flows (e.g. 100-year flows) based on full periods of record to design peak flows based on selected sub-periods

USGS
science for a changing world

Historical changes in annual peak flows in Maine

- Trends over time in the magnitude of annual peak flows through 2006
- Median increase 16% for 28 streamflow gages



USGS science for a changing world

Hodgkins, 2010

Implications for flood-frequency analyses

- Computed 100-year and 5-year design peak flows
  - Entire period of record
  - Rolling 30-year sub-periods
  - Pre/post 1970 peak flows
- Compared design peak flow estimates from sub-periods to those from the entire period

Implications for flood-frequency analyses

- Partial summary of results
  - Largest design peak flows were based on 1967-1996 sub-period (compared to estimates based on entire period)
    - 8 percent higher design peak flows for median river
  - Other recent periods also had higher design peak flows
    - Less than 8 percent

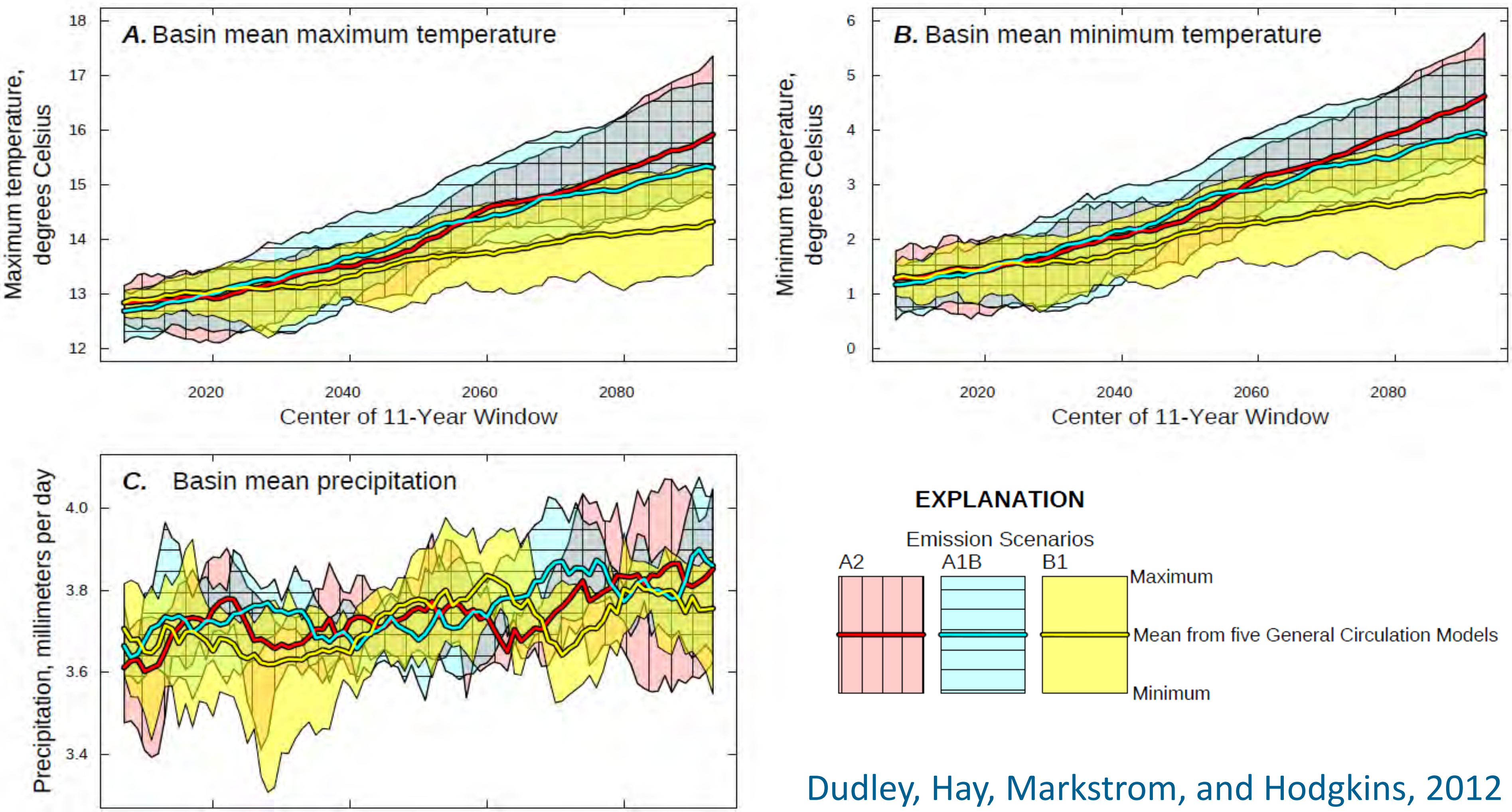
USGS science for a changing world

Hodgkins, 2010

Potential future streamflows in Maine

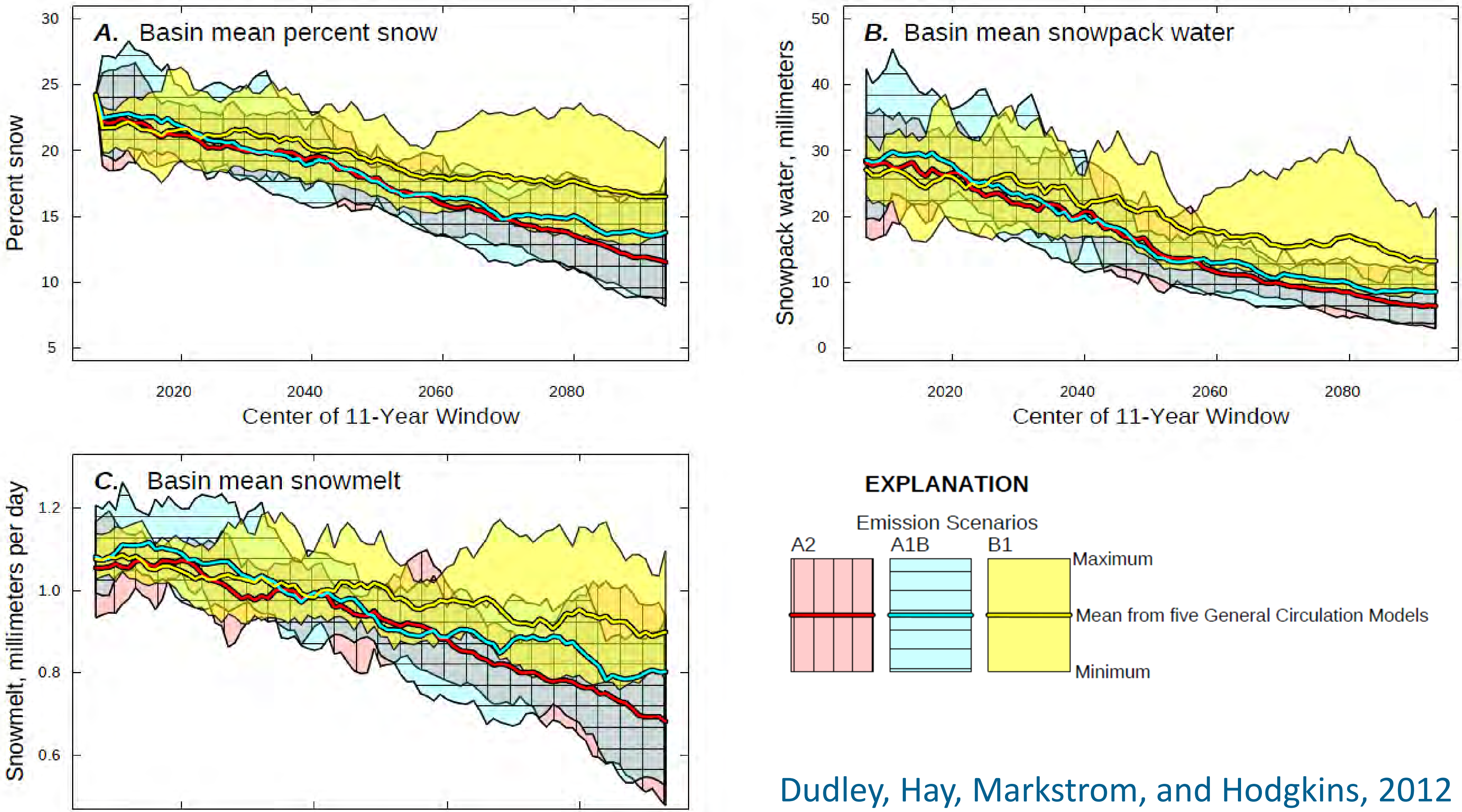
- PRMS models in 14 watersheds across the United States, including one in Downeast Maine
  - Used 5 different Global Circulation Models and 3 different carbon-emission scenarios to estimate future temperature and precipitation
  - PRMS-simulated streamflow based on future estimates of temperature and precipitation

Potential future streamflows in Maine
Cathance Stream watershed



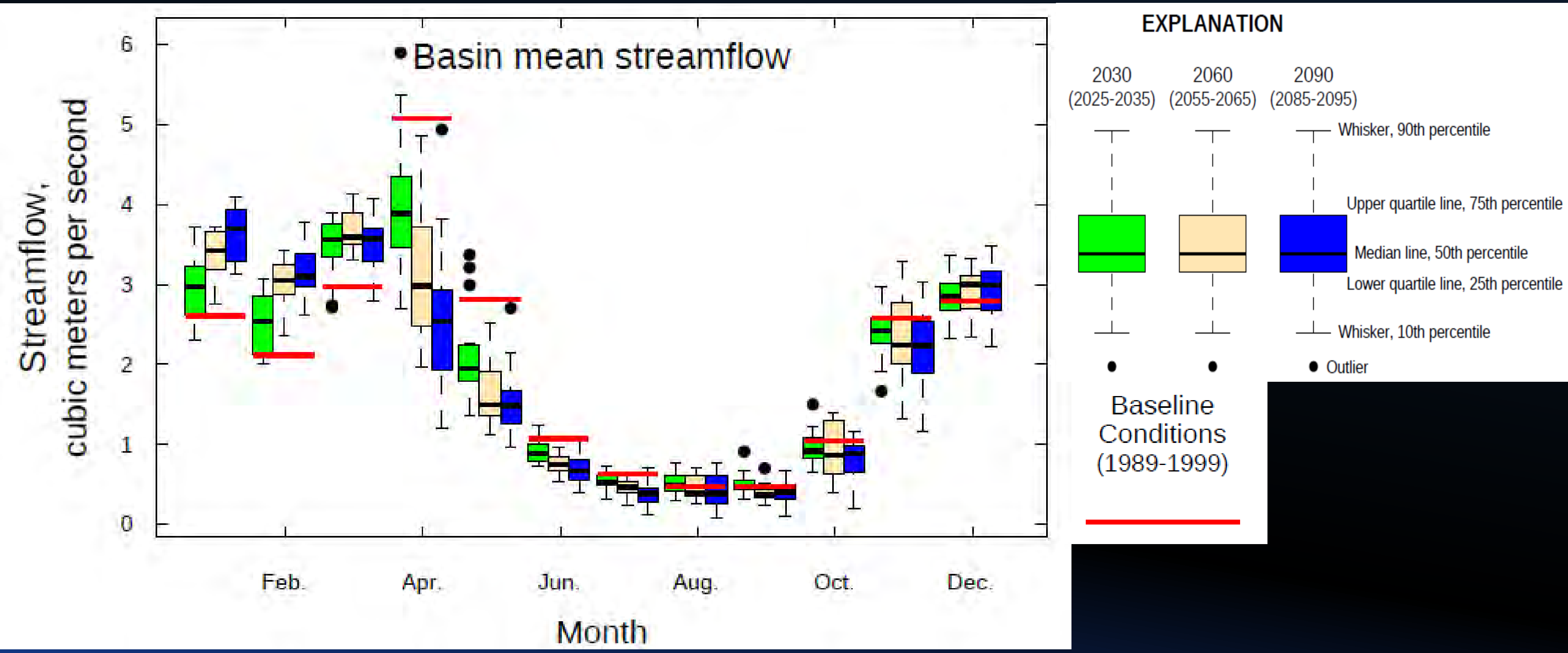
Dudley, Hay, Markstrom, and Hodgkins, 2012

Potential future streamflows in Maine
Cathance Stream watershed



Dudley, Hay, Markstrom, and Hodgkins, 2012

Potential future streamflows in Maine
Cathance Stream watershed



Dudley, Hay, Markstrom, and Hodgkins, 2012

Potential future changes in design peak flows in Maine

- Cooperative study with MaineDOT
- Calibrated PRMS watershed models of four Maine coastal basins
- Generated historical annual daily flows based on historical precipitation and temperatures
  - Compared to actual flows
- Computed design floods (e.g. 100-year peak flow) based on modeled historical daily flows
- Generated potential future design floods based on expected temperature and precipitation changes

Potential future changes in design peak flows in Maine

- Example model output: Change in 100-year peak flows for Royal River (southern Maine) based on selected temperature and precipitation changes
  - Compared to modeled peak flows with no changes

Temperature change

Precip Change	0° C	+2° C	+4° C	+6° C
0 %	0 %	-16 %	-24 %	-40 %
+15 %	+50 %	+20 %	+9 %	-12 %
+30 %	+94 %	+78 %	+55 %	+28 %

USGS science for a changing world

Hodgkins and Dudley, 2013

Potential future changes in design peak flows in Maine

- Why do flood flows decrease with increasing temperature?
- Modeled maximum annual snowpack water-equivalent changes in Royal River watershed

Temperature change

Precip Change	0° C	+2° C	+4° C	+6° C
0 %	0 %	-50 %	-75 %	-86 %
+15 %	+20 %	-38 %	-71 %	-83 %
+30 %	+42 %	-25 %	-67 %	-80 %

Hodgkins and Dudley, 2013

Summary

- Long-term streamflow data from minimally disturbed watersheds in different regions of Maine are important for looking at impacts of climate changes
- Historical annual peak flows have increased in Maine (median 16%)
- Historical design peak flows have increased modestly (median = or < 8%)
- Future design peak flows depend on relative future changes in temperature and precipitation

USGS science for a changing world

Glenn Hodgkins: gahodgki@usgs.gov

Assessing and Addressing Climate Change Impacts: *FHWA Resources*

Maine Climate Workshop

Cassie Chase, FHWA

October 10, 2014

Planning for the Future…

FHWA funds can be used for adaptation activities

FHWA can provide research and technical assistance: information, tools that State DOTs, MPOs and local agencies can use to assess risk and improve resilience

GROW AMERICA would add consideration of resilience, adaptation

"U.S. average temperature has increased by 1.3°F to 1.9°F since 1895, and most of this increase has occurred since 1970." – NCA

"Temperatures are projected to rise another 2°F to 4°F in most areas of the United States over [just] the next few decades." – NCA

Climate Change Adaptation at FHWA

Goal: Regular/Systematic consideration of climate change vulnerability and risk in transportation decision making, at:

- 1) **Systems Level**: Transportation Planning, Asset Management
- 2) **Project Level**: Environmental process, Preliminary Engineering, Design, Construction, Operations, Maintenance

Three breaches in NC12 after Hurricane Irene. Credit: Tom MacKenzie, FWS

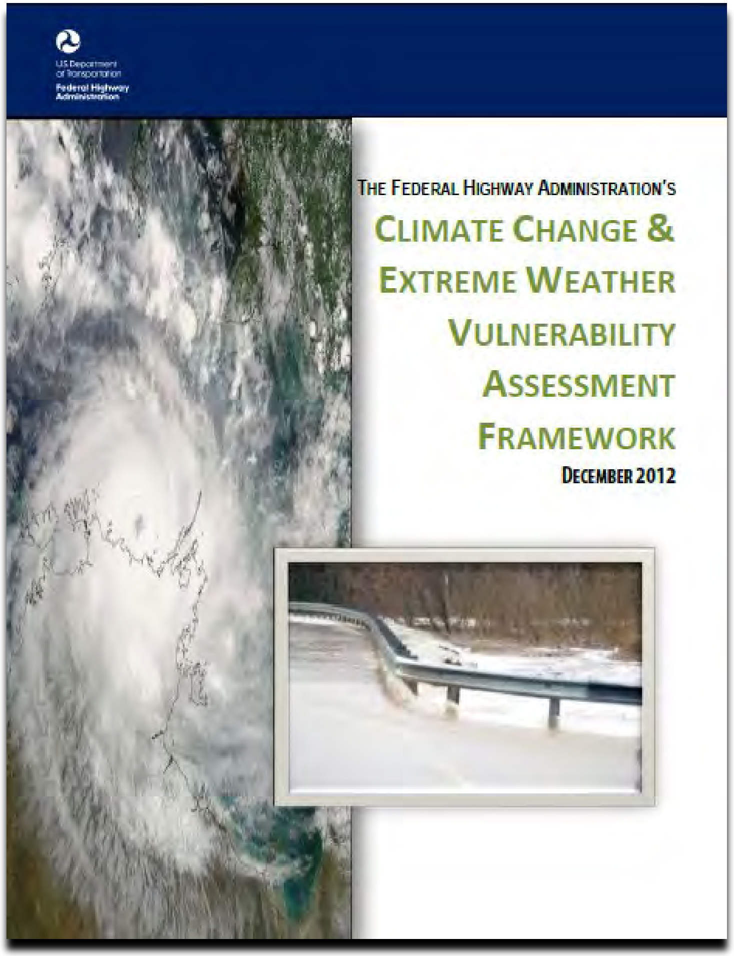
Systems Level Goal: Consideration in Transportation Planning, Asset Management

<u>Key Products</u>:

- *Climate Change & Extreme Weather Vulnerability Assessment Framework* (December 2012), currently being updated, expected release in 2015.

<u>Activities:</u>

- Climate Change Resilience Pilots
- *Gulf Coast 2 (Mobile)*
- *Hurricane Sandy Follow-up and Vulnerability Assessment & Adaptation Analysis*



Project Level Goal: Consideration in Environmental Process, Preliminary Engineering, Design, Construction, Operations, Maintenance

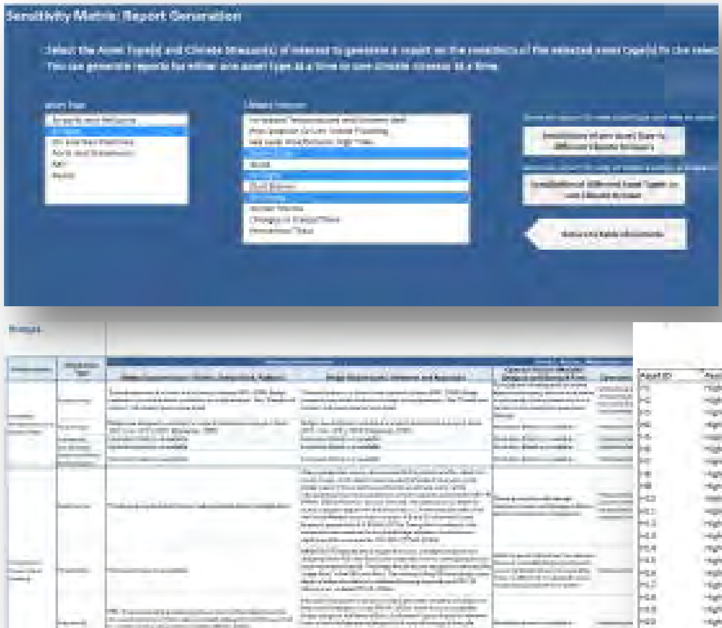
Key Products:

- Updated engineering manuals, methods and processes

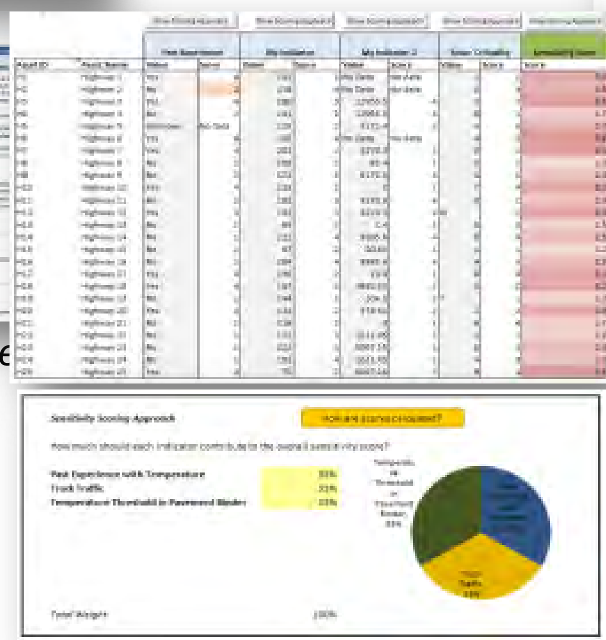
Activities:

- Engineering Assessments
- *HEC 25 - Vol 2: Highways in the Coastal Environment: Extreme Events*
- *HEC-17 - 2nd edition: Highways in the River Environment: Extreme Events, Risk and Resilience*
- Hydrology, hydraulic engineering research efforts, etc.

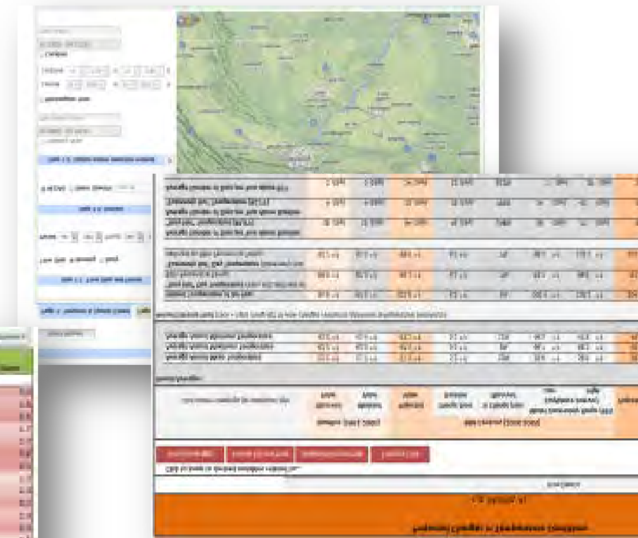
Tools



Transportation Climate Change Sensitivity Matrix



Vulnerability Assessment Scoring Tool (VAST)



CMIP Climate Data Processing Tool

U.S. Department of Transportation
Federal Highway Administration

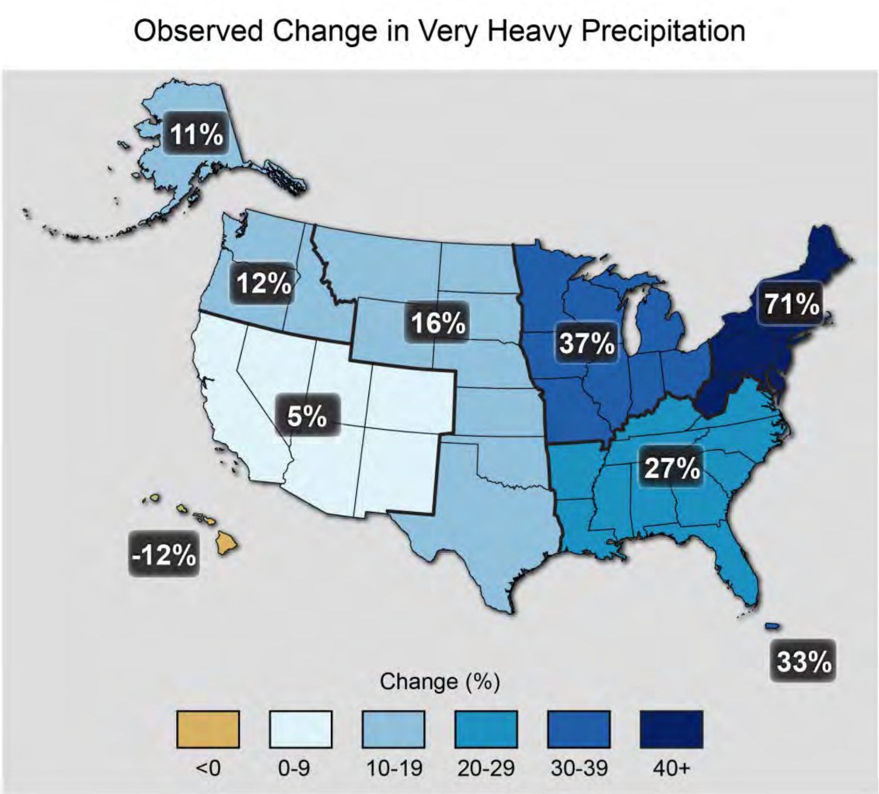
USDOT/FHWA Tools in Use

Pilots using the tools

- Tennessee DOT – CMIP and VAST
- Arizona DOT – CMIP
- CAMPO (Austin, TX) – Sensitivity Matrix, VAST
- Maryland SHA – VAST
- New York State DOT – CMIP
- Oregon DOT – CMIP
- Broward County – CMIP
- Maine DOT – "using tools" (didn't specify which ones)

Non-pilots using the tools

- Ohio DOT Resiliency Plan – VAST
- DVRPC – Sensitivity Matrix, CMIP
- Philadelphia Mayor's Office of Sustainability adaptation plan – CMIP



Percent increases in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events) from 1958 to 2012 for each region of the continental United States. Source: Karl et al. 2009.

Thank you!

http://www.fhwa.dot.gov/environment/climate_change/adaptation/

Cassie Chase
207-512-4921
Cassandra.chase@dot.gov

Becky Lupes
202-366-7808
Rebecca.lupes@dot.gov

Responding to Maine Climate Needs:
A Roundtable Showcasing Available Climate Data and Tools

October 10, 2014

Panel: Impacts of Sea Level Rise on Infrastructure

Impacts of Sea Level Rise on Infrastructure: Statewide Datasets and Highlighted Projects and Efforts
Peter Slovinsky, Maine Geological Survey

Climate Change Adaptation for Critical Infrastructure
William DeLong, Department of Homeland Security

Advancing Water Sector and Community Resiliency
Jane Downing, US EPA Region 1

Integrating Climate Considerations into Asset Management at Maine DOT
Judy Gates, Maine DOT

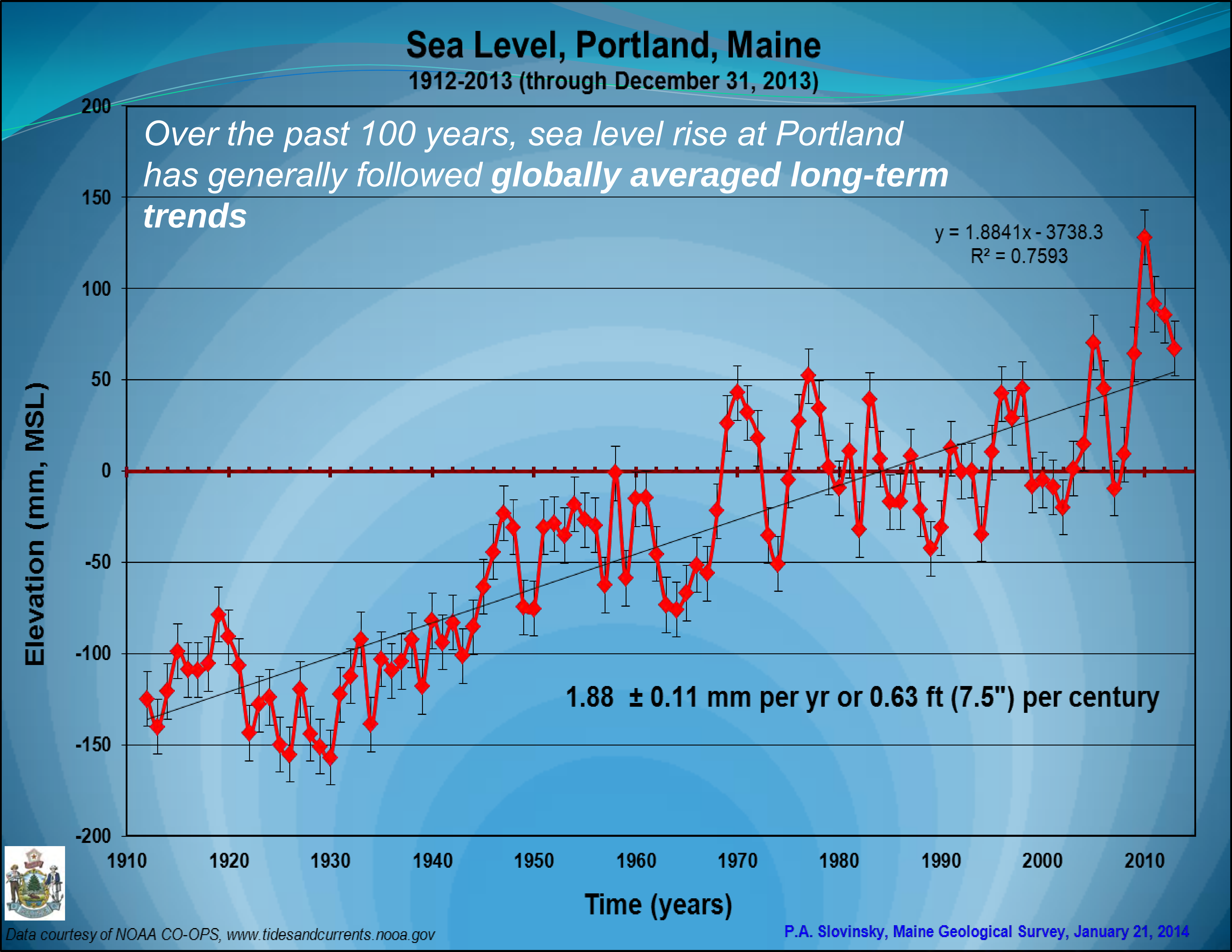
Impacts of Sea Level Rise on Infrastructure: Statewide Datasets and Highlighted Projects and Efforts

October 10, 2014

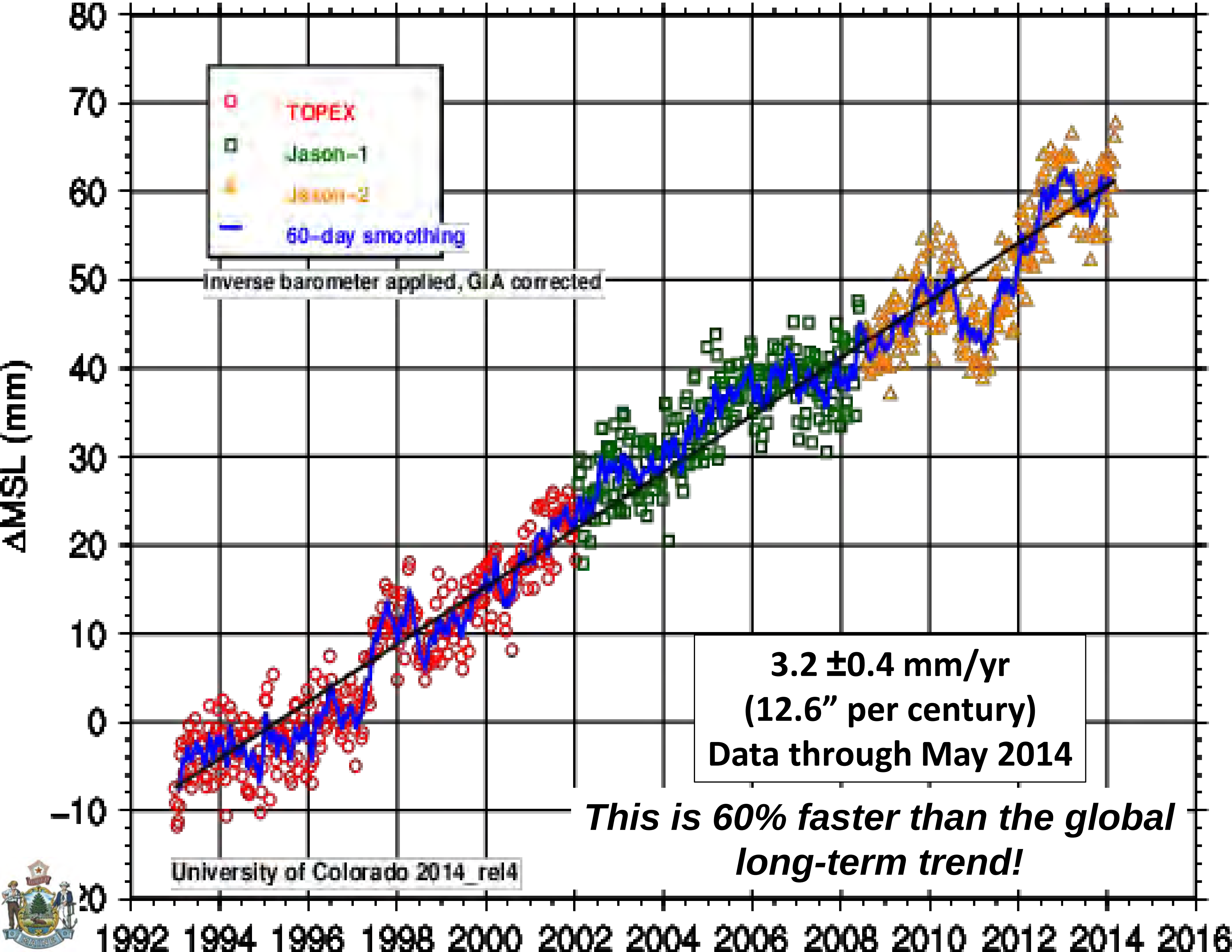
Peter A. Slovinsky, Marine Geologist
Maine Geological Survey
Bureau of Resource Information and Land Use Planning
Department of Agriculture, Conservation and Forestry

I'll quickly cover….

