Potential sea level rise, storm surge, marsh migration, and hurricane impacts in Biddeford, ME

Peter A. Slovinsky, Marine Geologist

Maine Department of Agriculture, Conservation and Forestry

Maine Geological Survey

Funded by:

Quickly, I'll cover….

- What drives sea level rise change?
- Setting the stage: Maine's glacial geology and historic sea level rise trends
- Current sea level trends from Maine
- Where might sea levels go in the future?
- Storm surges
- SLR/surge/marsh migration mapping
- Potential Hurricane Inundation mapping (PHIMs)

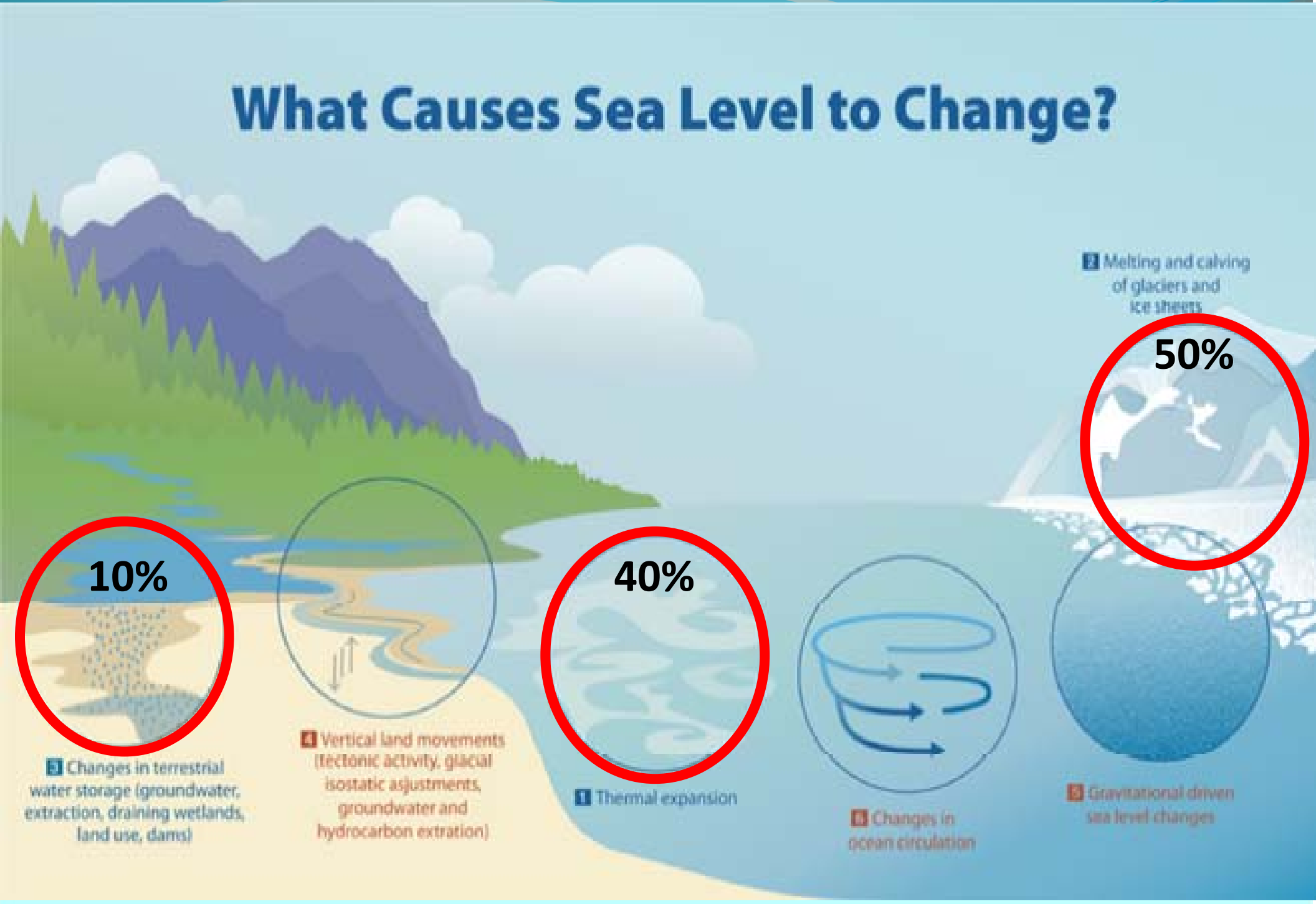
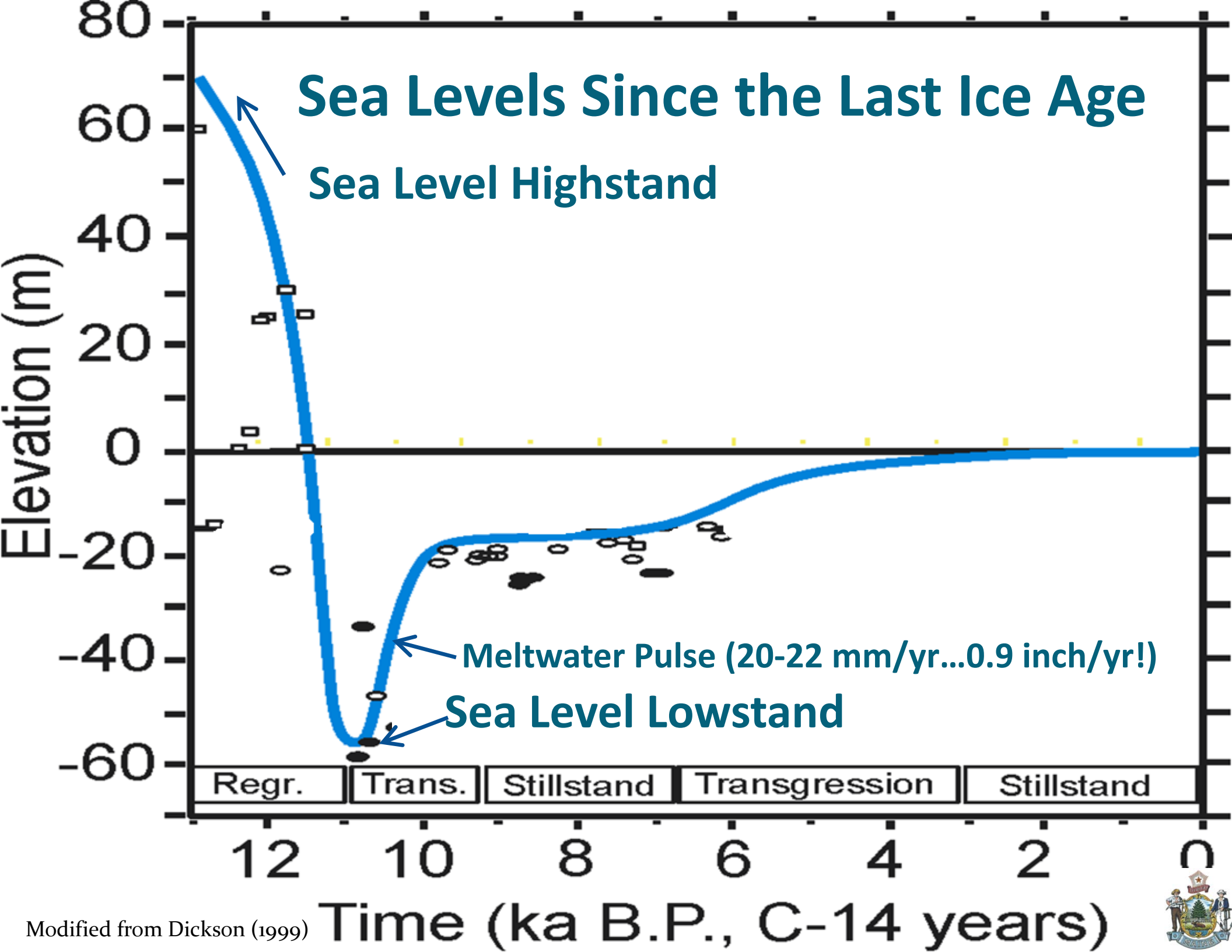
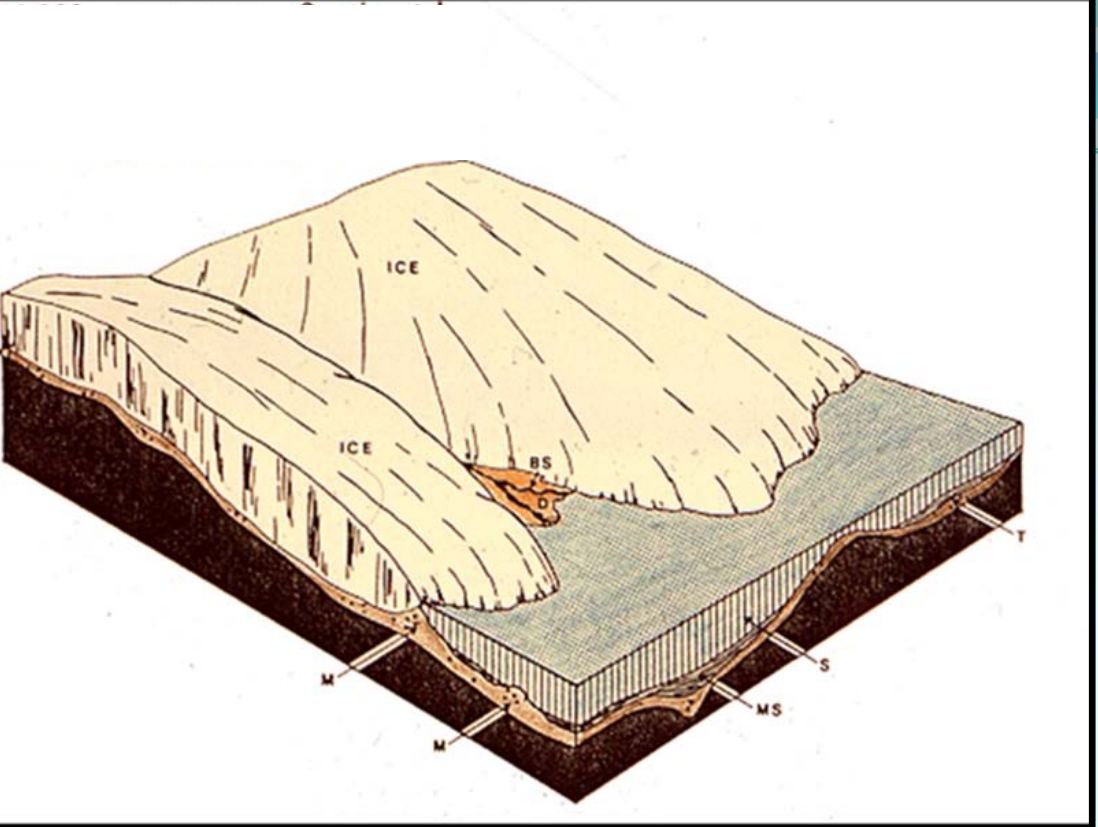


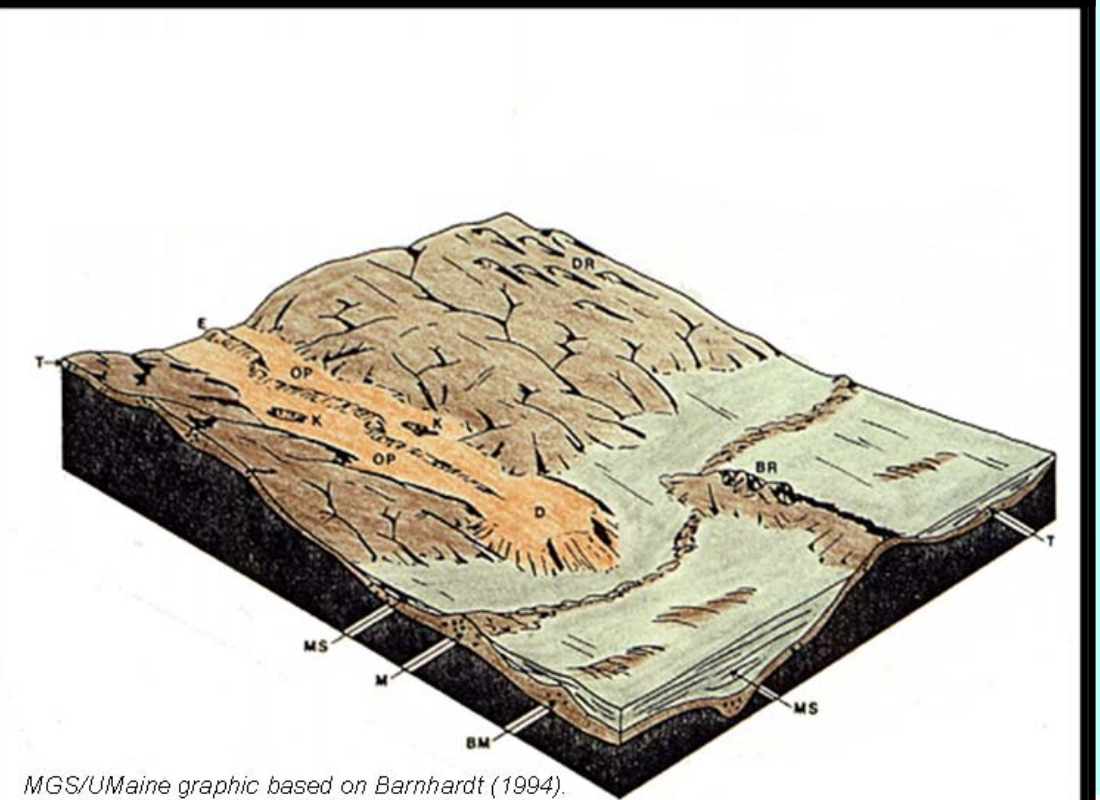
Figure modified from Griggs, 2001



Modified from Dickson (1999)

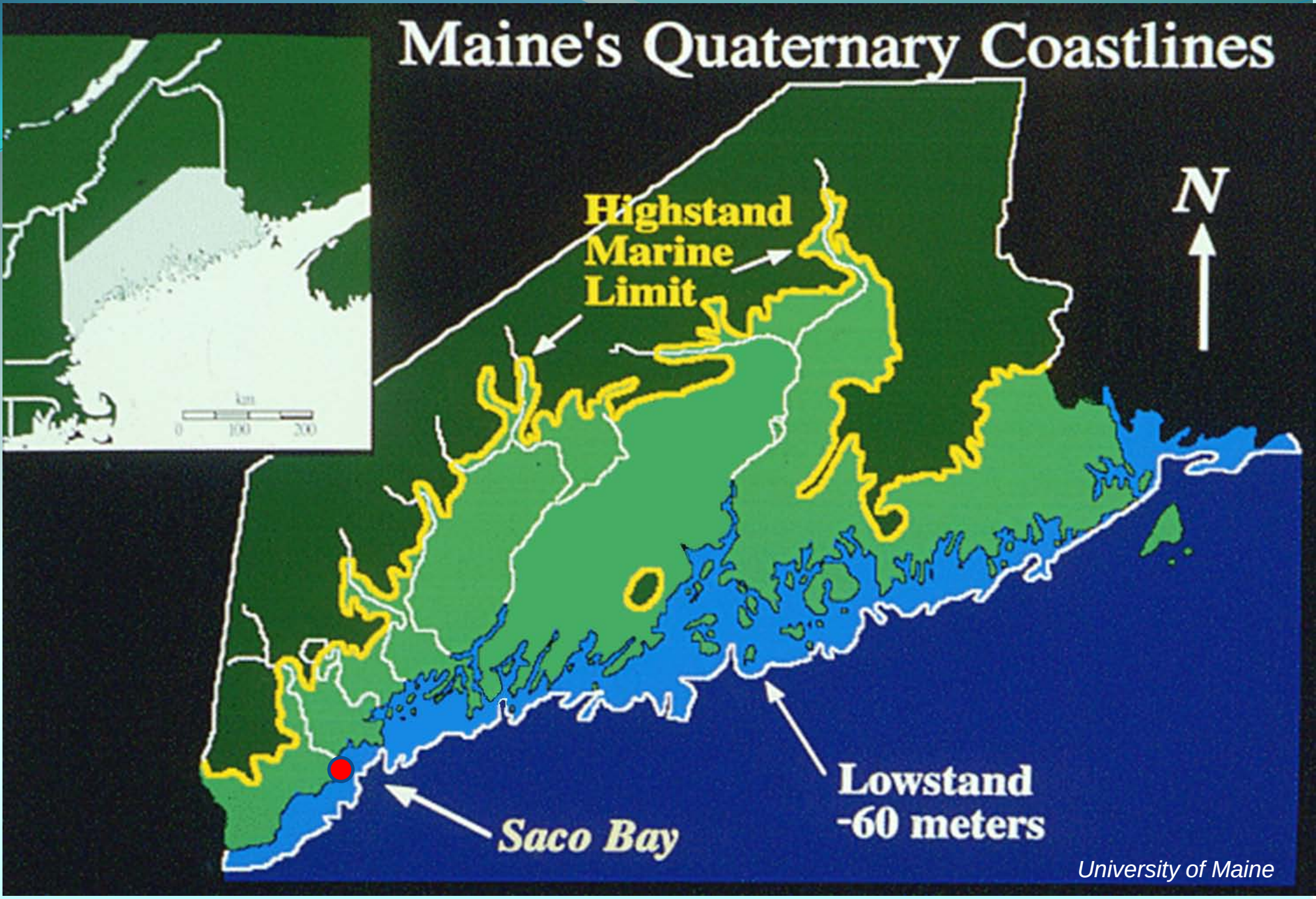


13,000 yrs ago, glaciers covered most of Maine, compressing the land surface so it was below sea level!

