

# **CLIMATE CHANGE, COASTAL GEOLOGIC HAZARDS and SEA-LEVEL RISE: SOME RHODE ISLAND STRATEGIES**

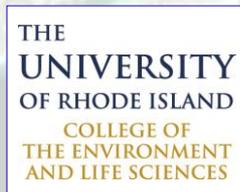
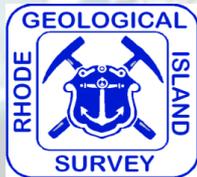
**On Pettaquamscutt Series  
27 January 2013**

**Jon C. Boothroyd, PhD  
Research Professor Emeritus – Quaternary Geology**

**\*Bryan A. Oakley, PhD  
Scott Rasmussen, MESM Candidate**

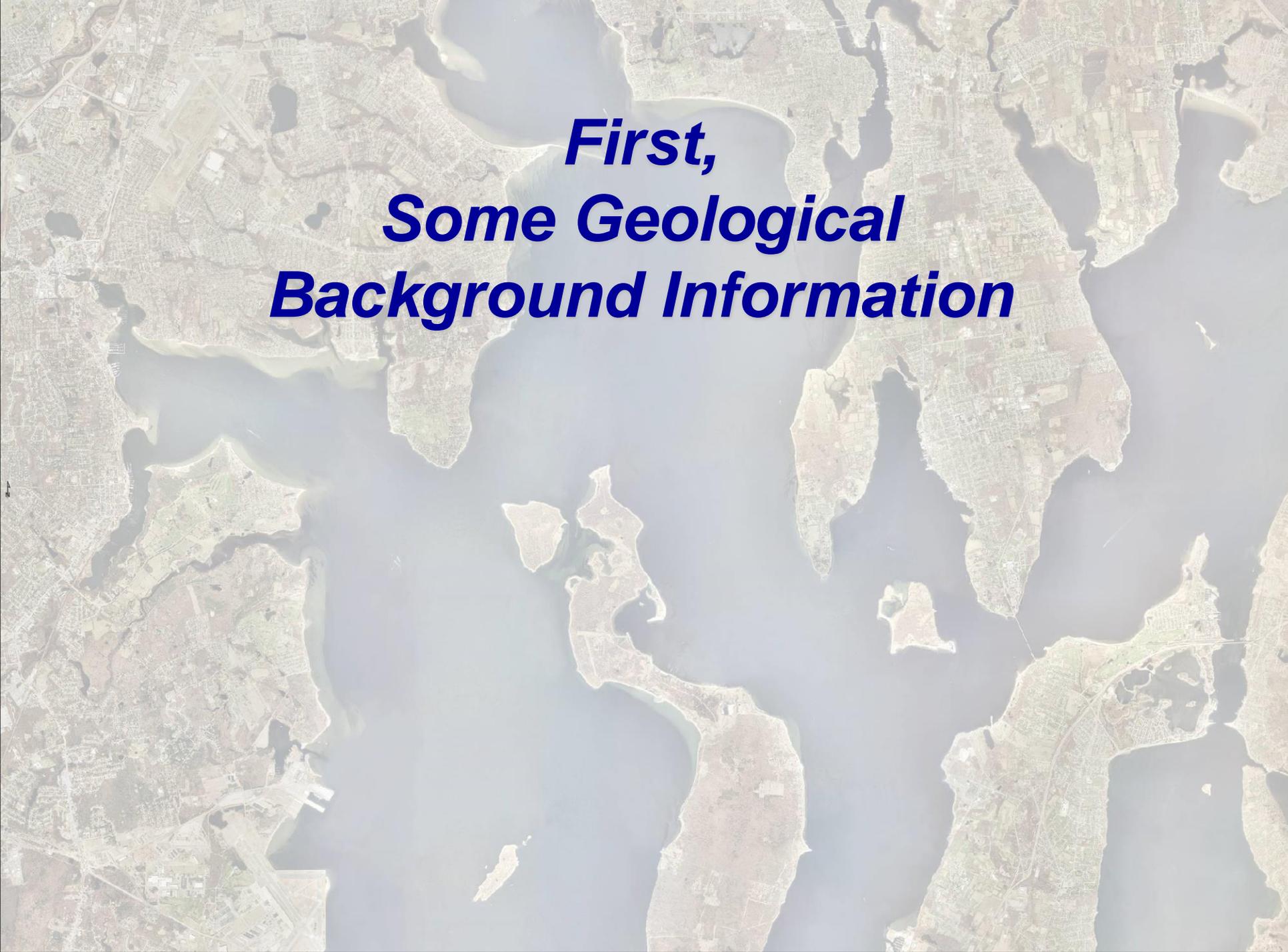
**Department of Geosciences  
College of the Environment and Life Sciences  
University of Rhode Island**