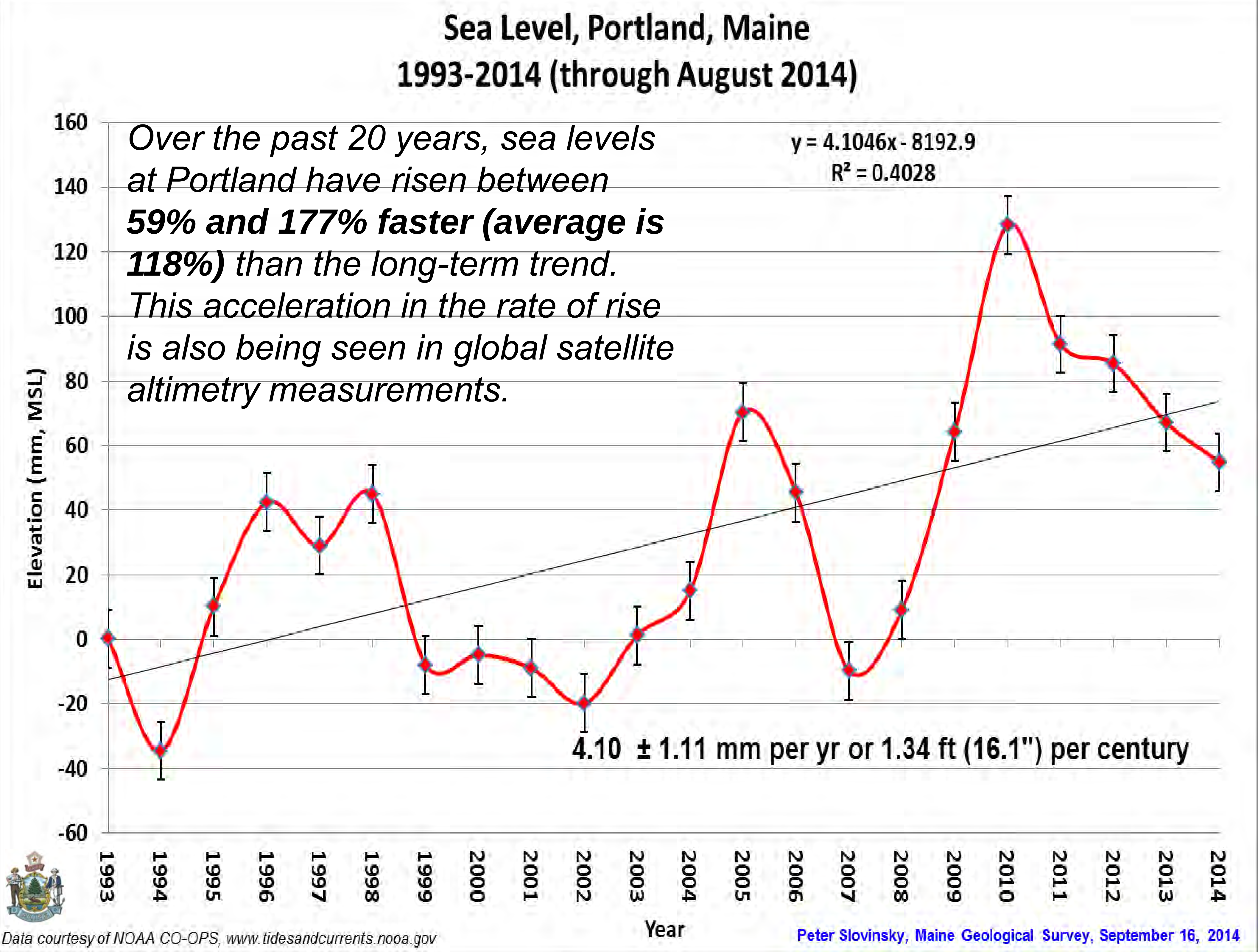
- Setting the stage: summary on the latest sea level rise trends and historical storm surge data in Maine
- Impacts of sea level rise on "nuisance flooding"
- Statewide datasets supporting infrastructure resiliency
  - Potential Hurricane Inundation Mapping Tool
  - Highest Annual Tide Mapping Tool
- A few local efforts on infrastructure resiliency

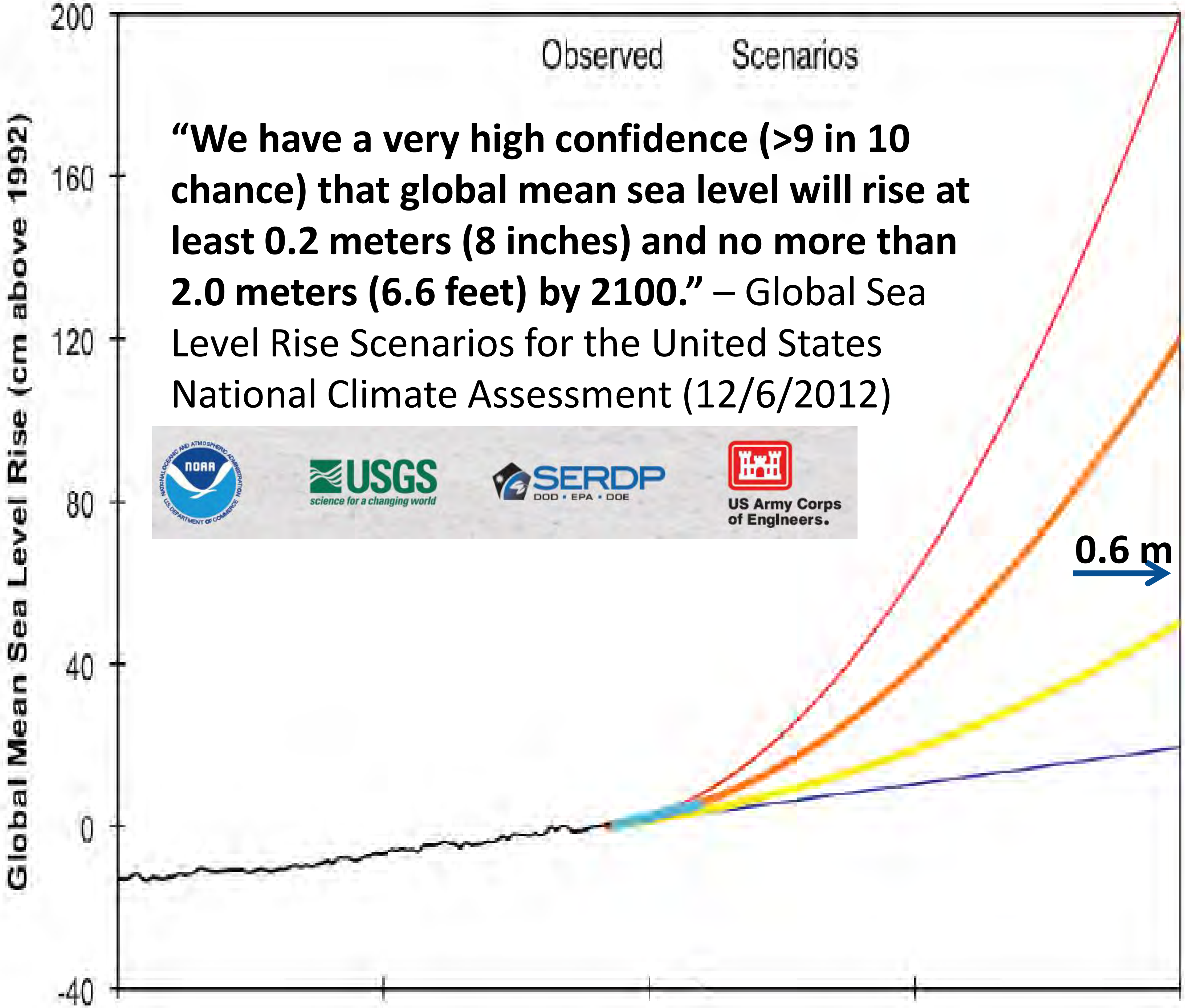


Sea Level, Portland, Maine
1912-2013 (through December 31, 2013)
Over the past 100 years, sea level rise at Portland has generally followed globally averaged long-term trends
y = 1.8841x - 3738.3
R² = 0.7593
1.88 ± 0.11 mm per yr or 0.63 ft (7.5") per century
Elevation (mm, MSL)
200
150
100
50
0
-50
-100
-150
-200
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Time (years)
Data courtesy of NOAA CO-OPS, www.tidesandcurrents.noaa.gov
P.A. Slovinsky, Maine Geological Survey, January 21, 2014



TOPEX
Jason-1
Jason-2
60-day smoothing
Inverse barometer applied, GIA corrected
ΔMSL (mm)
80
70
60
50
40
30
20
10
0
−10
20
1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016
3.2 ±0.4 mm/yr
(12.6” per century)
Data through May 2014
This is 60% faster than the global long-term trend!
University of Colorado 2014_rel4


Sea Level, Portland, Maine
1993-2014 (through August 2014)
Over the past 20 years, sea levels at Portland have risen between 59% and 177% faster (average is 118%) than the long-term trend. This acceleration in the rate of rise is also being seen in global satellite altimetry measurements.
y = 4.1046x - 8192.9
R² = 0.4028
4.10 ± 1.11 mm per yr or 1.34 ft (16.1") per century
Elevation (mm, MSL)
160
140
120
100
80
60
40
20
0
-20
-40
-60
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year
Data courtesy of NOAA CO-OPS, www.tidesandcurrents.noaa.gov
Peter Slovinsky, Maine Geological Survey, September 16, 2014



"We have a very high confidence (>9 in 10 chance) that global mean sea level will rise at least 0.2 meters (8 inches) and no more than 2.0 meters (6.6 feet) by 2100." – Global Sea Level Rise Scenarios for the United States National Climate Assessment (12/6/2012)

NOAA · USGS science for a changing world · SERDP DOD • EPA • DOE · US Army Corps of Engineers

Highest
(2.0 m, 6.6 ft)
*Combines maximum warming, thermal expansion, and possible ice sheet loss from semi-empirical models.

Intermediate-High
(1.2 m, 3.9 ft)
*Average of high end global predictions, combines recent ice sheet loss and thermal expansion

Intermediate-Low
(0.5 m, 1.6 ft)
*Includes only thermal expansion from warming from IPCC AR4.

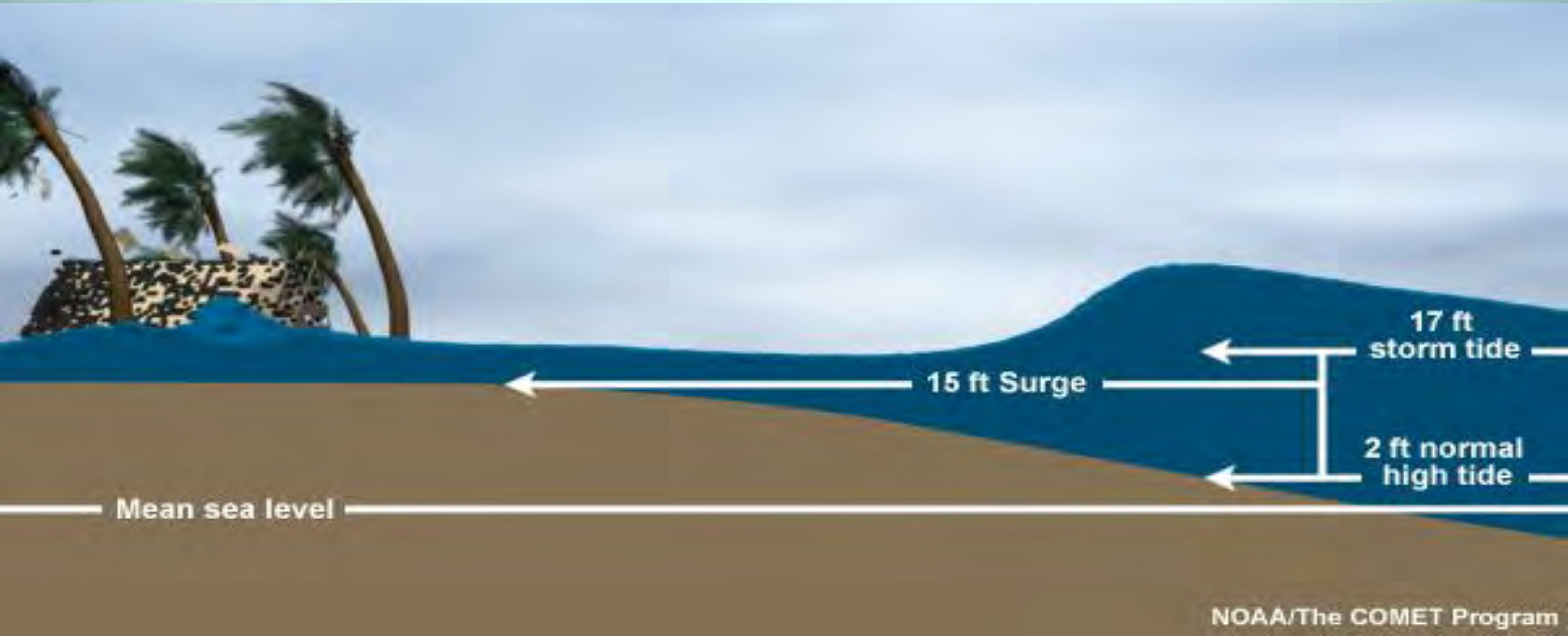
Lowest
(0.2 m, 0.7 ft)
* Historical trend continued; no additional thermal expansion from warming

Recommend using a "Scenario" Based Approach

What about storm tides and storm surges?

So what is storm surge?

Storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tides. Storm surge should not be confused with storm tide, which is defined as the water level rise due to the combination of storm surge and the astronomical tide (National Hurricane Center)



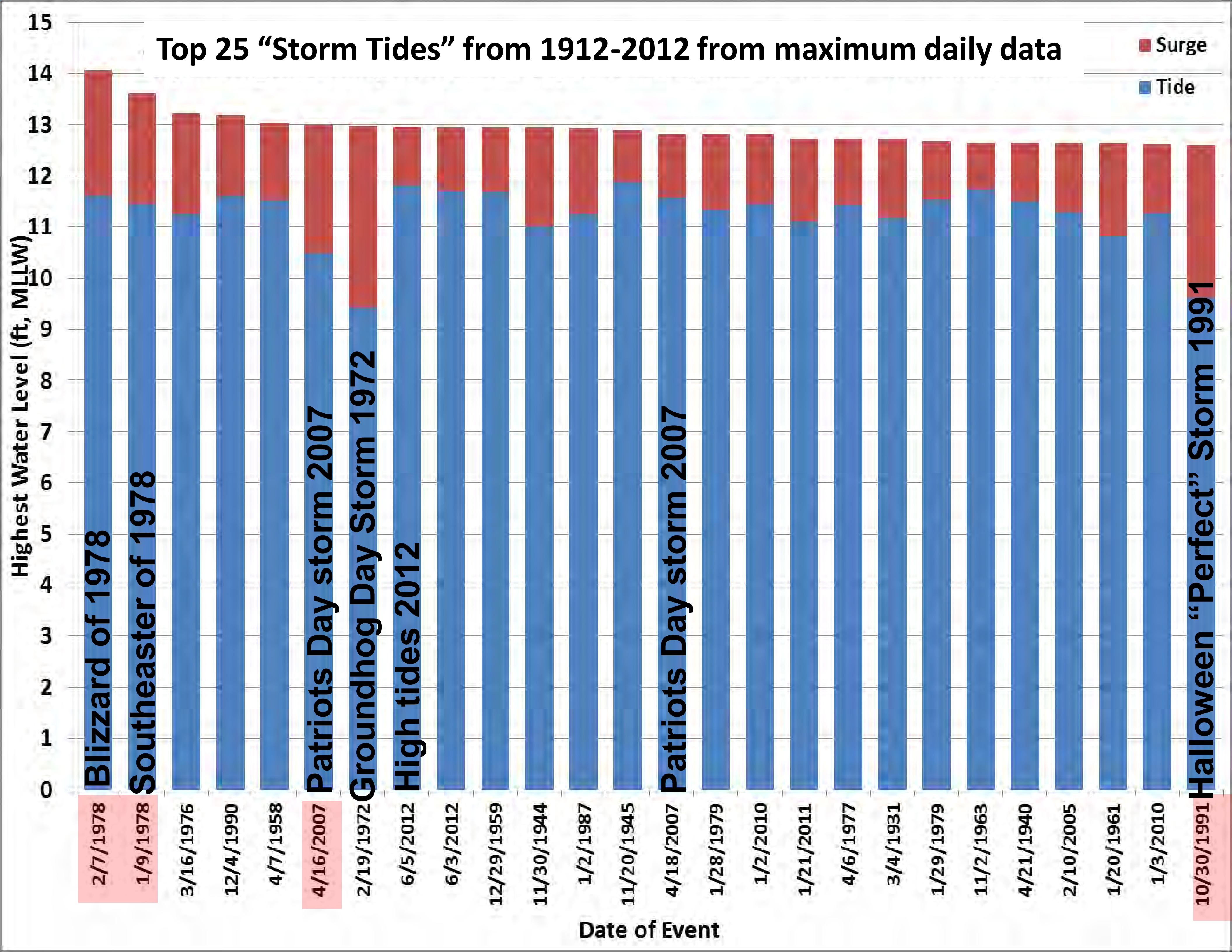
Portland Storm Surges, any tide (1912-2012)

Time Interval (years)	Surge Height (feet)
1 (100 %)	1.8
2 (50%)	2.4
5 (20%)	3.3
10 (10 %)	4.0
20 (5%)	4.7
25 (4 %)	4.9
50 (2 %)	5.6
75 (1.3 %)	6.0
100 (1%)	6.3

These numbers correlate ***well with overall longer term sea level rise planning!***

P.A. Slovinsky, MGS

Because of Maine’s tidal variation, it’s *the combination of astronomical tide and “storm surge” that are of concern* (NHC calls this overall water level the **“storm tide”**)


Top 25 "Storm Tides" from 1912-2012 from maximum daily data
Surge
Tide
Highest Water Level (ft, MLLW)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Blizzard of 1978
Southeaster of 1978
Patriots Day storm 2007
Groundhog Day Storm 1972
High tides 2012
Patriots Day storm 2007
Halloween "Perfect" Storm 1991
2/7/1978
1/9/1978
3/16/1976
12/4/1990
4/7/1958
4/16/2007
2/19/1972
6/5/2012
6/3/2012
12/29/1959
11/30/1944
1/2/1987
11/20/1945
4/18/2007
1/28/1979
1/2/2010
1/21/2011
4/6/1977
3/4/1931
1/29/1979
11/2/1963
4/21/1940
2/10/2005
1/20/1961
1/3/2010
10/30/1991
Date of Event

Portland “Storm Tides”, 1912-2012

ge	Interval (yrs)	“Storm Tide” Level (ft, MLLW)	ter
	1 (100 %)	1.1 11.7	
	5 (20%)	2 12.6	
	10 (10 %)	2.4 12.9	
	25 (4 %)	2.9 13.4	
	50 (2 %)	3.3 13.7	
	100 (1 %)	3.7 14.1	

Portland "Storm Tides", 1912-2012

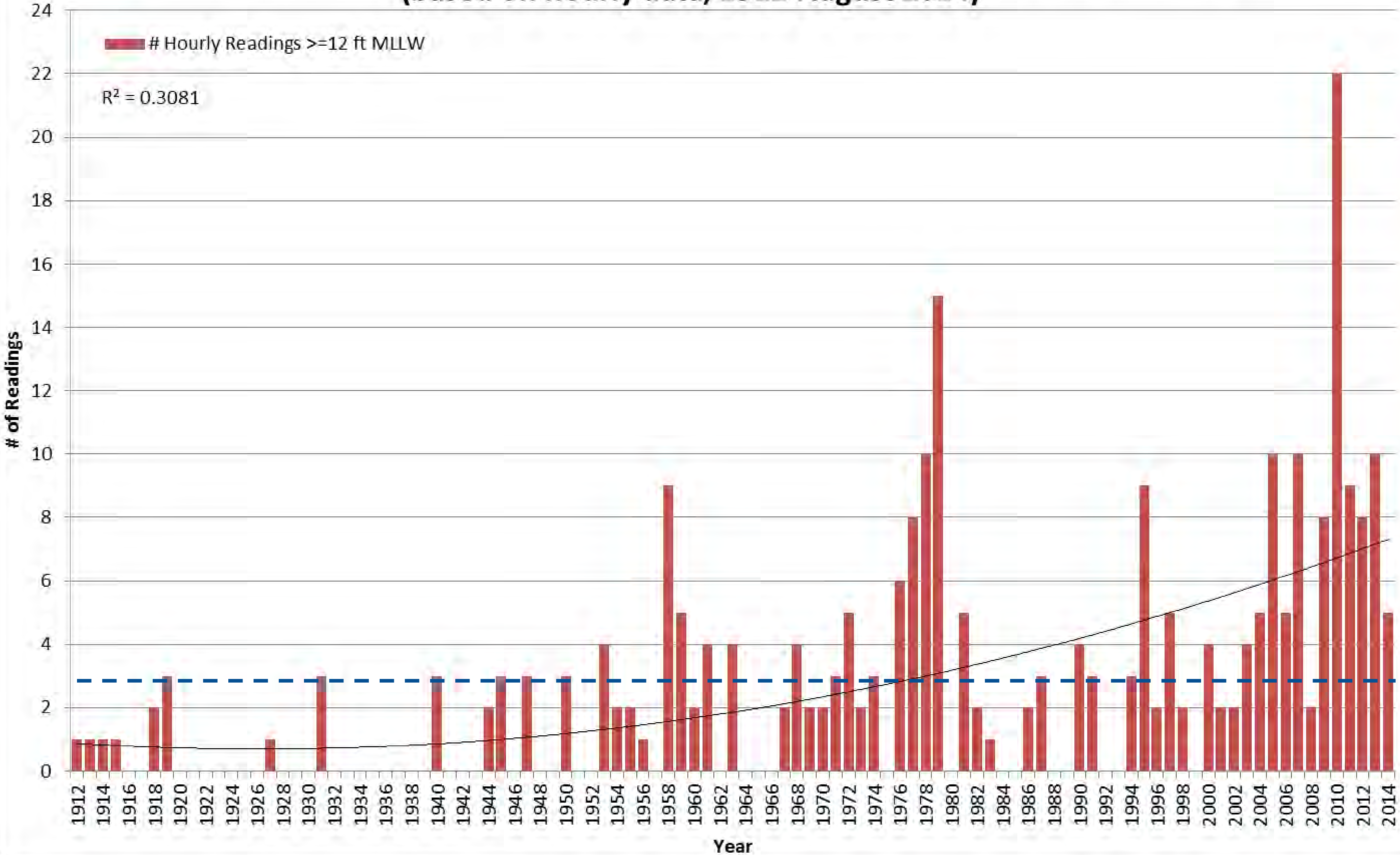
ge	Interval (yrs)	"Storm Tide" Level (ft, MLLW)	ter
	1 (100 %)	1.1 11.7	
	5 (20%)	2 12.6	
	10 (10 %)	2.4 12.9	
	25 (4 %)	2.9 13.4	
	50 (2 %)	3.3 13.7	
	100 (1 %)	3.7 14.1	

1 foot difference!

How has "nuisance" flooding along Portland's waterfront infrastructure increased, and how might SLR impact it?

"King Tide" 12:15 pm, October 9, 2014
Cameron Adams, MGS

Existing Frequency of Inundation meeting or exceeding 12 ft MLLW at Portland (based on hourly data, 1912-August 2014)



Existing Conditions (flood stage = 12 ft MLLW)
Historic Average # of hourly readings/year = 2.6
Current Trend ~ 8 readings/year

Data from NOAA CO-OPS

Changes in Annual Flooding Duration with SLR (using 2013 as a “representative” year)

Scenario	Flood Stage (ft, MLLW)	# times inundated	% of high tides	Duration, hrs
Existing Flood	12.0	8	1.1%	8.6
+1 ft SLR	11.0	87	12.4%	121.8
+2 ft SLR	10.0	312	44.4%	575.3
+3.3 ft SLR	8.7	616	87.6%	1748.5
+6 ft SLR	6.0	702	99.9%	3816.3

based on 2013 Portland tidal station data from the NOAA Inundation Analysis Tool

Based on this, there would potentially be a *tenfold increase in the frequency of flooding* with one foot of sea level rise.

Similar types of analyses can be completed using the Inundation Analysis Tool or longer-term hourly datasets for almost **any critical infrastructure as long as the flood elevation is known, and tidal prediction data exists proximal to the site.**

Sea Level and Storm Surge Summaries

- Latest scientific predictions for SLR:
  - Short Term: approximately 1 ft by 2050
  - Long Term: 2-4 ft *but potentially more* by 2100;
  - the **State of Maine has adopted 2 feet by the year 2100 for areas with regulated Coastal Sand Dunes**.
- Along the Maine coast, there is only about a one foot difference between the "10 year" event and the "100 year" event ; **a one-foot rise in sea level by 2050 would lower the "100 year" event recurrence interval to about 10 years.**
- Sea level rise increases both the **frequency and duration of annual tidal and storm-driven flood events.**
- We suggest examining scenarios of **1 foot, 2 feet, 3.3 feet, and 6 feet** on top of the highest annual tide (HAT). These scenarios relate to the National Climate Assessment, and also **correspond well with evaluating potential impacts from storm surges that may coincide with higher tides today.**

Statewide Datasets supporting Infrastructure Resiliency

Maine's Potential Hurricane Inundation Mapping Tool

Maine's Highest Annual Tide Mapping Tool

Potential uses of these datasets…

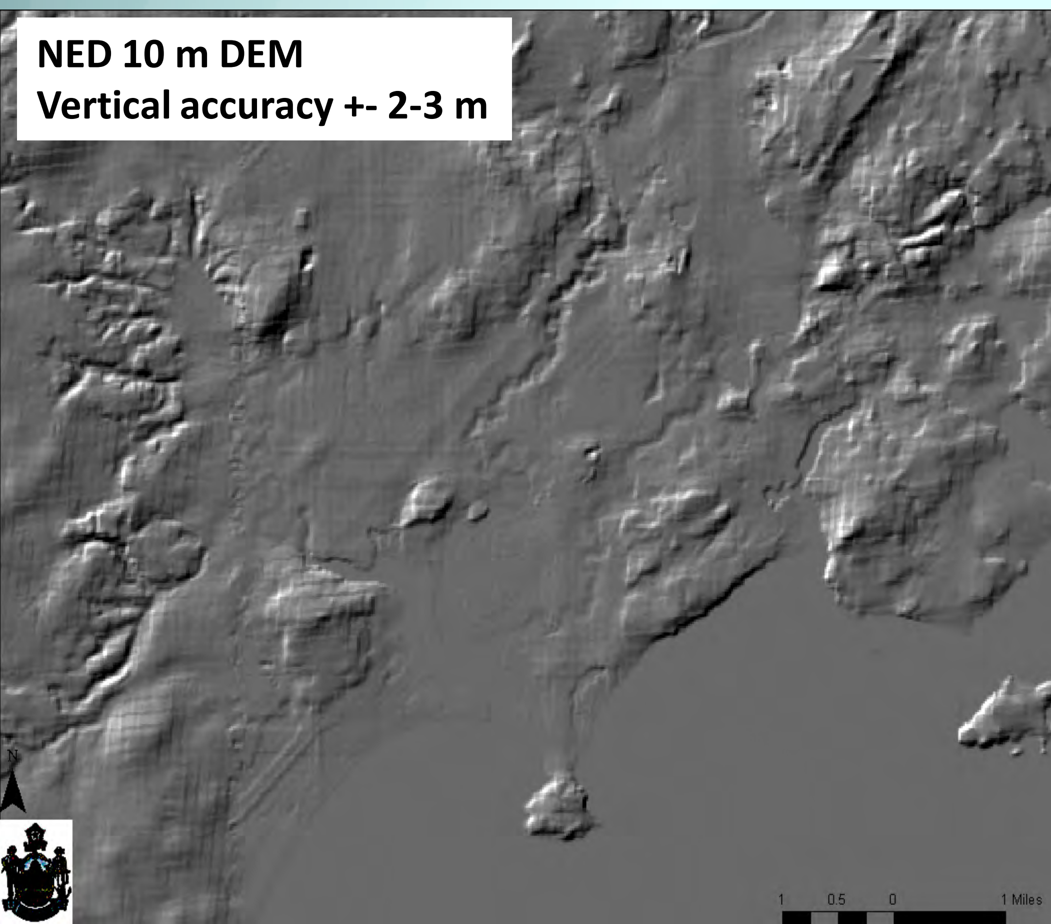
Potential Hurricane Inundation Mapping – emergency preparedness and management purposes only.

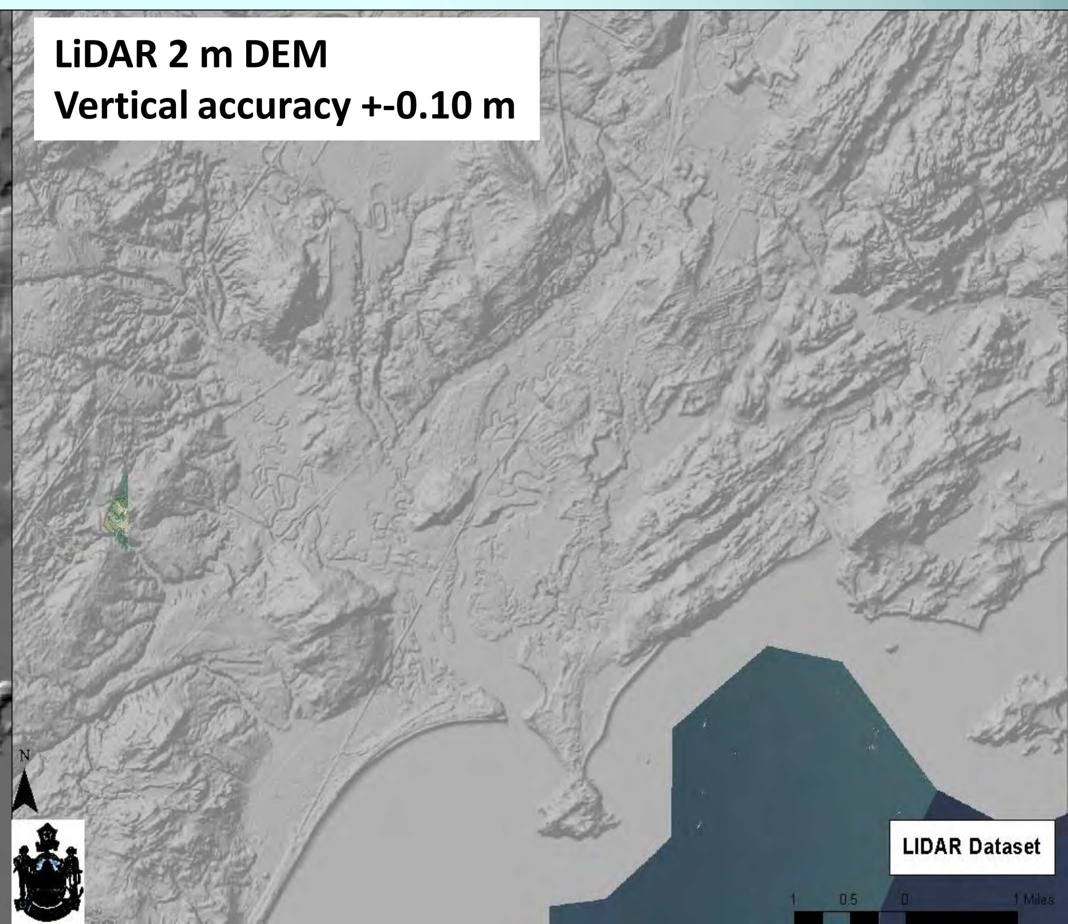
Highest Annual Tide Mapping – coastal infrastructure planning and resiliency, natural resource resiliency, sea level rise and storm surge planning, regulatory purposes (Shoreland Zoning).

Potential Hurricane Inundation Mapping (or PHIM) Tool

Previous (2005) Sea, Lake, and Overland Surges from Hurricanes (SLOSH) mapping was completed by US Army Corps as part of the National Hurricane Partnership. This dataset used an older version of the SLOSH Model, and National Elevation (NED) topographic data.