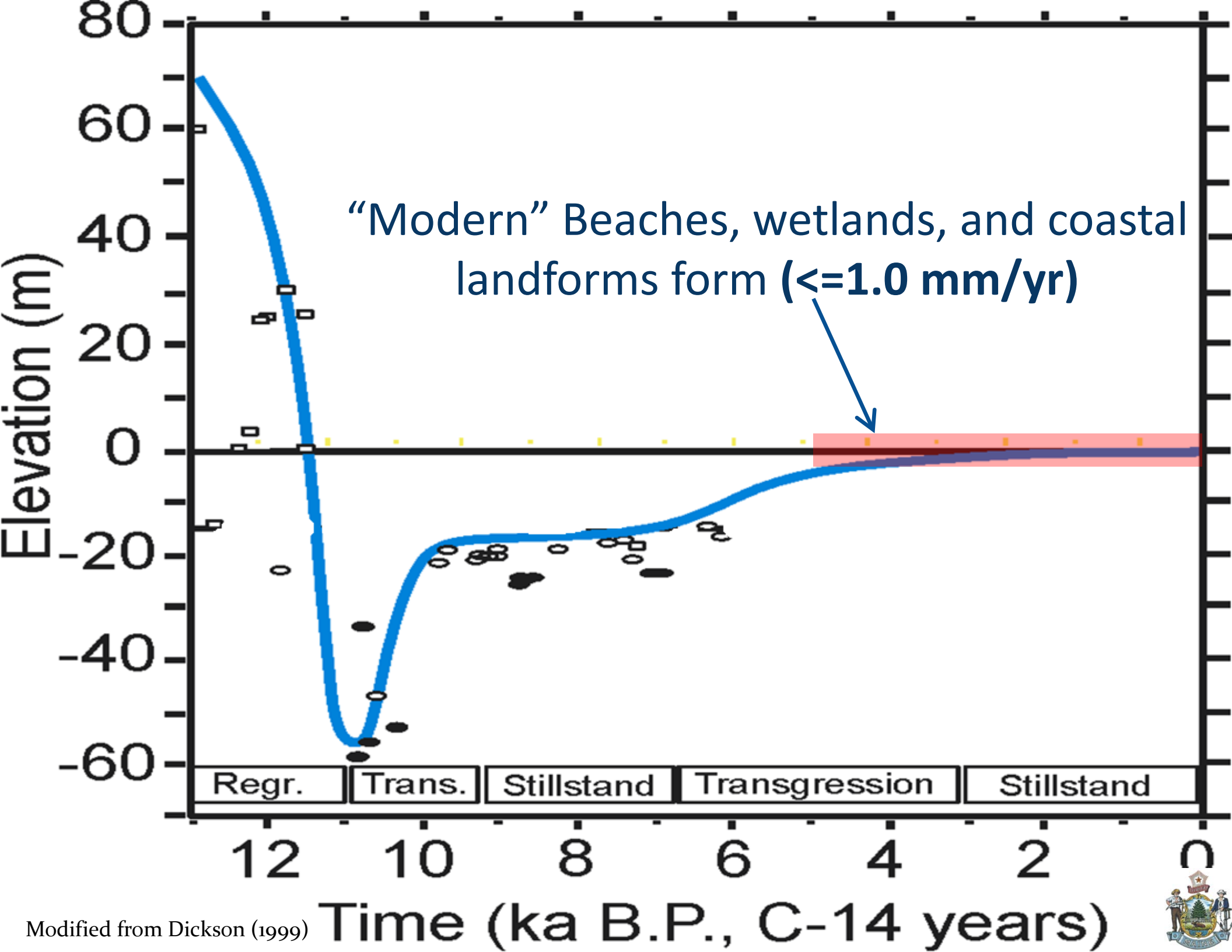


MGS/UMaine graphic based on Barnhardt (1994).

By 11,000 yrs ago, the glaciers had rapidly (geologically speaking) receded, and the land "rebounded" in response.

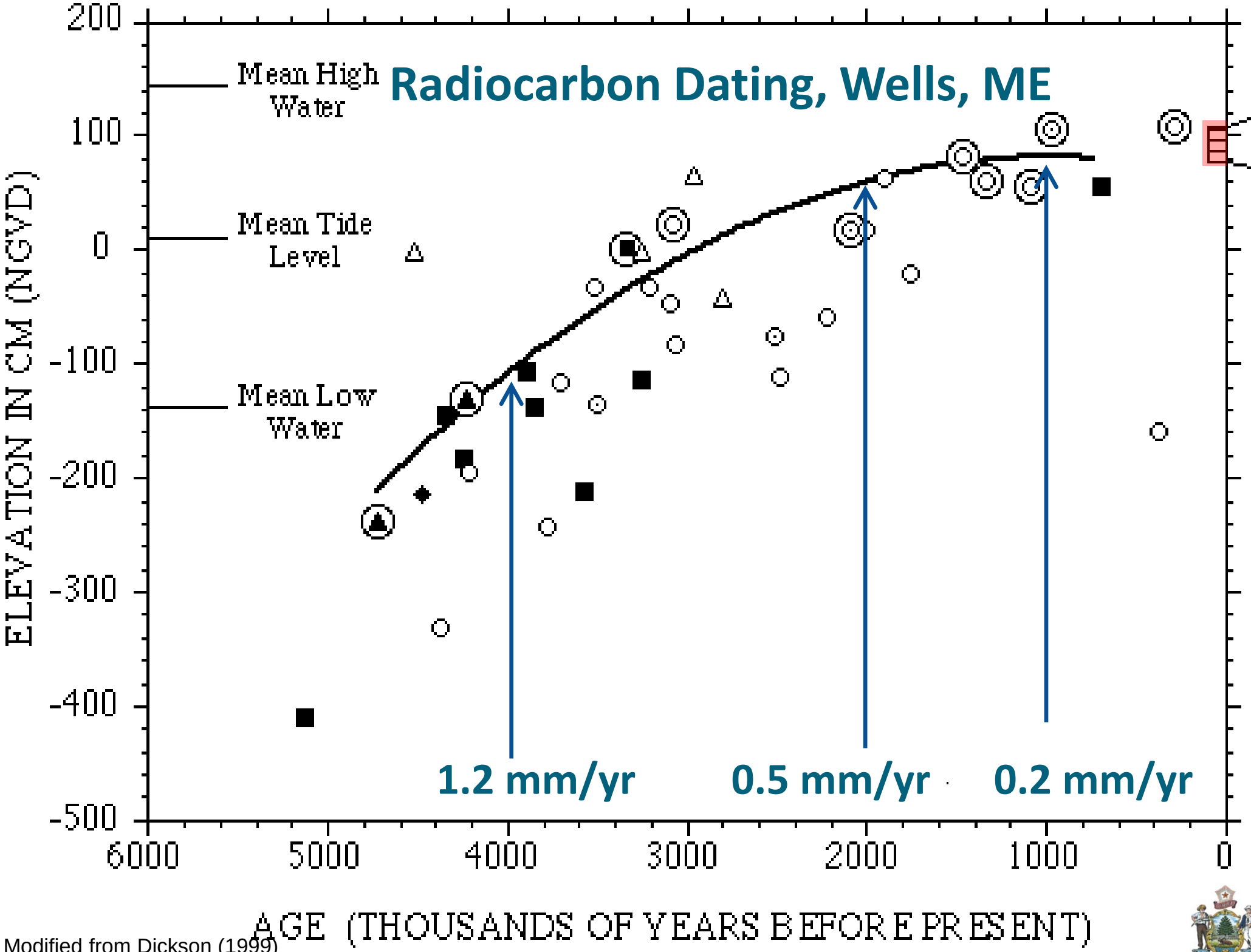


Massive adjustments in response to glaciation drove much of Maine's sea level changes…



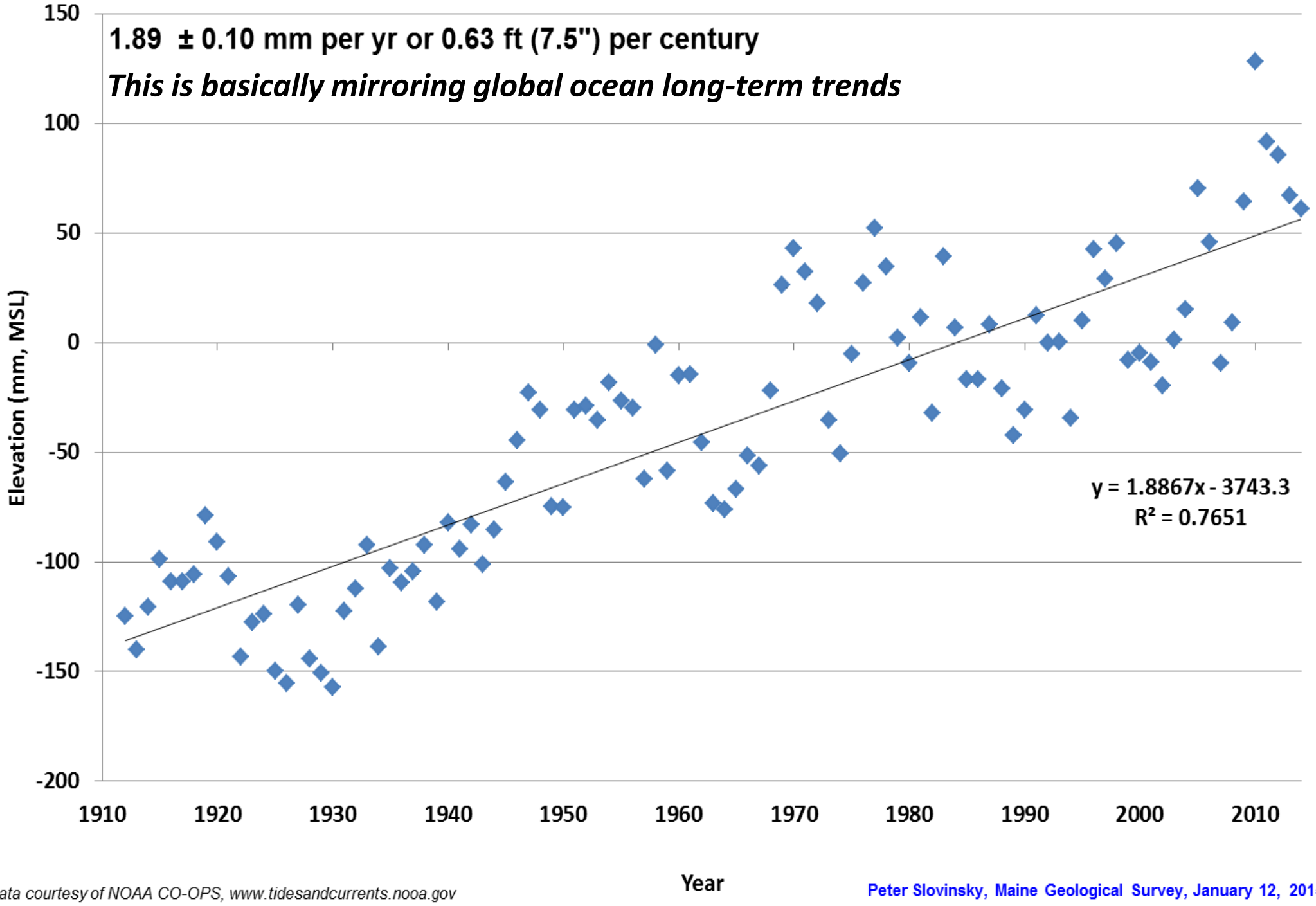
Modified from Dickson (1999)

Radiocarbon Dating, Wells, ME



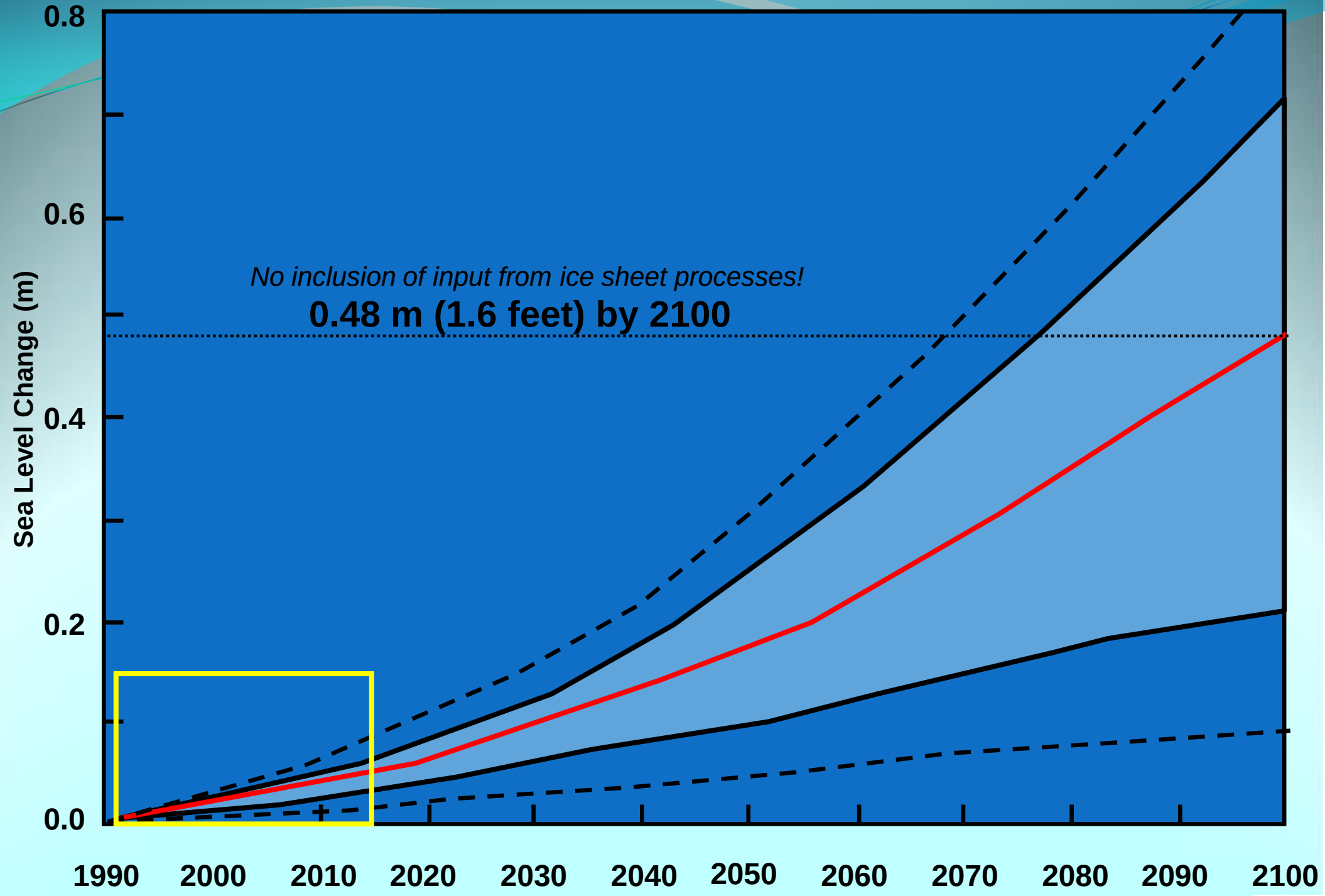
Modified from Dickson (1999)

Sea Level, Portland, Maine
1912-2014 (through December 31, 2014)