**\*Present Address: Assistant Professor (non-tenure track),  
Eastern Connecticut State University**



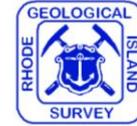
# ***Summary for Rhode Island:***

- **Glacial Geology, Past and Present, the Underlying Key to Understanding Processes and Products**
- **Storms the Most Important Driver in Coastal Change**
- **Sea-Level Rise a Secondary Effect**
- **Future Major Storms Combined With Sea-Level Rise a Very Large Problem**
- **Accelerated Sea-Level Rise Resulting in Inundation also a Very Large Potential Problem**
- **RICRMC Planning for a 3-5 foot Rise by 2100**

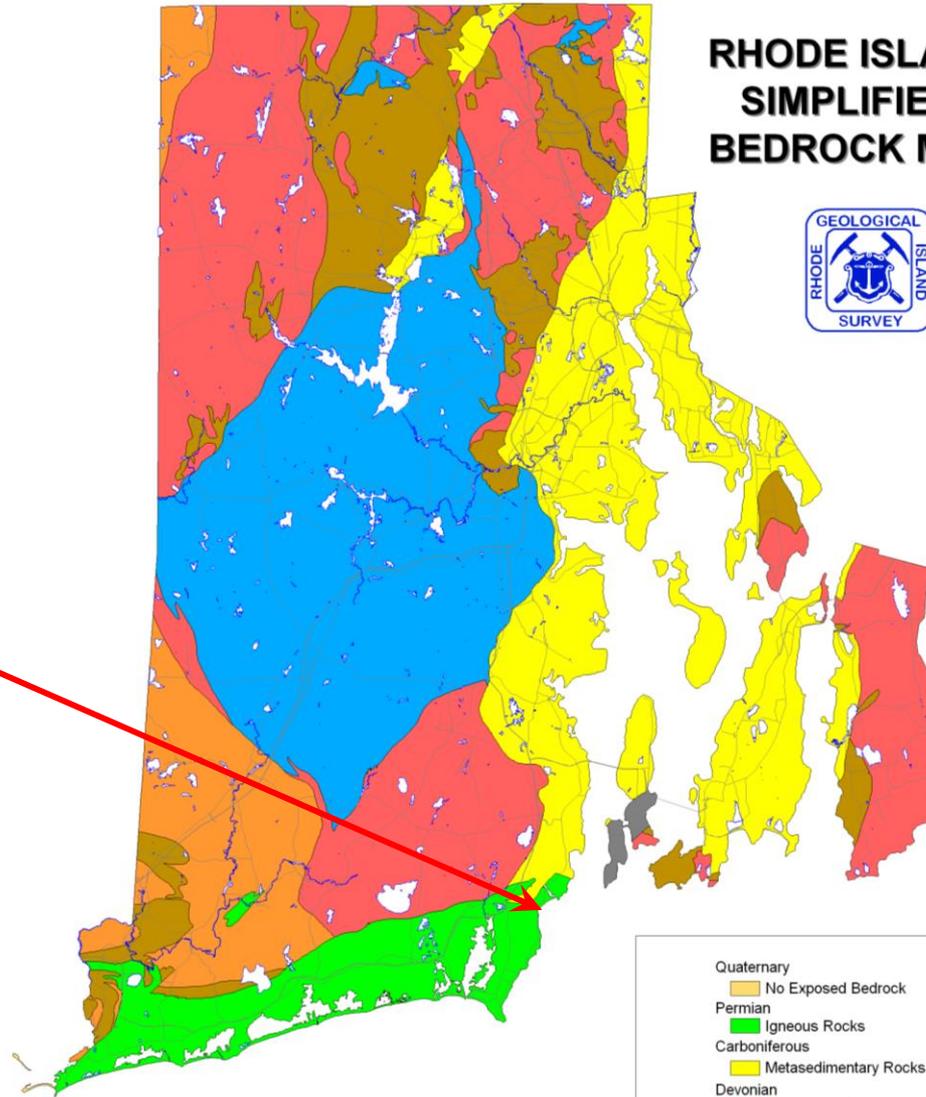
An aerial photograph of a coastal region, likely the Chesapeake Bay area, showing a large body of water in the center surrounded by land with a grid-like street pattern and some industrial or airport-like structures. The text is overlaid on the water area.