Since then, the SLOSH model was improved, and Maine now has LiDAR.





Potential Hurricane Inundation Mapping Process

- Effort **funded by FEMA** through a grant to Maine's Floodplain Management Office.

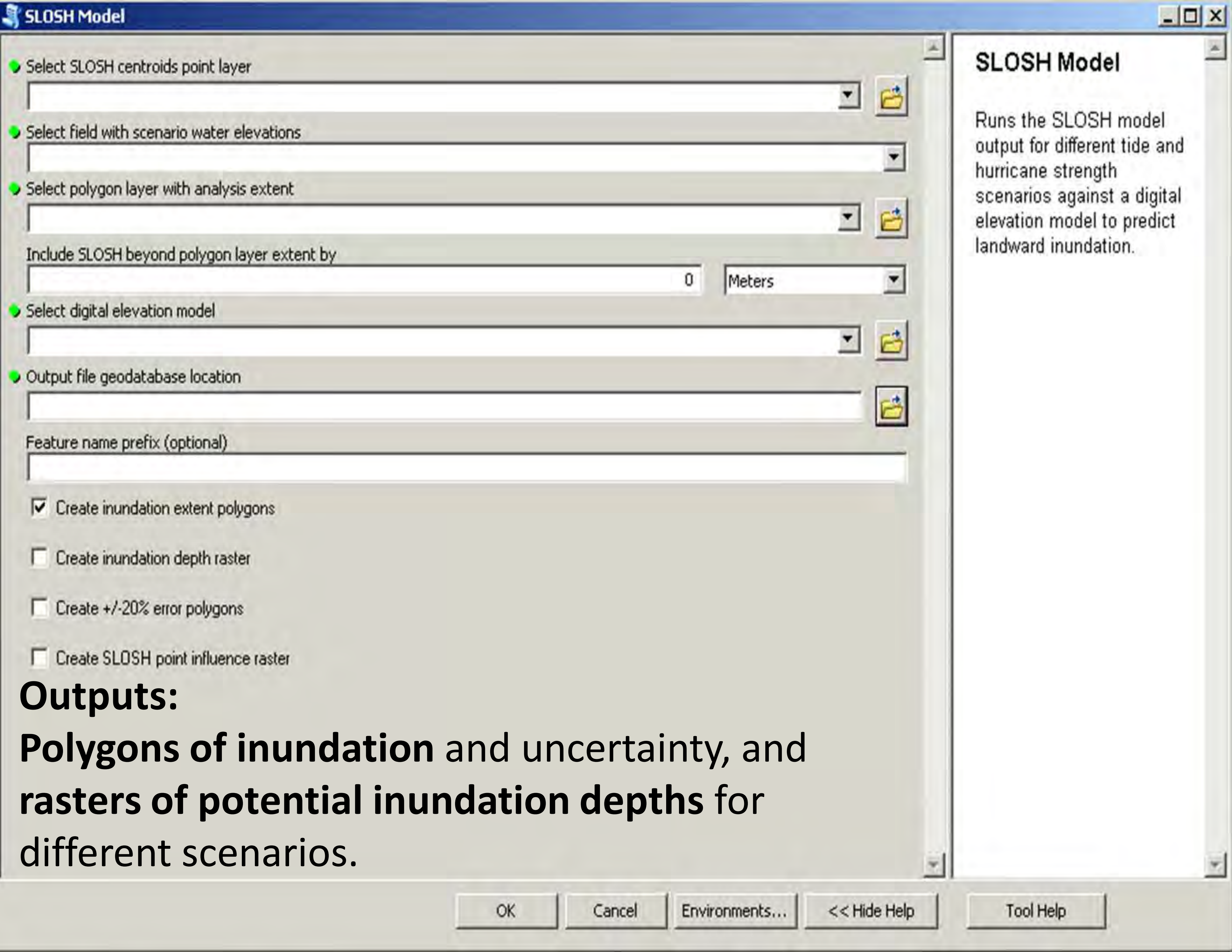
- **Consulted with National Hurricane Partnership representatives** on tool development, proposed process, and techniques

- Developed a GIS-based tool that uses **SLOSH model outputs, LiDAR data, and interpolation** to inundate areas

- "Ground-truthed" the tool by using NED topographic data to **re-create the older (2005) SLOSH inundation layers**.

- Ran the tool for the Maine coastline using **worst-case scenarios** (Maximum of Maximum Envelopes of Water, or MOMs)

- Created a **state-wide SLOSH dataset for Category 1 and 2 events, with a +20% model uncertainty.**



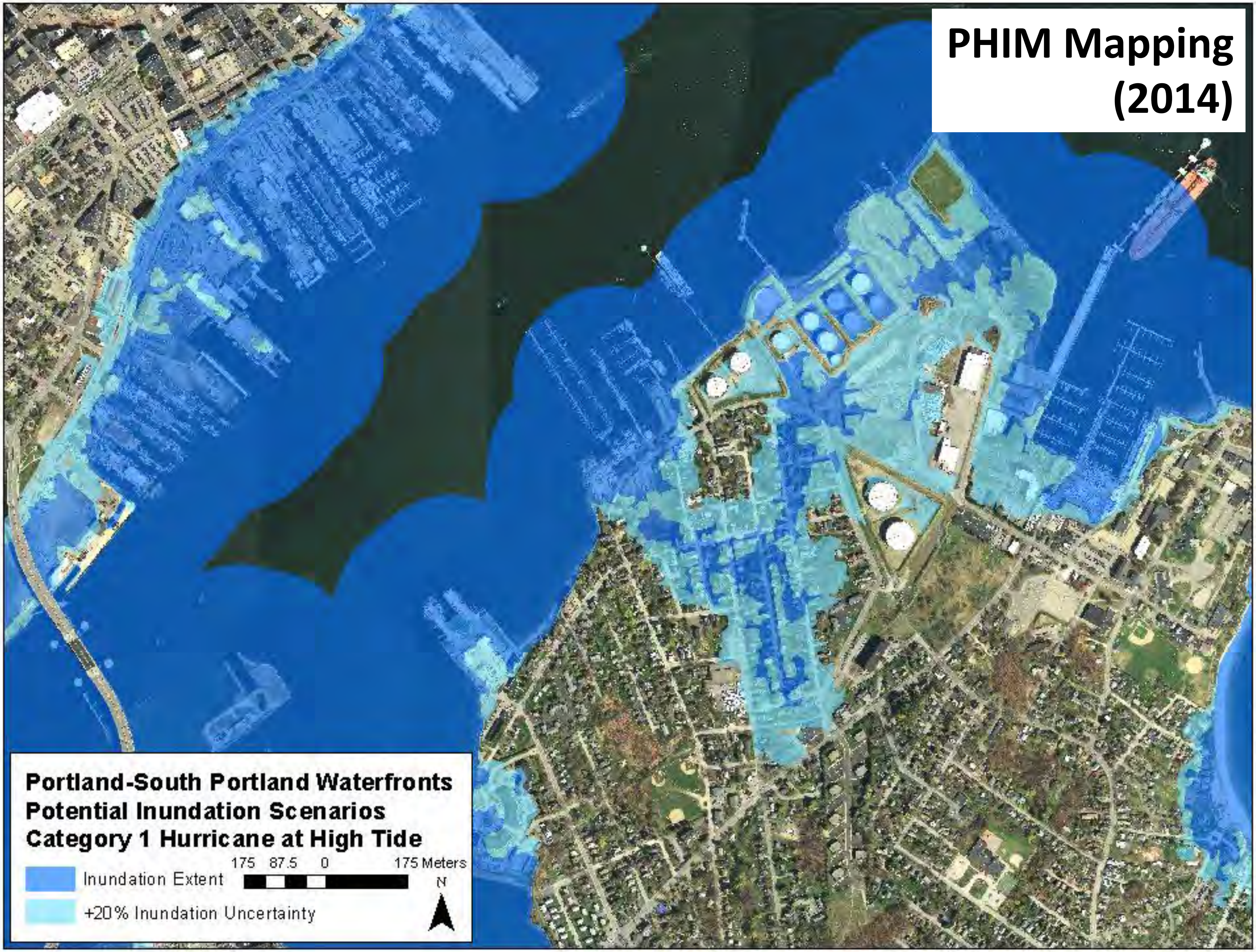
Outputs:

Polygons of inundation and uncertainty, and **rasters of potential inundation depths** for different scenarios.

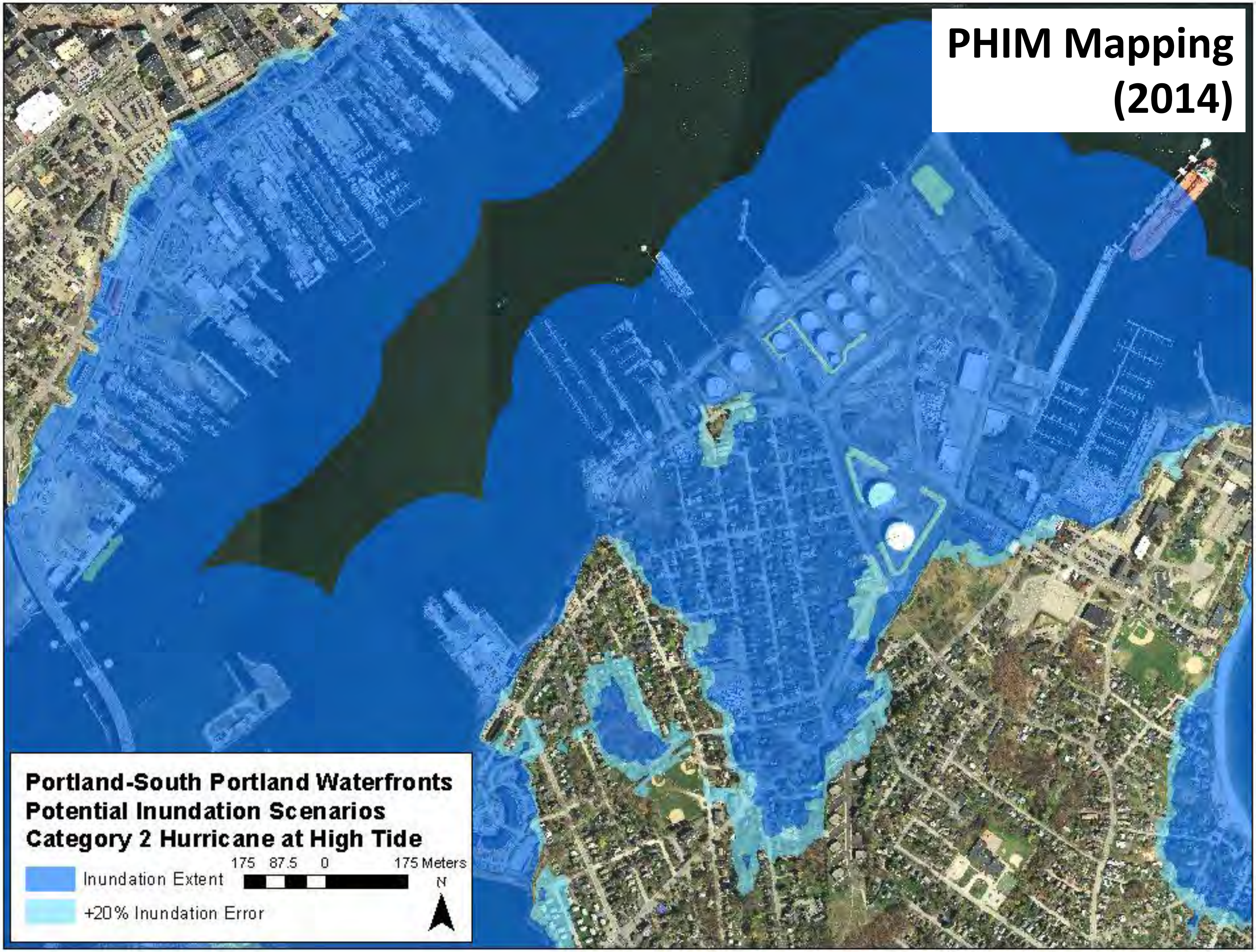

0
175 Meters
Portland-South Portland Waterfronts
Potential Inundation Scenarios

SLOSH Mapping (2005)

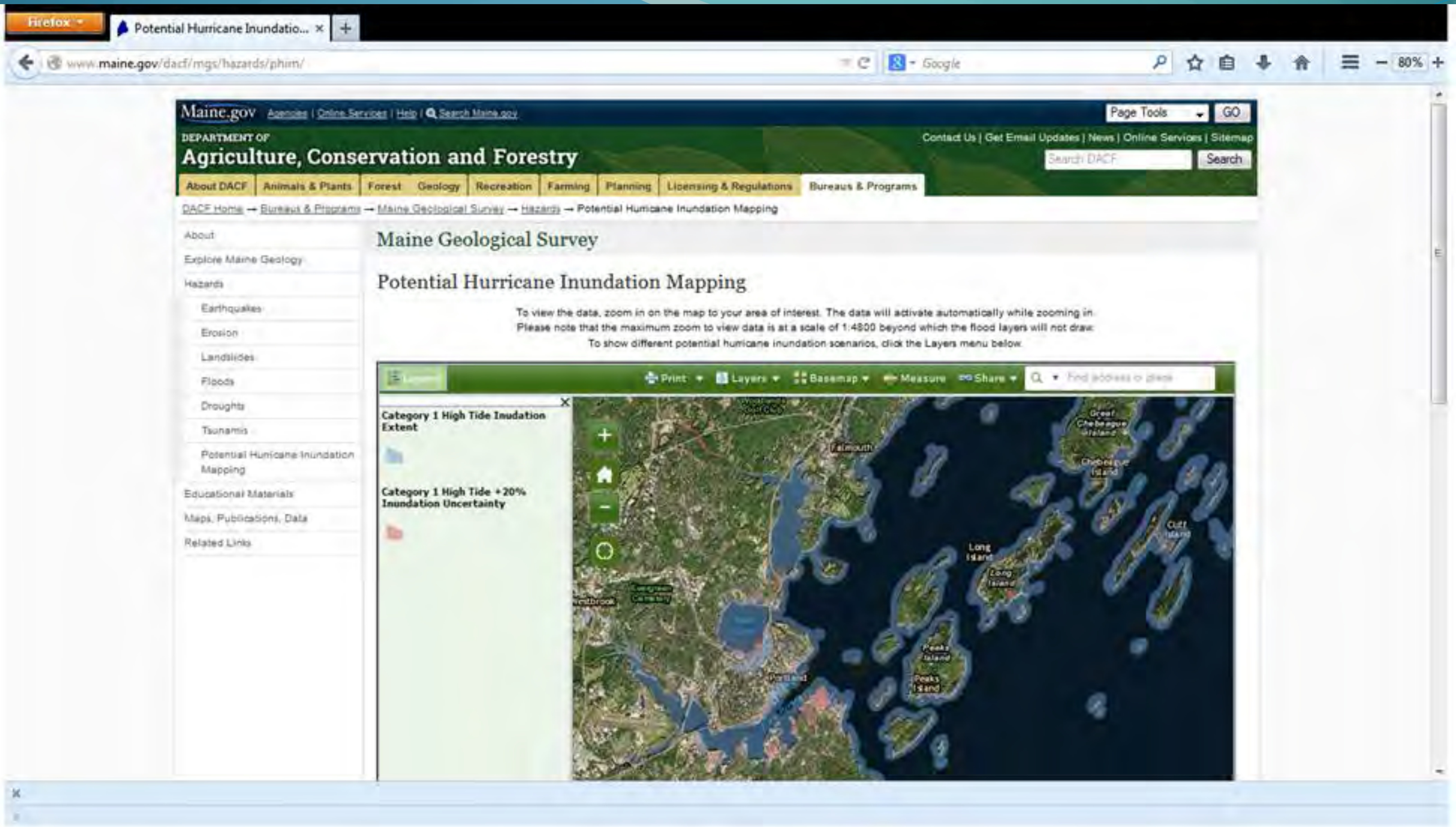
For general planning purposes only



For general planning purposes only



For general planning purposes only



Developed a Potential Hurricane Inundation Mapping Website

http://www.maine.gov/dacf/mgs/hazards/phim/

Includes ArcGIS online data viewer, FAQs, assumptions and limitations, etc.

Postcard mailings to local and county EMAs, planners, etc.

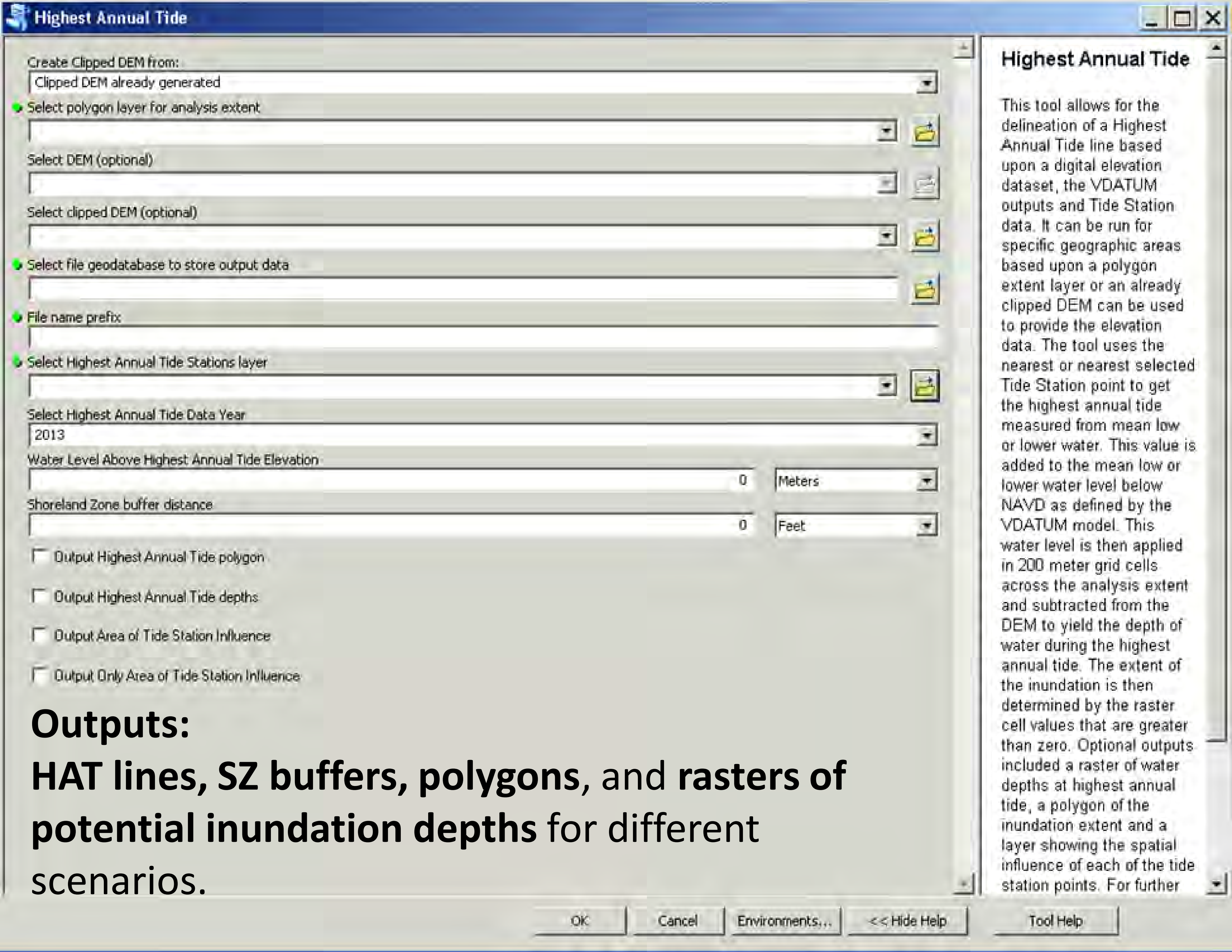
Maine's Highest Annual Tide Mapping Tool

- Unlike other SLR viewers (NOAA's Sea Level Rise and Coastal Flooding Impacts Viewer, or Climate Central's Surging Seas), we used the **Highest Annual Tide (HAT)** as the starting point instead of Mean Higher High Water (MHHW). *In Maine, these two numbers can vary by 2-3 feet.* The Highest Annual Tide is a regulatory (Shoreland Zoning) boundary in Maine.

- GIS based tool uses **LiDAR data , 113 different NOAA CO-OPs tidal prediction stations, Hydrologic Unit Code (HUC) 10 digit boundaries, and NOAA's VDATUM to account** for variation of water surfaces.

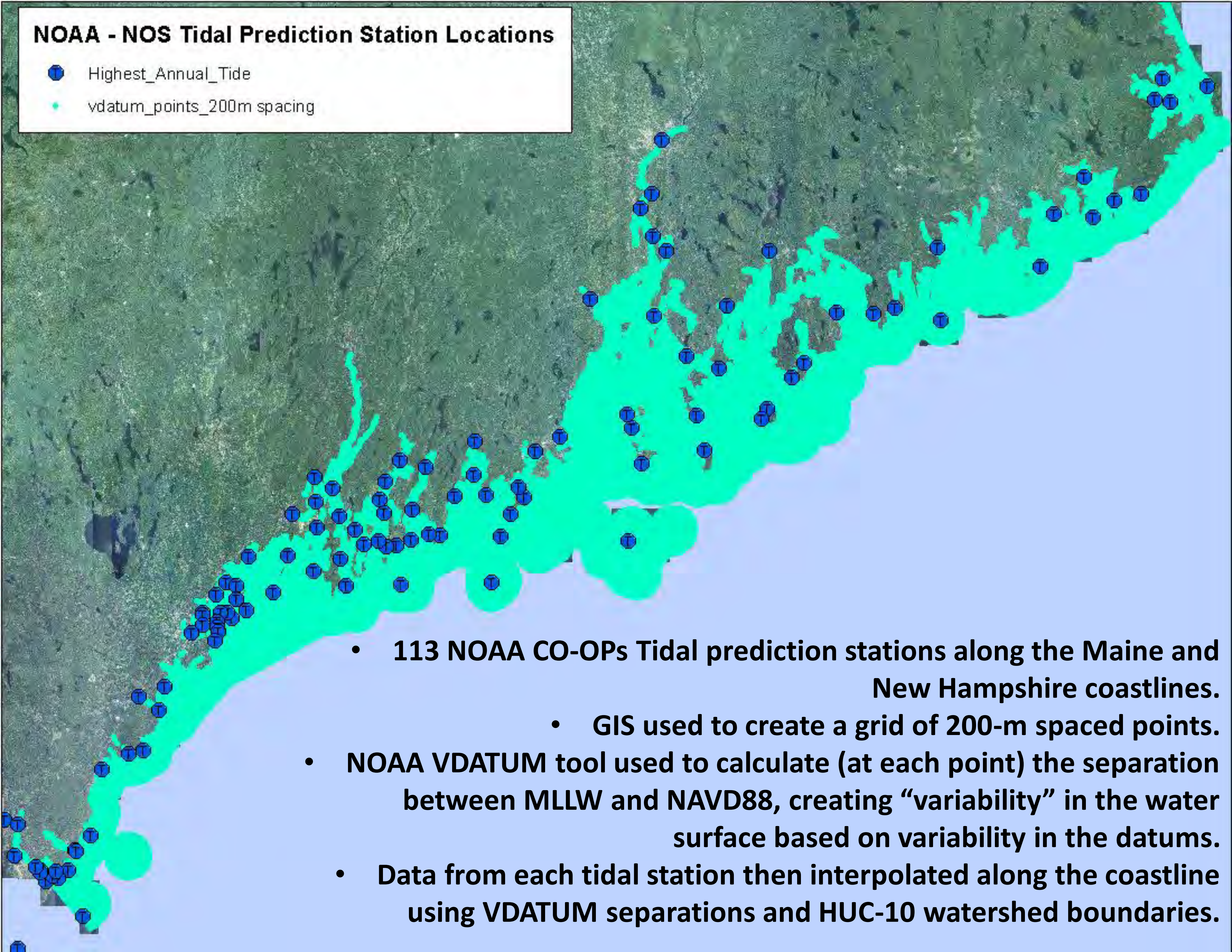
- Used **scenarios of 1, 2, 3.3, and 6 feet of sea level rise or storm surge on top of the HAT**.

- Developed as part of a **NOAA-funded Project of Special Merit** to support Marsh Migration Mapping.



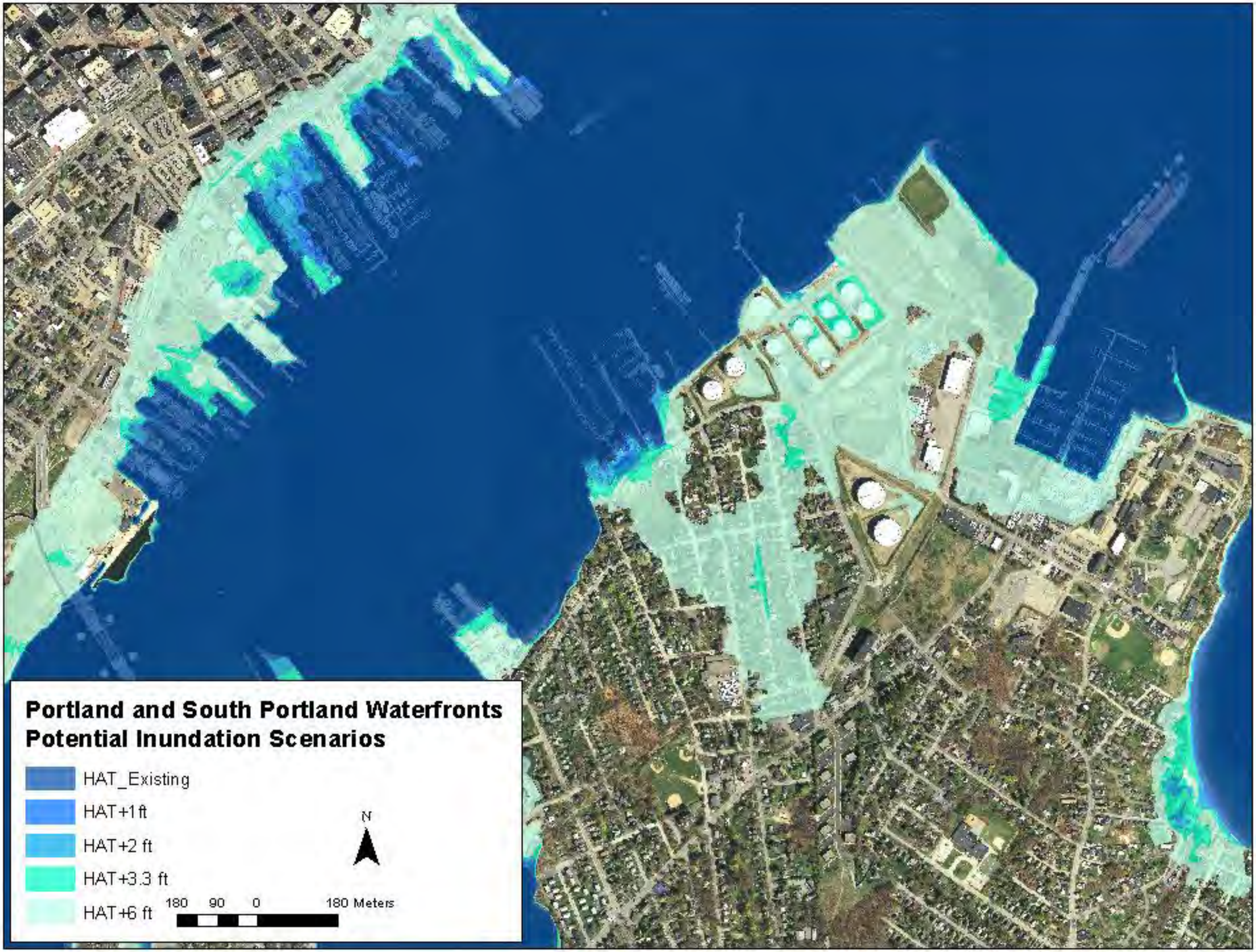
Outputs:

HAT lines, SZ buffers, polygons, and **rasters of potential inundation depths** for different scenarios.



- 113 NOAA CO-OPs Tidal prediction stations along the Maine and New Hampshire coastlines.
- GIS used to create a grid of 200-m spaced points.
- NOAA VDATUM tool used to calculate (at each point) the separation between MLLW and NAVD88, creating "variability" in the water surface based on variability in the datums.
- Data from each tidal station then interpolated along the coastline using VDATUM separations and HUC-10 watershed boundaries.

Portland and South Portland Waterfronts
Potential Inundation Scenarios



For general planning purposes only

Highest Annual Tide Mapping…next steps

- Currently field verifying predicted adjusted tidal elevations at a variety of locations along the Maine coastline using RTK-GPS (for Shoreland Zoning purposes).

- Final QA/QC of the sea level rise/storm surge inundation layers.

- Release of a website and online mapping tool similar to the PHIM data layers in next few weeks.