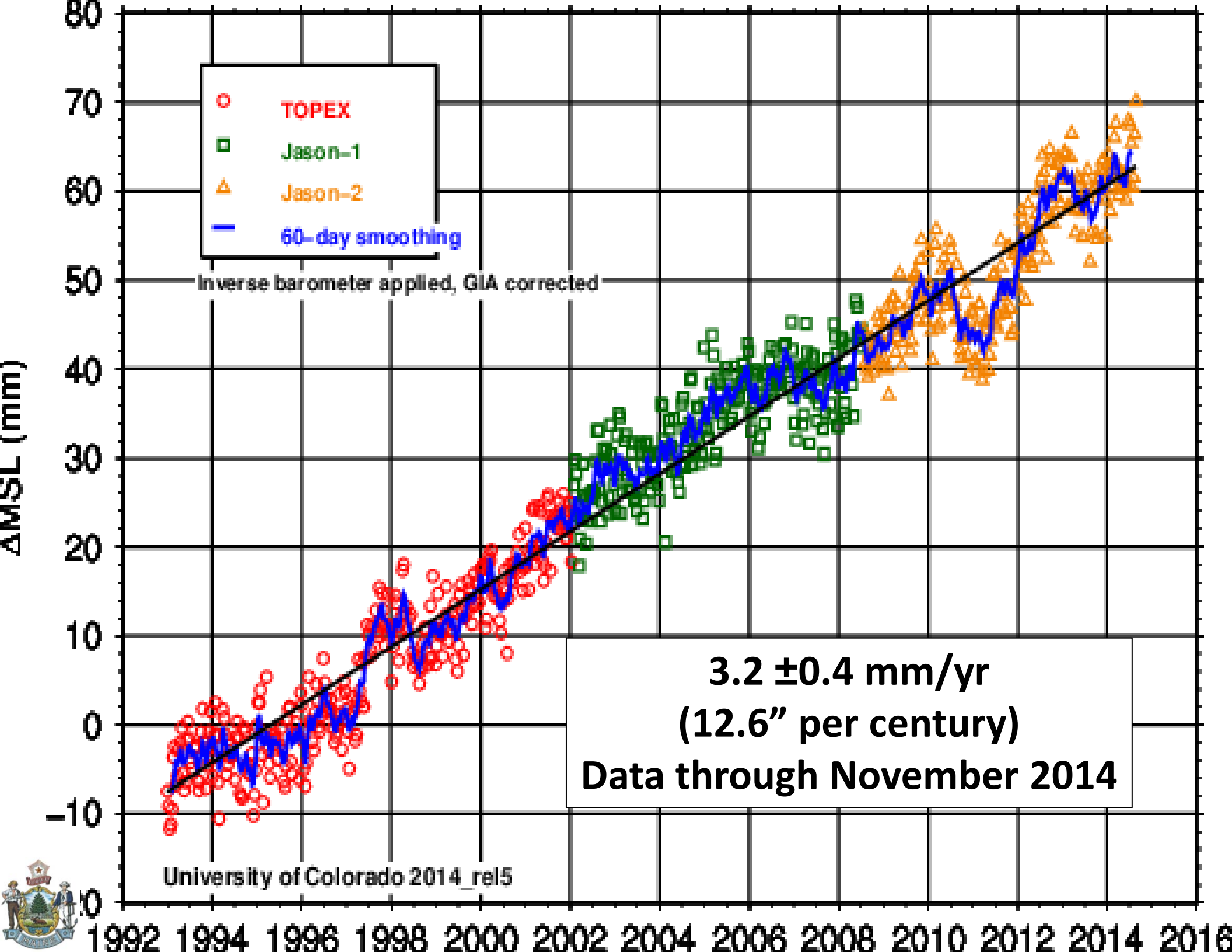


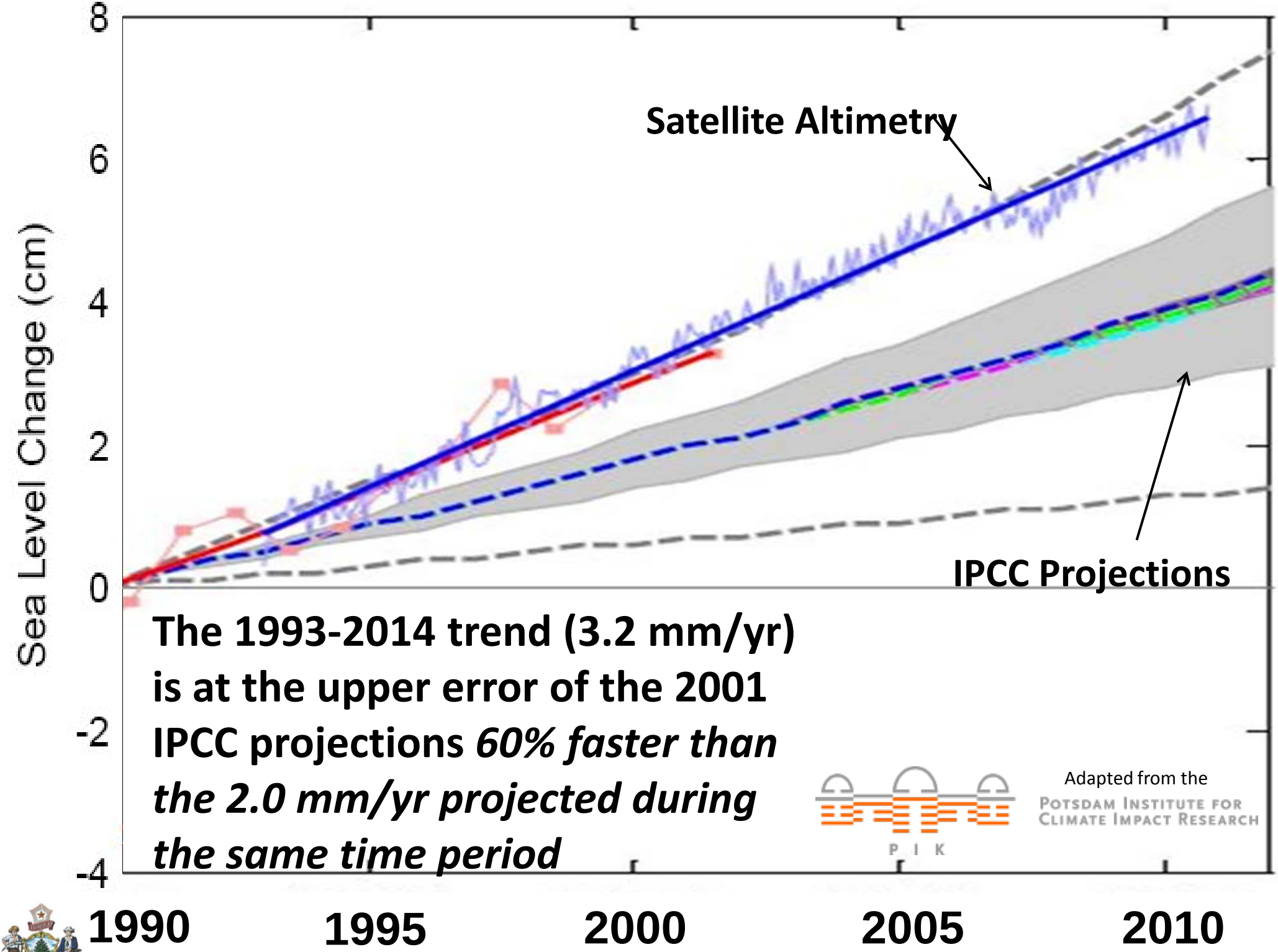
Data courtesy of NOAA CO-OPS, www.tidesandcurrents.nooa.gov

Peter Slovinsky, Maine Geological Survey, January 12, 2015



Adapted from the IPCC 3rd Assessment (Tech. Summary of Working Group I Report, Fig. 24, p. 74., 2001)

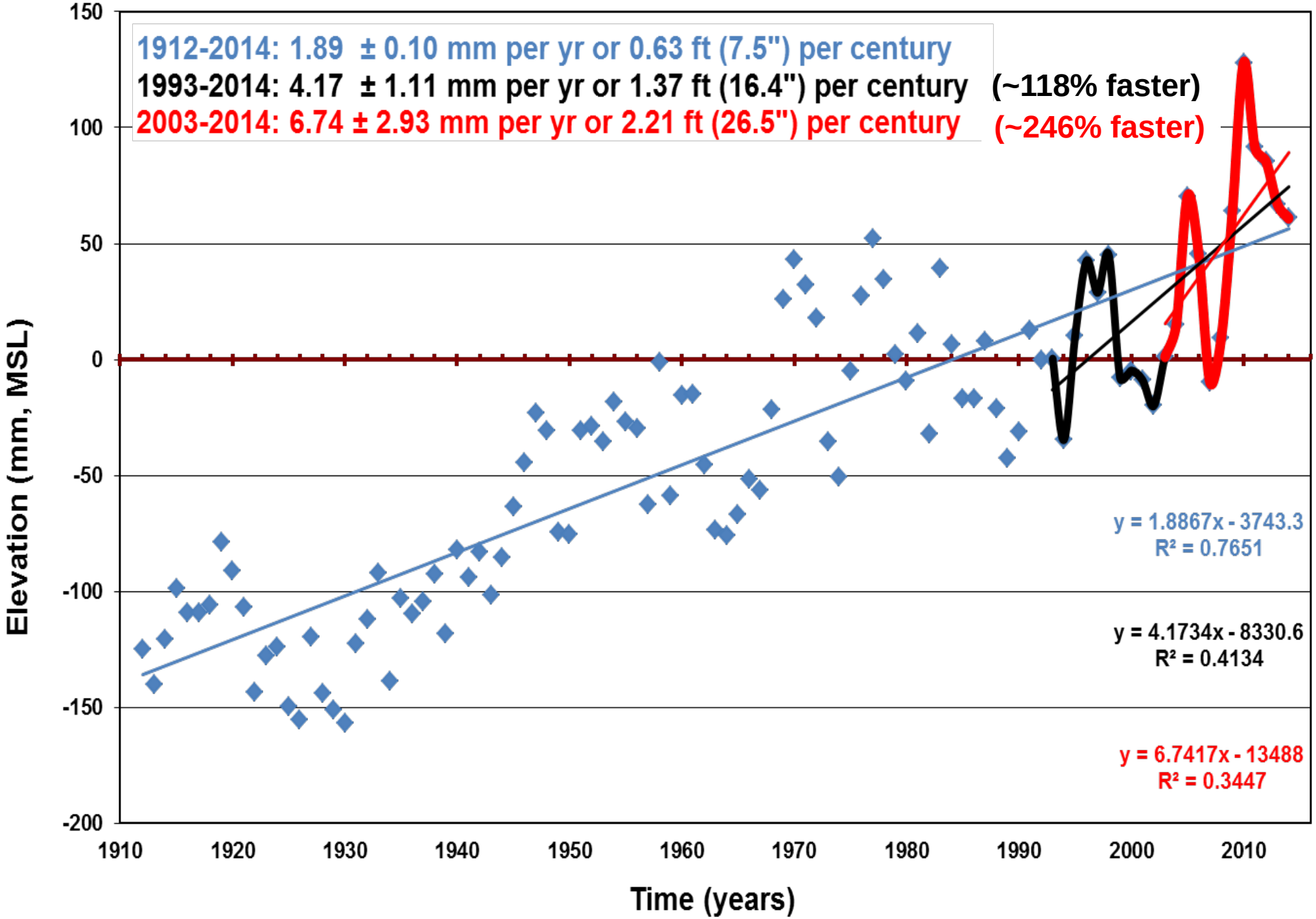

TOPEX
Jason-1
Jason-2
60-day smoothing
Inverse barometer applied, GIA corrected
ΔMSL (mm)
3.2 ±0.4 mm/yr
(12.6" per century)
Data through November 2014
University of Colorado 2014_rel5
80
70
60
50
40
30
20
10
0
−10
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016



The 1993-2014 trend (3.2 mm/yr) is at the upper error of the 2001 IPCC projections *60% faster than the 2.0 mm/yr projected during the same time period*

Sea Level, Portland, Maine

1912-2014 (through December 31, 2014)



Data courtesy of NOAA CO-OPS, www.tidesandcurrents.nooa.gov

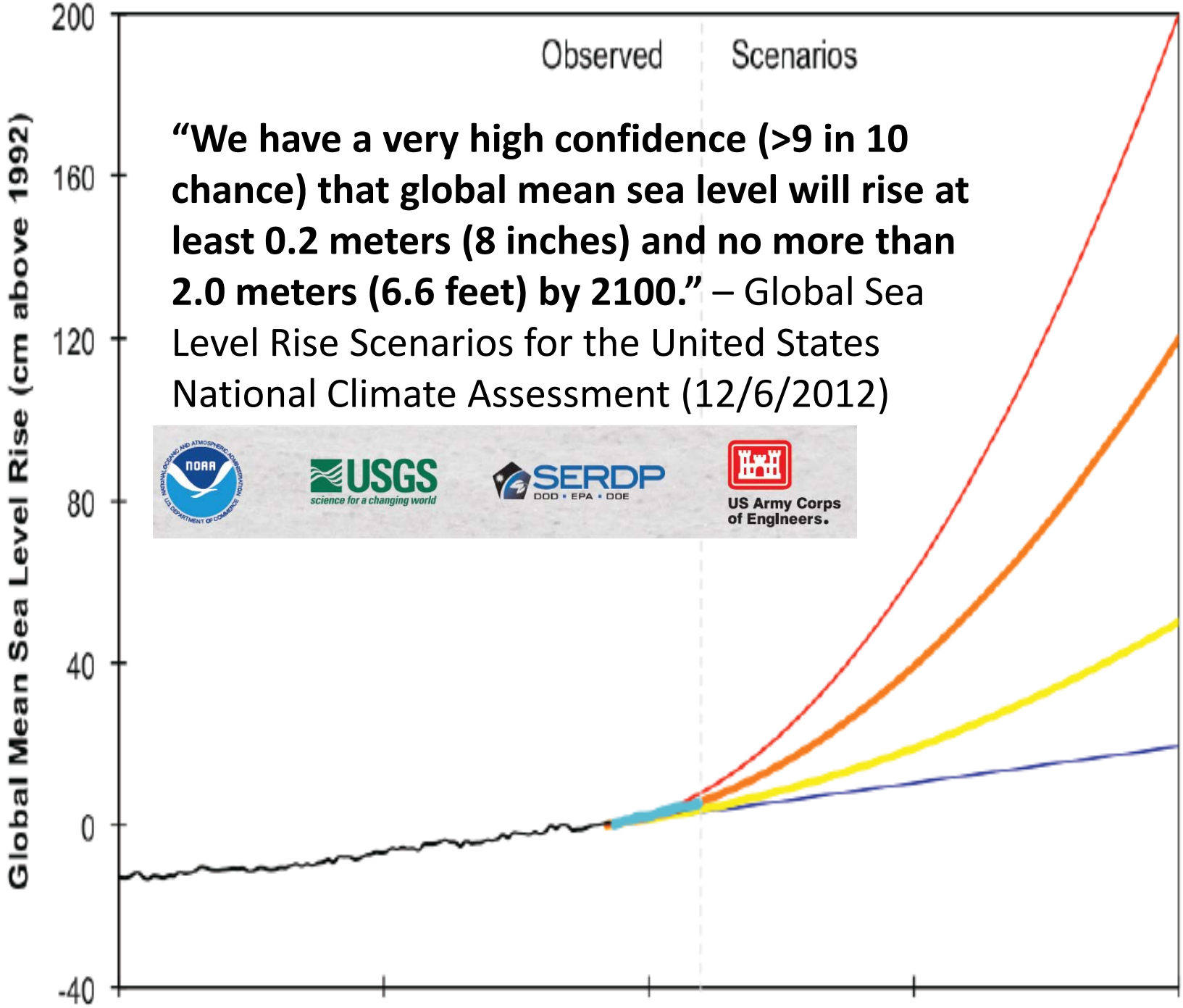
P.A. Slovinsky, Maine Geological Survey, January 12, 2015

…if current [Antarctic and Greenland] ice sheet melting rates continue for the next four decades, their cumulative loss could raise sea level by 15 centimeters (5.9 inches) by 2050. When this is added to the predicted sea level contribution of 8 centimeters (3.1 inches) from glacial ice caps and 9 centimeters (3.5 inches) from ocean thermal expansion, total sea level rise could reach 32 centimeters **(12.6 inches) by the year 2050**.

Rignot and others, March 2011

http://www.agu.org/news/press/pr_archives/2011/2011-09.shtml

Image from www.swisseduc.ch



"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)

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

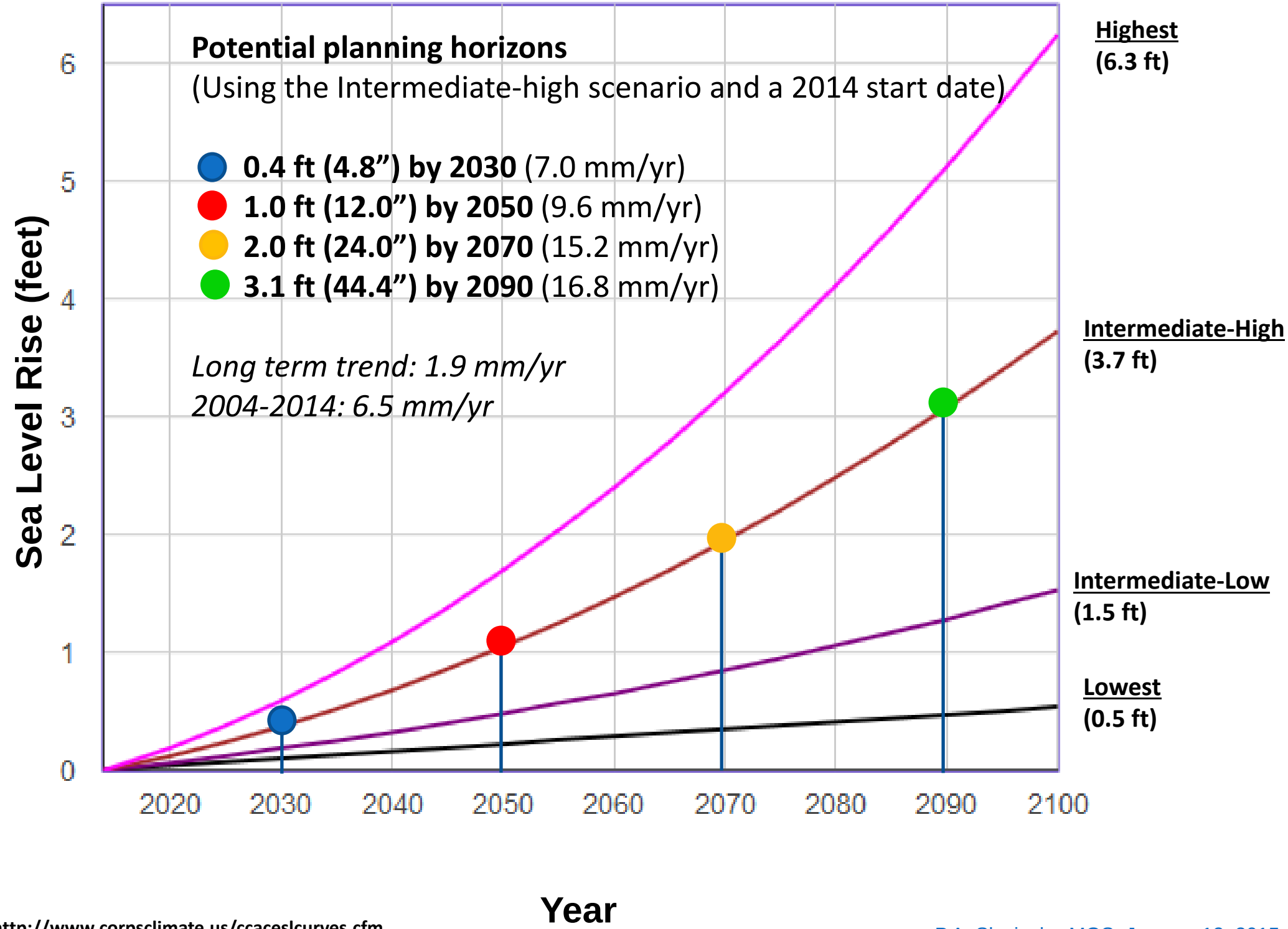
Intermediate-High
(1.2 m, 3.9 ft)
***Average of high end global predictions, combines recent ice sheet loss and thermal expansion**