***First,  
Some Geological  
Background Information***

# RHODE ISLAND SIMPLIFIED BEDROCK MAP

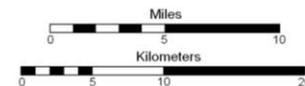


You are  
here

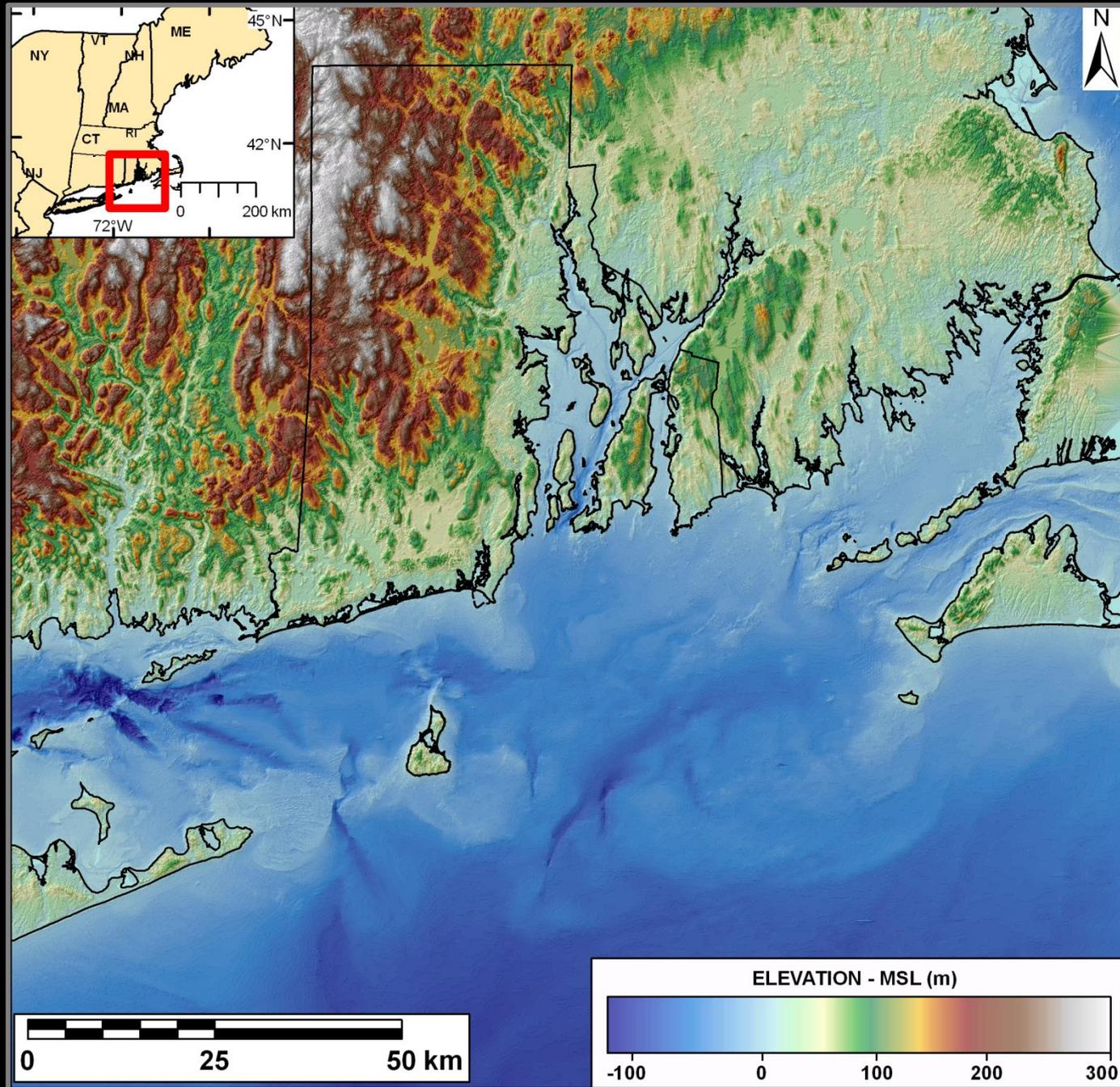


- Quaternary
  - No Exposed Bedrock
- Permian
  - Igneous Rocks
- Carboniferous
  - Metasedimentary Rocks
- Devonian
  - Igneous Rocks
- Cambrian
  - Metasedimentary Rocks
- PreCambrian
  - Igneous Rocks
  - Gneissic Rocks
  - Metastratified Rocks