A few examples of transferable local infrastructure resiliency efforts…

Treatment Plants, Historic Downtowns and Roads

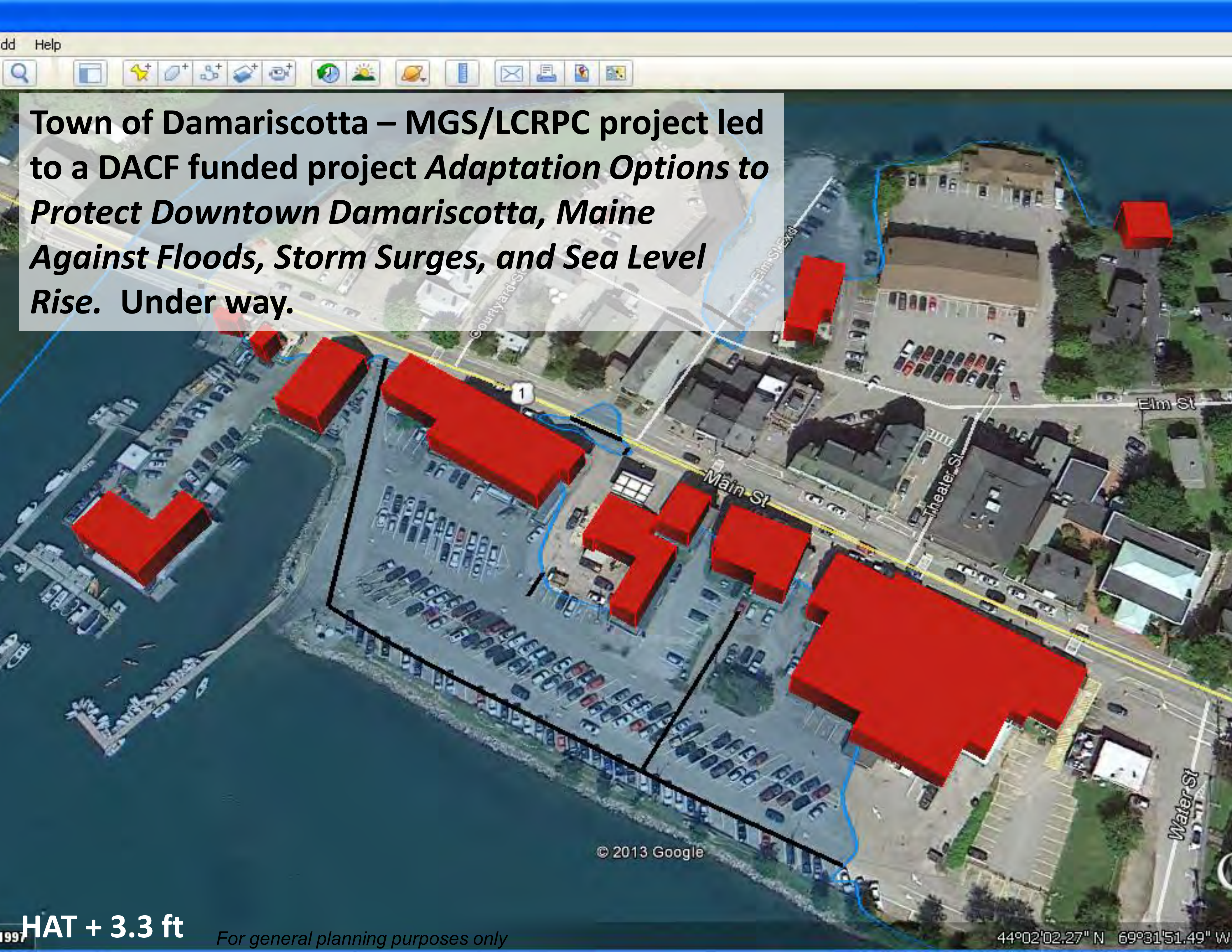
Ogunquit Sewer District – MGS/SMRPC and NROC municipal grants program funded project assessing vulnerability to storms and SLR and development of adaptation options for the wastewater treatment facility. First of its kind.

http://necca.stormsmart.org/municipal-grants/ogunquit-maine/

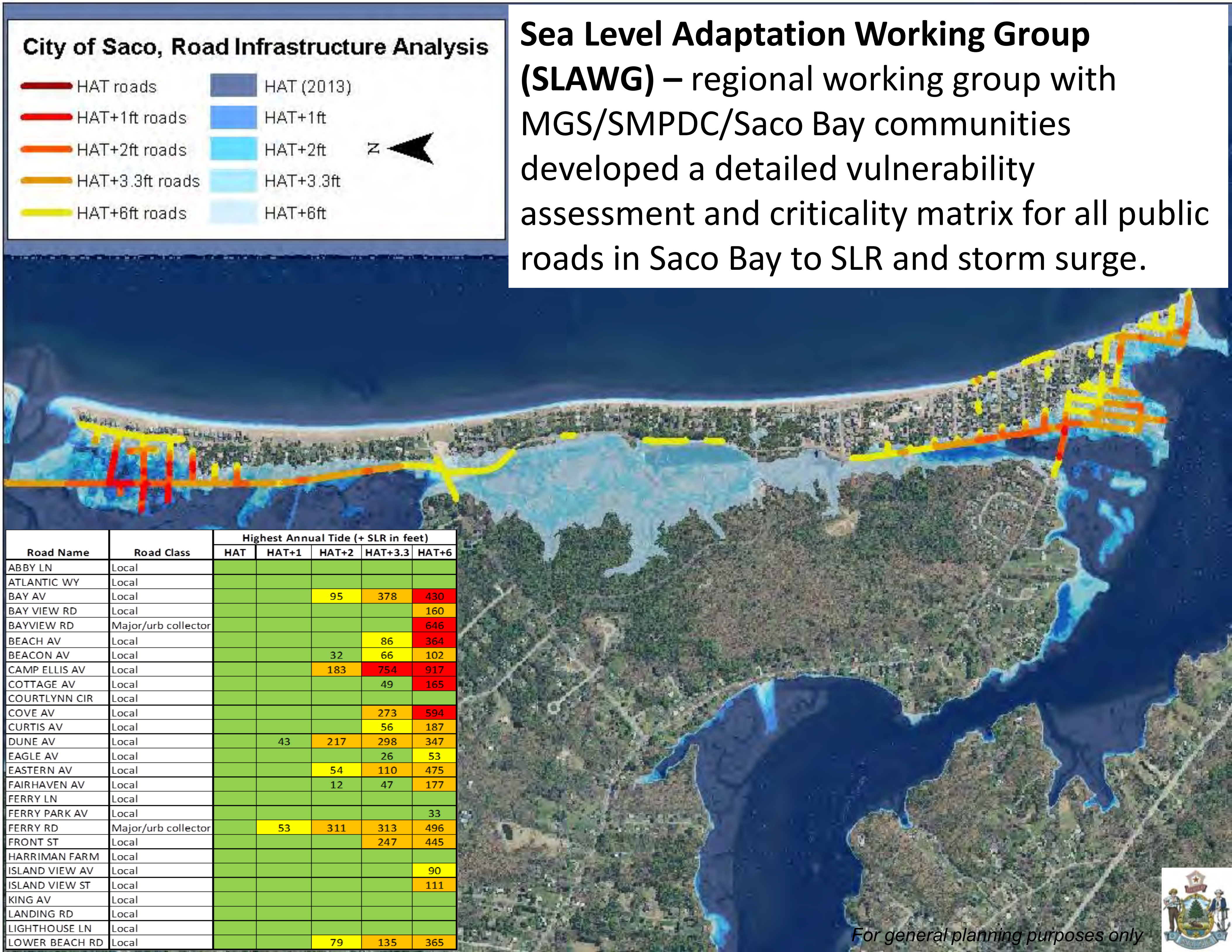
HAT + 3.3 ft

For general planning purposes only

Town of Damariscotta – MGS/LCRPC project led to a DACF funded project *Adaptation Options to Protect Downtown Damariscotta, Maine Against Floods, Storm Surges, and Sea Level Rise.* Under way.



Sea Level Adaptation Working Group (SLAWG) – regional working group with MGS/SMPDC/Saco Bay communities developed a detailed vulnerability assessment and criticality matrix for all public roads in Saco Bay to SLR and storm surge.



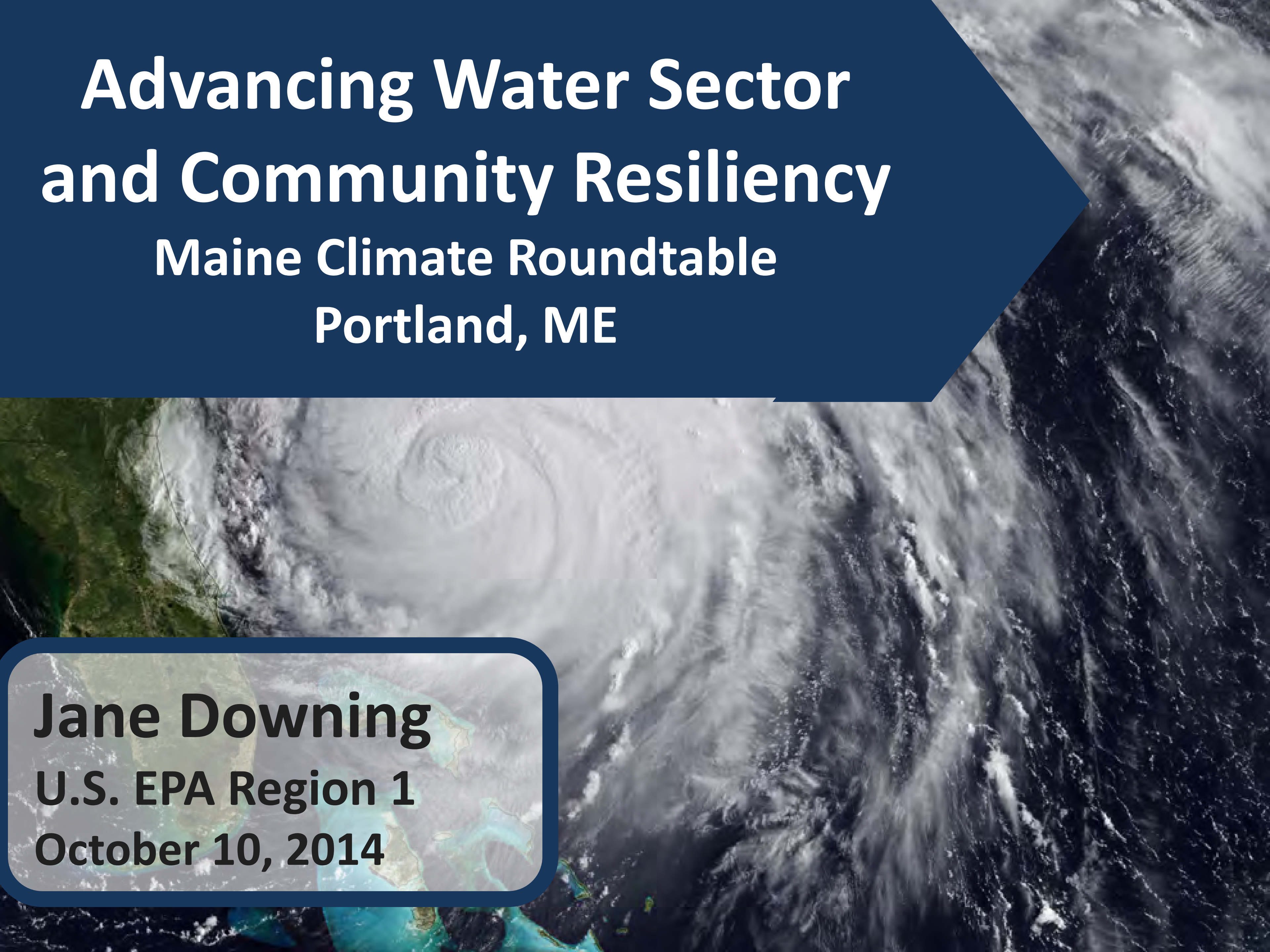
Road Name	Road Class	Highest Annual Tide (+ SLR in feet)				
		HAT	HAT+1	HAT+2	HAT+3.3	HAT+6
ABBY LN	Local					
ATLANTIC WY	Local					
BAY AV	Local			95	378	430
BAY VIEW RD	Local					160
BAYVIEW RD	Major/urb collector					646
BEACH AV	Local				86	364
BEACON AV	Local			32	66	102
CAMP ELLIS AV	Local			183	754	917
COTTAGE AV	Local				49	165
COURTLYNN CIR	Local					
COVE AV	Local				273	594
CURTIS AV	Local				56	187
DUNE AV	Local		43	217	298	347
EAGLE AV	Local				26	53
EASTERN AV	Local			54	110	475
FAIRHAVEN AV	Local			12	47	177
FERRY LN	Local					
FERRY PARK AV	Local					33
FERRY RD	Major/urb collector		53	311	313	496
FRONT ST	Local				247	445
HARRIMAN FARM	Local					
ISLAND VIEW AV	Local					90
ISLAND VIEW ST	Local					111
KING AV	Local					
LANDING RD	Local					
LIGHTHOUSE LN	Local					
LOWER BEACH RD	Local			79	135	365

Impacts of Sea Level Rise on Infrastructure: Statewide Datasets and Highlighted Projects and Efforts

Peter Slovinsky, Marine Geologist
Maine Geological Survey
Department of Agriculture, Conservation and Forestry
Peter.a.slovinsky@maine.gov
(207) 287-7173

Advancing Water Sector and Community Resiliency

Maine Climate Roundtable
Portland, ME



Jane Downing
U.S. EPA Region 1
October 10, 2014

THE EVENTS

Water Security

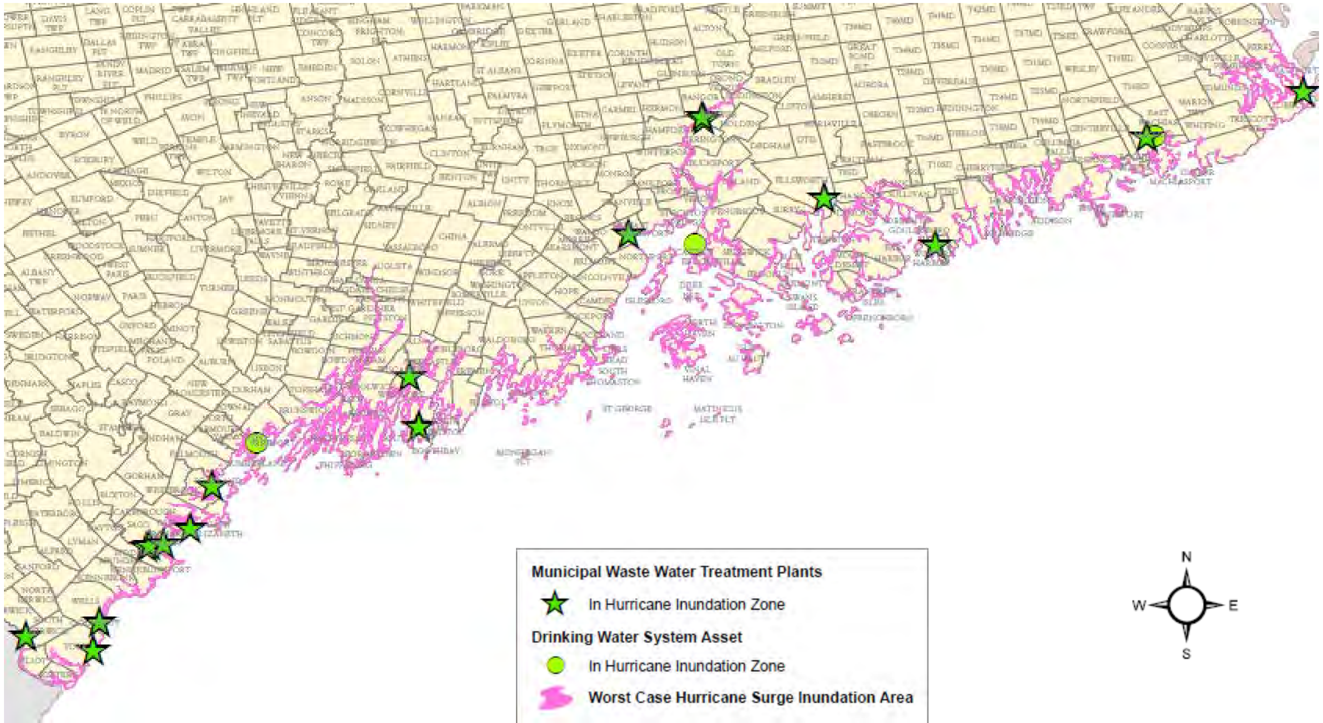
Droughts

Floods

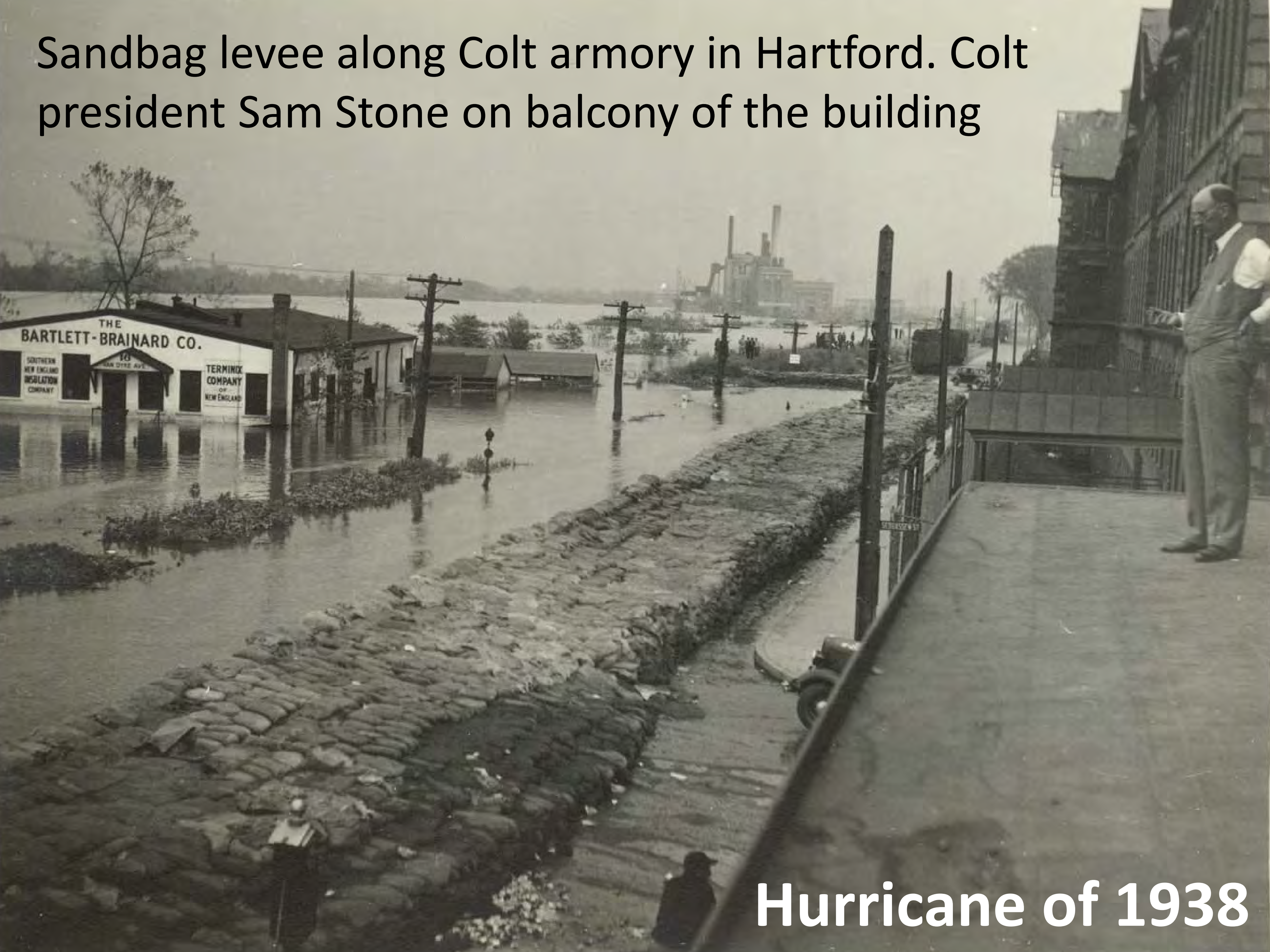
Ice Storms

Tropical Storm Irene & Hurricane Sandy

OH MY!!!

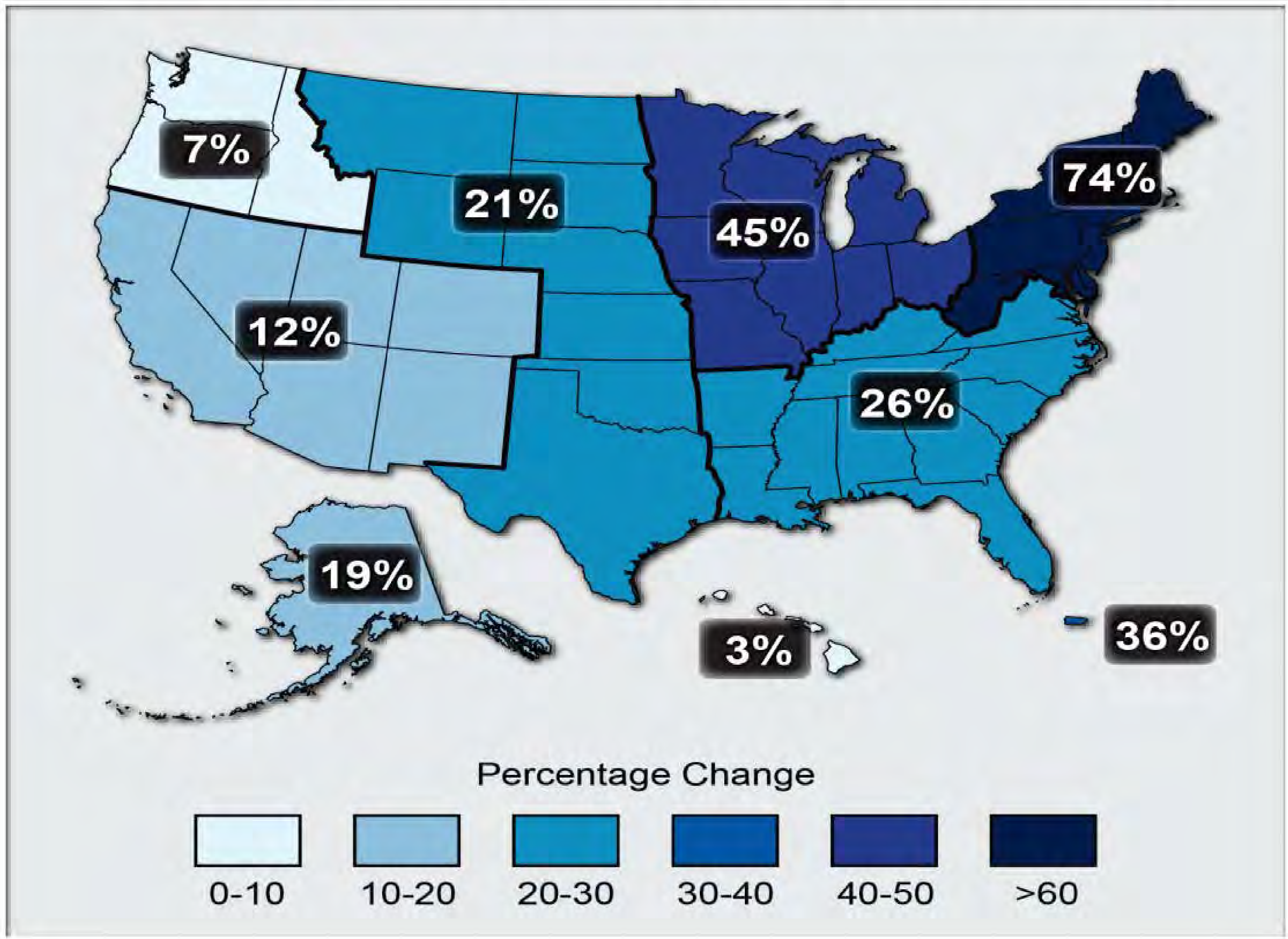


Sandbag levee along Colt armory in Hartford. Colt president Sam Stone on balcony of the building

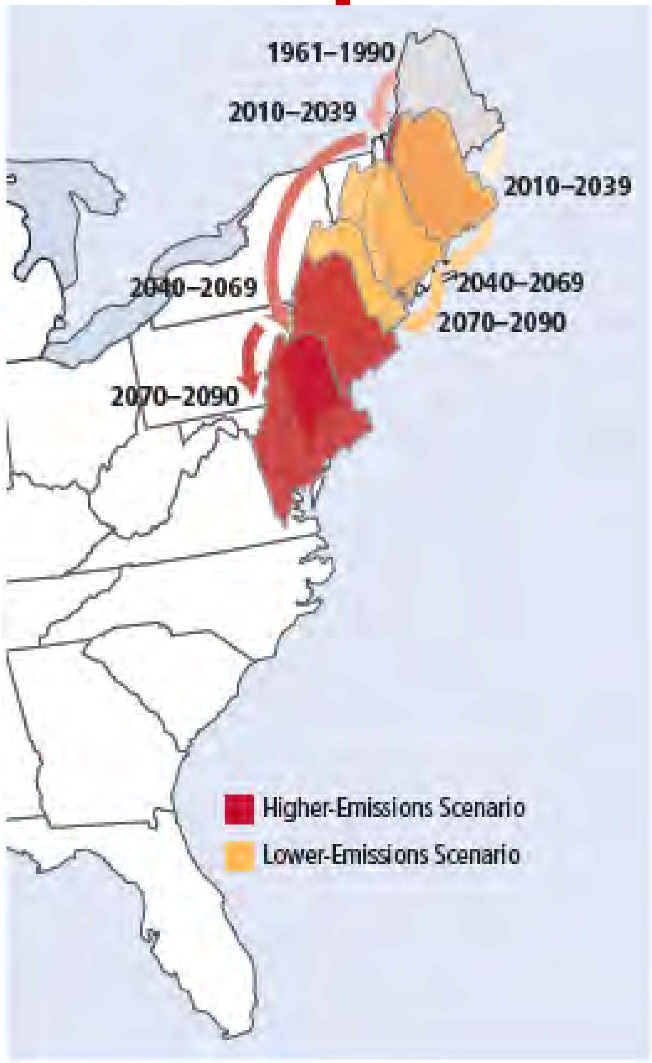


Hurricane of 1938

Percentage Change in Very Heavy Precipitation



Climate Change Impacts



Temperature

Flooding water infrastructure

Sea Level Rise

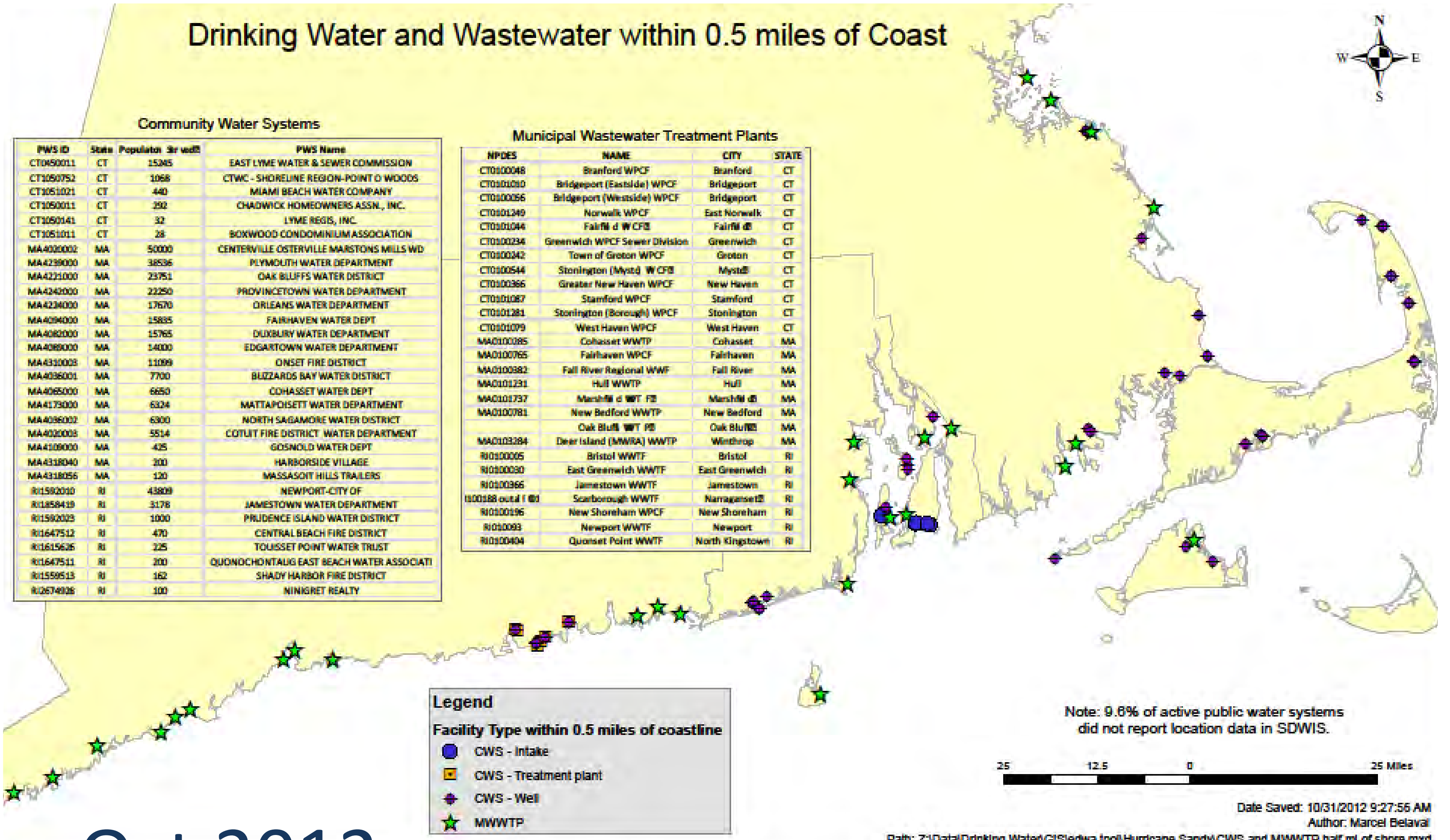
Treatment Plant Warwick, RI | March 2010

Hurricane Irene

Water Main Crossing
Woodstock, VT | Aug 2011

6” main was fully encased in concrete before the storm

The Story of Superstorm Sandy



Community Water Systems

PWS ID	State	Population Served	PWS Name
CT0450011	CT	15245	EAST LYME WATER & SEWER COMMISSION
CT1050752	CT	1068	CTWC - SHORELINE REGION-POINT O WOODS
CT1051021	CT	440	MIAMI BEACH WATER COMPANY
CT1050011	CT	292	CHADWICK HOMEOWNERS ASSN., INC.
CT1050141	CT	32	LYME REGIS, INC.
CT1051011	CT	28	BOXWOOD CONDOMINIUM ASSOCIATION
MA4020002	MA	50000	CENTERVILLE OSTERVILLE MARSTONS MILLS WD
MA4239000	MA	38536	PLYMOUTH WATER DEPARTMENT
MA4221000	MA	23751	OAK BLUFFS WATER DISTRICT
MA4242000	MA	22250	PROVINCETOWN WATER DEPARTMENT
MA4224000	MA	17670	ORLEANS WATER DEPARTMENT
MA4094000	MA	15835	FAIRHAVEN WATER DEPT
MA4082000	MA	15765	DUXBURY WATER DEPARTMENT
MA4089000	MA	14000	EDGARTOWN WATER DEPARTMENT
MA4310003	MA	11099	ONSET FIRE DISTRICT
MA4036001	MA	7700	BUZZARDS BAY WATER DISTRICT
MA4065000	MA	6650	COHASSET WATER DEPT
MA4173000	MA	6324	MATTAPOISETT WATER DEPARTMENT
MA4036002	MA	6300	NORTH SAGAMORE WATER DISTRICT
MA4020003	MA	5514	COTUIT FIRE DISTRICT WATER DEPARTMENT
MA4109000	MA	425	GOSNOLD WATER DEPT
MA4318040	MA	200	HARBORSIDE VILLAGE
MA4318056	MA	120	MASSASOIT HILLS TRAILERS
RI1592010	RI	43809	NEWPORT-CITY OF
RI1858419	RI	3178	JAMESTOWN WATER DEPARTMENT
RI1592023	RI	1000	PRUDENCE ISLAND WATER DISTRICT
RI1647512	RI	470	CENTRAL BEACH FIRE DISTRICT
RI1615626	RI	225	TOUISSET POINT WATER TRUST
RI1647511	RI	200	QUONOCHONTAUG EAST BEACH WATER ASSOCIATI
RI1559513	RI	162	SHADY HARBOR FIRE DISTRICT
RI2674026	RI	100	NINIGRET REALTY

Municipal Wastewater Treatment Plants

NPDES	NAME	CITY	STATE
CT0100048	Branford WPCF	Branford	CT
CT0101010	Bridgeport (Eastside) WPCF	Bridgeport	CT
CT0100056	Bridgeport (Westside) WPCF	Bridgeport	CT
CT0101249	Norwalk WPCF	East Norwalk	CT
CT0101044	Fairfield WPCF	Fairfield	CT
CT0100234	Greenwich WPCF Sewer Division	Greenwich	CT
CT0100242	Town of Groton WPCF	Groton	CT
CT0100544	Stonington (Mystic) WPCF	Mystic	CT
CT0100366	Greater New Haven WPCF	New Haven	CT
CT0101087	Stamford WPCF	Stamford	CT
CT0101281	Stonington (Borough) WPCF	Stonington	CT
CT0101079	West Haven WPCF	West Haven	CT
MA0100285	Cohasset WWTP	Cohasset	MA
MA0100765	Fairhaven WPCF	Fairhaven	MA
MA0100382	Fall River Regional WWF	Fall River	MA
MA0101231	Hull WWTP	Hull	MA
MA0101737	Marshfield WWTF	Marshfield	MA
MA0100781	New Bedford WWTP	New Bedford	MA
	Oak Bluffs WWTF	Oak Bluffs	MA
MA0103284	Deer Island (MWRA) WWTP	Winthrop	MA
RI0100005	Bristol WWTF	Bristol	RI
RI0100030	East Greenwich WWTF	East Greenwich	RI
RI0100366	Jamestown WWTF	Jamestown	RI
I100188 outfall 001	Scarborough WWTF	Narragansett	RI
RI0100196	New Shoreham WPCF	New Shoreham	RI
RI010093	Newport WWTF	Newport	RI
RI0100404	Quonset Point WWTF	North Kingstown	RI

Oct 2012

Lessons Learned

utility perspective

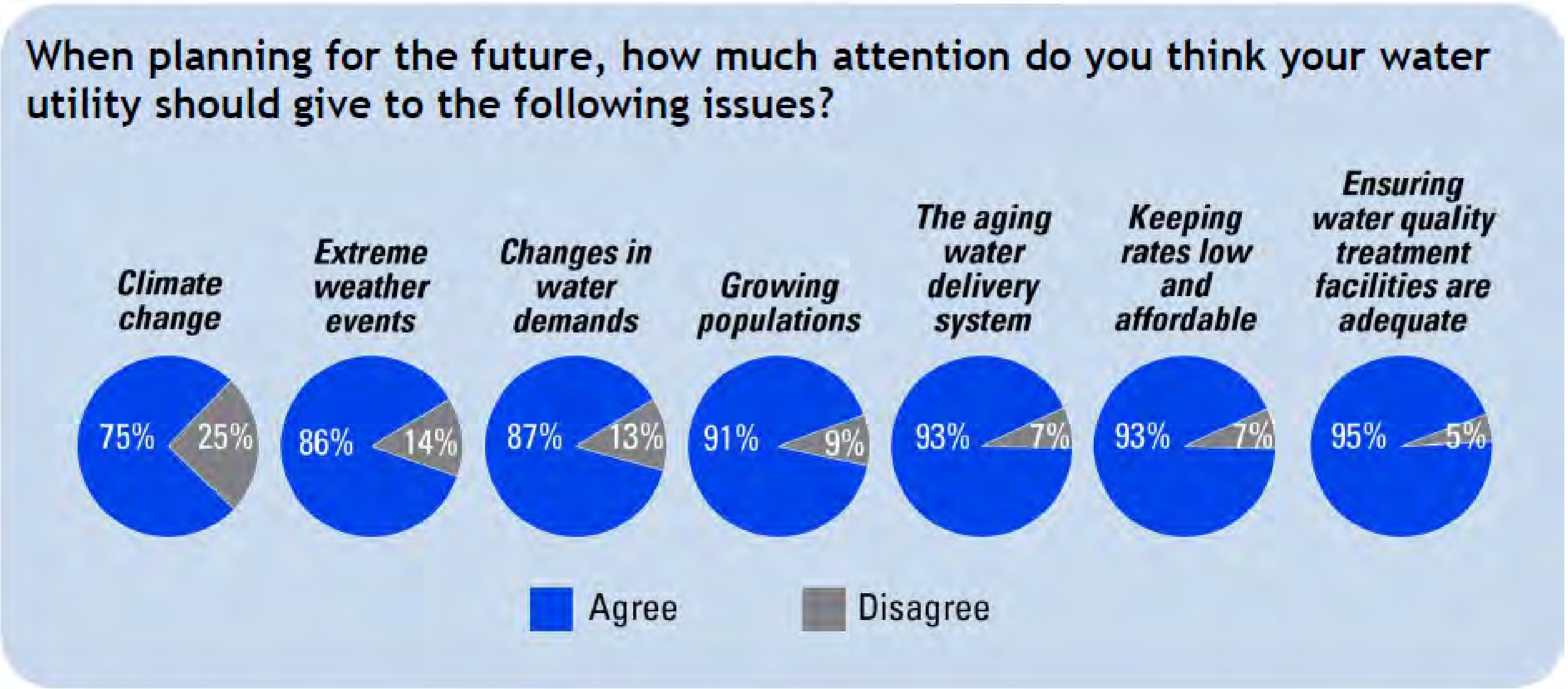
Water Research Foundation

Effective Climate Change Communication for Water Utilities

http://www.waterrf.org/Pages/Projects.aspx?PID=4381

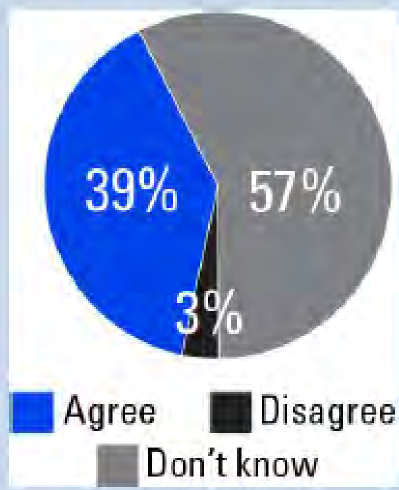
"92% of Americans think their water utility should play a leadership role in helping communities prepare for impacts of climate change"

Additional WRF Research Results



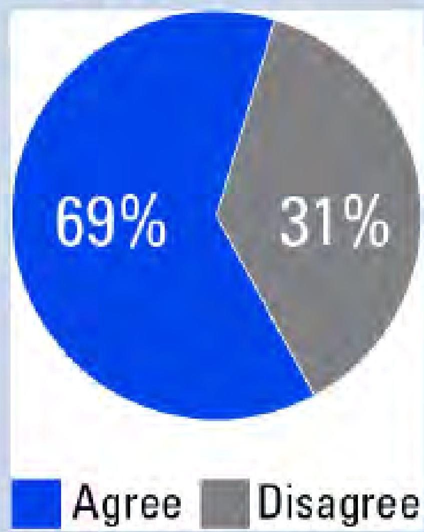
Additional WRF Research Results Cont.