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

Sea Level Rise Projections for Portland, ME



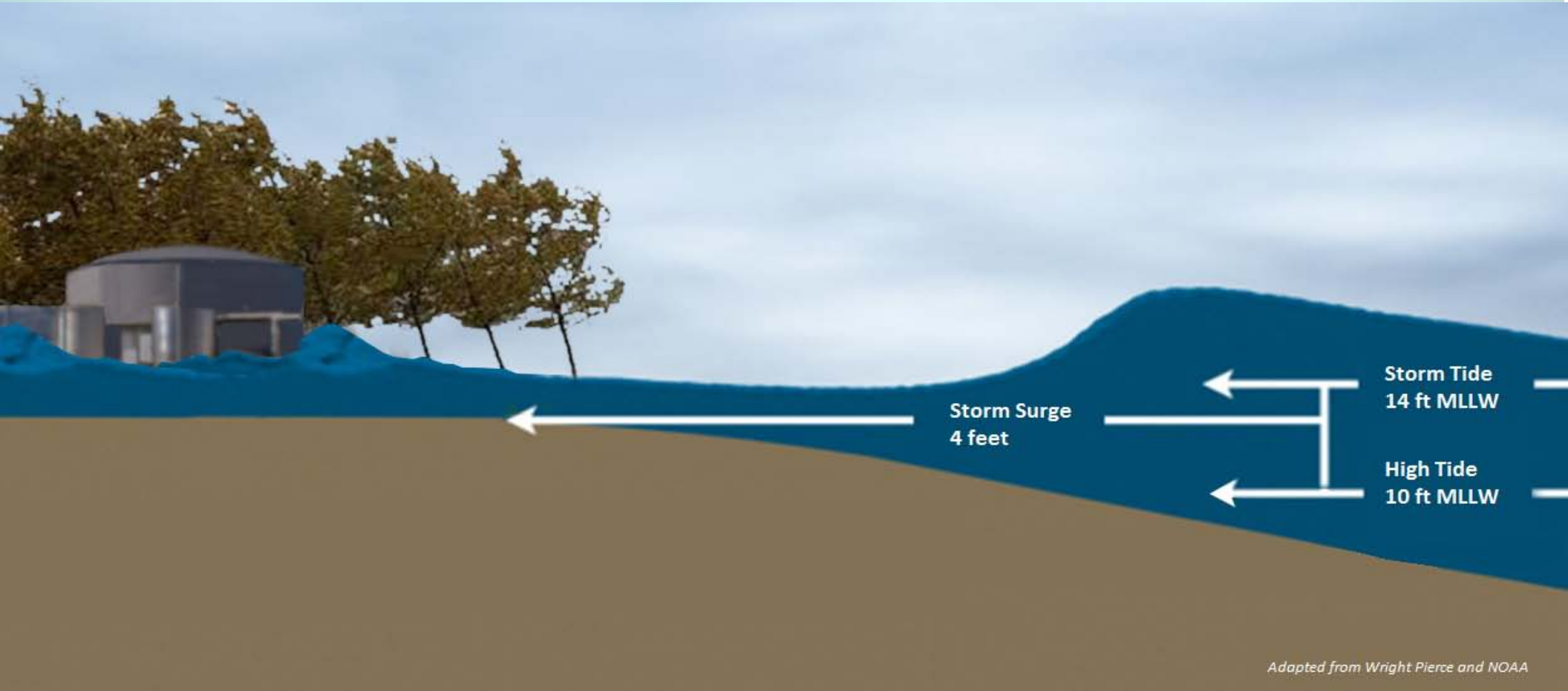
http://www.corpsclimate.us/ccaceslcurves.cfm

P.A. Slovinsky, MGS, January 12, 2015

What about storm tides and storm surges?

So what is storm surge?

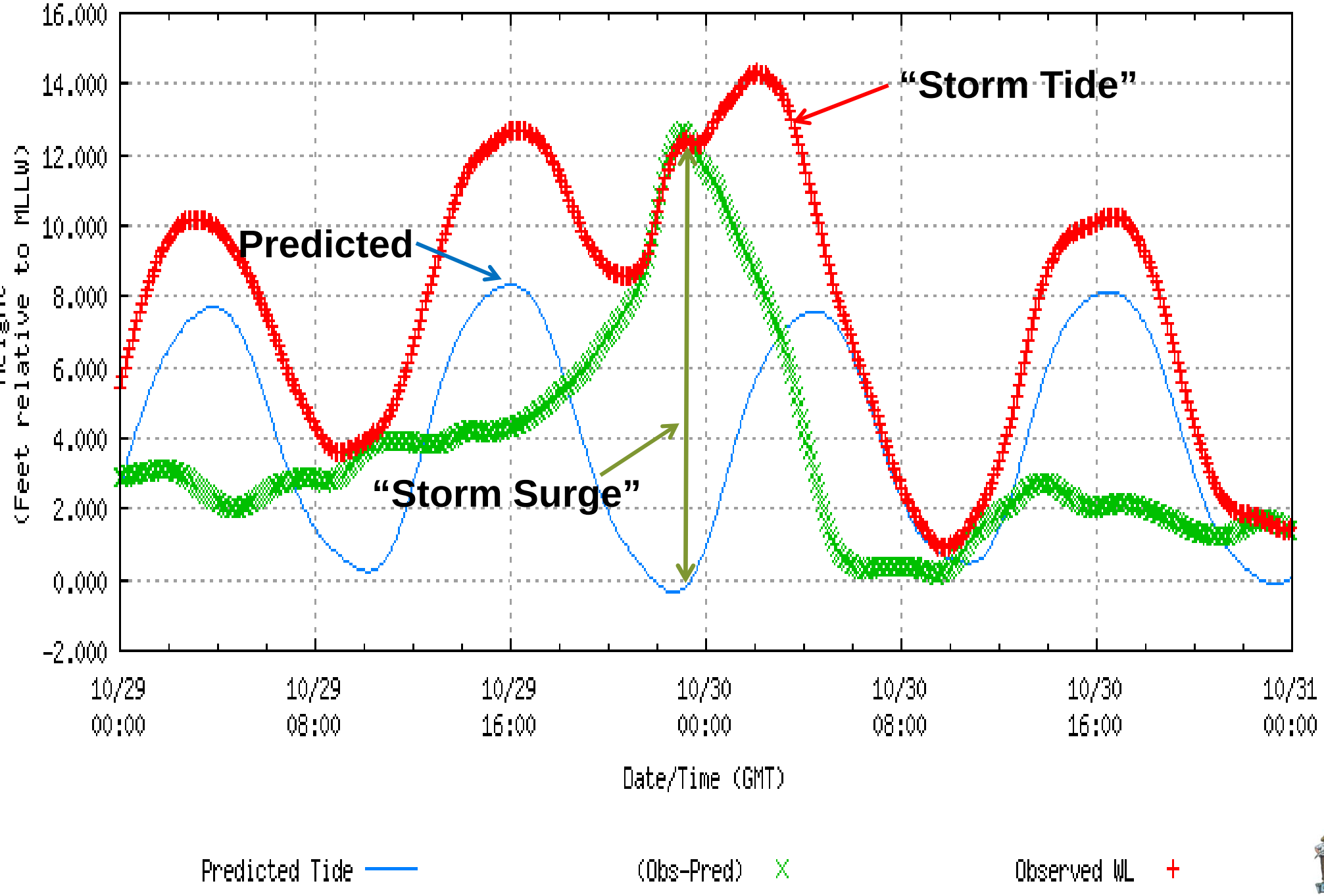
Storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tides. Storm surge should not be confused with storm tide, which is defined as the water level rise due to the combination of storm surge and the astronomical tide (National Hurricane Center)



Storm Surge
"Superstorm Sandy"

NOAA/NOS/CO-OPS
Verified Water Level vs. Predicted Plot
8516945 Kings Point, NY
from 2012/10/29 - 2012/10/30

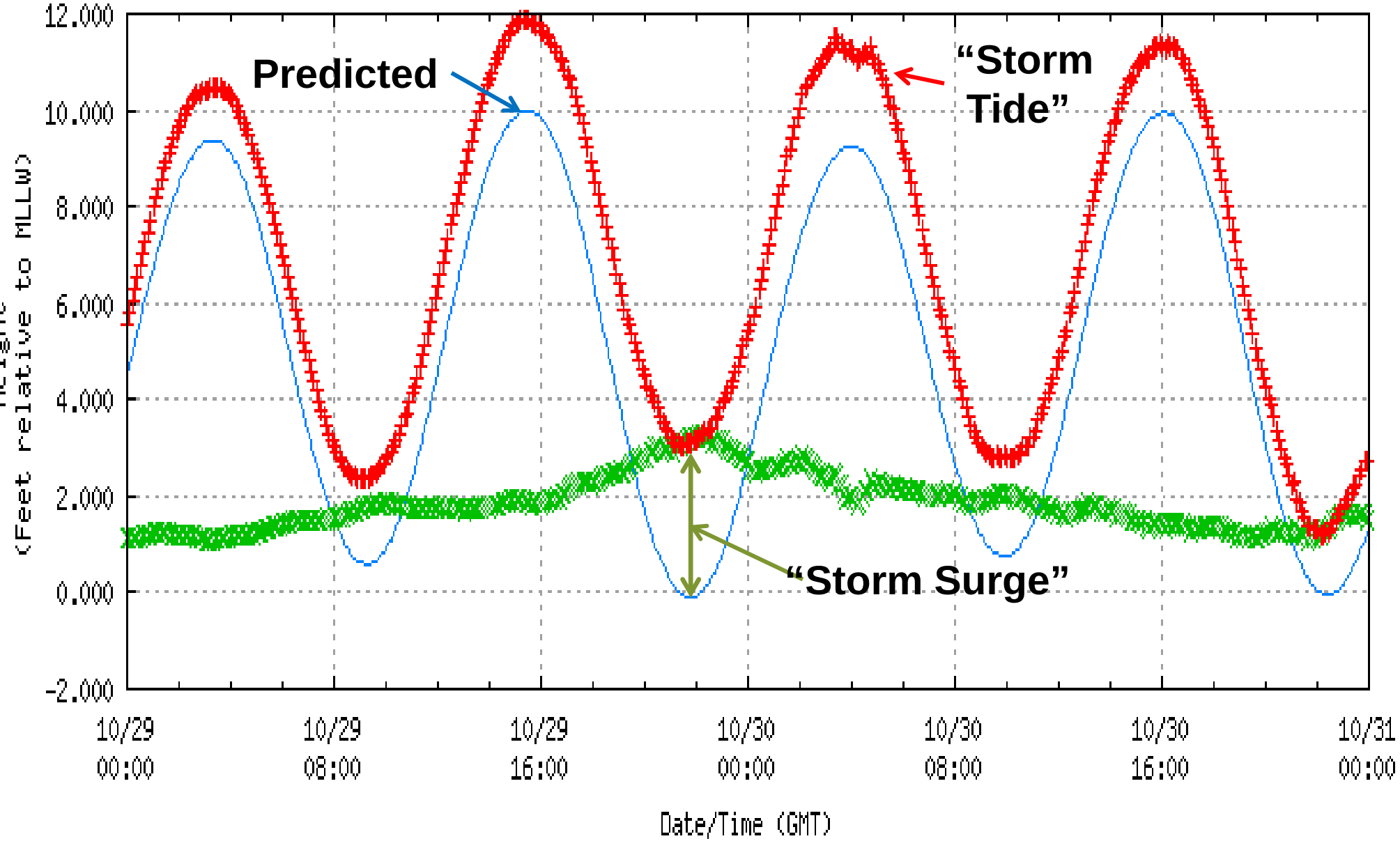
Kings Point, NY
10/29-10/30/2012



Storm Surge
"Superstorm Sandy"

NOAA/NOS/CO-OPS
Verified Water Level vs. Predicted Plot
8418150 Portland, ME
from 2012/10/29 - 2012/10/30

Portland, ME
10/29-10/30/2012



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 ***relatively 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"**)

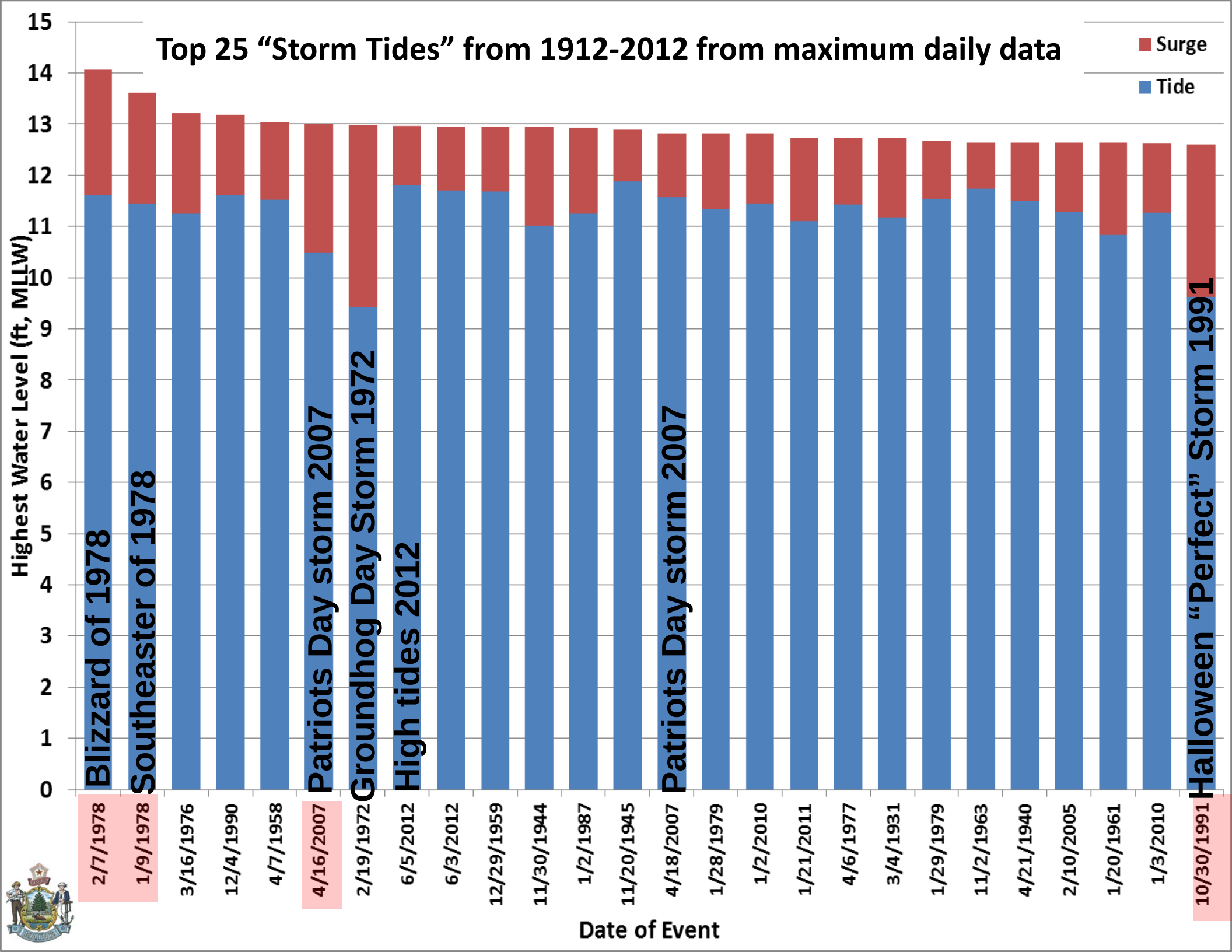
Portland "Storm Tides", 1912-2012

Interval (yrs)	"Storm Tide" Level (ft, MLLW)
1 (100 %)	11.7
5 (20%)	12.6
10 (10 %)	12.9
25 (4 %)	13.4
50 (2 %)	13.7
100 (1 %)	14.1

Portland "Storm Tides", 1912-2012

Interval (yrs)	"Storm Tide" Level (ft, MLLW)
1 (100 %)	11.7
5 (20%)	12.6
10 (10 %)	12.9
25 (4 %)	13.4
50 (2 %)	13.7
100 (1 %)	14.1

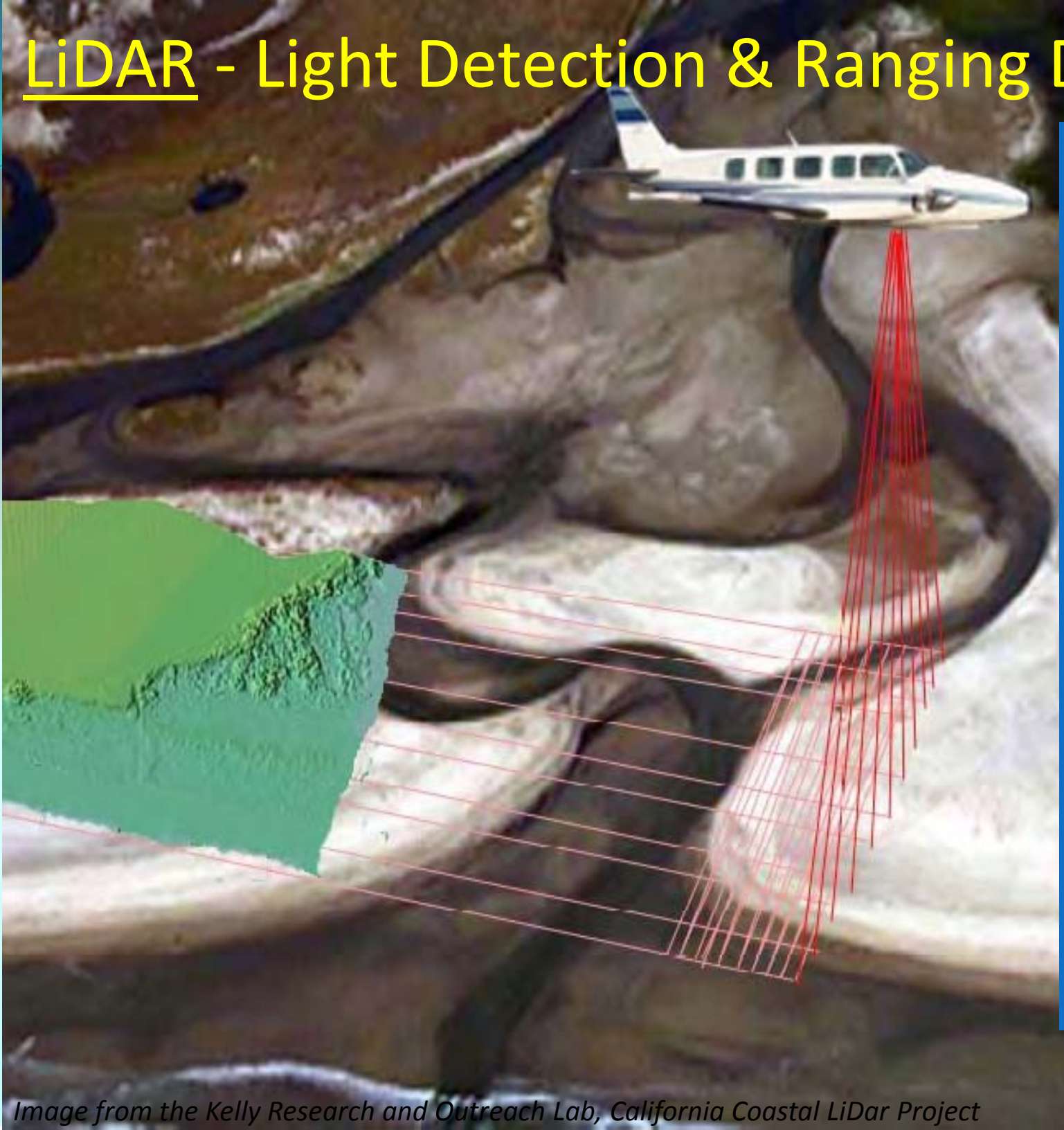
1 foot difference!