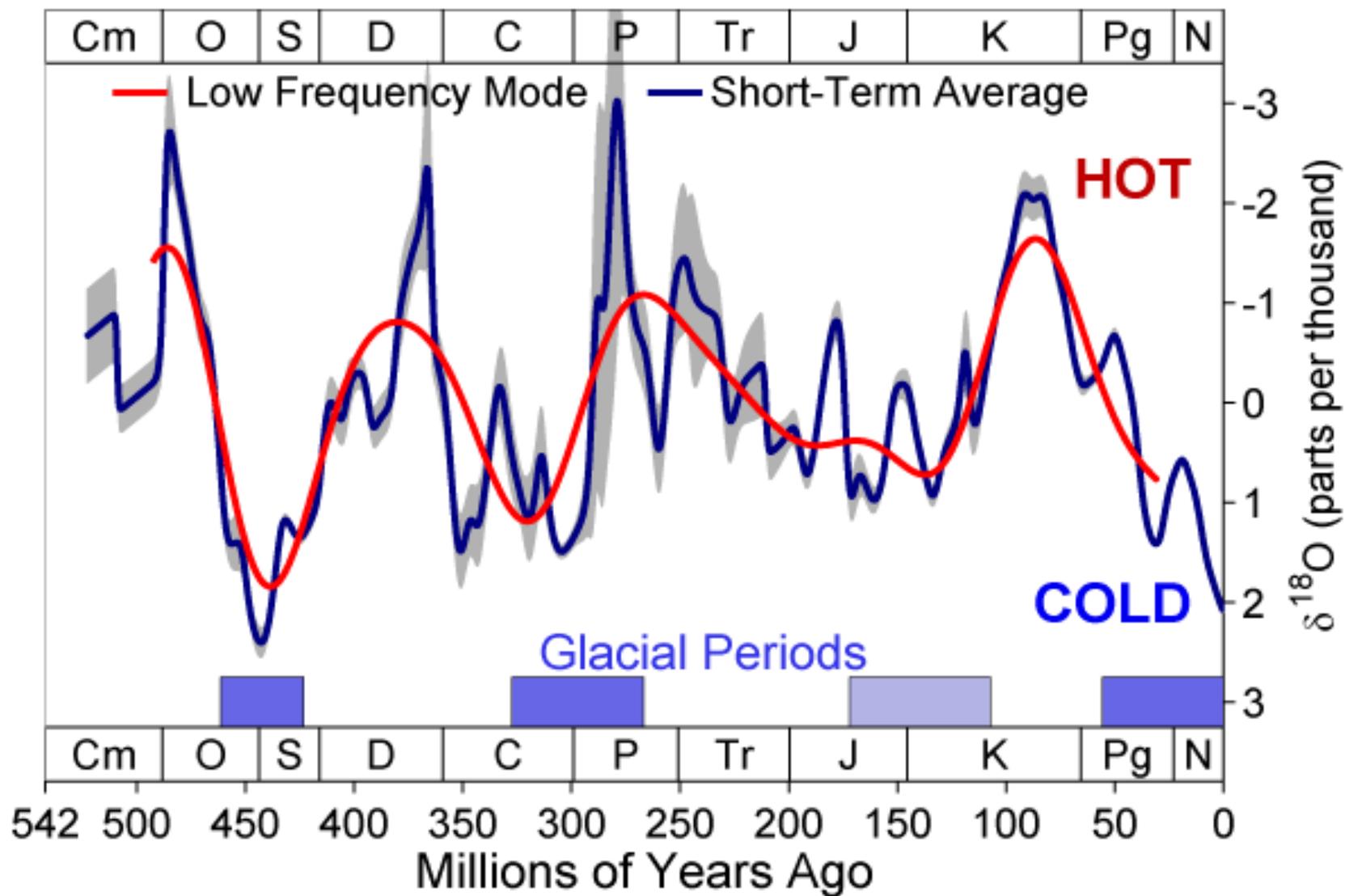
Modified from:  
Hermes, O.D., Gromet, L.P., and Murray, D.P. (compilers), 1994.  
Bedrock geologic map of Rhode Island.  
Rhode Island Map Series No. 1,  
University of Rhode Island, Kingston.  
Scale 1:100,000.