My water utility has a plan, has taken the necessary actions, and is adequately prepared for extreme weather.



Additional WRF Research Results

Assuming the money is needed, and would be spent wisely and efficiently, would you be willing to pay extra each month to ensure that your community has *access to abundant*, *safe water for the next 10-40 years*?

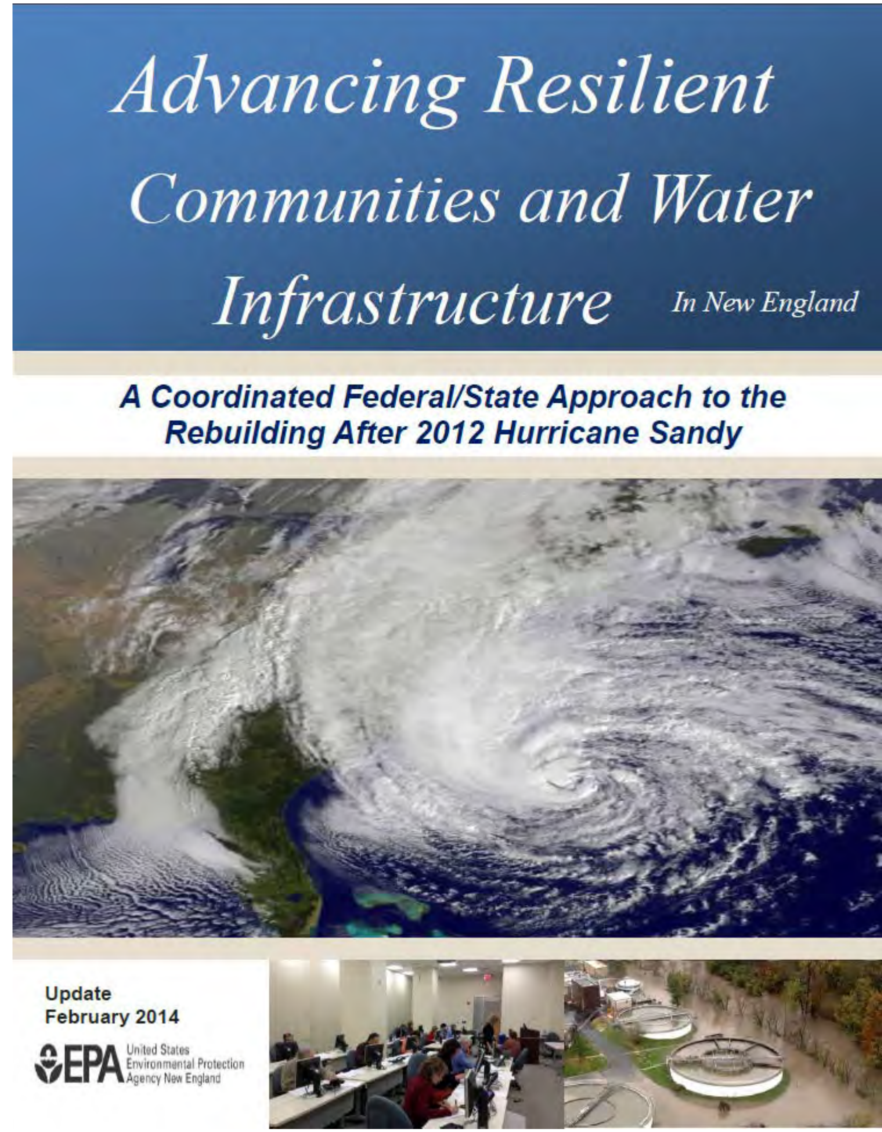


Resiliency Needs

- Planning and Projects
  - WW +DW Vulnerability Assessments and Upgrades
  - DW Interconnections
  - Debris Management – Local
  - Dam Safety Studies
  - Storm Water/Green Infrastructure Opportunities
  - Evaluation of Design Standards (SW/WW/DW) and Land Use Planning – State and Local
  - Generators/Microgrids
  - Habitat Restoration

EPA R1 Resiliency Support

- Emergency Preparedness
  - 2013 Hurricane Summit
  - Water Operator Training
  - GIS Maps of Assets At-Risk
  - Irene Lessons Learned Report
  - WARN support
- Federal/State Leveraging
  - HUD Sandy Disaster Relief Coordination (CT+RI)
  - FEMA/USACE Generator Assessments
  - DHS: Portland ME Pilot

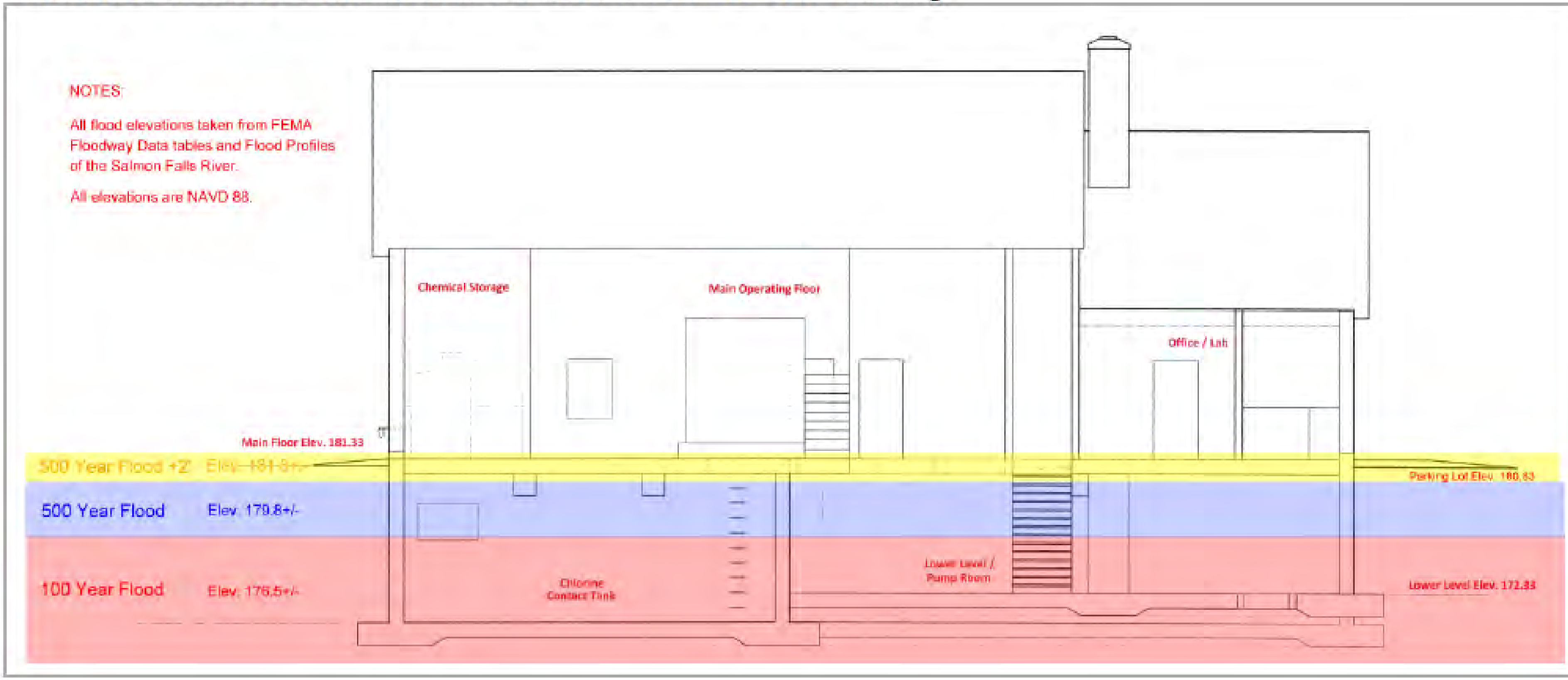


EPA R1 Resiliency Support Continued

- Community-Based Pilots
  - Buzzards Bay Extreme Weather Workshop
  - Cape Cod Extreme Weather Workshop
  - North Kingston, RI: (WHEAT)
  - Portsmouth, NH,
    Manchester-by-the-Sea: (CREAT)
  - Berwick, ME National Pilot:
    (Flood Guide)

BERWICK, ME – NATIONAL PILOT STEP 1

Flood Risk Scenario Elevations on Inside Elevation of BWD WTP Building



BERWICK RESILIENCE PLAN

- Immediate Examples ($5K)
  - Fill in foundation cracks and outside taps
  - Use sandbags to seal doors and prevent water flow to lower level
  - Waterproof main floor slab
  - New Operating Procedures
- Near-Term Examples ($88k)
  - Permanent, removable stop logs for doors
  - Replace and add sump pumps
  - Permanently seal floor and openings
  - Secure propane tank
- Long-Term Examples ($582K)
  - Relocate or flood-proof assets in basement*
  - Replace pumps with water proof or submersible models
  - Upgrade electrical system

*can be done during life cycle replacement

EPA

FLOODING

RISE TO THE CHALLENGE —
BEFORE IT IMPACTS YOUR UTILITY

Flood Resilience: A Basic Guide for Water and Wastewater Utilities

- Designed for small and mid-sized utilities
- Contains interactive worksheets, flood maps, videos
- Lists practical mitigation measures (see other side)

4 STEPS TO FLOOD RESILIENCE

01 Understand Flooding Threat → 02 Identify Vulnerable Assets, Determine Consequences → 03 Identify/Evaluate Mitigation Measures → 04 Develop Plan to Implement Mitigation Measures

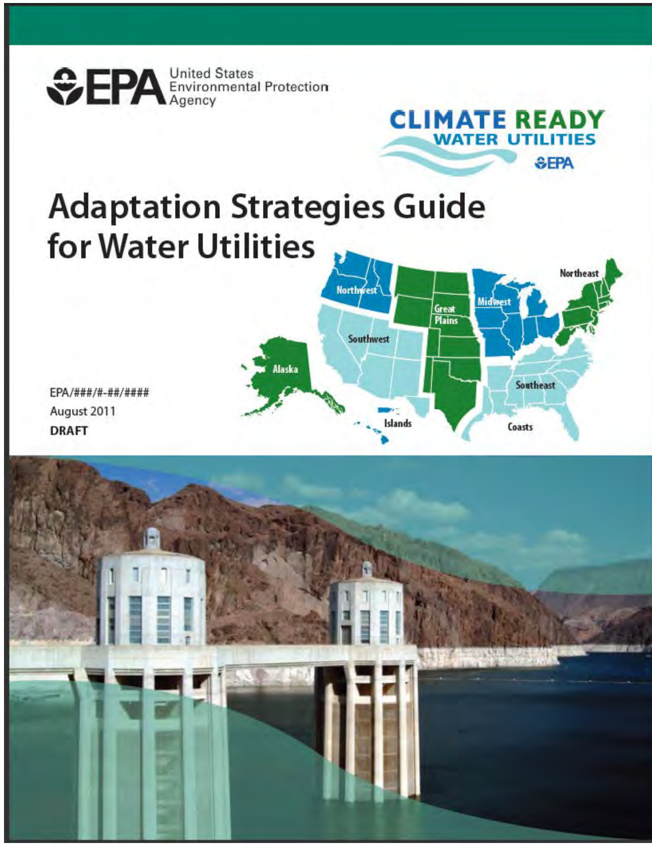
To access Guide:
water.epa.gov/infrastructure/watersecurity/emerplan/

For video on flood resilience:

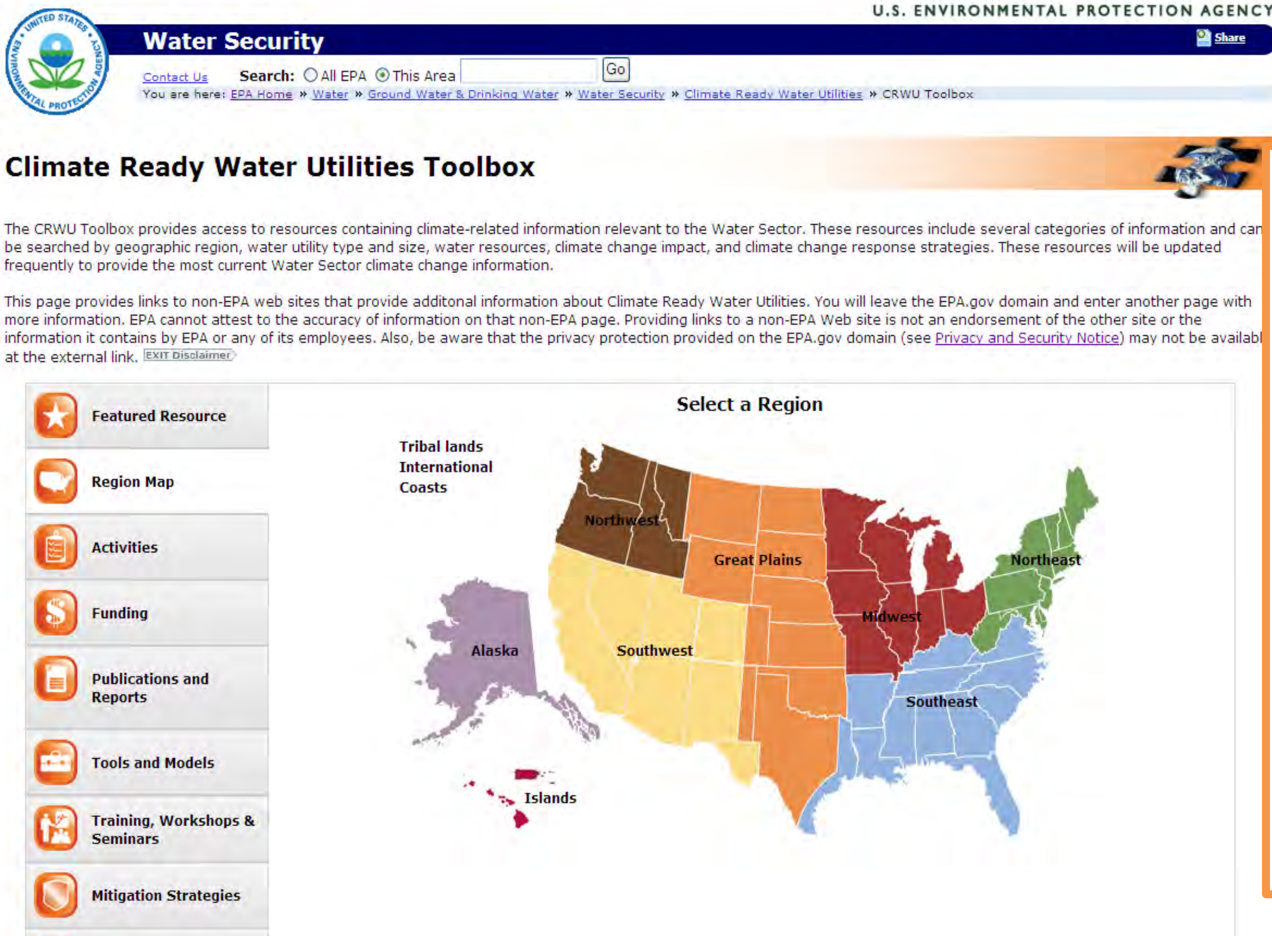
EPA Adaptation Strategies Guide

The purpose of the guide is to provide drinking water and wastewater utilities and stakeholders with:

- Easy to understand, regionally-relevant climate science,
- An overview of what impacts (referred to as "challenges") changes in the climate may have on utilities,
- Adaptation options currently being implemented at utilities and recommendations with relative costs, and
- Worksheets for adaptation planning.



Climate Ready Water Utilities Toolbox



Features:

- Browse by Tabs
- Region Map
- Highlighted Resources
- Link Direct to Web Page
- Option to Show Searchable Database/Resources List

EPA Tools

Adaptation Tools for Public Officials

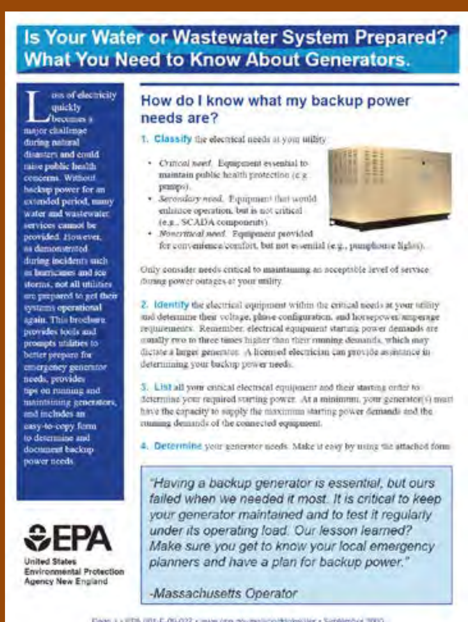
www.epa.gov/climatechange/impacts-adaptation/adapt-tools.html

Climate Ready Water Utilities

http://water.epa.gov/infrastructure/watersecurity/climate/

All Hazards Emergency Preparedness for Drinking Water Systems

www.epa.gov/region1/eco/drinkwater/emergency_preparedness.html



OTHER TOOLS

- FEMA Flood Maps
  www.msc.fema.gov
- FEMA Flood Design Advisories/Fact Sheets
  www.fema.gov/building-science
- Weather & Hydrologic Forecasting for Water Utility Incident Preparedness and Response
  water.epa.gov/infrastructure/watersecurity/emerplan/upload/epa817f13005.pdf
- USACE Emergency Power
  http://eportal.usace.army.mil/sites/ENGlink/EmergencyPower/

EPFAT

Emergency Power Facility Assessment Tool

FEMA

US Army Corps Of Engineers

June 2014

Is your drinking water or wastewater system *power* prepared?

What is EPFAT?

The U.S. Army Corps of Engineers (USACE) is often called upon by FEMA to assist in providing temporary emergency power for critical infrastructure identified by state officials, such as drinking water and wastewater facilities. The facility's electrical specifications are required before the appropriate generator can be found and installed.

The Emergency Power Facility Assessment Tool (EPFAT) is a secure web-based tool that can be used by water and wastewater facility owners/operators, or emergency response agencies, to input, store, update and/or view temporary emergency power assessment data. The data can also be used by facility owners, or local and state emergency management personnel to determine if a local source for a generator can be obtained versus reliance on federal government support.

Be Ready.

Benefits of using EPFAT for the Water Sector?

Having the pre-existing assessment data in advance helps the USACE provide temporary power faster, getting you the right generator at the right time.

The database also provides your utility and the local/state/federal Emergency Management staff a permanent off-site, secure repository for this information.

If EPFAT is utilized and maintained by the facilities, it allows their State/Local emergency managers to estimate in advance of a storm or predicted event the number and sizes of generators necessary to assist the greatest number of eligible facilities as possible.

The EPFAT data can be a good backup for generator information already tracked and maintained by utilities and Water & Wastewater Agency Response Networks (WARNs) for mutual aid purposes.

Actions to take next?

Order a critical facility assessment, to be completed by qualified electricians (Journeyman or Master Electricians, Electrical Engineers) who are on-site/staff, contracted electricians, or volunteers.

Know your facility's critical electrical needs: what does your system view as essential power needs to maintain public health protection, and what equipment would enhance operation but is not as critical?

Go to USACE's EPFAT website to securely enter your generator needs data in case of future emergencies.

Consider installing generators and/or providing transfer switches to speed the delivery of temporary power following a disaster.

Contact your Local/County Emergency Management office to ensure your utility is deemed "critical" and qualifies for State or Federal post-disaster generator assistance.

Contacts:

David Bishop (724) 459-4708 [illegible] (Primary)

Peter Navesky (918) 669-7327 [illegible] (Alternate)

Links to EPFAT tool & info:

[illegible]

[illegible]

Upcoming Dates

- **October 15, 2014**: Regional Resiliency Assessment Program
  Casco Bay Region/Portland
  Department of Homeland Security
- **October 16, 2014**: Resilient Design: Transitioning to the New Built Environment Antioch University/EPA
  www.antiochne.edu/community/center-climate-preparedness-community
- **October 23, 2014**: WARN Workshop
  Old Town, ME
  EPA/ME CDC/ MRWA
- **October 29, 2014**: Webinar: Climate Resilience: What to Expect, How to Prepare, and What you can Learn from Others
  EPA
  http://water.epa.gov/learn/training/wacademy/webcasts_index.cfm
- **October 29 + 30, 2014**: Source Water Protection: Workshops for ME Public Water Suppliers
  Bangor/Presque Isle
  EPA/ME DEP/NRCS/ME CDC
- **November 13, 2014**: Salmon Falls Watershed Chemical Spill Workshop & Tabletop Exercise
  South Berwick, ME Community Center
  ME CDC/MEDEP/MEMA/MRWA
- **December 3, 2014**: Climate Change Adaptation for Wastewater Treatment Facilities
  Saco City Hall
  ME DEP

Thank You

Jane Downing

downing.jane@epa.gov | 617.918.1571

INTEGRATING CLIMATE CONSIDERATIONS INTO ASSET MANAGEMENT AT MAINEDOT

JUDY GATES, DIRECTOR

MAINE DOT ENVIRONMENTAL OFFICE

MAINE CLIMATE ROUNDTABLE

OCTOBER 10, 2014

PROJECT BACKGROUND

What inspired or motivated you to apply to become an FHWA Climate Resilience pilot?

- Billions of dollars of future infrastructure decisions to be made.
- Program ties in well with recent work looking at the effect of projected sea level rise on coast bridge infrastructure.

Project context:

- Six towns included are already part of an EPA-funded Project of Special Merit, which will map three sea level rise scenarios and model effects on marsh migration.

PROJECT OVERVIEW

Assess vulnerability to sea level rise and storm surge projected by a NOAA Project of Special Merit for six coastal Maine communities.

- Exposure
- Sensitivity
- Adaptive capacity

Criticality analysis

- Function in multiple systems
- Physical characteristics

Benefit-cost

- Depth-damage function of T-COAST

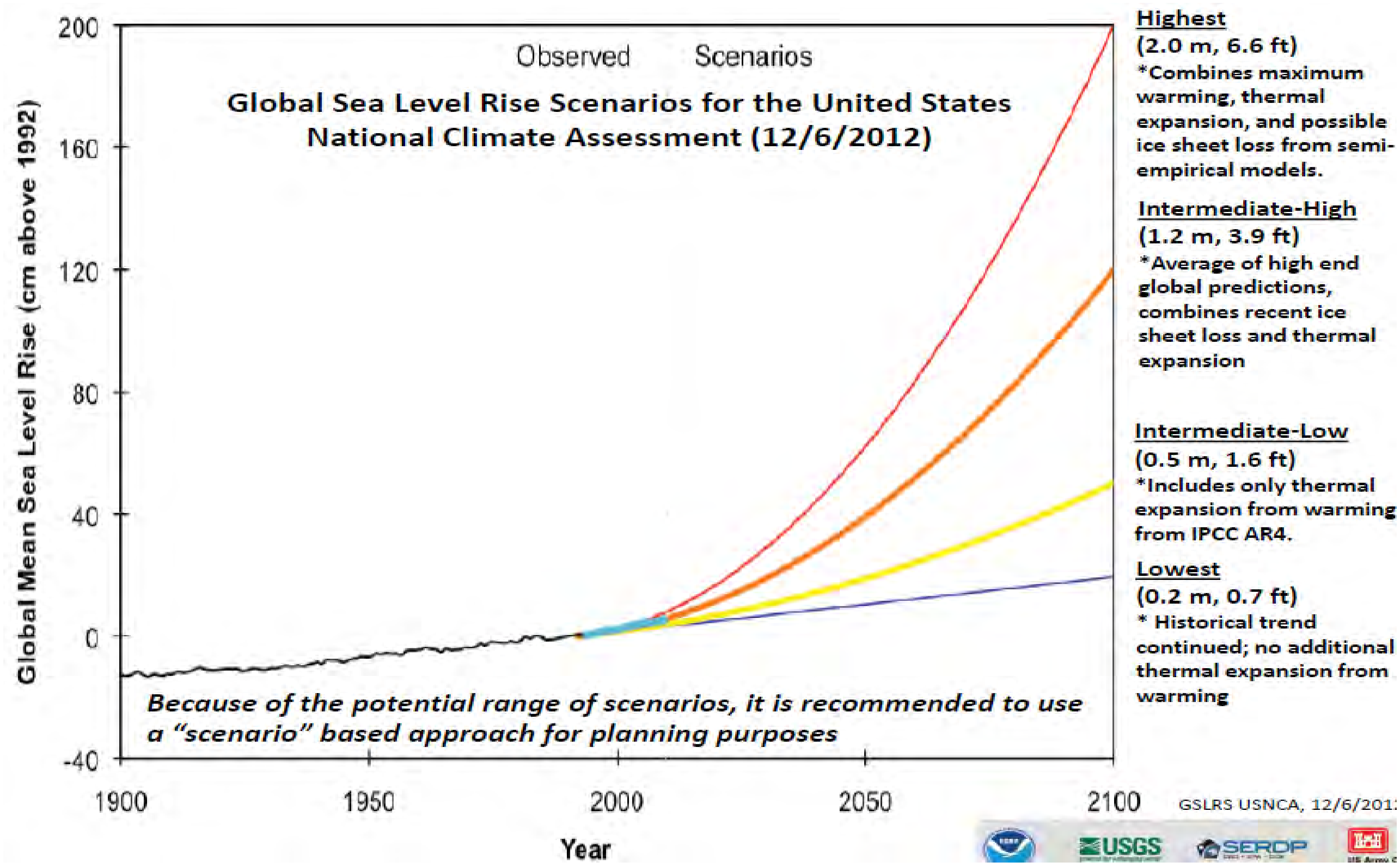
PROJECT PARTNERS

- Maine Department of Transportation
  - Oversight, vision, project management, and engineering design
- Maine Department of Agriculture, Conservation, and Forestry
  - Coordination with several projects on a larger "Project of Special Merit" (POSM)
- Catalysis Adaptation Partners, LLC
  - Development of criticality ranking software for roads and bridges
  - Enhancement of a tool to evaluate costs and benefits of alternative design structures
  - Use of these tools in six Maine communities
- Maine Geological Survey
  - Creation and management of relevant data layers in the six Maine towns
- Maine Department of Inland Fisheries and Wildlife
  - Collaboration on natural resources issues raised in the six Maine towns
- Maine Natural Areas Program
  - Collaboration on natural resources issues raised in the six Maine towns

FHWA CLIMATE CHANGE INITIATIVE GRANT: PLAN A

1. Apply three sea level rise scenarios to identify vulnerable state transportation assets;
2. Use Decision Support Tool to rate criticality of vulnerable assets;
3. Compare DST results to "I remember when…";
4. Develop design options for selected asset in each town…in-kind versus adaptation;
5. Apply depth-damage function to estimate costs of no action versus adaptation;
6. Assess feasibility of applying analysis in MaineDOT asset management process.

SLR SCENARIO PREDICTIONS



From Slovinsky 2014

FHWA CLIMATE CHANGE INITIATIVE GRANT: PLAN A

1. Apply three sea level rise scenarios to identify vulnerable state transportation assets;
2. Use Decision Support Tool to rate criticality of vulnerable assets;
3. Compare DST results to “I remember when…”;
4. Develop design options for selected asset in each town…in-kind versus adaptation;
5. Apply depth-damage function to estimate costs of no action versus adaptation;
6. Assess feasibility of applying analysis in MaineDOT asset management process.

DST DATA NEEDS

VULNERABILITY ← → SENSITIVITY

1. Feet of freeboard under bridge between lowest chord and 100 yr BFE or road segments ≤ 5 ft above 100 yr BFE
2. % of bridge length at height of lowest chord or degree culverts/drainage structures are prone to failure during rain/tidal storm events
3. Approaches flood or road included in TIP for rehab or reconstruction
4. Scour critical
5. NBIS score ≥ 5 or road surface asphalt or concrete
6. Functional classification of roadway
7. Utilities/other modes associated with bridge or road
8. Roadway is identified evacuation route
9. Hospital, emergency access way?