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

SLR scenarios selected for mapping

- Latest Predictions:
  - Short Term: approximately 1 ft by 2050
  - Long Term: 2-3 ft *but potentially more* by 2100;
- We decided to examine scenarios of **1 foot, 2 feet, 3.3 feet, and 6 feet** on top of the **highest annual tide (HAT).**
- These SLR scenarios relate well to the National Climate Assessment, and also **correspond well with evaluating potential impacts from storm surges that may coincide with higher tides today.**

LiDAR - Light Detection & Ranging Data



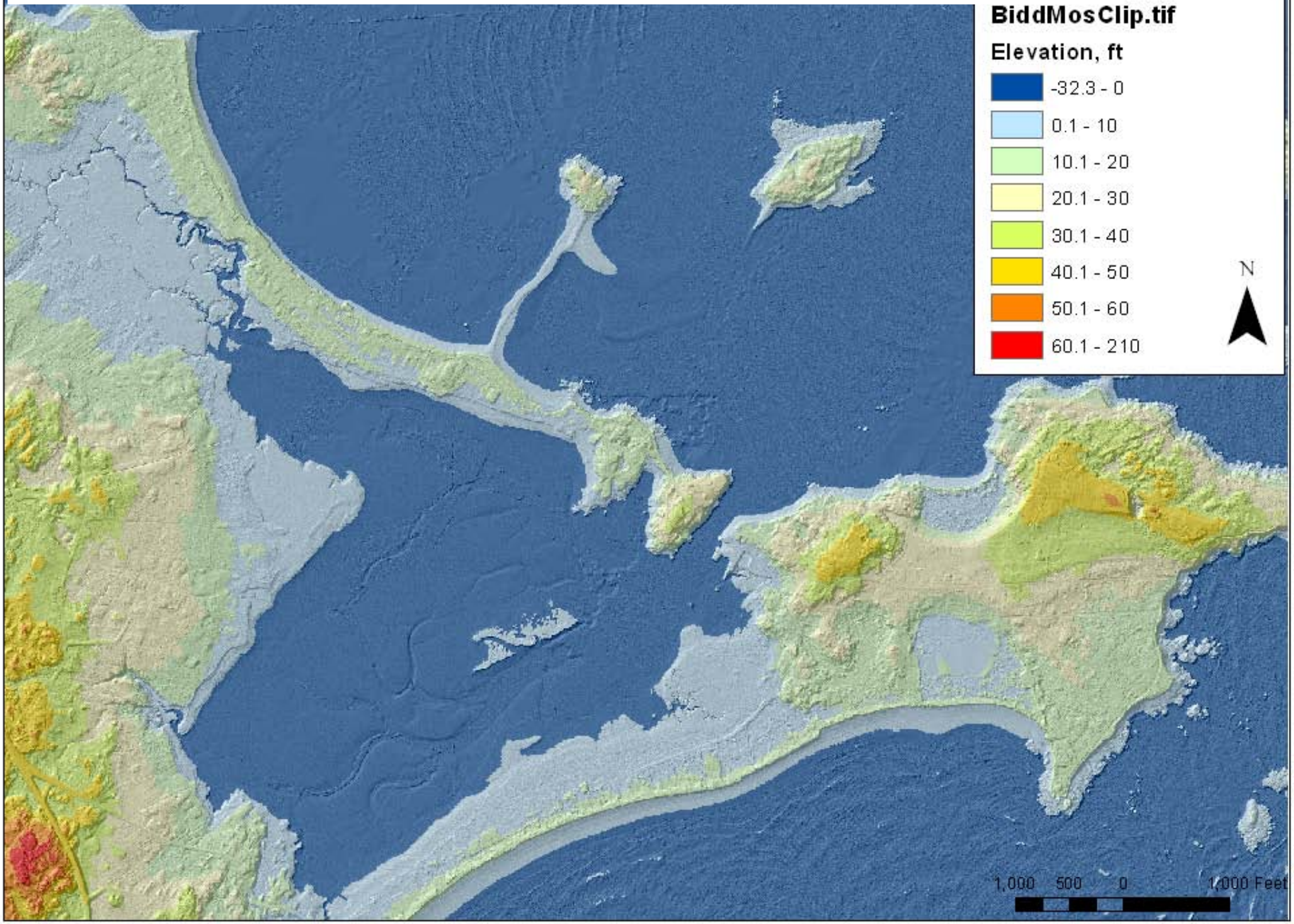
100,000 pulses of laser light per second are sent to the ground in sweeping lines

Sensors measure how long it takes each pulse to reflect back to the unit and calculates an "elevation"

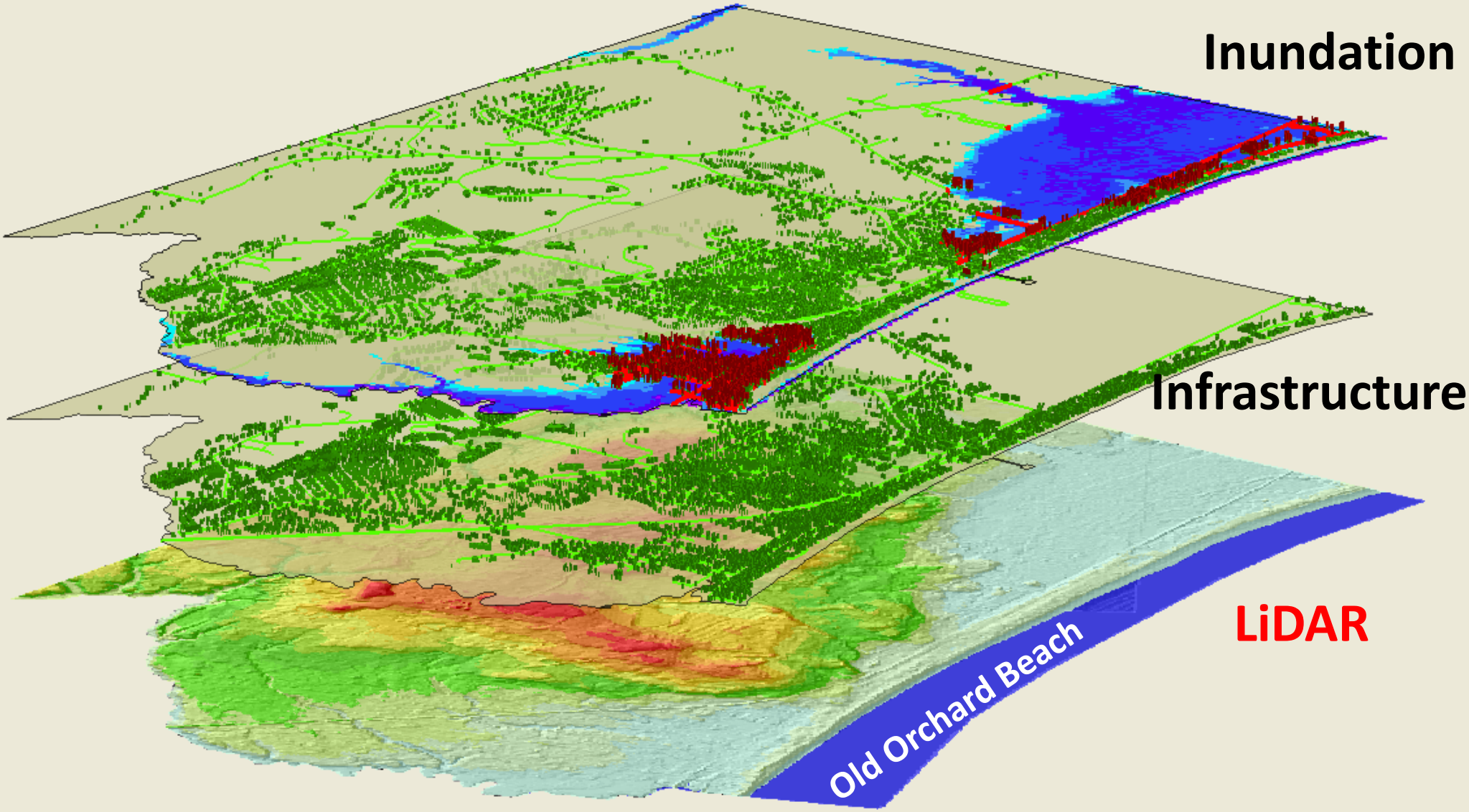
Algorithms are used to "remove" buildings and vegetation types to create a "bare earth" digital elevation model (DEM)

Image from the Kelly Research and Outreach Lab, California Coastal LiDar Project

Couldn’t do it without **Li**ght **D**etection **a**nd **R**anging data!



GIS-based Visualization



Data and tools critical to communicating coastal vulnerability

Coastal wetlands

"Coastal wetlands" means all tidal and subtidal lands; all areas with vegetation present that is tolerant of salt water and occurs primarily in salt water or estuarine habitat; and any swamp, marsh, bog, beach, flat or other contiguous lowland that is subject to tidal action during the highest tide level for each year in which an activity is proposed as identified in tide tables published by the National Ocean Service. Coastal wetlands may include portions of coastal sand dunes.