AND MOST IMPORTANTLY….

$$N \gtrsim 1$$

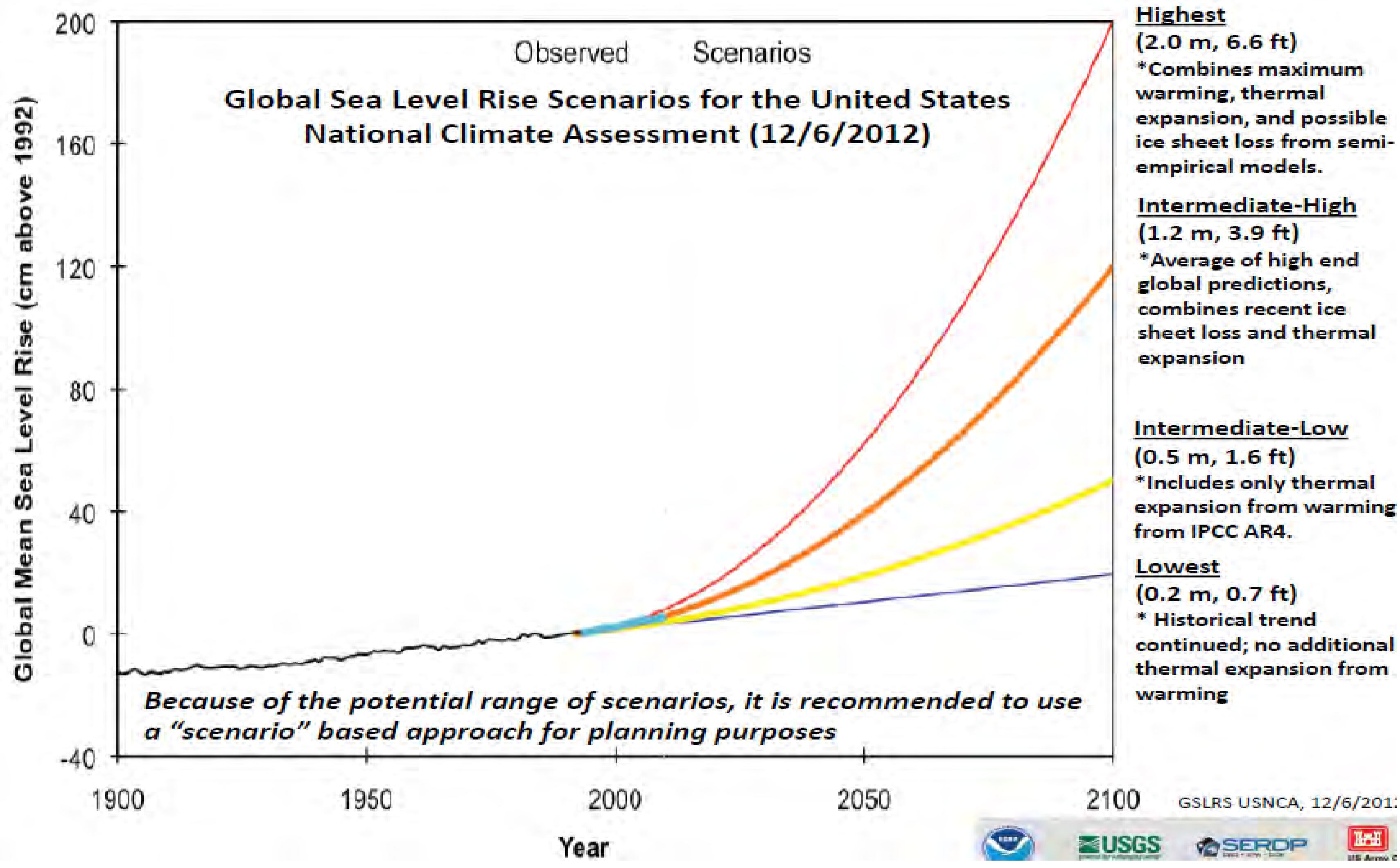
THE ASSETS:

- ME Route 209, south of Sam Day Hill Rd, Phippsburg
- ME Route 127, at Sequinland Rd, Georgetown
- ME Route 1 over Scarborough Marsh, Scarborough
- New Meadows Rd on Old Bath Road, Bath
- ~~ME Route 25, Bowdoinham~~
- ~~Meadow Rd, Topsham~~

FHWA CLIMATE CHANGE INITIATIVE GRANT: PLAN B

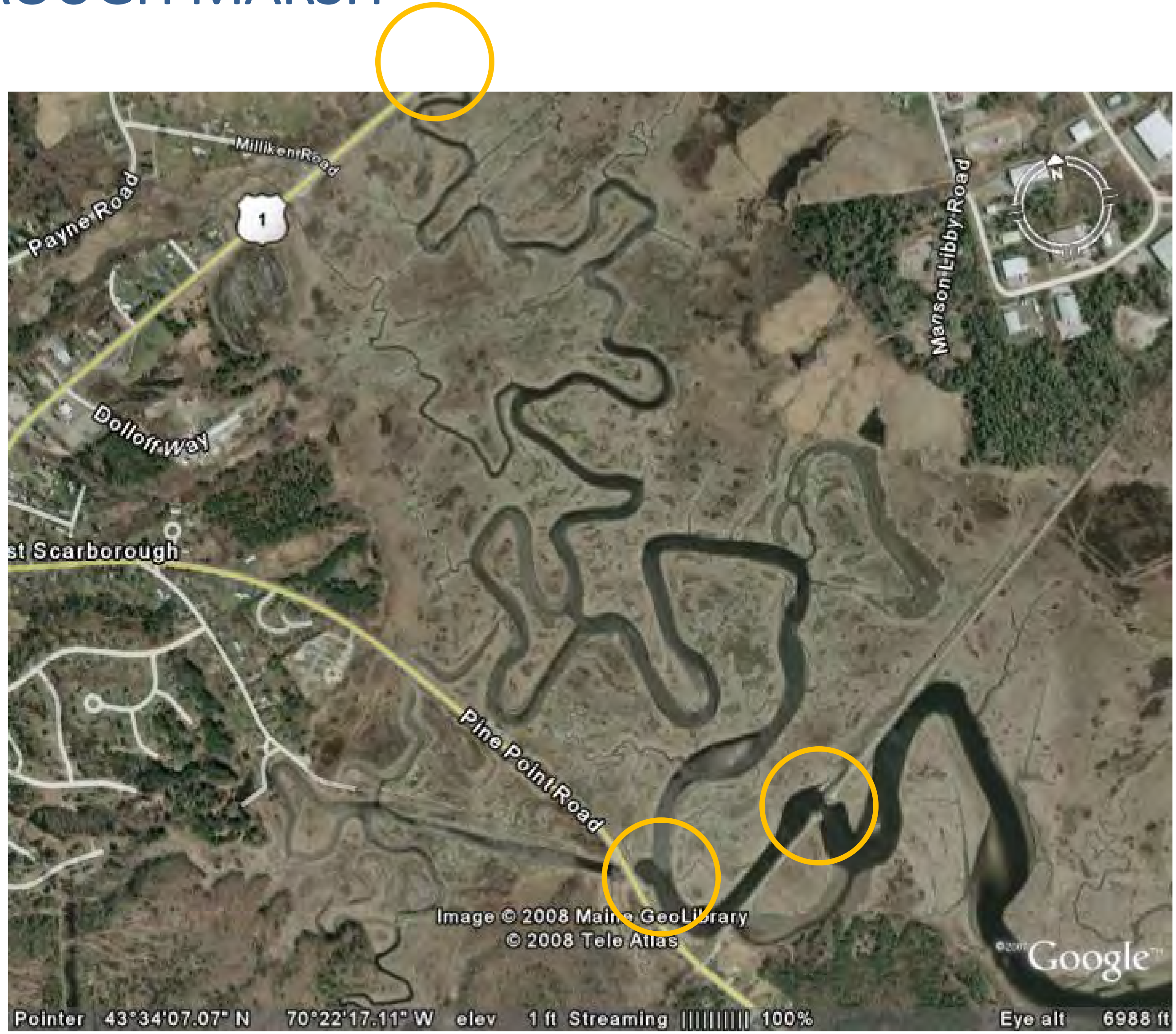
1. Apply three sea level rise scenarios to identify vulnerable state transportation assets. Select modeled scenarios;
2. Use historical flooding reports and practioners' knowledge to select state asset per town.
3. Develop design options for selected asset in each town…in-kind vs. 3.3 ft of SLR vs. 6 ft of SLR;
4. Apply depth-damage function to estimate costs of replacement to current design standards versus two approaches to adaptation;
5. Assess feasibility of applying analysis in MaineDOT asset management process.
6. Explore opportunities to run DST on a region-wide basis and include modern precipitation data.

SLR SCENARIO PREDICTIONS

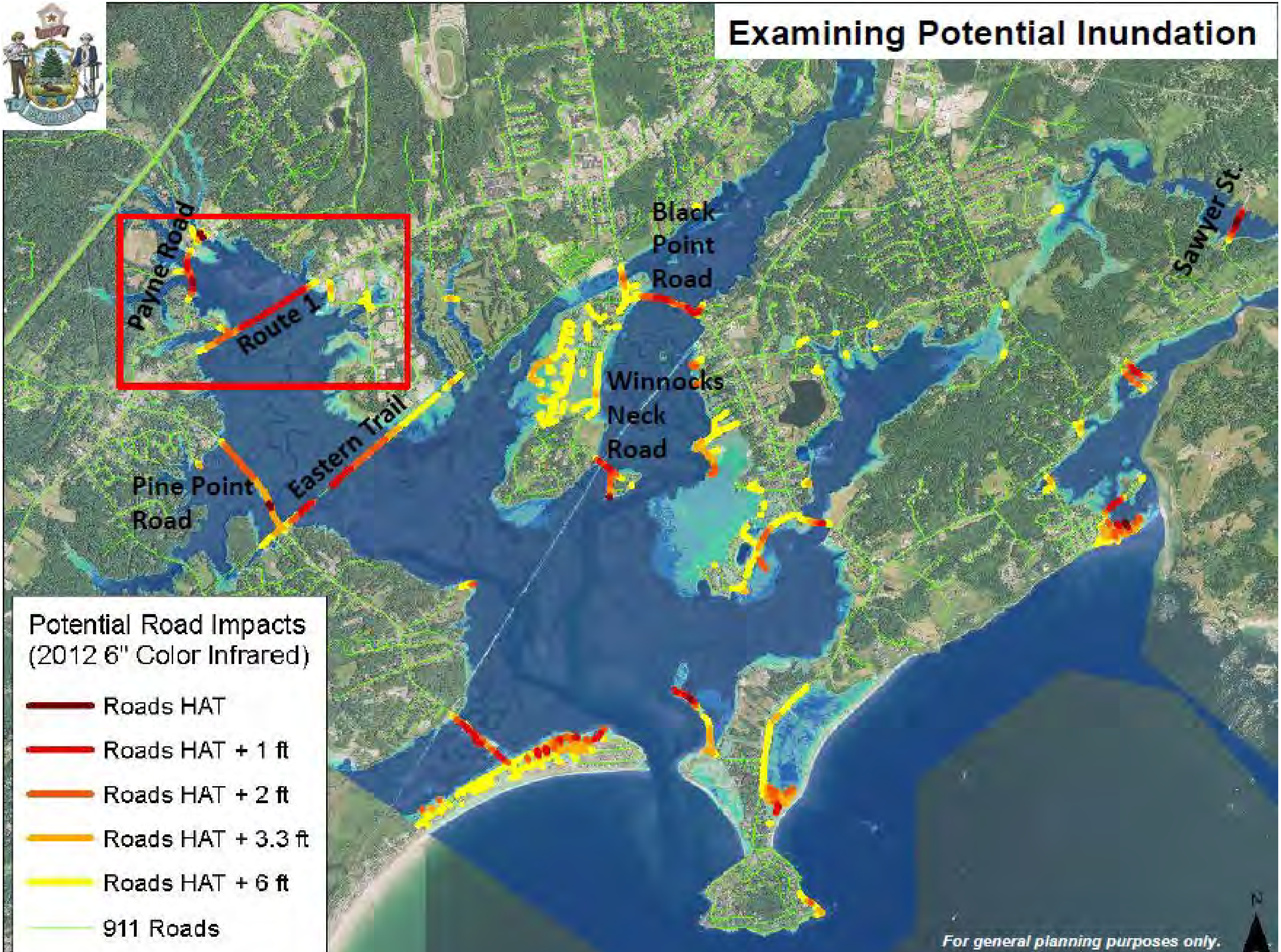


From Slovinsky 2014

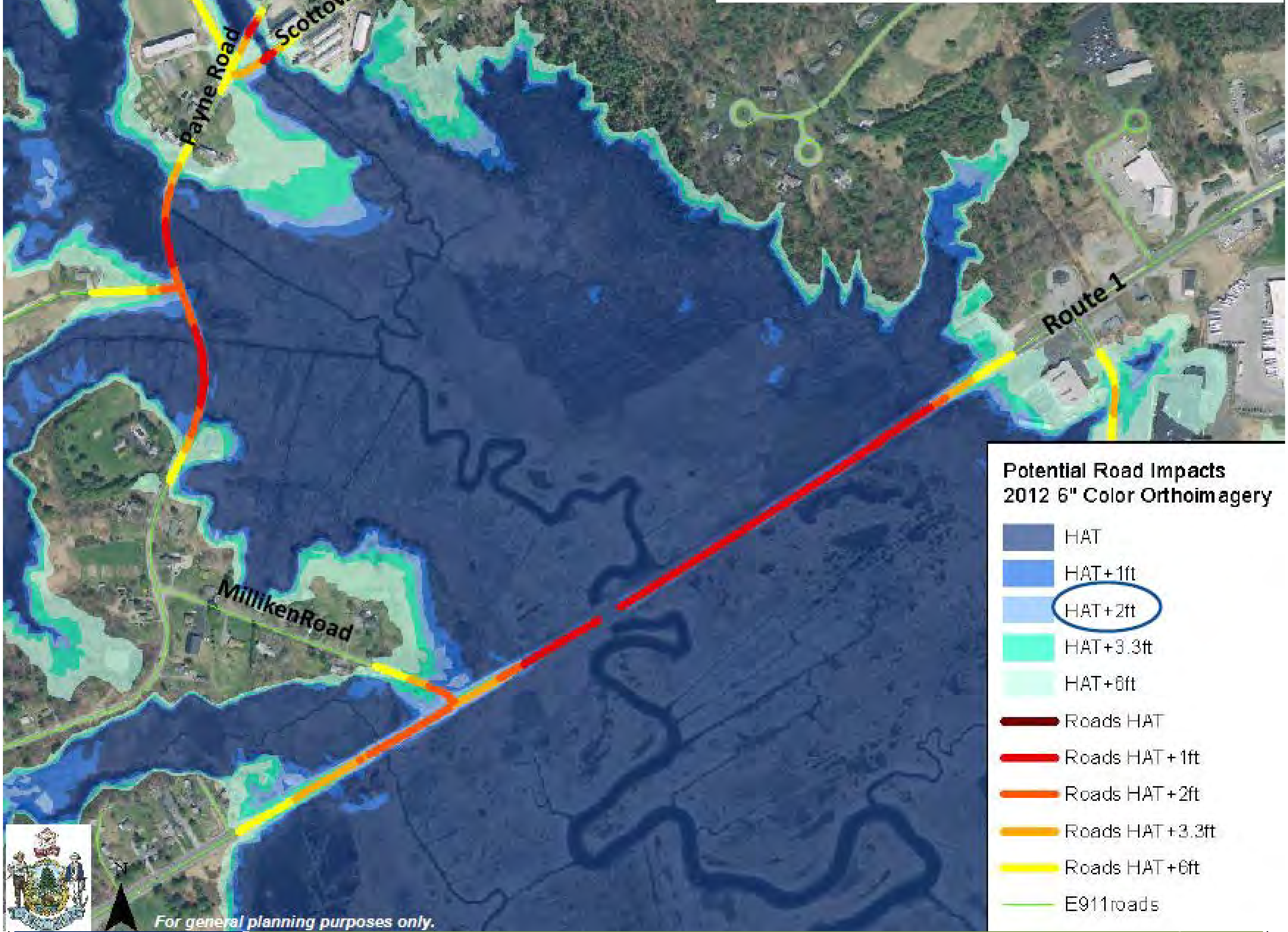
SCARBOROUGH MARSH

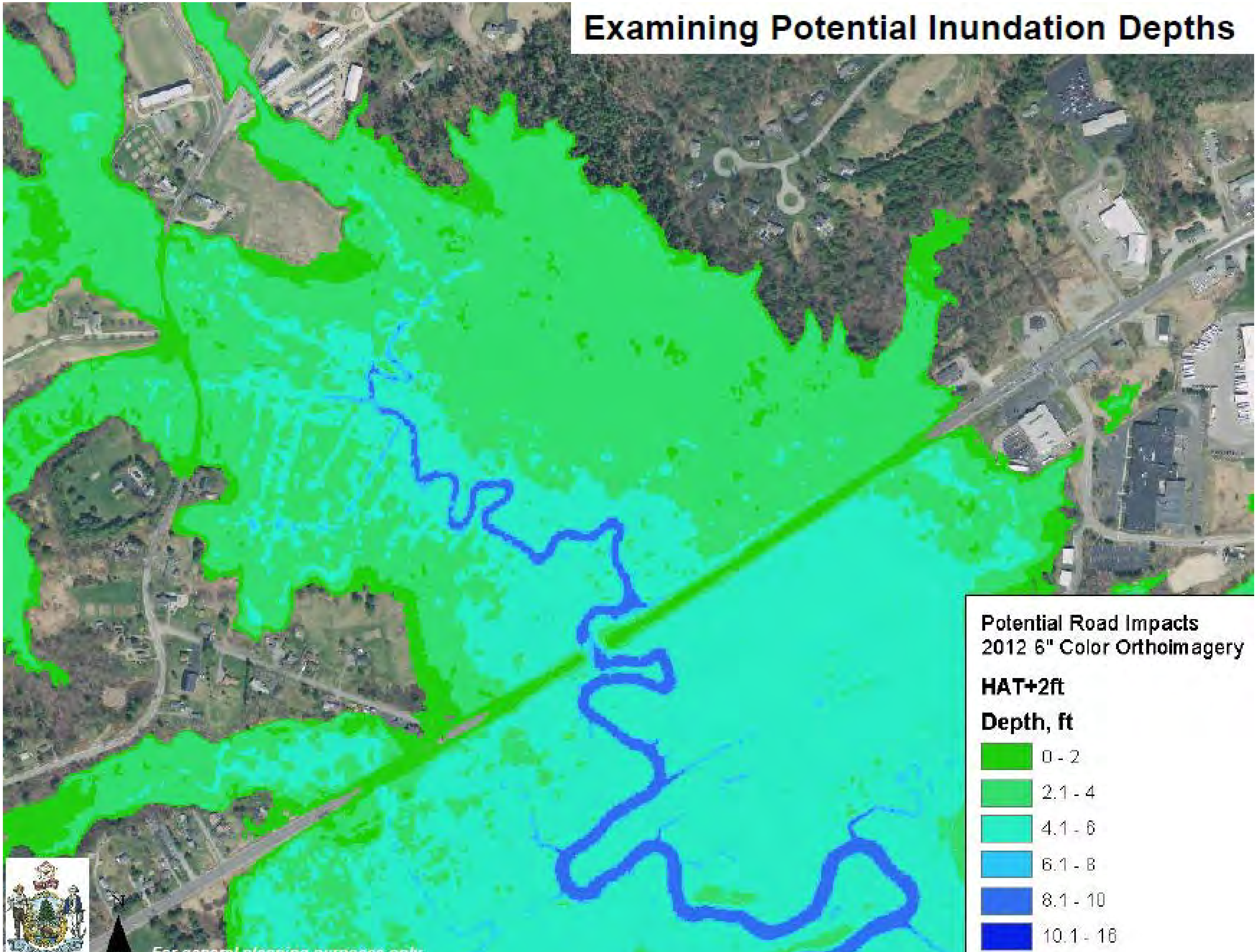


SCARBOROUGH MARSH


Examining Potential Inundation
Payne Road
Route 1
Black Point Road
Sawyer St.
Winnocks Neck Road
Eastern Trail
Pine Point Road
Potential Road Impacts (2012 6" Color Infrared)
Roads HAT
Roads HAT + 1 ft
Roads HAT + 2 ft
Roads HAT + 3.3 ft
Roads HAT + 6 ft
911 Roads
For general planning purposes only.

Examining Potential Inundation

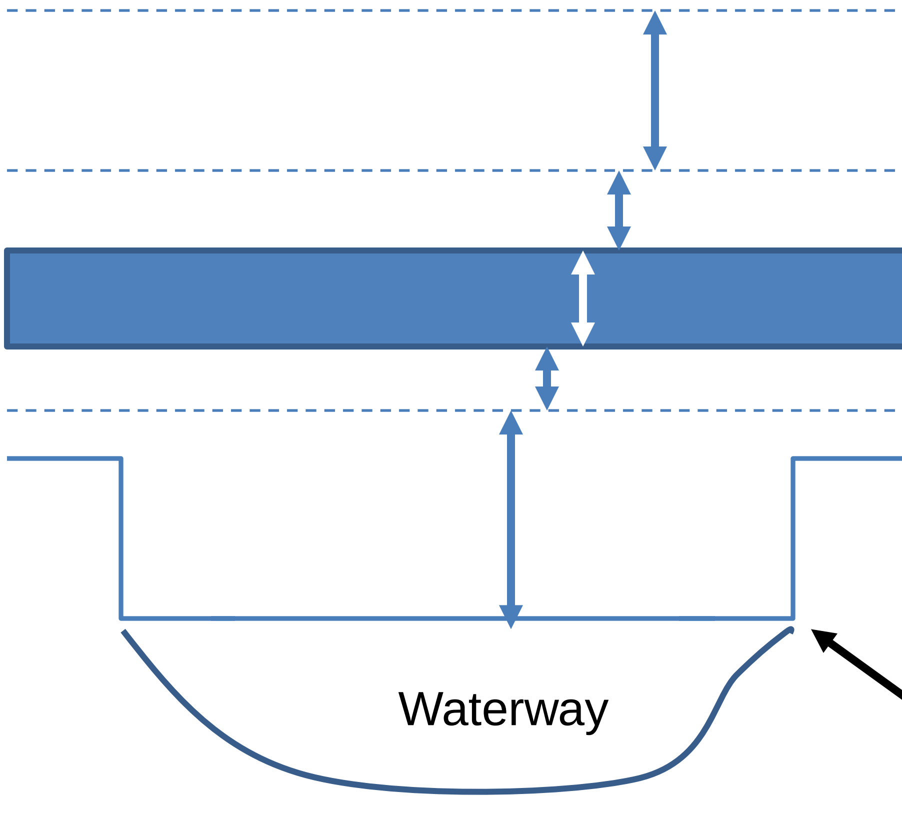



Examining Potential Inundation Depths
Potential Road Impacts
2012 6" Color Orthoimagery
HAT+2ft
Depth, ft
0 - 2
2.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
10.1 - 16
N
For general planning purposes only.

Key Elements of the Approach

- For each of four assets, we are examining cost-benefit relationships of three alternatives:
  - Replace "in-kind"
  - Replace with structure built to standards for 3.3' of SLR + SS
  - Replace with structure built to standards for 6.6' of SLR + SS
- In general:
  - Costs:
    - Initial replacement or construction costs
    - Maintenance and repair over time, after each storm surge event
  - Benefits:
    - Avoided damages provided by each structure in the face of a range of SLR and storm surge scenarios.

Depth Damage Functions Are Designed for Each Structure



Elev.	Damage	Cost
12-16’	Extreme	= $E/event
11-12’	Severe	= $D/event
8-11’	Moderate	= $C/event
7-8’	Minor	= $B/event
0-7’	Slight	= $A/event

Framework for financial efficiency estimates (model output)

For Each of Four Assets:	*In Kind* (=existing design standards)		*Adaptation 1* (Structure designed to 3.3' SLR)		*Adaptation 2* (Structure designed to 6.6' SLR)	
if	3.3'	6.6'	3.3'	6.6'	3.3'	6.6'
Cumulative Damage if No Action	$	$	$	$	$	$
Cumulative Damage with Structure in Place	$	$	$	$	$	$
Avoided Damage (*Row 1 – Row 2*)	$	$	$	$	$	$
Cost of Structure	$	$	$	$	$	$
Benefit:Cost Ratio (*Row 4/Row 5*)	____	____	____	____	____	____

Note: "Damage" = repair and replacement costs for each structure, for each Depth Damage Function increment, as developed by MDOT engineers.

SO WHAT DO WE DO IN THE MEANTIME?

- Precipitation data has recently been updated from the 1960s data that was in use and the intent is to continue to keep the regression equations that use this data up-to-date on a 10 to 20 year cycle.
- Bridges currently designed to a 100-year precipitation event and checked for scour at a 500 year event.
- MaineDOT is currently evaluating its sizing criteria for minor spans and culverts replaced under both capital and maintenance programs.
- Other landscape factors may also be part of the sizing criteria, such as upstream land cover, potential damage downstream, history of past flooding events, debris potential, risk of failure, scour potential, and presence of sensitive species.

CLIMATE CHANGE AND INTERACTING STRESSORS

Responding to Coastal Change in Casco Bay

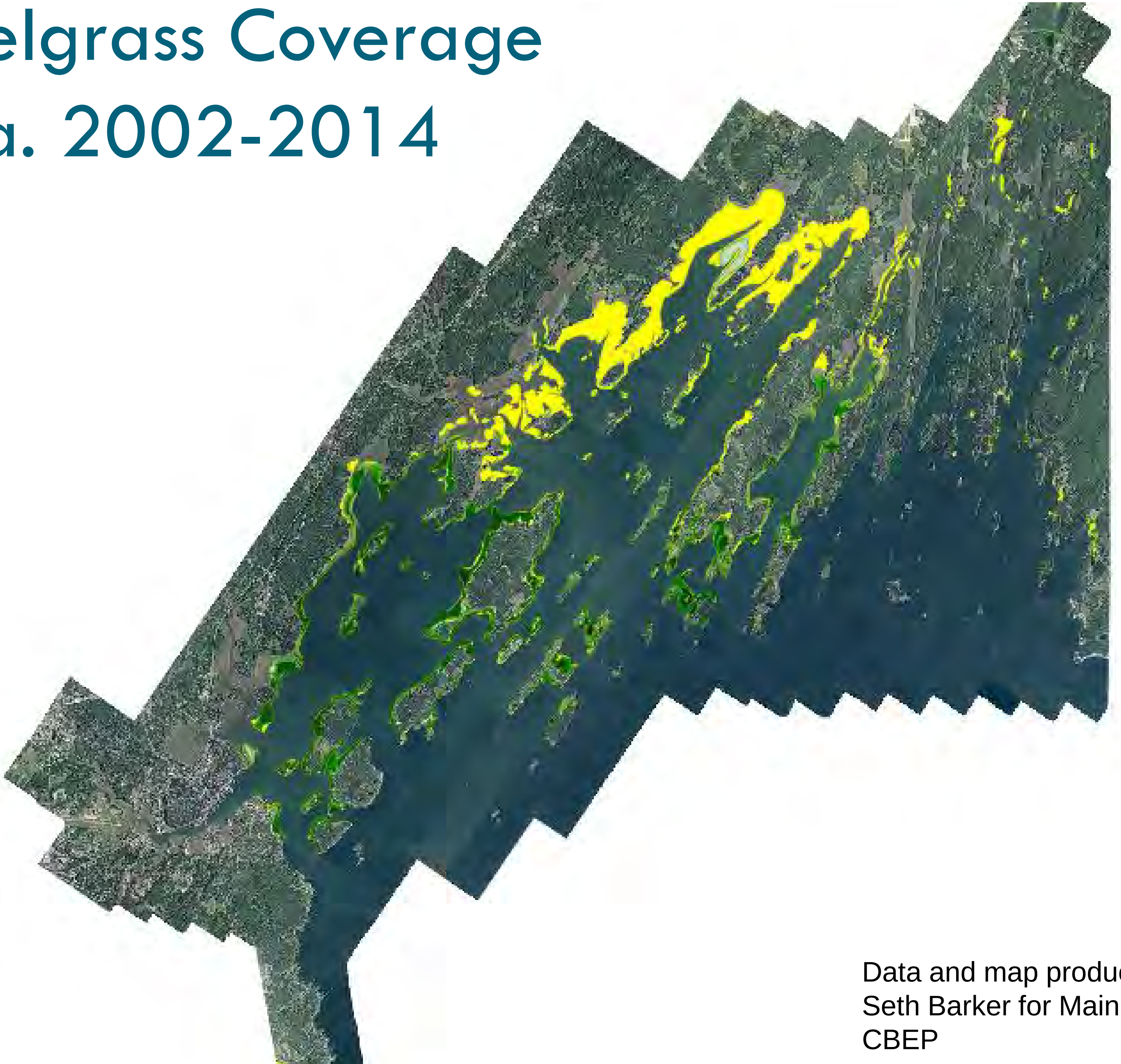
Curtis C. Bohlen
Director, Casco Bay Estuary Partnership

A Changing Ocean…

- That's me, after catching a 64 lb halibut off Jonesport in 1967
- That was a big enough fish to be newsworthy even then

Photos: Hillary Neckles USGS

Eelgrass Coverage ca. 2002-2014



Data and map produced by Seth Barker for Maine DEP and CBEP

Disappearing and Declining Marine Resources

- Eelgrass
- Clams
- Mussels
- Northern Shrimp
- Scallops
- Cod
- Sea Stars




Mid-Atlantic Species Coming Our Way


MD DNR


George Grall, National Aquarium

- Sightings of species with southern affinities have increased
- Harbingers of coastal change
- Marine resources of the future?

Invasion of the Jellies?

Beroe ovata

http://combjellies.wikispaces.com/Order+Beroida-Beroe+ovata

Pleurobrachia pileus

Misjel Decleer
www.marinespecies.org

Peter Schuchert, **World Hydrozoa database. http://www.marinespecies.org/hydrozoa on**

Sarsia spp.

High populations of lions mane and moon jellies were widely reported in local media in 2014

It's not just Climate, It's Change

- Entering an unprecedented period of (relatively) rapid change
  - Climate
  - Coastal acidification
  - Seal level rise
  - Invasive species
  - Altered marine food webs
  - Coastal development
  - ….

Atlantic Salmon, New Brunswick, 1920s

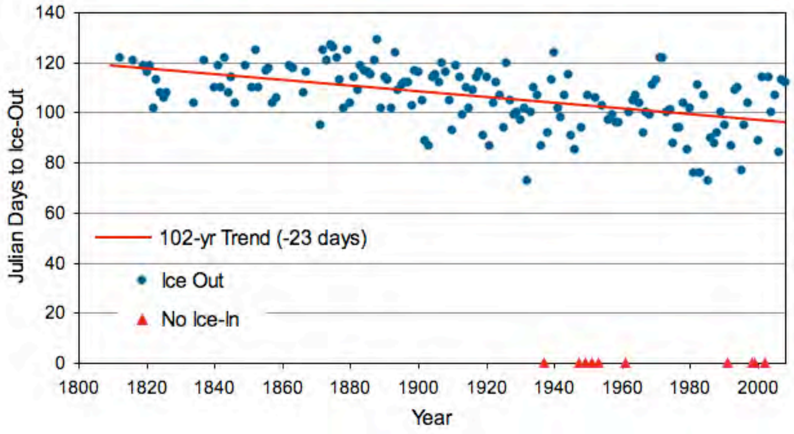
The Popular Villain

P. Erickson for MIT Sea Grant College Program (from NEANS website)

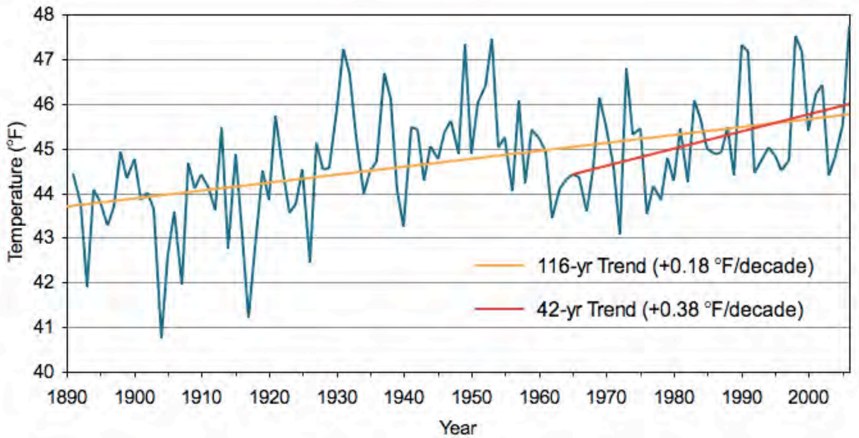
Eurasian Green Crab

- First noted in Casco Bay in 1905
- Why a problem now?
- Northern genotype in Eastern Canada, NOT documented here
- Boom in abundance in 1950s, many similar ecosystem effects

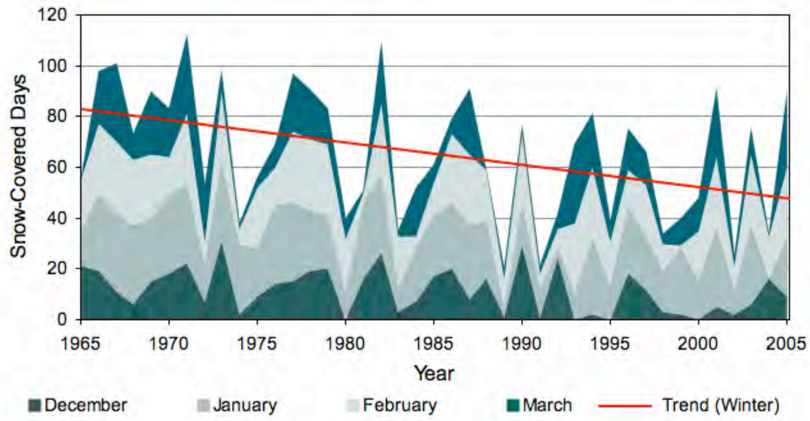
Historical Change



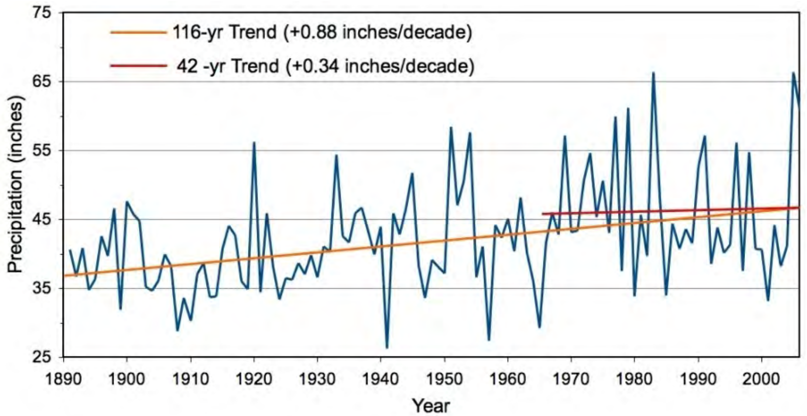
Ice Out Day on Sebago Lake



Average Annual Temperature

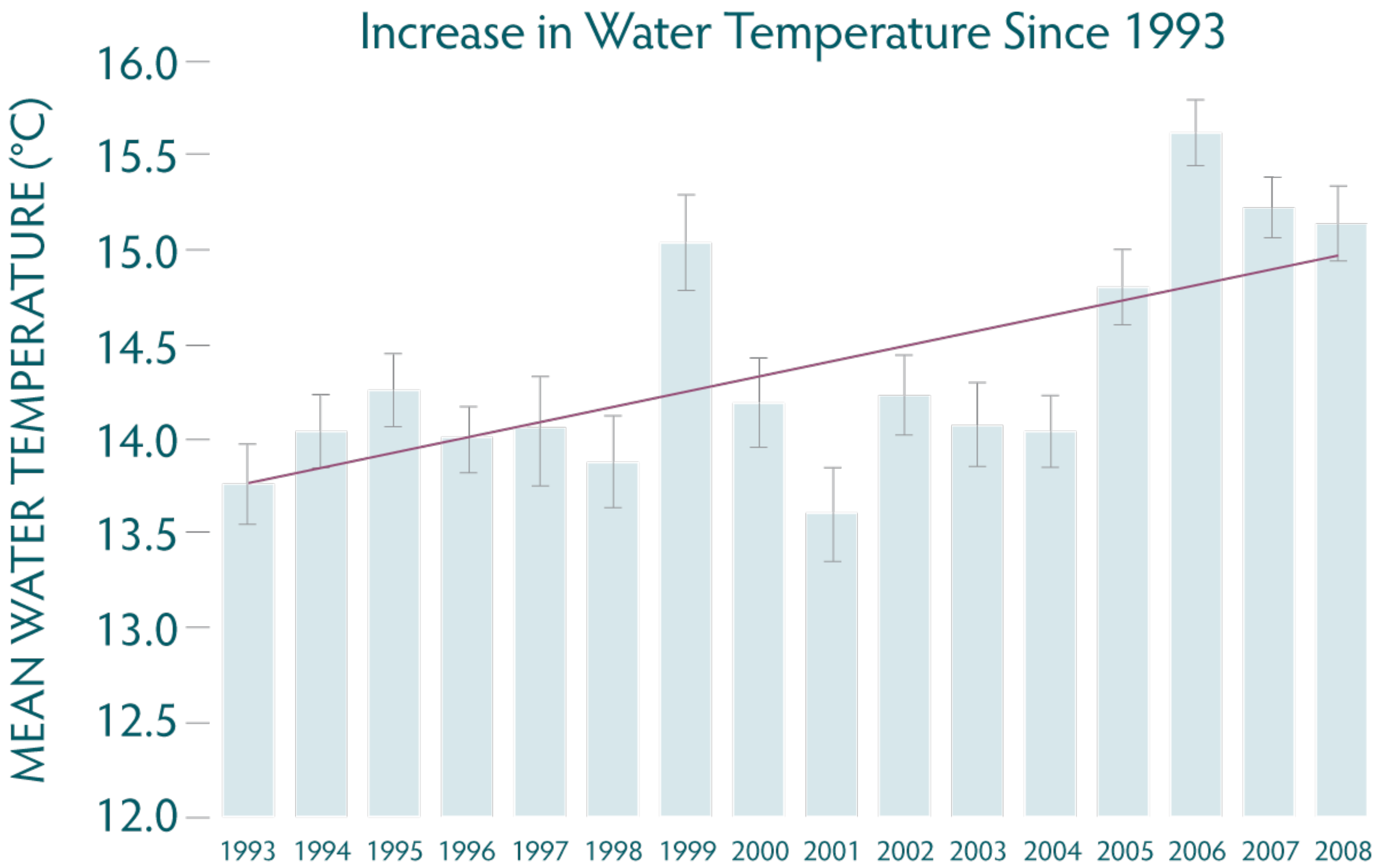


Days with Snow on the Ground



Total Annual Precipitation

Casco Bay Water Temperature



Data from FOCB water quality monitoring

Non-Native species

Gretchen Lambert
www.exoticsguide.org

Oregon DFW

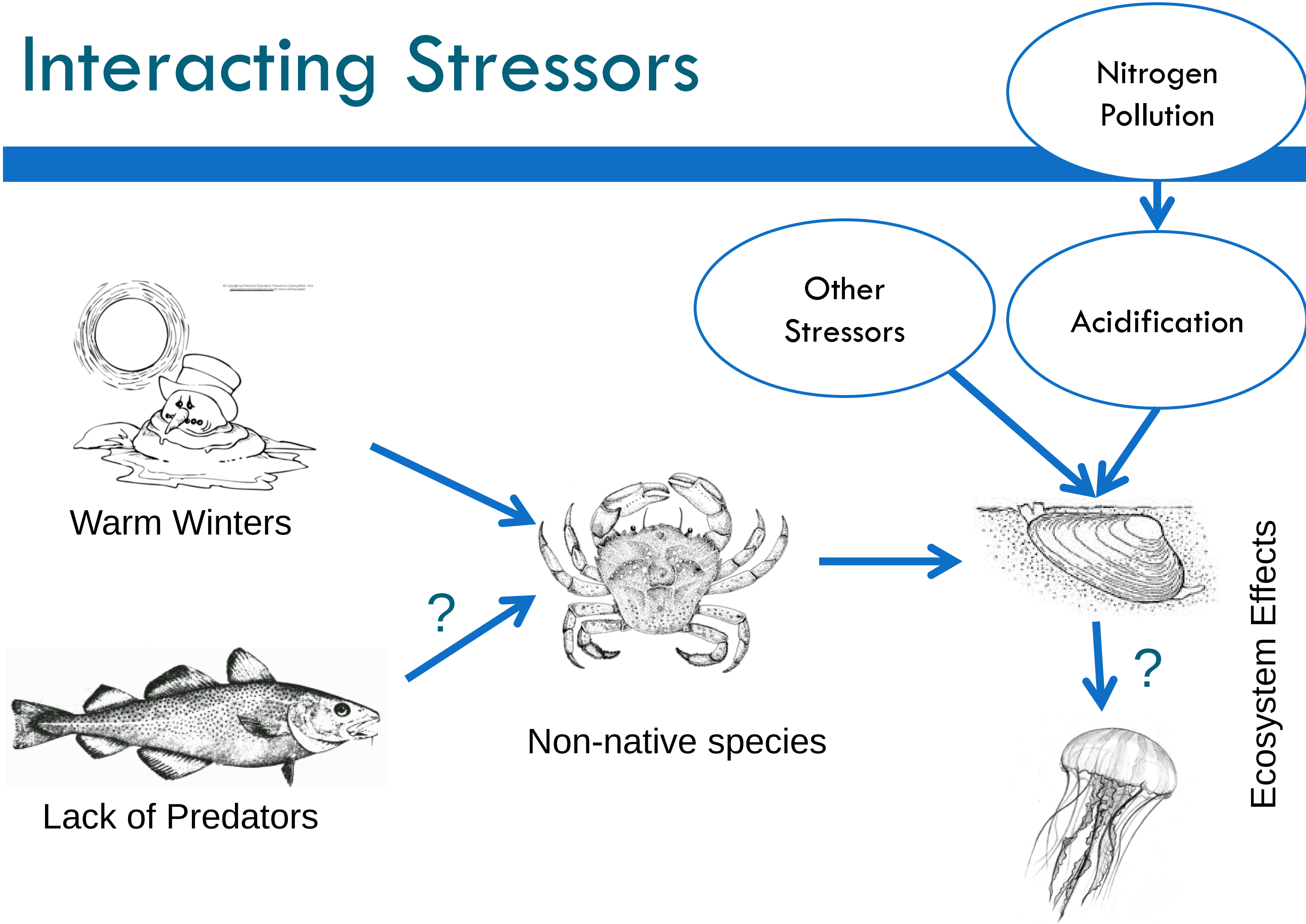
Gail Ashton (Creative Commons
Non-Commercial use)

GMRI, Vital Signs Program

Coastal Acidification

- More CO_2 in the atmosphere leads to more CO_2 in the oceans
- Higher primary production in coastal waters leads to more CO_2 in our Bays
- Effects on shellfish

Interacting Stressors



Planning for Change

- We are not controlling the drivers of change
- What are our conservation goals if the past can no longer be our guide?
- How do we build coastal ecosystems and communities that respond constructively to change?

No one said it would be easy….

Coastal Resilience

- Ecosystem Resilience
  - Ecosystem will continue to provide valued environmental goods and services despite changes

- Economic Resilience
  - Coastal communities will continue to thrive in a changing world

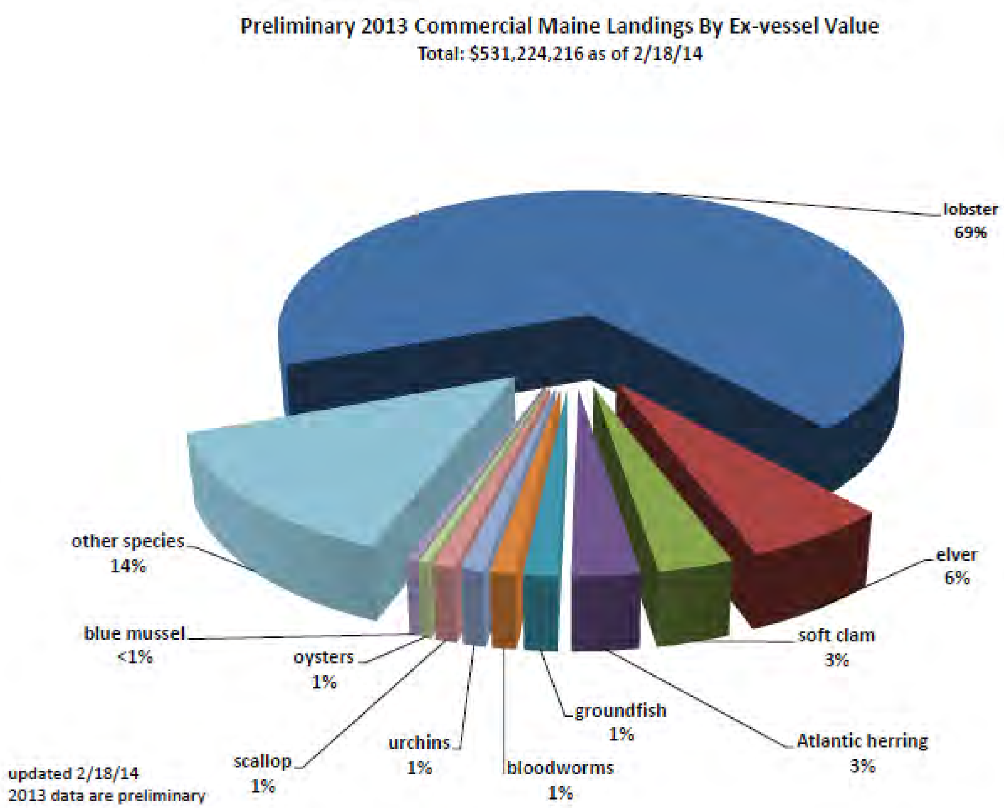
Ecosystem Resilience

P. Erickson for MIT Sea Grant College Program (from NEANS website)

Eurasian Green Crab

- Maine marine ecosystems
  - Already stressed
  - Reduced species diversity
  - Loss of top predators (e.g. cod, haddock)
- Green crabs are
  - Reducing harvests (e.g., shellfish)
  - Reducing habitat (eelgrass)
- Emerging ecosystem
  - Less economically productive
  - Probably less resilient

Economic and Social Resilience



Source: Maine DMR

- Lobster in king, creating what has been called a “Gilded Trap”
- Communities rely on a single marine resource
- Less resilient to ecosystem change

Protecting Ecosystem Resilience

- Protect a variety of (future) habitats
- Protect connections between habitats
- Protect functional diversity within ecosystems
- Protect options
- Address known and controllable stressors

Looking Forward

- Maine's coastal communities will continue to depend on our coastal ocean
- But we don't know how
  - Novel fisheries?
  - Aquaculture?
  - Ocean energy?
  - Tourism?
  - Sense of place?

Policies for A Changing Ocean

- Support innovation to identify economic opportunities that reflect the changing ocean
- Employ short term strategies (like green crab controls or liming of tidal flats) to protect economic relationships and support orderly transitions to new economic models
- Develop regulatory tools that can respond constructively to change

Thank you

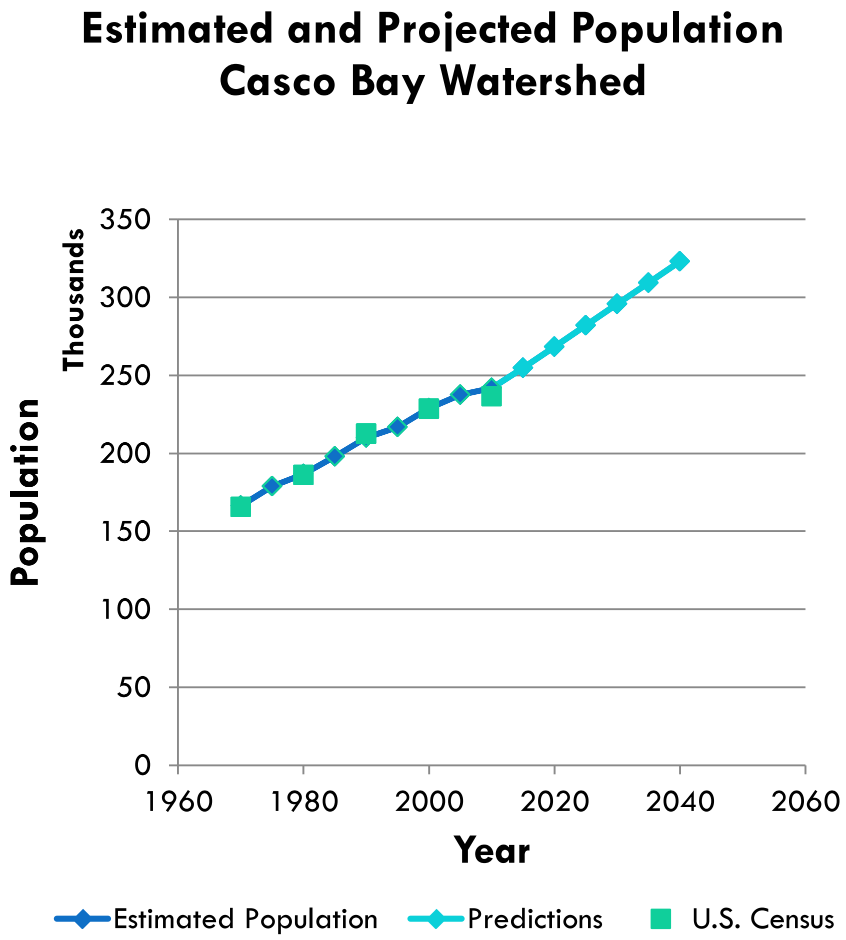
Curtis Bohlen

Director, Casco Bay Estuary Partnership

cascobayestuary.org

cbohlen@usm.maine.edu

Population in the Casco Bay Watershed



Source: Woods and Poole Economics, Inc., via
NOAA's Spatial Trends in Coastal Socioeconomics (STICS)

- Population has been growing ~ 1% per year
- Slow compared to many areas in US, globally
- Projections suggest continued moderate increases

Regional Planning Tools for Coastal Resource Management

Maine Climate Roundtable

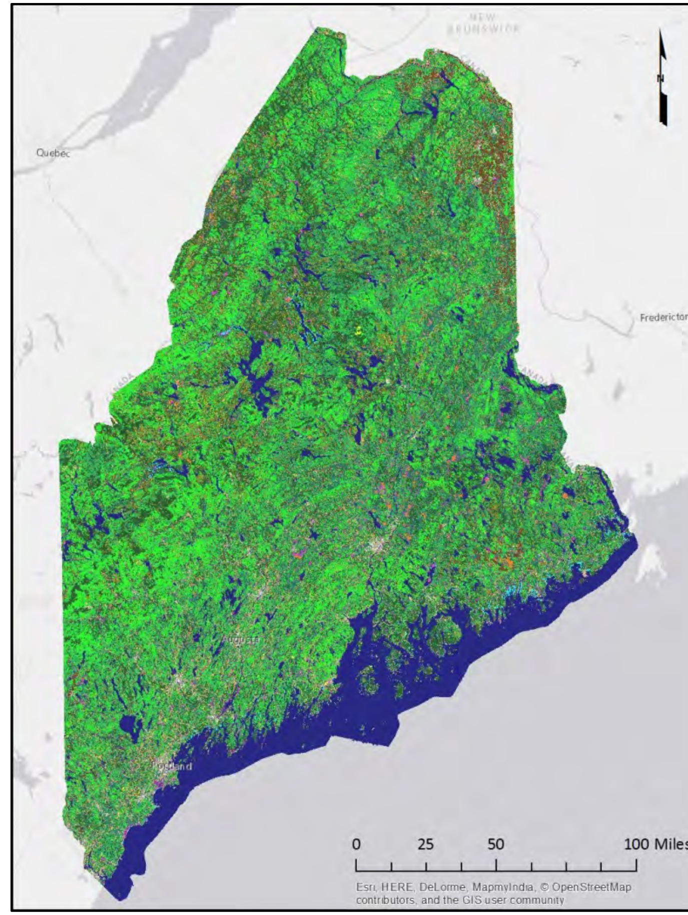
October 10, 2014

Jamie Carter, Geospatial Solutions Program

NOAA Office for Coastal Management

Objectives

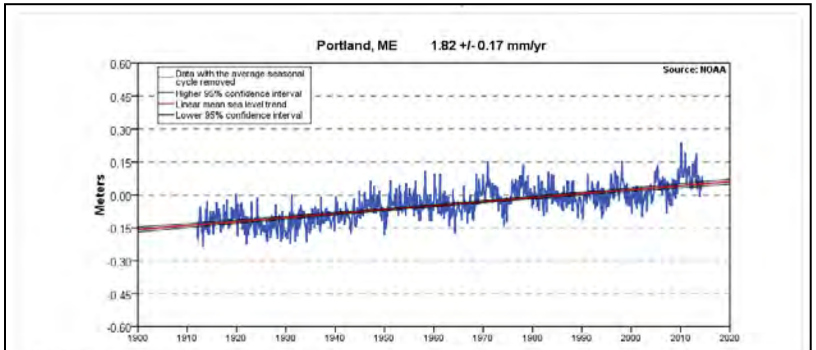
- Introduce the Coastal-Change Analysis Program (C-CAP) land cover data
- Explore state and county land cover change
- Highlight relevant decision support tools



Climate Change is a Spatial Issue

Incipient Threats

- Warmer Temperatures
- Rising Sea Levels
- More Precipitation
- More Extreme Precipitation
- Acidification



The mean sea level trend is 1.82 millimeters/year with a 95% confidence interval of +/- 0.17 mm/yr based on monthly mean sea level data from 1912 to 2006 which is equivalent to a change of 0.60 feet in 100 years.

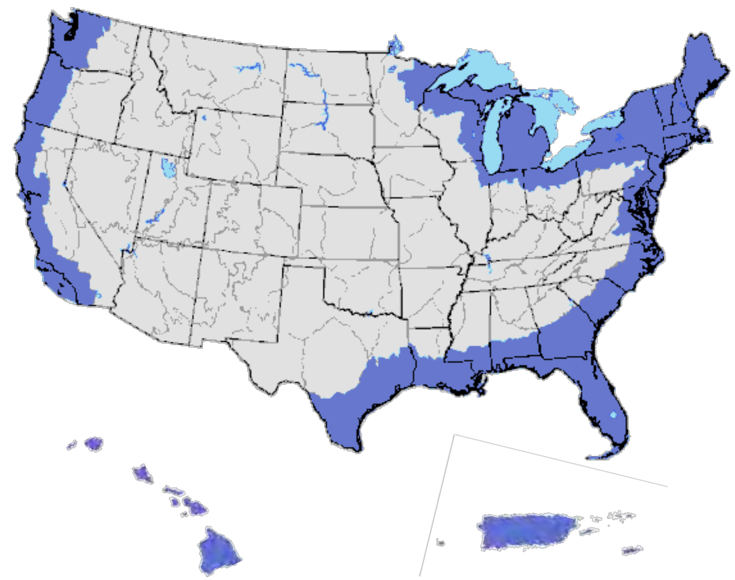
Potential Impacts

- Flooding
  - Riverine
  - Coastal
  - Daily tidal inundation
  - Groundwater levels
- Erosion
- Water quality degradation
- Ecosystem stress
- Habitat change
- Ecological regime shifts




The Coastal-Change Analysis Program (C-CAP)

- National coastal land cover and change mapping program
- Authoritative source for land cover in coastal U.S.
- Detailed intertidal areas and wetlands
- Consistent, accurate products via standard data and methods

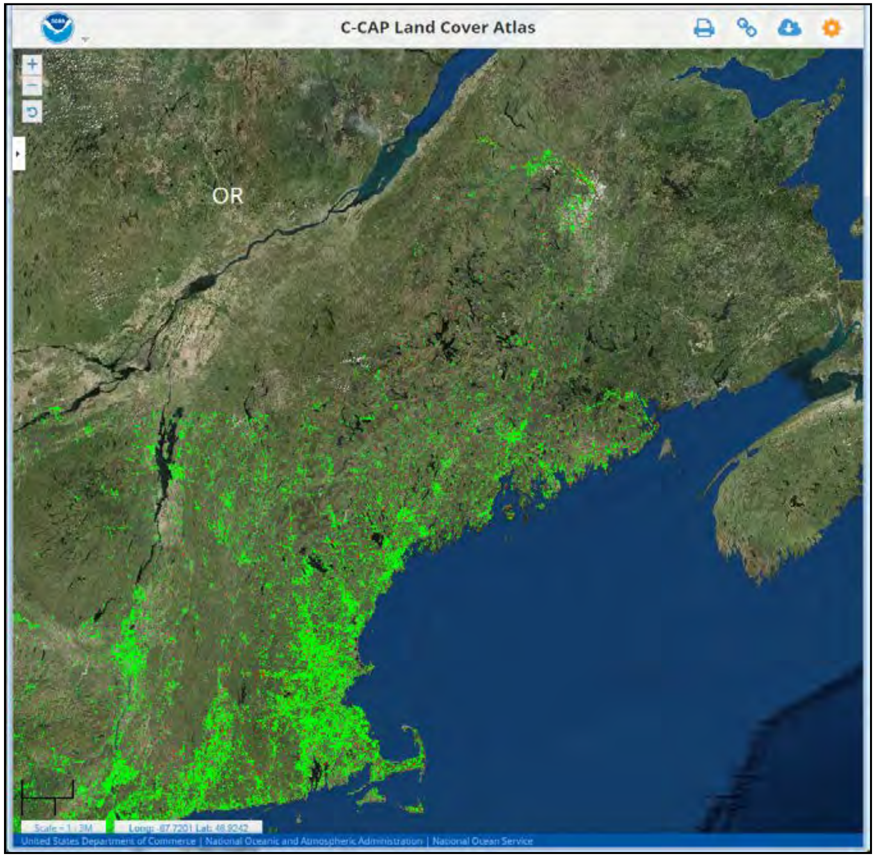


Designed to help understand links between land use change and the environment

State Development Trends

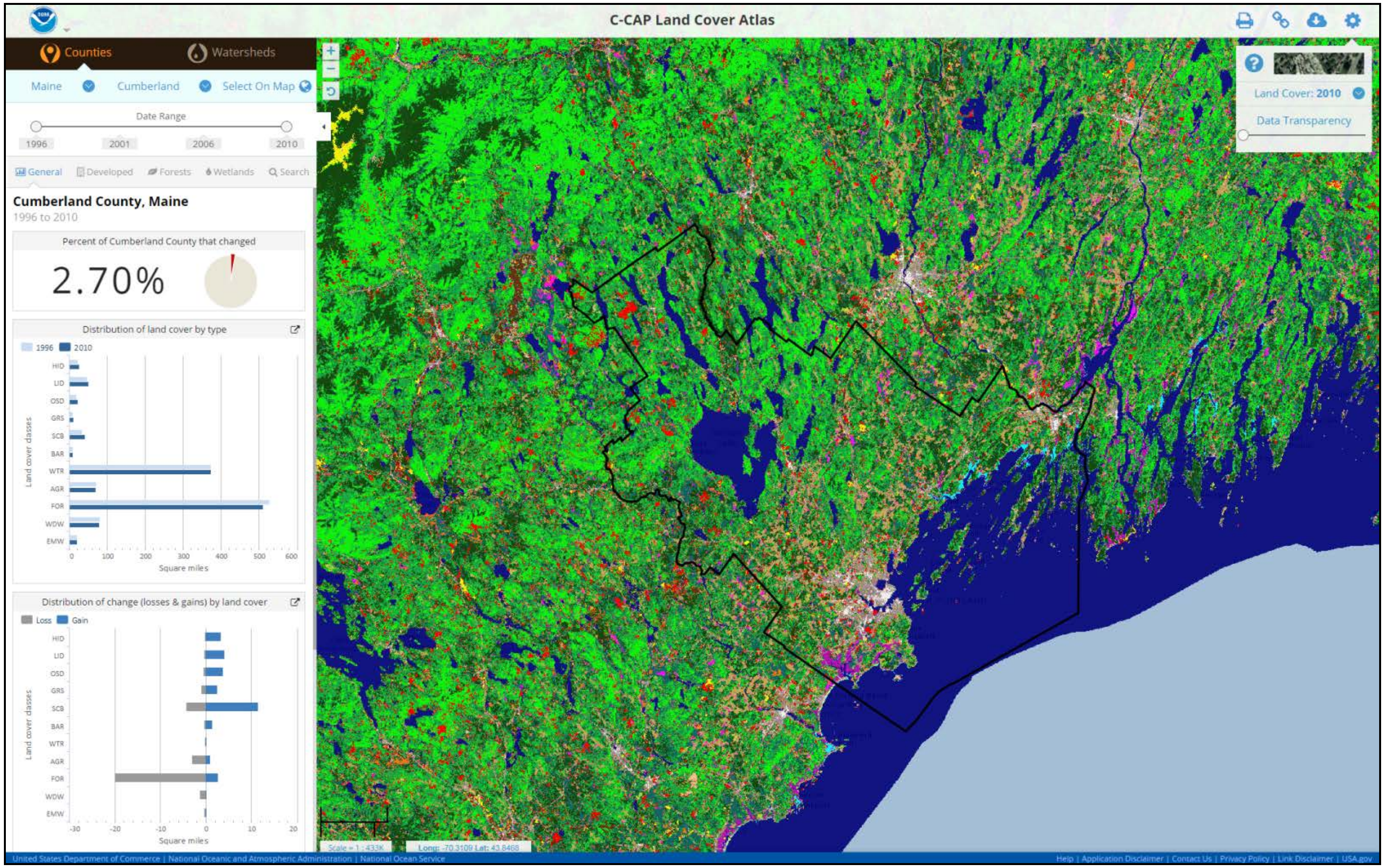
1996 – 2010

- 9% increase in developed area (57 sq mi.)
- Majority of new development is low intensity and open space
- Most new development replaced upland forests and agricultural areas
- Development intensity increased in some areas



County Land Cover Distributions

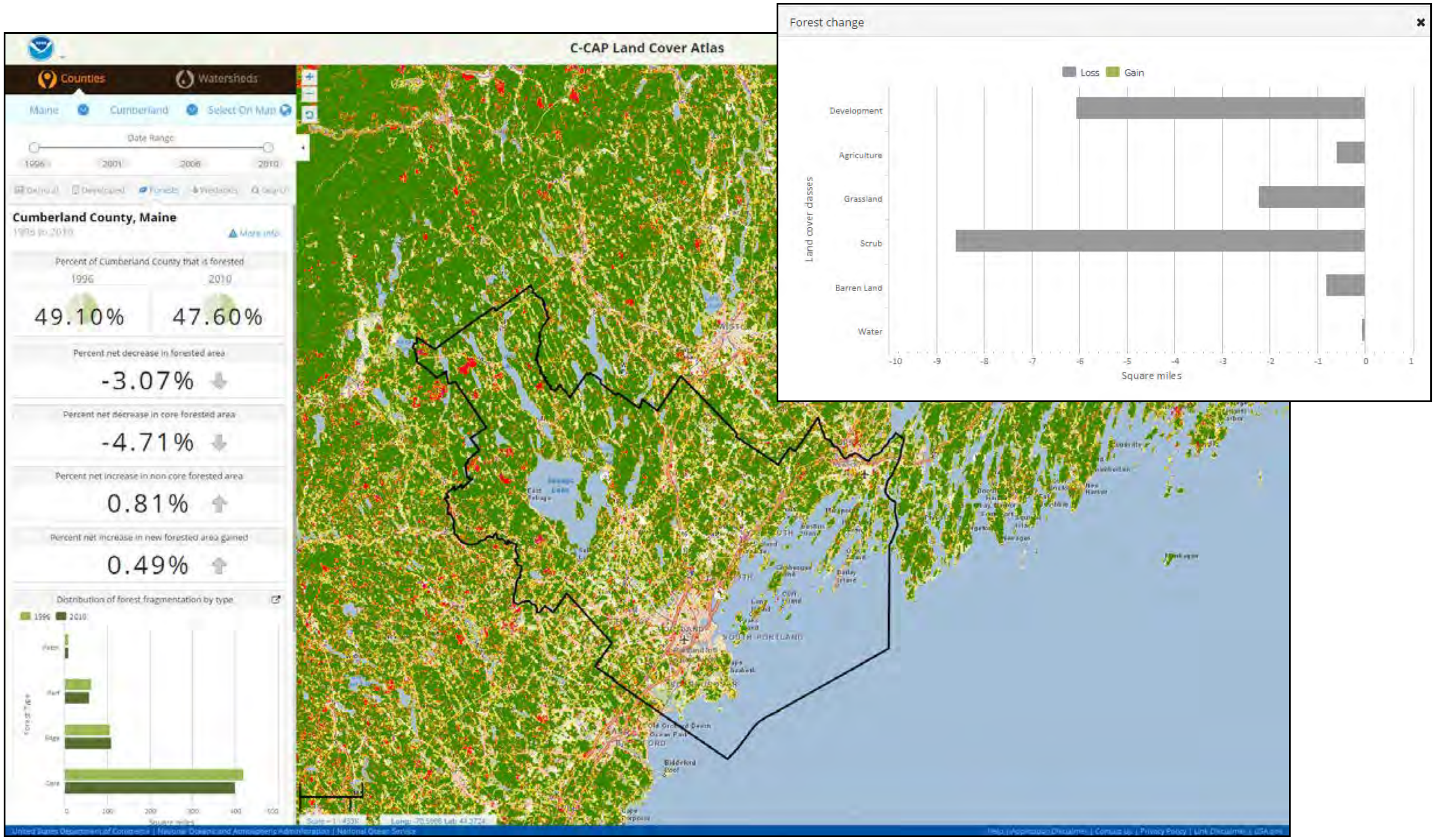
Cumberland County: 1996 – 2010



OFFICE FOR COASTAL MANAGEMENT
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