Required in Maine's Municipal Shoreland Zoning

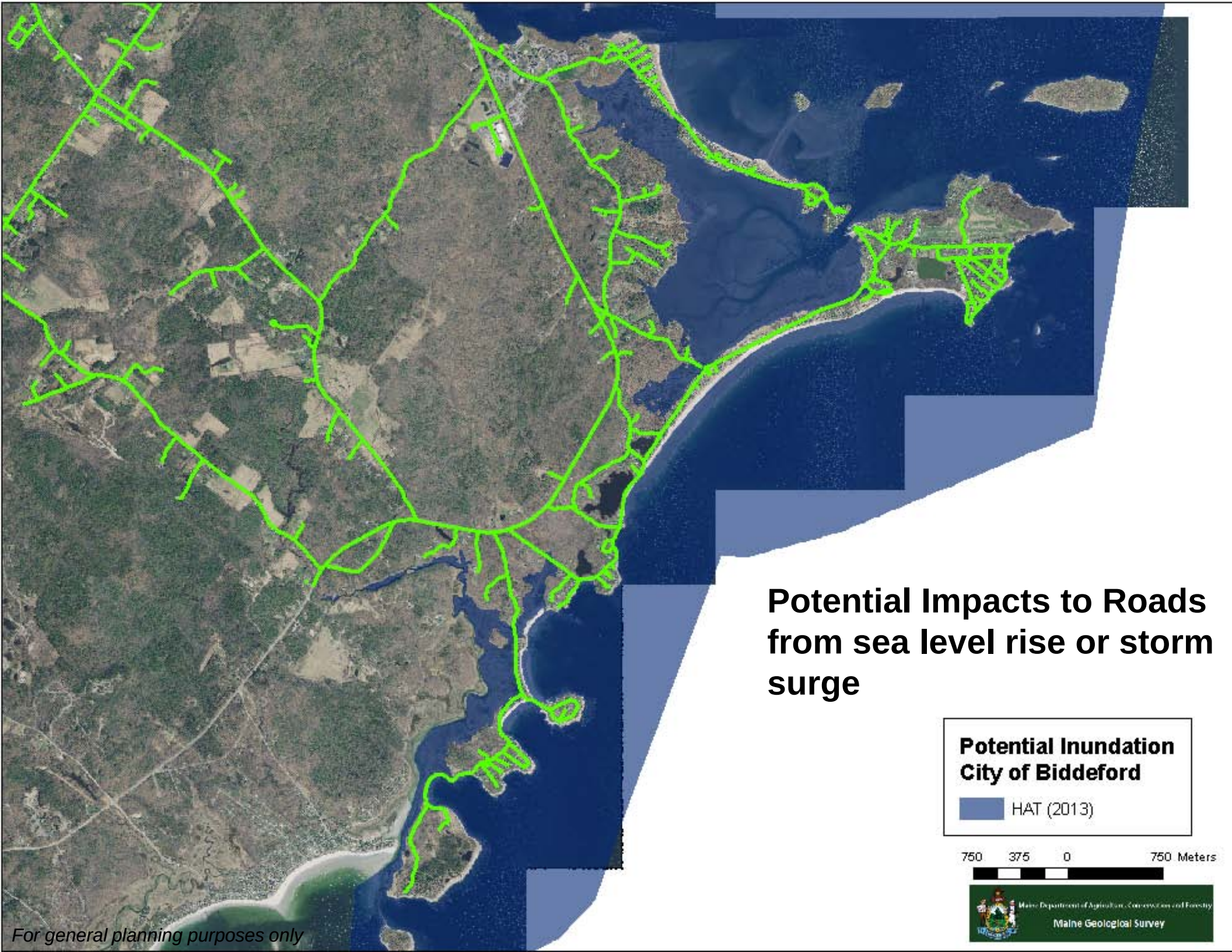
P.A. Slovinsky, MGS

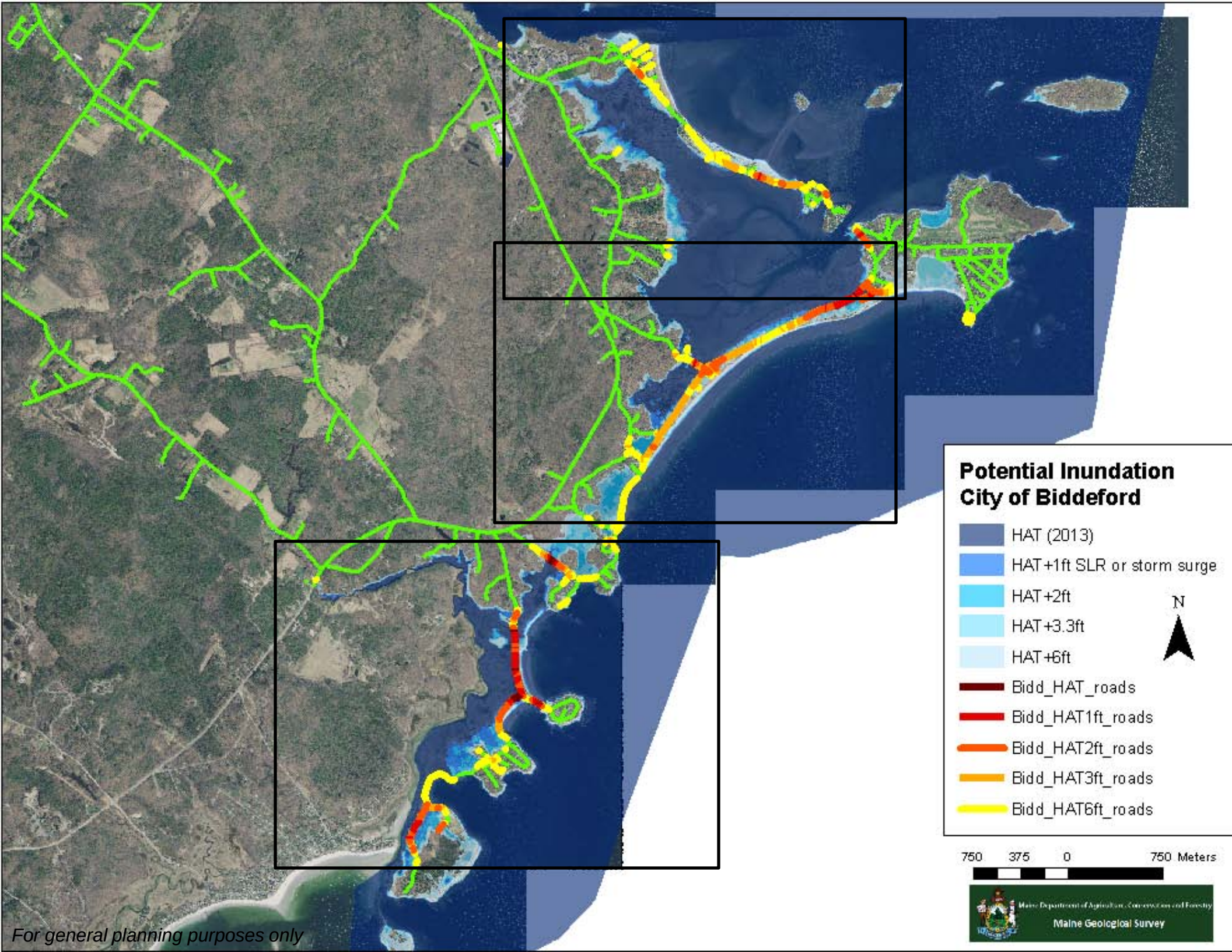
Some Assumptions and Limitations

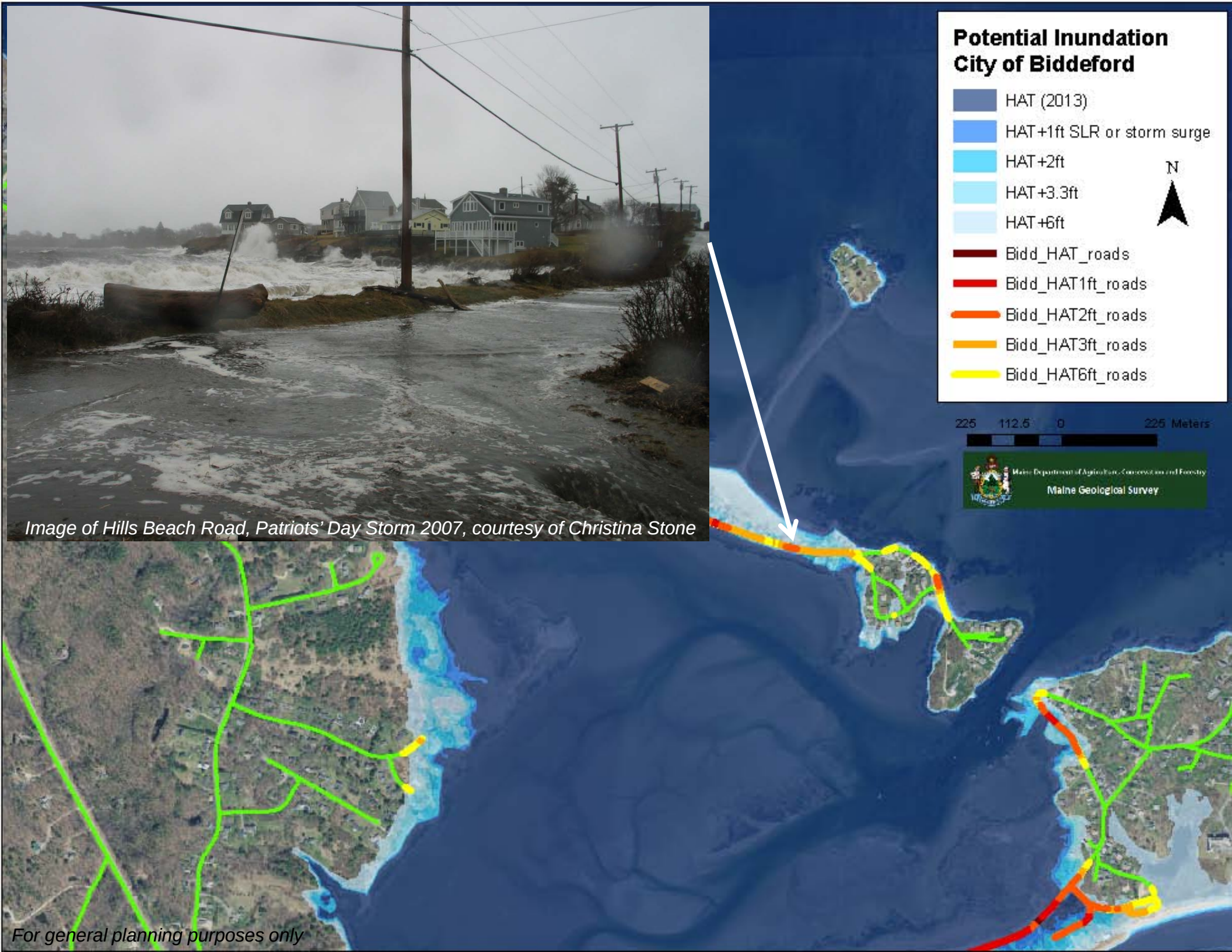
- Our mapping differs from other states in that we use the **Highest Annual Tide** per Shoreland Zoning regulations, not MHHW. **In Maine, the HAT is between 2-3 feet higher than the MHHW level. We are trying to both map the limits of existing HAT for Shoreland Zoning and visualize the impacts of SLR scenarios on potential wetland expansion and inundation, *not necessarily map the actual limits of wetlands.***

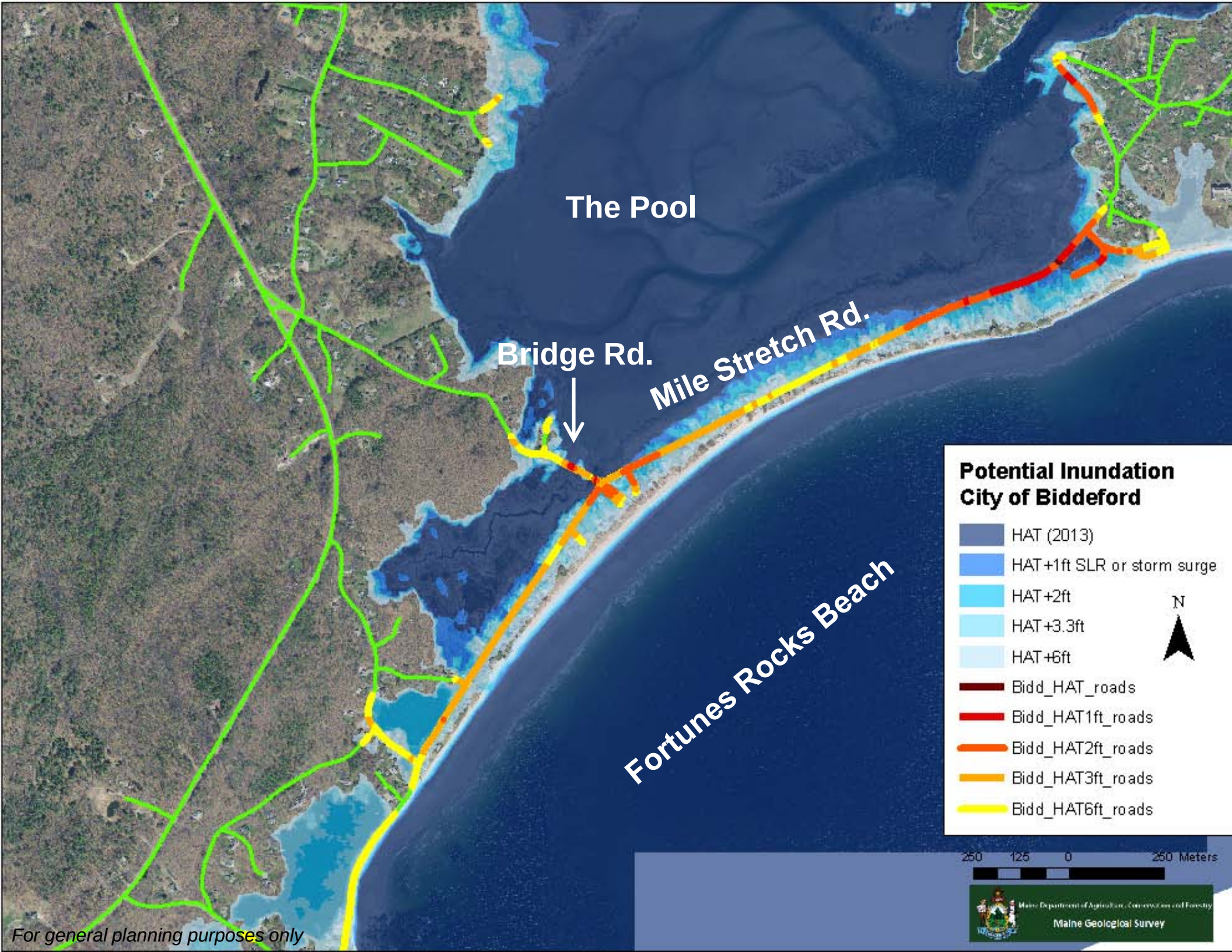
- We use a "bare earth" LiDAR DEM that represents a "snapshot" of topography that **may have changed since the data was captured**. Also, many **bridges have been removed.**

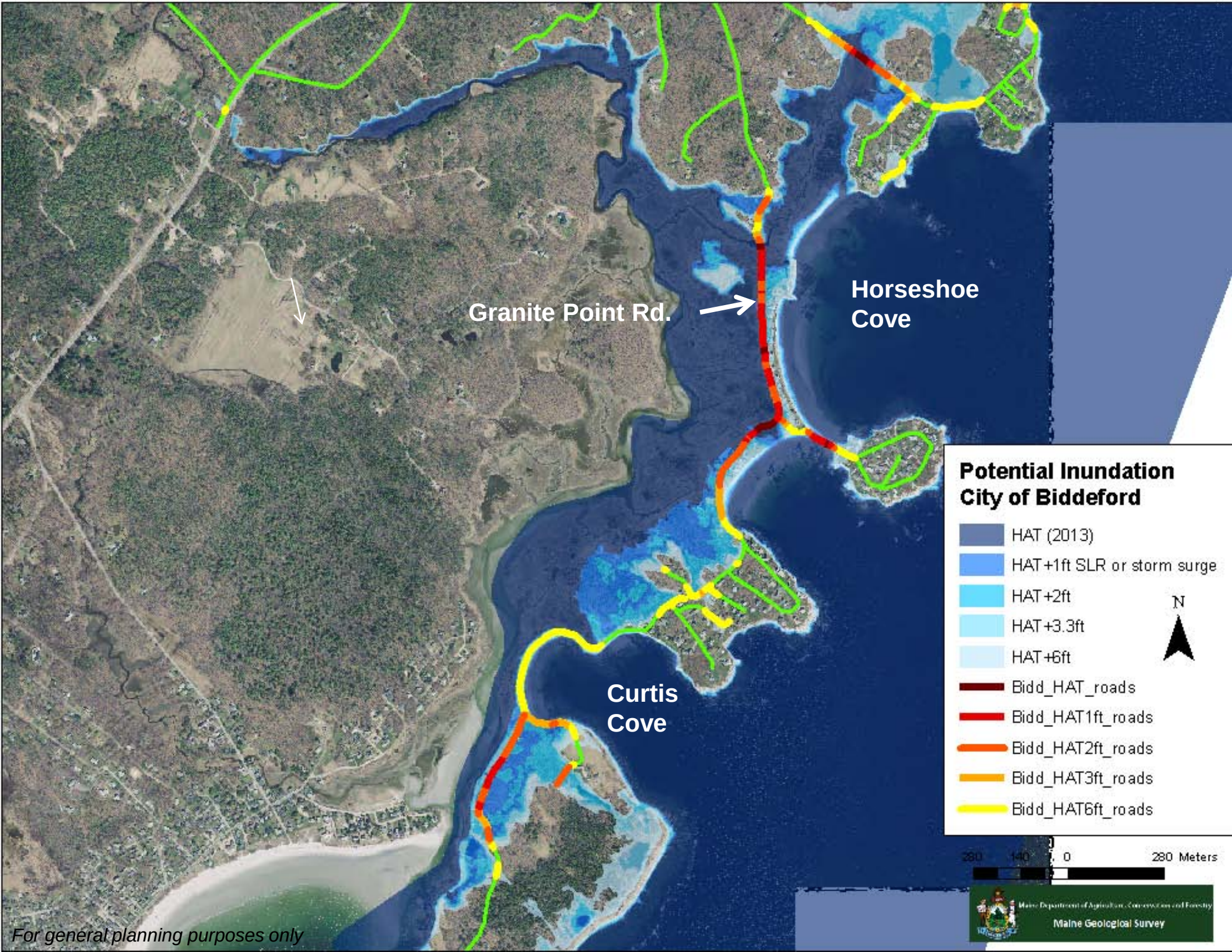
- Our simulations use a **bathtub approach** that **doesn't account for erosion, sedimentation, or dynamic influences like freshwater flow or waves**.


Potential Impacts to Roads from sea level rise or storm surge
Potential Inundation
City of Biddeford
HAT (2013)
750 375 0 750 Meters
Maine Geological Survey
For general planning purposes only


Potential Inundation
City of Biddeford
HAT (2013)
HAT+1ft SLR or storm surge
HAT+2ft
HAT+3.3ft
HAT+6ft
Bidd_HAT_roads
Bidd_HAT1ft_roads
Bidd_HAT2ft_roads
Bidd_HAT3ft_roads
Bidd_HAT6ft_roads
N
750 375 0 750 Meters
Maine Geological Survey
For general planning purposes only


Potential Inundation
City of Biddeford
HAT (2013)
HAT+1ft SLR or storm surge
HAT+2ft
HAT+3.3ft
HAT+6ft
Bidd_HAT_roads
Bidd_HAT1ft_roads
Bidd_HAT2ft_roads
Bidd_HAT3ft_roads
Bidd_HAT6ft_roads
N
225 112.5 0 225 Meters
Maine Geological Survey
Image of Hills Beach Road, Patriots' Day Storm 2007, courtesy of Christina Stone
For general planning purposes only


The Pool
Bridge Rd.
Mile Stretch Rd.
Fortunes Rocks Beach
Potential Inundation
City of Biddeford
HAT (2013)
HAT+1ft SLR or storm surge
HAT+2ft
HAT+3.3ft
HAT+6ft
Bidd_HAT_roads
Bidd_HAT1ft_roads
Bidd_HAT2ft_roads
Bidd_HAT3ft_roads
Bidd_HAT6ft_roads
N
250 125 0 250 Meters
Maine Geological Survey
For general planning purposes only


Granite Point Rd.
Horseshoe Cove
Curtis Cove
Potential Inundation
City of Biddeford
HAT (2013)
HAT+1ft SLR or storm surge
HAT+2ft
HAT+3.3ft
HAT+6ft
Bidd_HAT_roads
Bidd_HAT1ft_roads
Bidd_HAT2ft_roads
Bidd_HAT3ft_roads
Bidd_HAT6ft_roads
N
280 140 0 280 Meters
Maine Geological Survey
For general planning purposes only

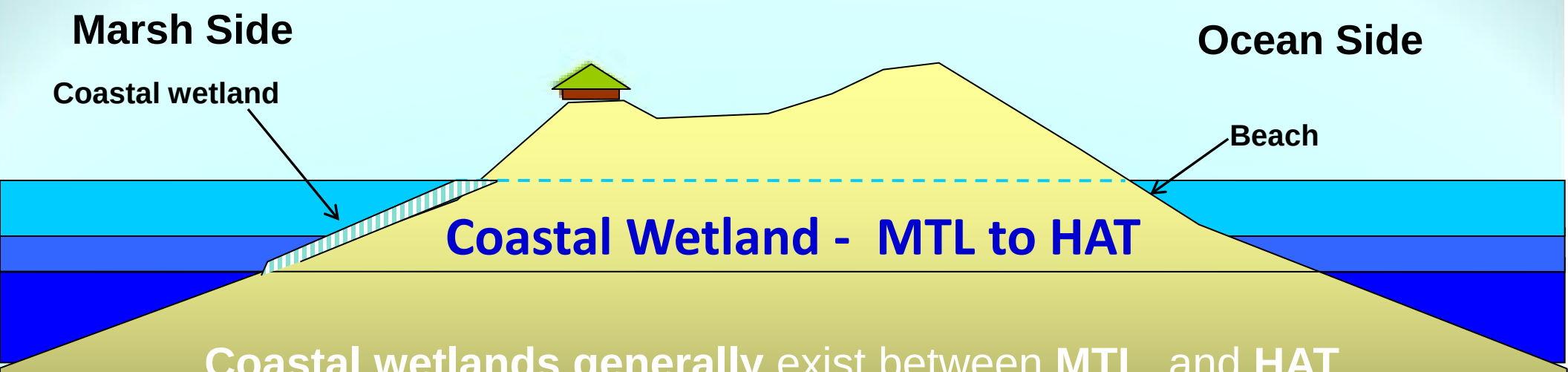
What about potential wetland migration or conversion? (examples from potential 2 feet of sea level rise)

Using Tidal Elevations as Proxies for the Marsh…

Highest Annual Tide (HAT) - "spring" tide, the highest predicted water level for any given year but is reached within several inches numerous tides a year