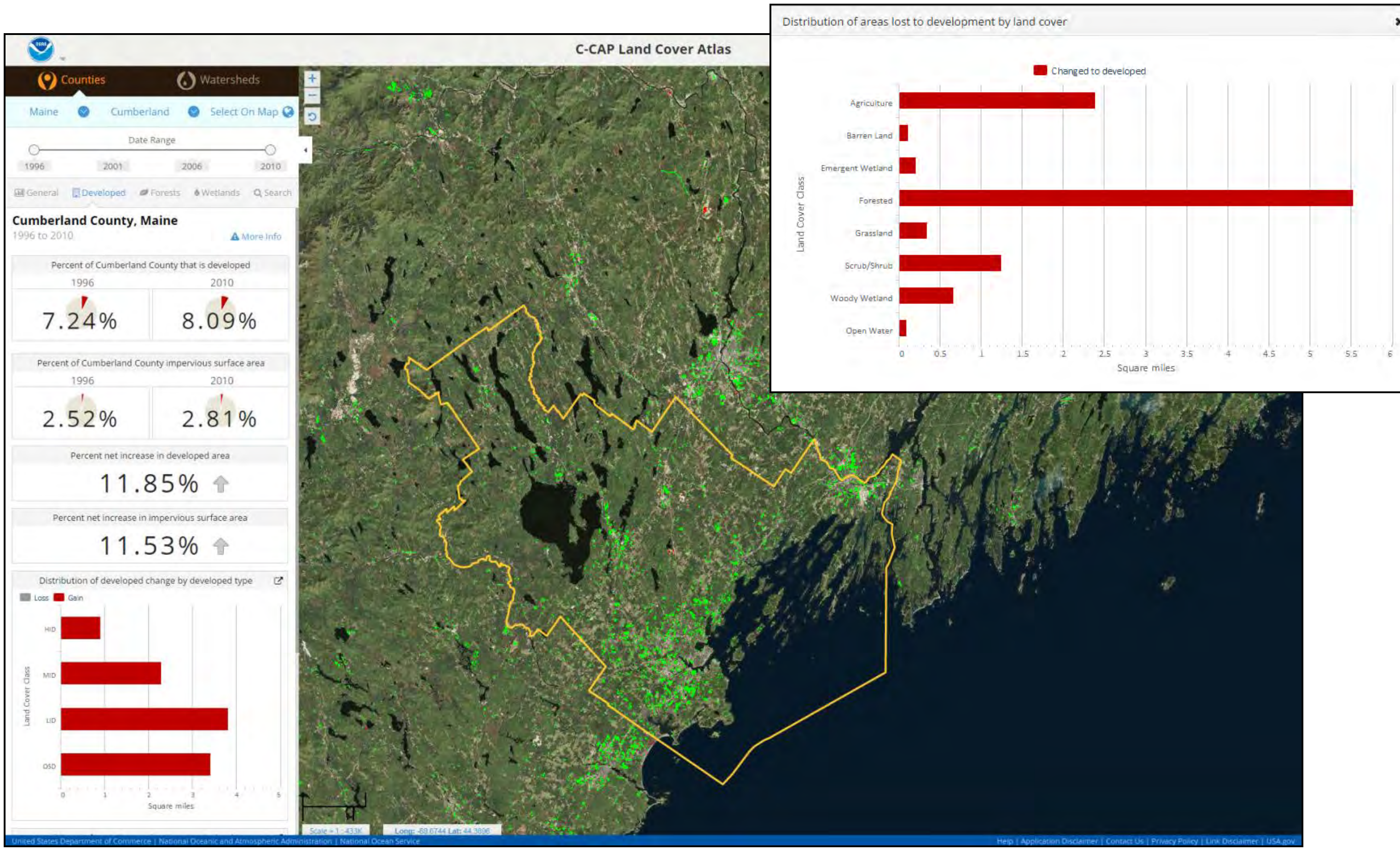
County Forest Change

1996 – 2010



County Development Trends

1996 – 2010

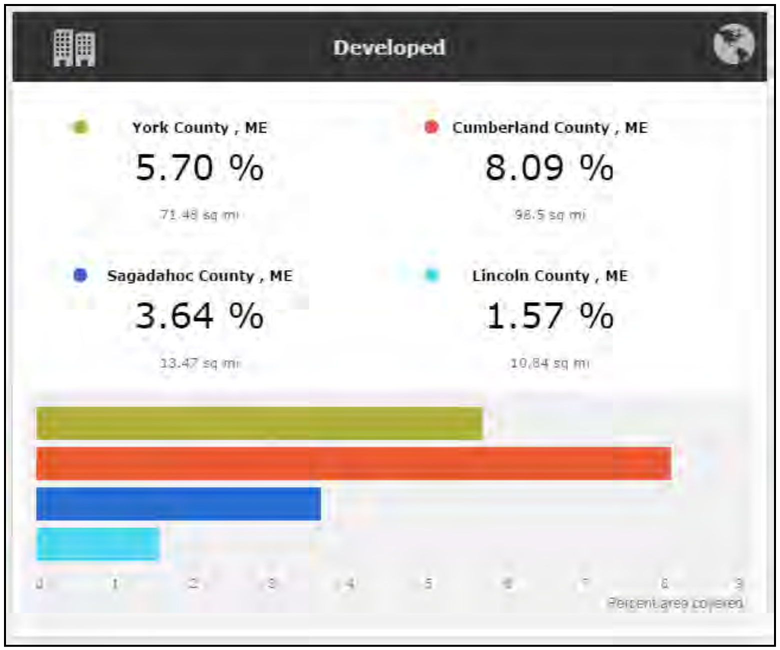


OFFICE FOR COASTAL MANAGEMENT
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

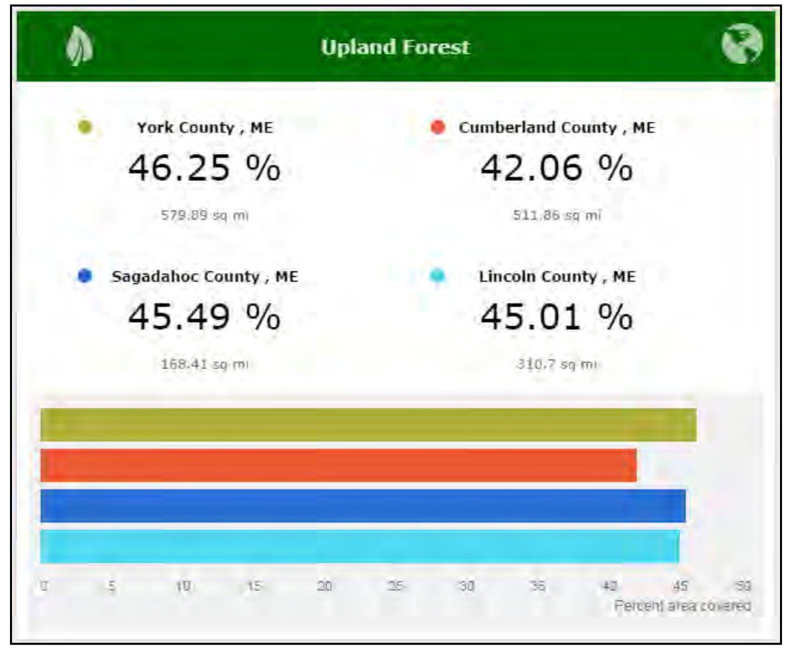
County Comparisons

2010

Developed



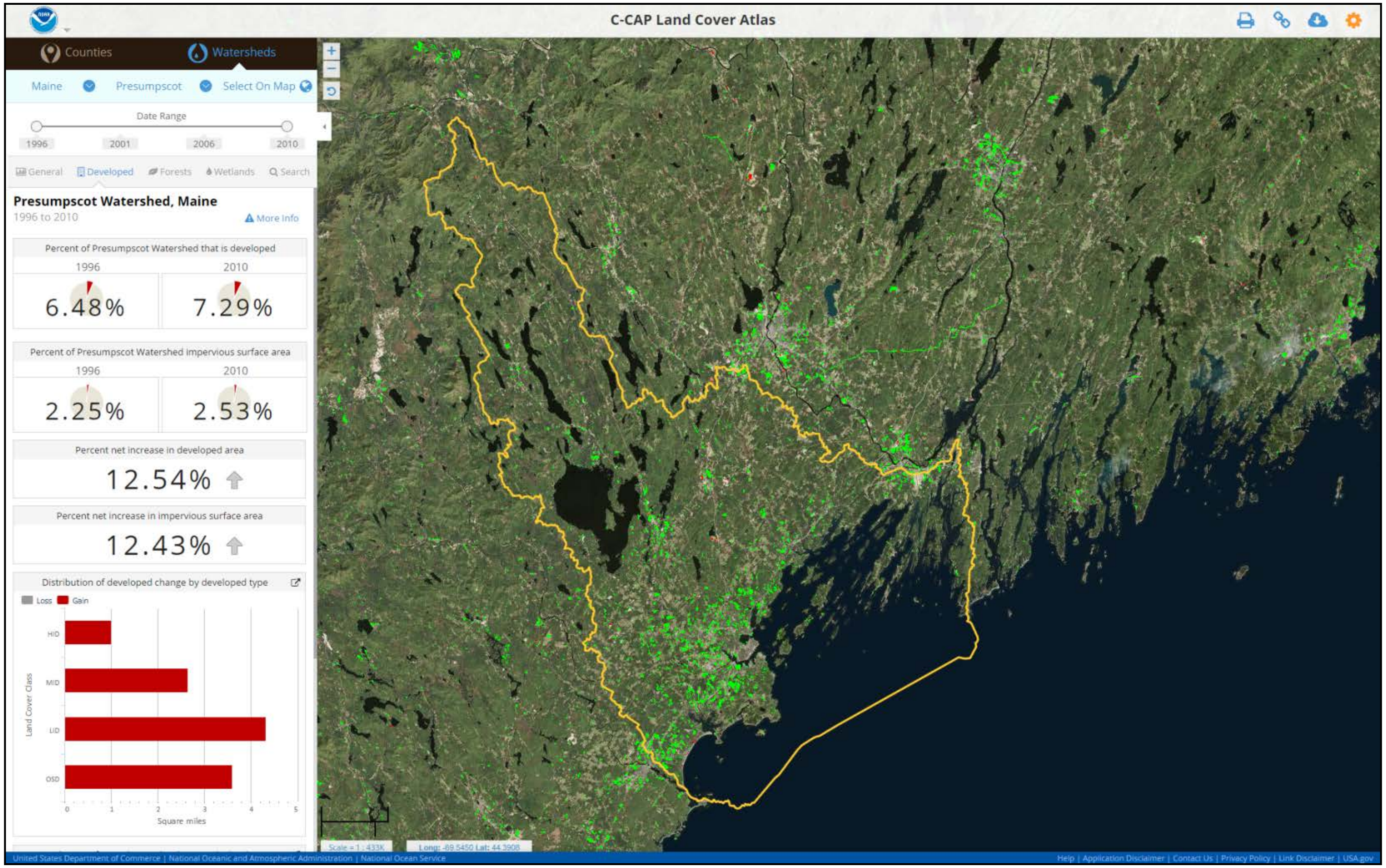
Upland Forest



York County
Cumberland County
Sagadahoc County
Lincoln County

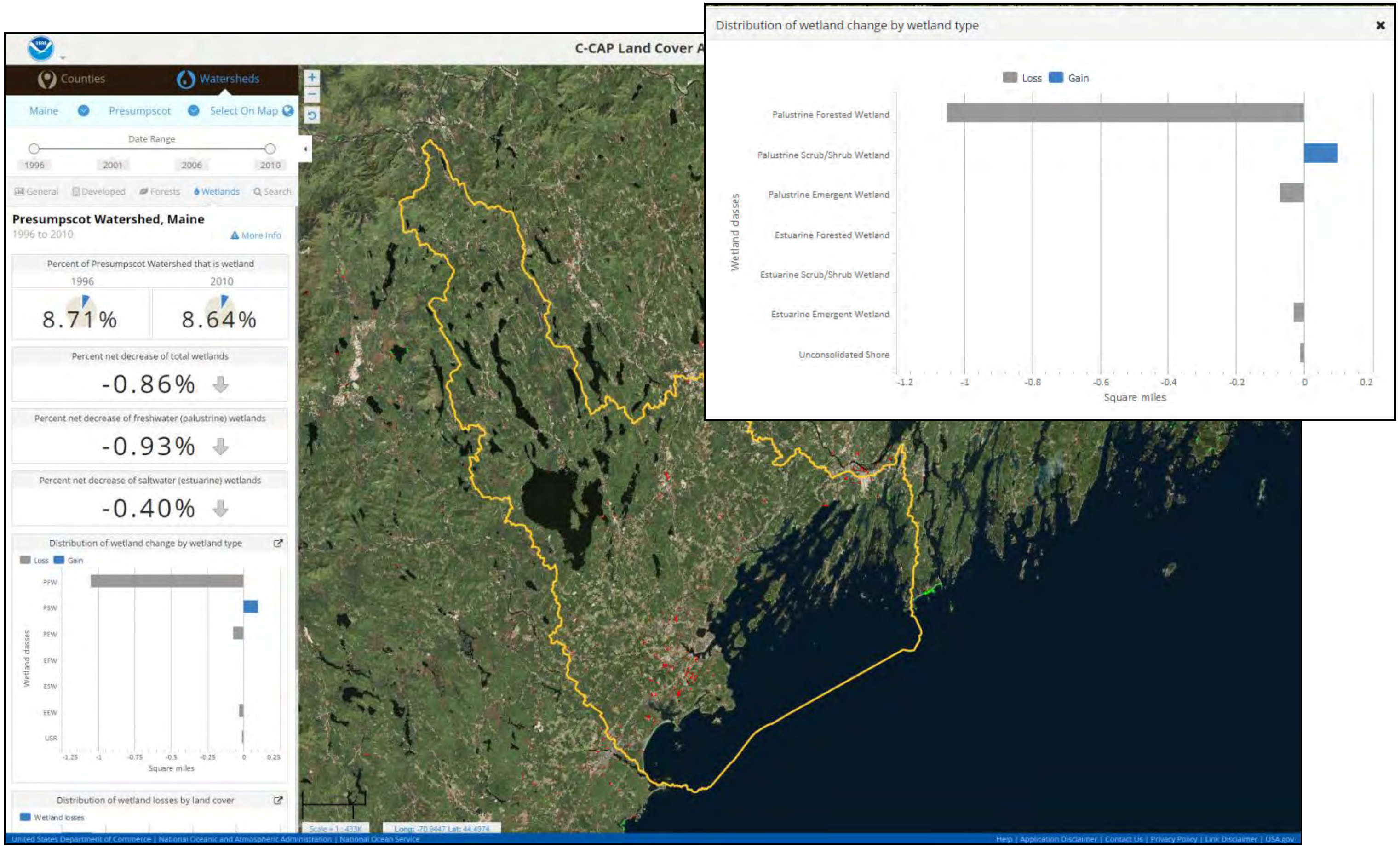
Watershed Development Trends

Presumpscot: 1996 – 2010



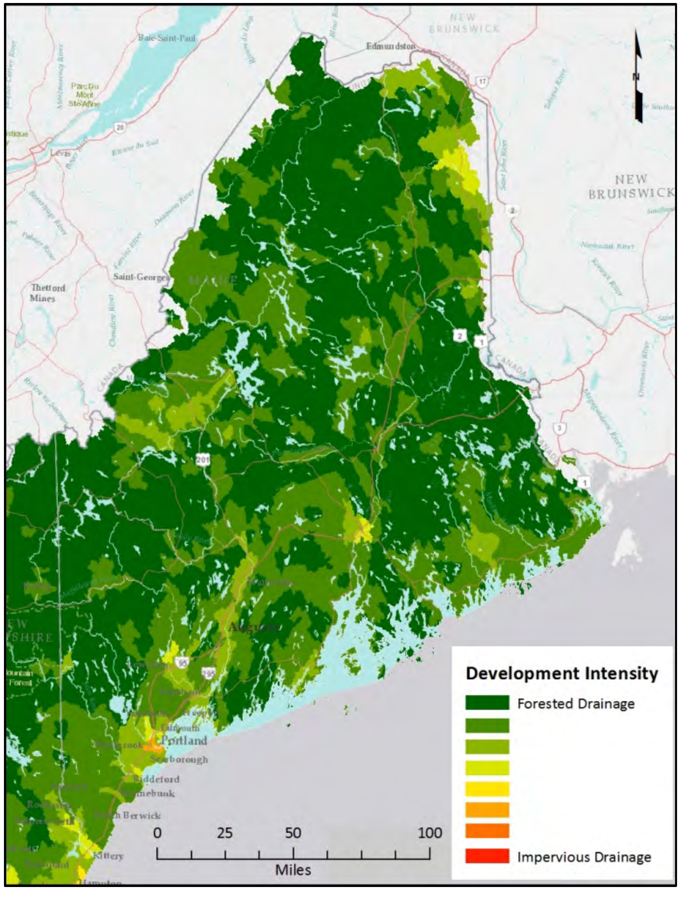
Watershed Wetland Change

1996 – 2010



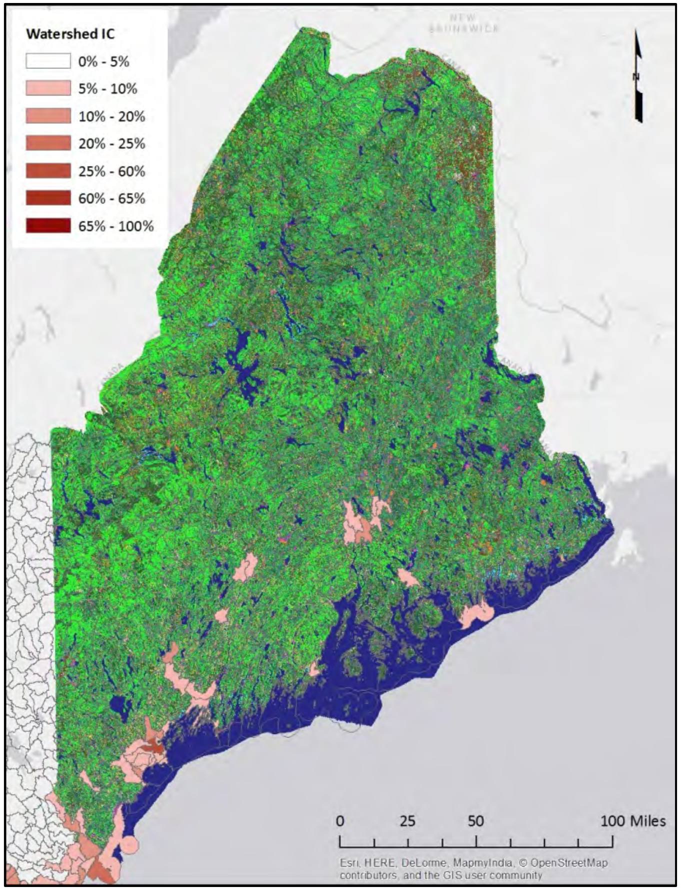
Watershed Resilience

- Mapped using 12-digit hydrologic units
- Represents balance between impervious cover and forest cover
- Proxy for infiltration capacity and potential for water quality protection

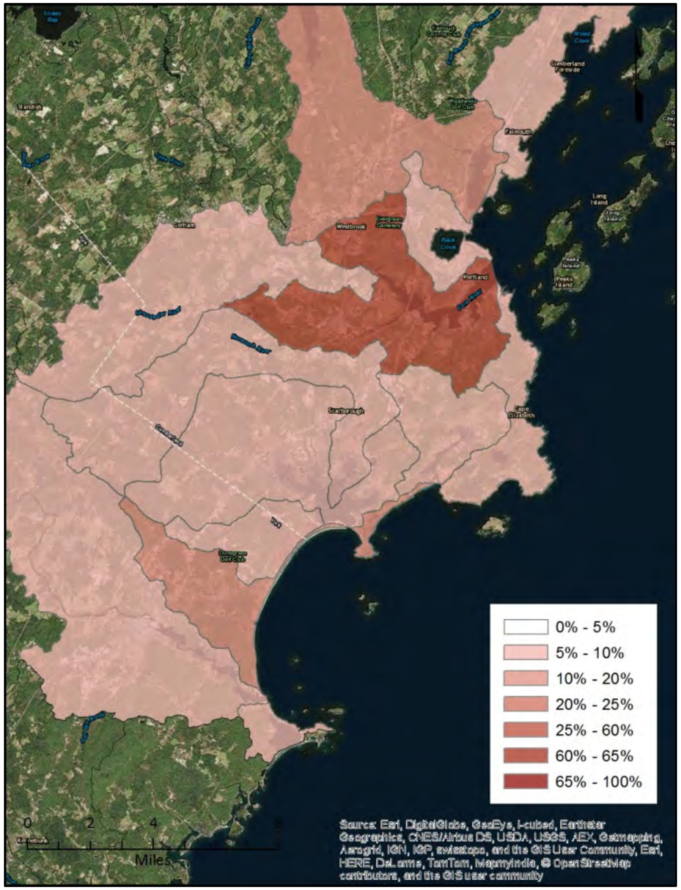


Watershed Impervious Cover

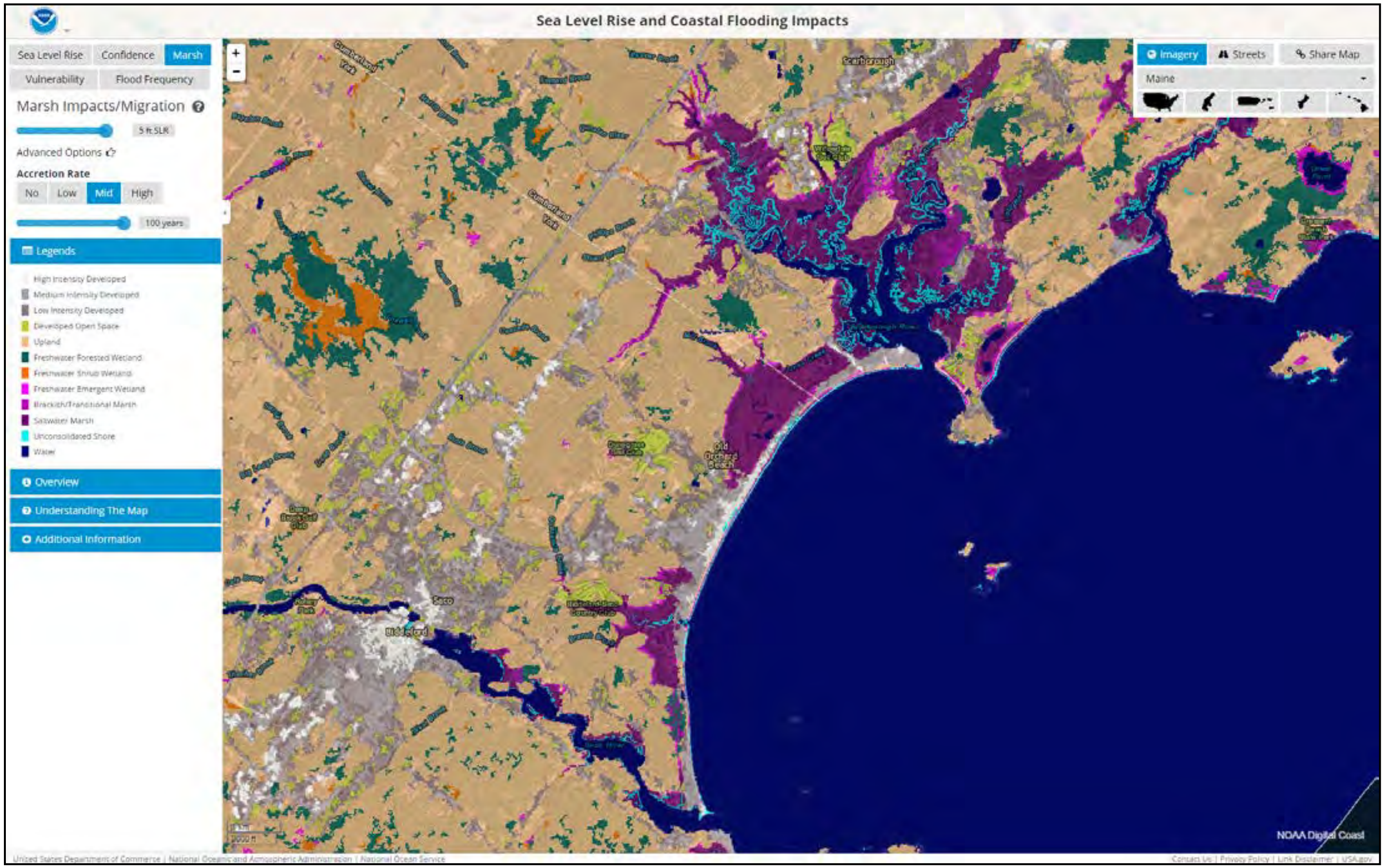
- Impervious cover relates directly to water quality, quantity, and ecosystem health
- Hot spots around Greater Portland, Brunswick, Lewiston, Augusta, Waterville, Bangor, and Ellsworth
- Saco Bay is vulnerable



Impaired Waters vs. Impervious Surfaces

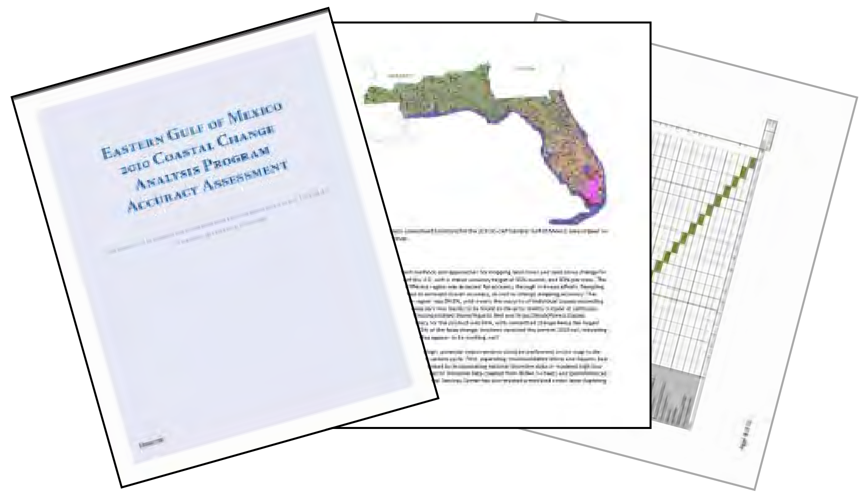


Coastal Wetlands and Migration Potential



C-CAP Resources in Digital Coast

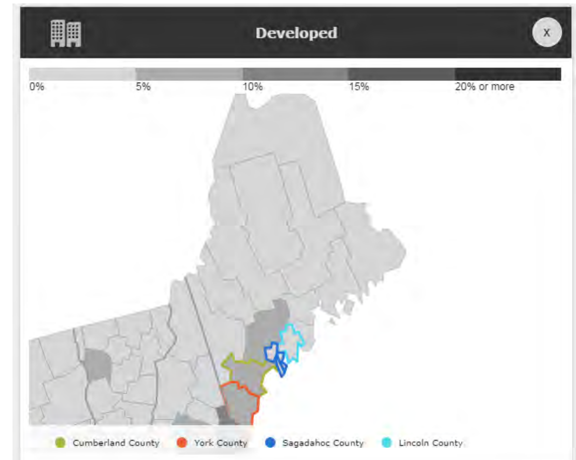
- Access to the data
- Technical documentation and support items
- Example applications and case studies
- Decision support tools



www.coast.noaa.gov/landcover

C-CAP Comparison Tool

- **Provides** land cover statistics for coastal counties in the contiguous U.S.
- **Compares** land coverage of a county to the coastal regions of its state and the U.S.
- **Allows** users to compare land cover data for up to four different counties



www.coast.noaa.gov/ccap-comparison

Sea Level Rise and Coastal Flooding Impacts Viewer

- **Displays** potential flooding from sea level rise
- **Provides** simulations of flooding at local landmarks
- **Communicates** the spatial uncertainty of mapped SLR
- **Models** marsh migration
- **Overlays** flood scenarios on socio-economic data

www.coast.noaa.gov/slr/

C-CAP Land Cover Atlas

- **Facilitates** visualizing areas of land cover change
- **Summarizes** general land cover change trends
- **Allows** for custom analysis of change patterns

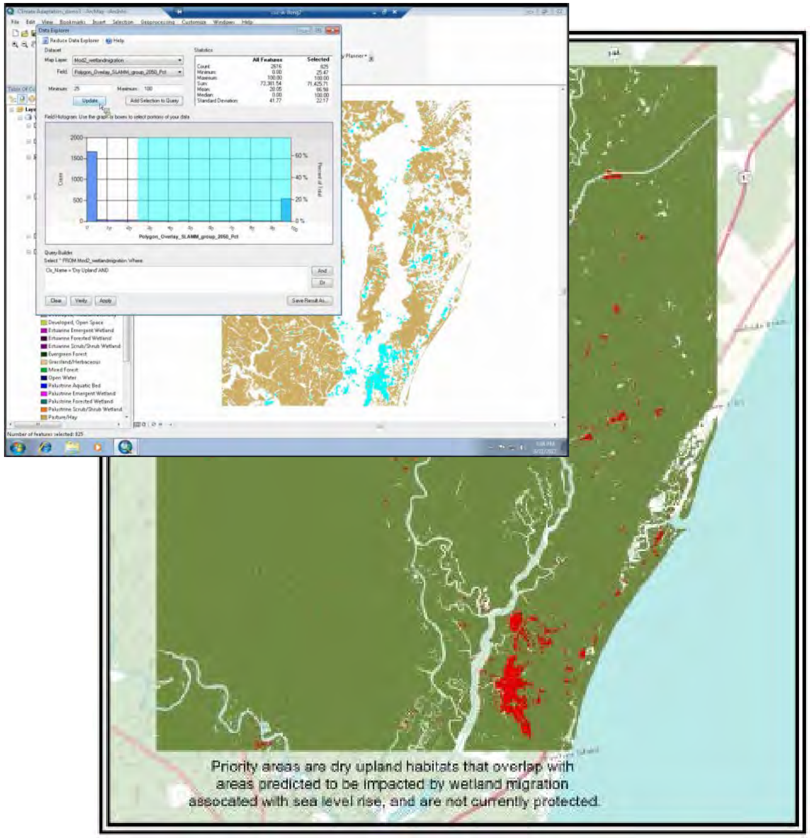
Improvements:

- 2010 data included
- Printable reports
- Ability to add historic dates (and islands) will be added soon

www.coast.noaa.gov/landcoveratlas

Habitat Priority Planner

- **Inventories** specific habitat relevant to the study area
- **Assesses** target habitat conditions with pre-packaged spatial analysis
- **Creates** maps, reports, and data tables to enhance communication and the decision-making process
- **Facilitates** participation



www.coast.noaa.gov/digitalcoast/tools/hpp

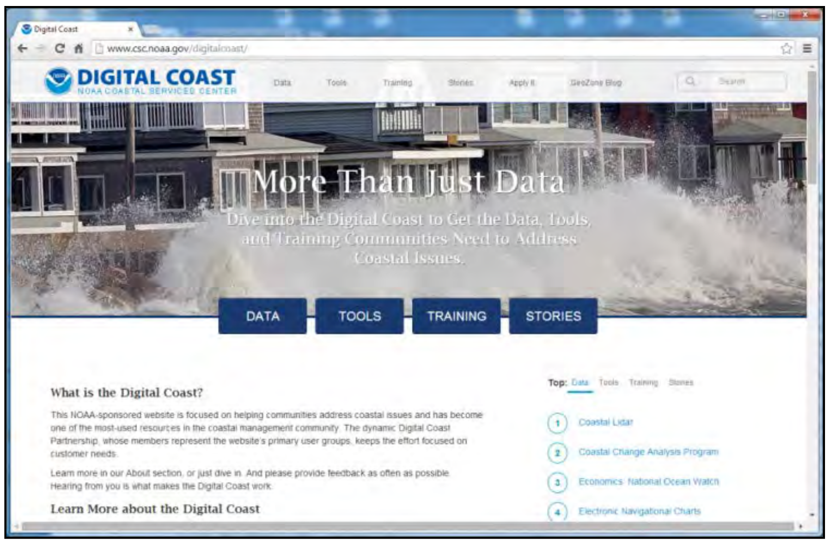
Nonpoint Source Pollution and Erosion Comparison Tool (OpenNSPECT)

- **Provides** maps and estimates of surface water runoff, erosion, and nonpoint source pollution
- **Provides** a means to analyze land use change scenarios
- **Provides** a means to model impacts from different precipitation scenarios

www.coast.noaa.gov/digitalcoast/tools/opennspect

Visit the Digital Coast

- Curated, authoritative sources of coastal data
- Tools, training, case studies, and example uses
- How-to guides and toolkits



www.coast.noaa.gov/digitalcoast

Partner organizations:

Contact Information

Jamie.Carter@noaa.gov

www.coast.noaa.gov/digitalcoast

Digital.Coast@noaa.gov

www.facebook.com/NOAADigitalCoast

@NOAADigCoast

Coastal Land Cover Classes

Developed

- Developed, High Intensity
- Developed, Medium Intensity
- Developed, Low Intensity
- Developed, Open Space

Agricultural

- Cultivated Crops
- Pasture/Hay

Rangeland

- Grassland and Herbaceous
- Scrub / Shrub

Forest Land

- Deciduous Forest
- Evergreen Forest
- Mixed Forest

Barren Land

- Barren Land
- Perennial Ice/Snow

Water

- Open Water
- Palustrine Aquatic Bed
- Estuarine Aquatic Bed

Wetlands

- ***Woody Wetlands***
  - *Palustrine Forested Wetland*
  - *Palustrine Scrub/Shrub Wetland*
  - *Estuarine Forested Wetland*
  - *Estuarine Scrub/Shrub Wetland*
- ***Herbaceous Wetlands***
  - *Palustrine Emergent Wetland*
  - *Estuarine Emergent Wetland*

Unconsolidated Shore

Alaska Only Classes*

- Dwarf Scrub
- Sedge/Herbaceous
- Lichens
- Moss