Mean High Water (MHW) – the averaged daily high water mark

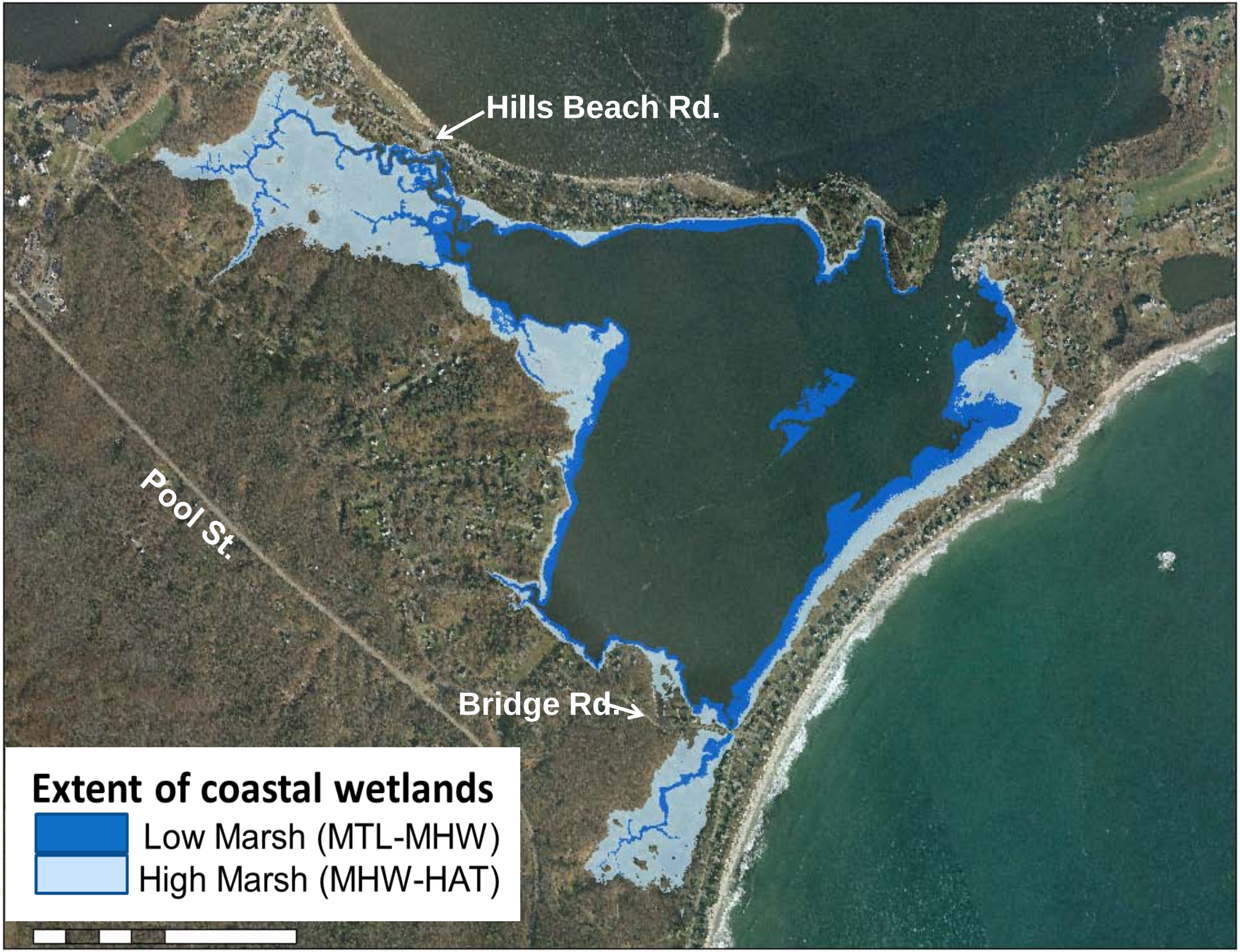
Mean Tide Level (MTL) = average height of the ocean's surface (between mean high and mean low tide).



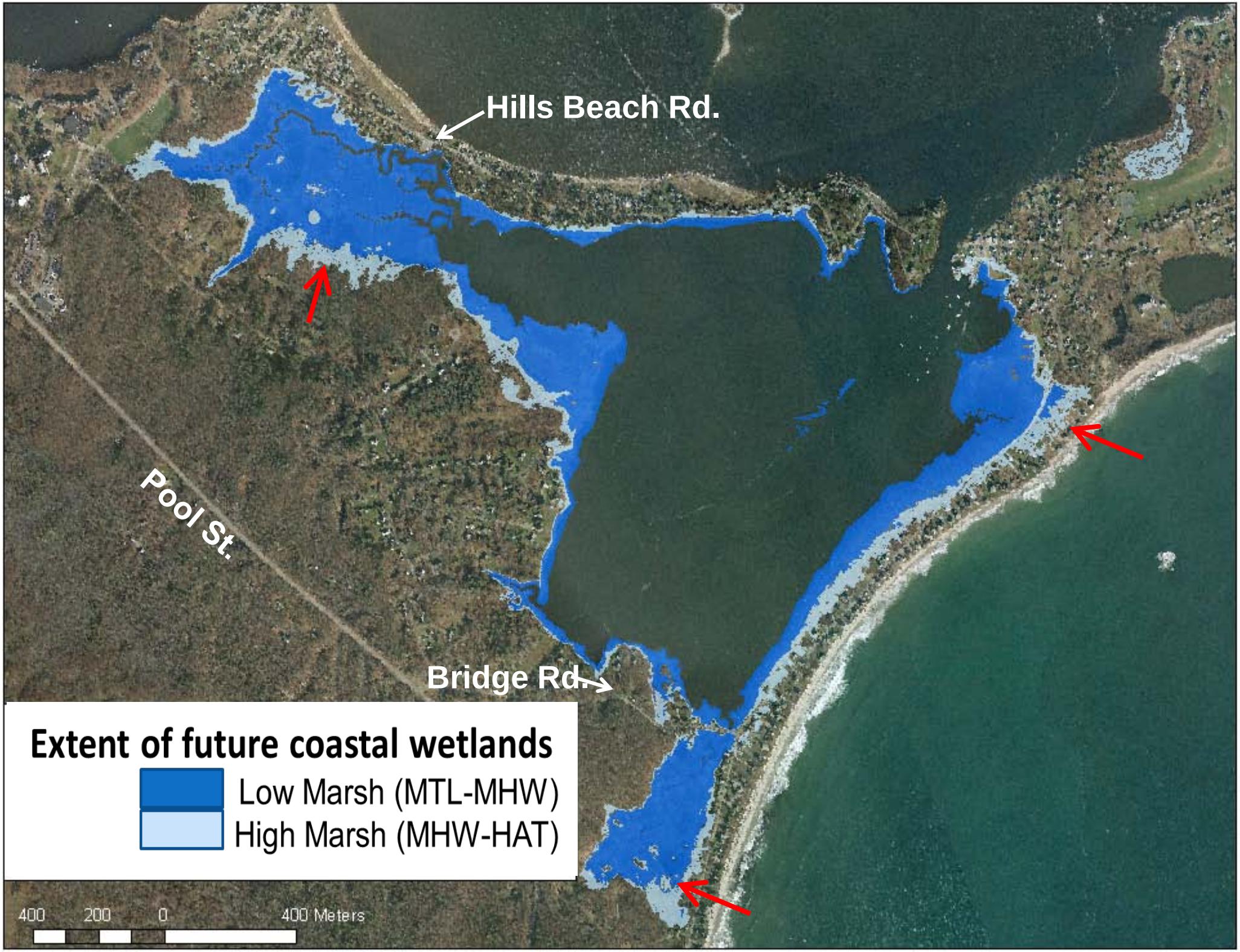
Coastal wetlands generally exist between **MTL** and **HAT**.
Low marsh generally exists between **MTL and MHW.**
High marsh generally exists between **MHW and HAT.**

Tidal elevations are determined from nearby applicable NOAA National Ocean Service/CO-OPs tidal prediction stations (Old Orchard Beach)
http://tidesandcurrents.noaa.gov

P.A. Slovinsky, MGS



For general planning purposes only; does not include dynamic inundation.



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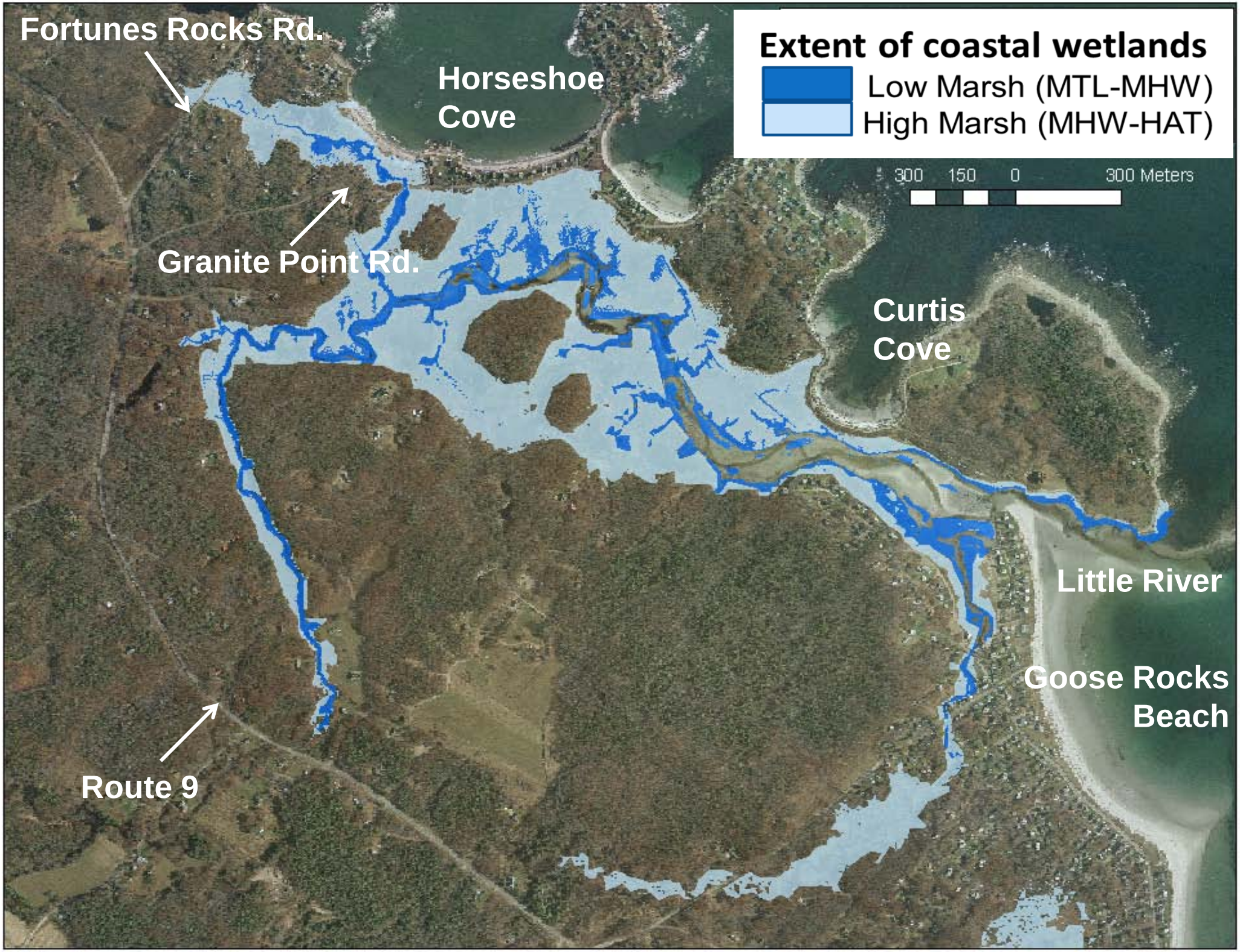
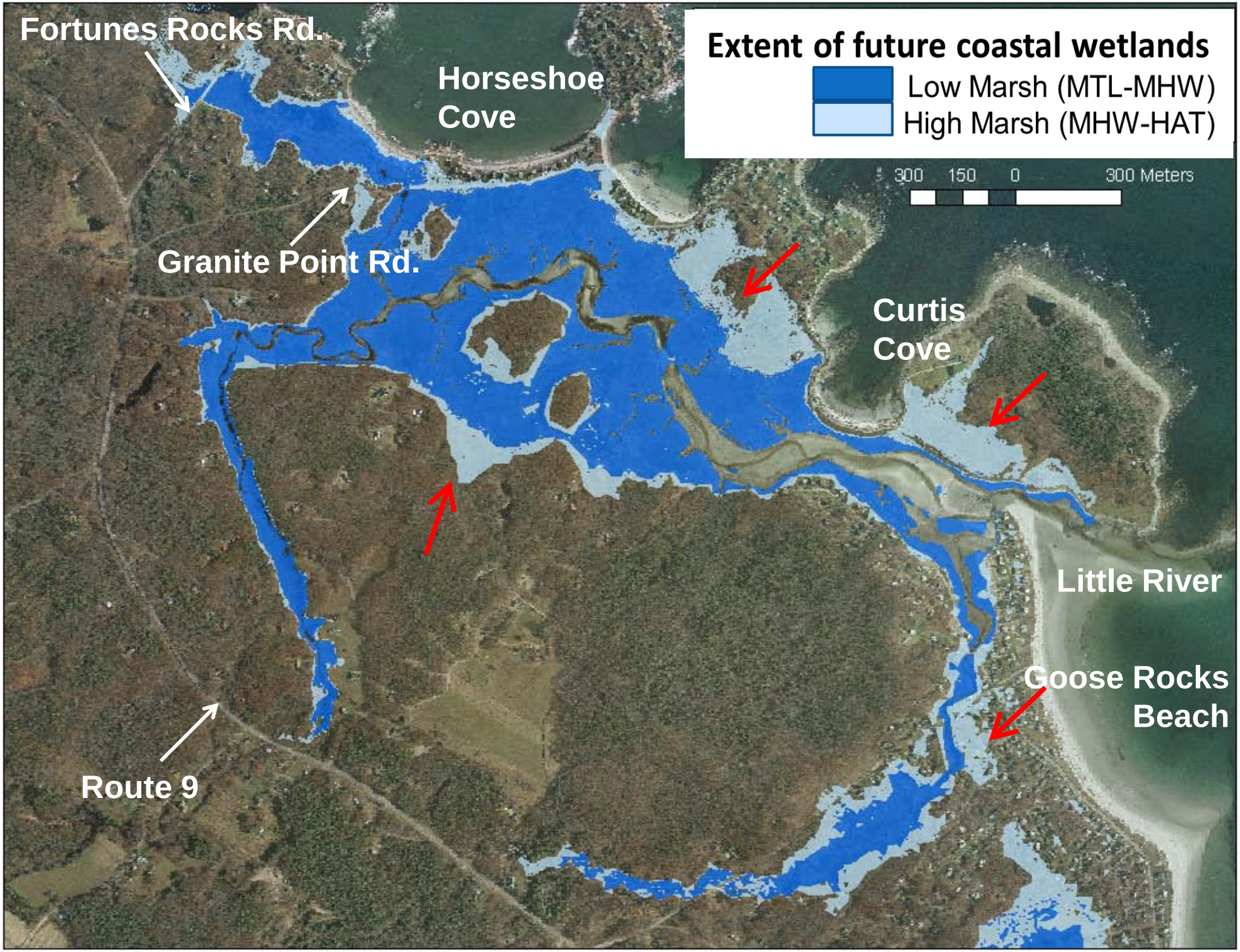


For general planning purposes only; does not include dynamic inundation.



For general planning purposes only; does not include dynamic inundation.

Acreage of different marsh types for both existing conditions, and potential future conditions after 2 feet of sea level rise, based on waterbody.

Waterbody	Coastal Wetland Type	Wetland Area in Acres			
		Existing Conditions	after 2 ft SL Rise	Change	% Change
Biddeford Pool	Low Marsh	62	163	101	162.9%
	High Marsh	131	54	-77	-58.8%
	Coastal Wetland	193	217	24	12.4%
Little River**	Low Marsh	57	212	155	271.9%
	High Marsh	186	94	-92	-49.5%
	Coastal Wetland	243	306	63	25.9%

**Includes acreage from Kennebunkport*

How can we use this data?

- More accurate mapping of existing shoreland zone boundaries (using current HAT or a Highest Astronomical Tide, HAsT)
- Potential future scenario planning
- Determining areas that will likely be inundated due to sea level rise or storm surge
- Pinpointing potential “marsh migration areas” for conservation easements or land trusts
- Investigating potential impacts to critical infrastructure networks (i.e., roads)
- Community education and outreach

Hurricane surge mapping has shown to be an effective for estimating potential flooding associated with landfalling events….so what have we done in Maine?

Sea, Lake, and Overland Surges from hurricanes (SLOSH)

Sea, Lake, and Overland Surges from Hurricanes (SLOSH) - Mozilla Firefox

File Edit View History Bookmarks Tools Help

National Weather Service
National Hurricane Center

Home | News | Organization | Search

Local forecast by "City, St" or "ZIP"
Go

Alternate Formats
Text | Mobile
Email | RSS
About Alternates

Cyclone Forecasts
Latest Advisory
Past Advisories
Audio/Podcasts
About Advisories

Marine Forecasts
Atlantic & E Pacific
Gridded Marine
About Marine

Tools & Data
Satellite | Radar
Analysis Tools
Aircraft Recon
GIS Datasets
Data Archive

Development
Experimental
Research
Forecast Accuracy

Outreach & Education
Prepare
Storm Surge
About Cyclones
Cyclone Names
Wind Scale
Most Extreme

Sea, Lake, and Overland Surges from Hurricanes (SLOSH)

Surge Overview | Storm Surge Unit | SLOSH | Surge Products | Local Impacts | FAQ | Resources

Contents

- SLOSH Model
  - Introduction
  - Modeling Approaches
  - Reference Level
  - Surge Inundation
  - Basin Coverage
  - Basin Updates
  - Strengths and Limitations
- SLOSH Display Program

SLOSH Model

Introduction

The Sea, Lake and Overland Surges from Hurricanes (SLOSH) model is a computerized numerical model developed by the National Weather Service (NWS) to estimate storm surge heights resulting from historical, hypothetical, or predicted hurricanes by taking into account the atmospheric pressure, size, forward speed, and track data. These parameters are used to create a model of the wind field which drives the storm surge.

The SLOSH model consists of a set of physics equations which are applied to a specific locale's shoreline, incorporating the unique bay and river configurations, water depths, bridges, roads, levees and other physical features.

Modeling Approaches

National Weather Service • Since 1

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****

Some important assumptions and limitations

1) SLOSH model **does not model the impacts of waves on top of the surge**, **normal river flow or rain flooding**, nor does it explicitly model changes in the astronomical tide. The model may thus **under-predict coastal flooding, especially along low-lying coastal barriers that may be overtopped by wave action**. Hence why we included a 20% uncertainty band.

2) LiDAR data represents a "snapshot" in time of topography, and conditions may have changed. **It is not 100% accurate in representing ground conditions which may have changed since data was acquired.**

3) Results from these SLOSH simulations should be considered for **general planning purposes only**. Data is especially geared towards **emergency management planning and response**.

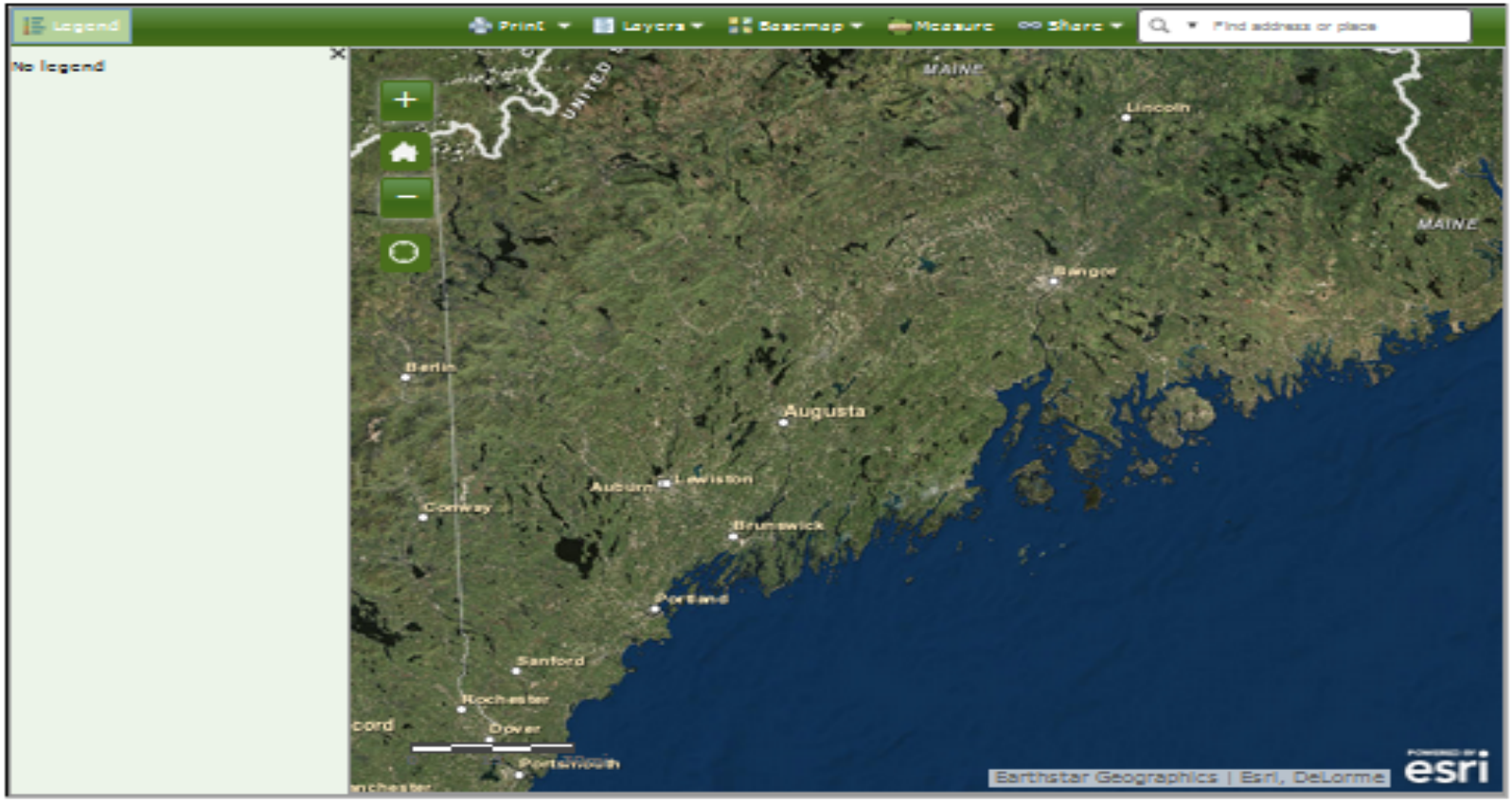
About
Explore Maine Geology
Hazards
- Earthquakes
- Erosion
- Landslides
- Floods
- Droughts
- Tsunamis
- Potential Hurricane Inundation Mapping

Educational Materials
Maps, Publications, Data
Related Links

Maine Geological Survey

Potential Hurricane Inundation Mapping

To view the data, zoom in on the map to your area of interest. The data will activate automatically while zooming in.
Please note that the maximum zoom to view data is at a scale of 1:4800 beyond which the flood layers will not draw.
To show different potential hurricane inundation scenarios, click the Layers menu below.



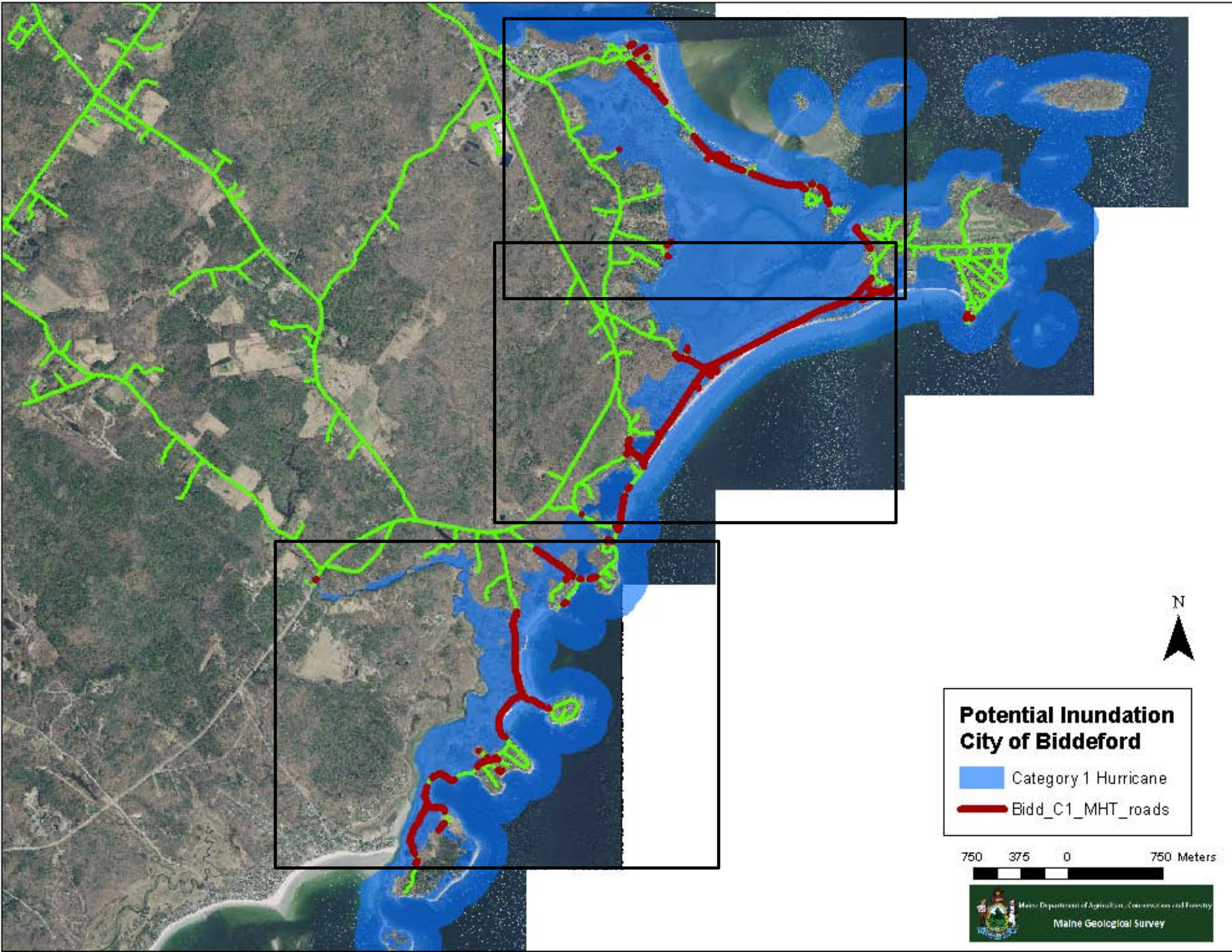
Data Disclaimer

Usage of this data is limited to general and emergency planning purposes only. Users must assume responsibility in determining the usability of this data for their purposes. It is important to note that LIDAR data used to create these data represents bare earth conditions at the time it was captured (2006, 2010, and 2011); thus, topography may have undergone changes since initial mapping occurred. It is also important to note that these datasets only account for combined predicted astronomical tides and potential storm surges from the SLOSH model, and thus do not account for the additional impacts of waves, precipitation, or freshwater flow. The Maine Geological Survey nor the Department of Agriculture, Conservation and Forestry, nor its employees or agents: (1) make any warranty, either expressed or implied for merchantability or fitness for a particular purpose, as to the accuracy or reliability of the information shown on the map; nor are they (2) liable for any damages, including consequential damages, from using the map or the inability to use the map.

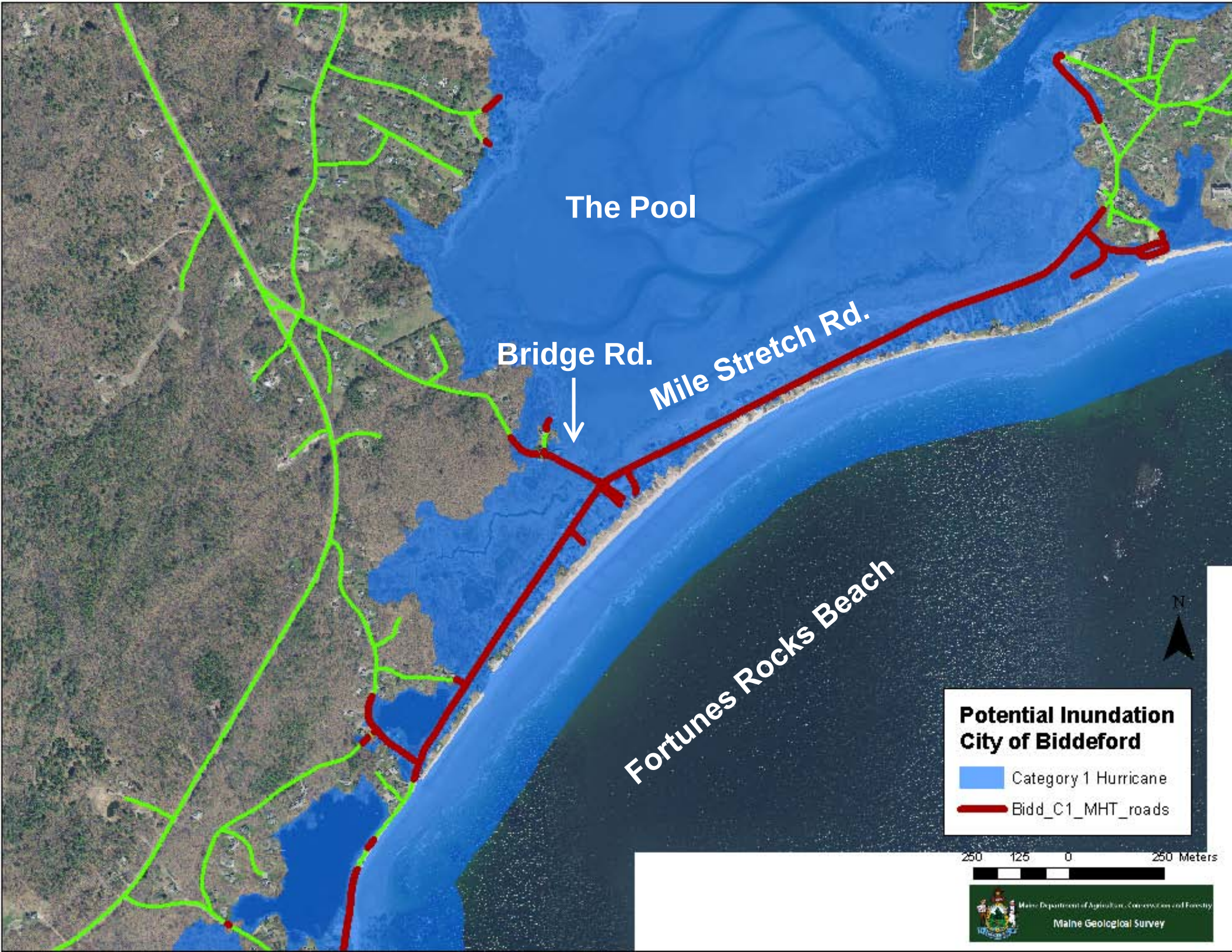
Frequently Asked Questions

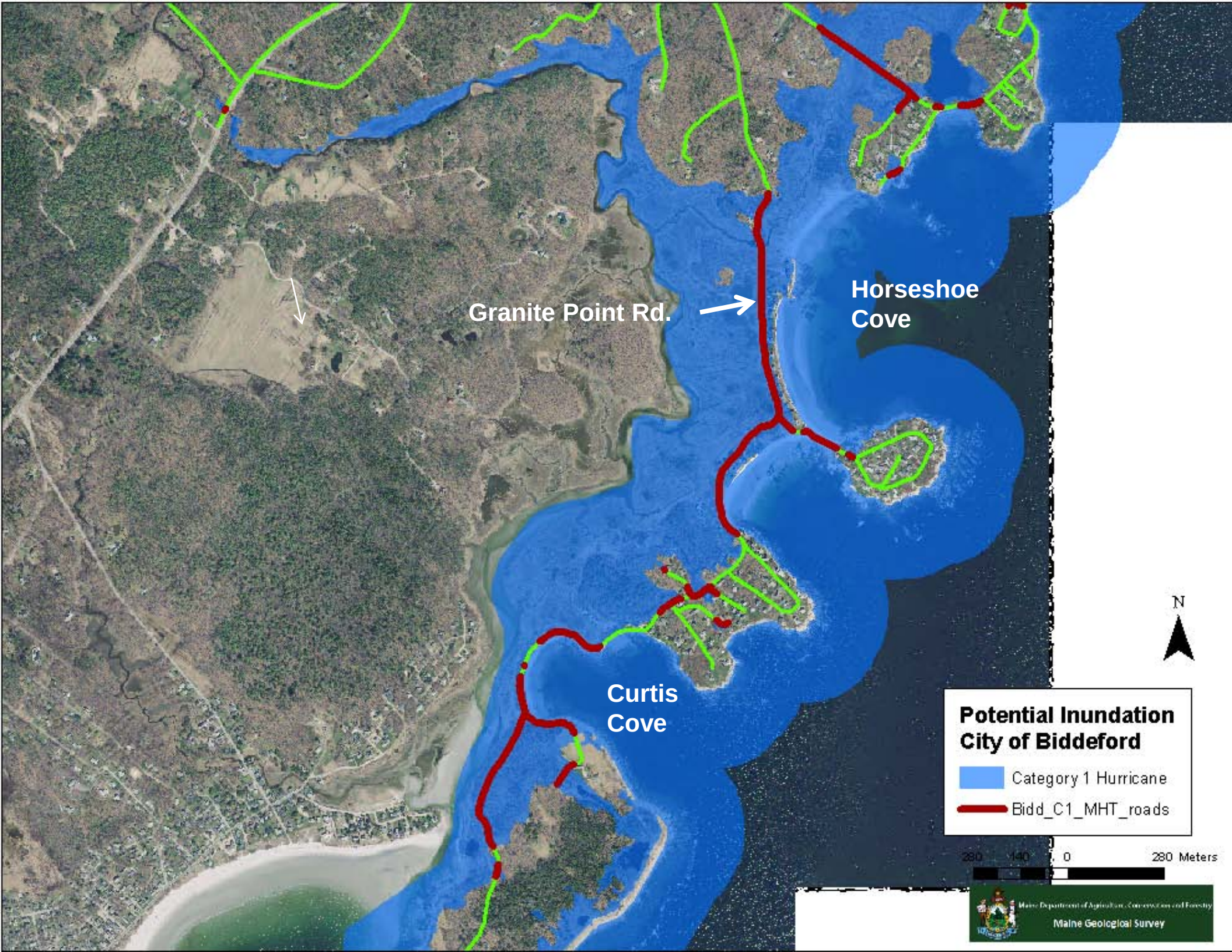
The frequently asked questions provide more information about how the data layers were created, what they should be used for, usage limitations and general information on hurricanes in Maine.

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


N
Potential Inundation
City of Biddeford
Category 1 Hurricane
Bidd_C1_MHT_roads
750 375 0 750 Meters
Maine Geological Survey

Potential Inundation
City of Biddeford
Category 1 Hurricane
Bidd_C1_MHT_roads
N
225 112.5 0 225 Meters
Maine Geological Survey


The Pool
Bridge Rd.
Mile Stretch Rd.
Fortunes Rocks Beach
N
Potential Inundation
City of Biddeford
Category 1 Hurricane
Bidd_C1_MHT_roads
250 125 0 250 Meters
Maine Geological Survey


Granite Point Rd.
Horseshoe Cove
Curtis Cove
N
Potential Inundation
City of Biddeford
Category 1 Hurricane
Bidd_C1_MHT_roads
280 140 0 280 Meters
Maine Geological Survey

How can we use this data?

- Investigating potential impacts to critical infrastructure networks (i.e., roads, critical facilities)
- Storm evacuation planning and emergency management planning
- Community education and outreach

Thank you!

Potential sea level rise, storm surge, marsh migration, and hurricane impacts in Biddeford, ME

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