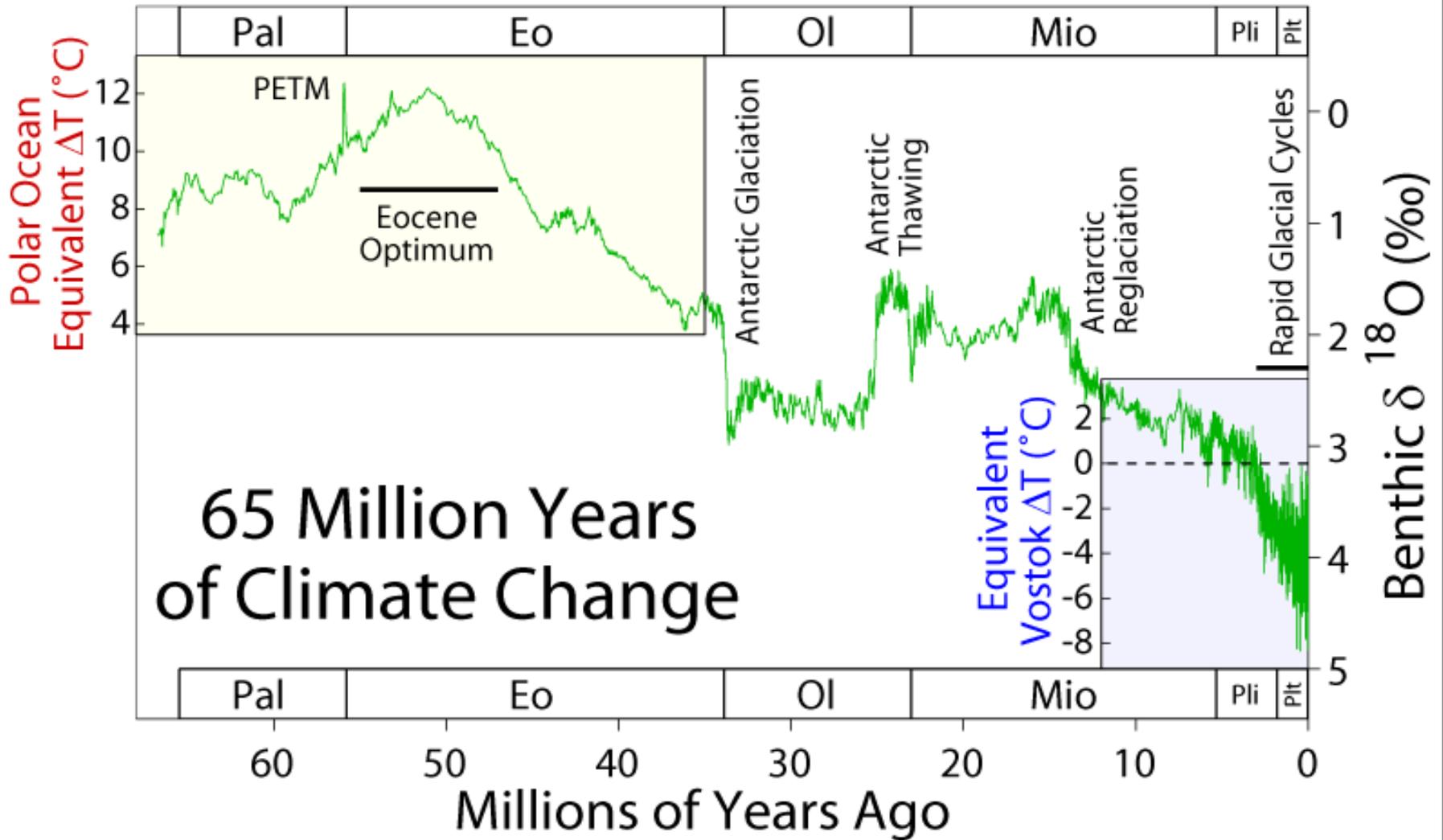


# Geomorphology of Southeastern New England

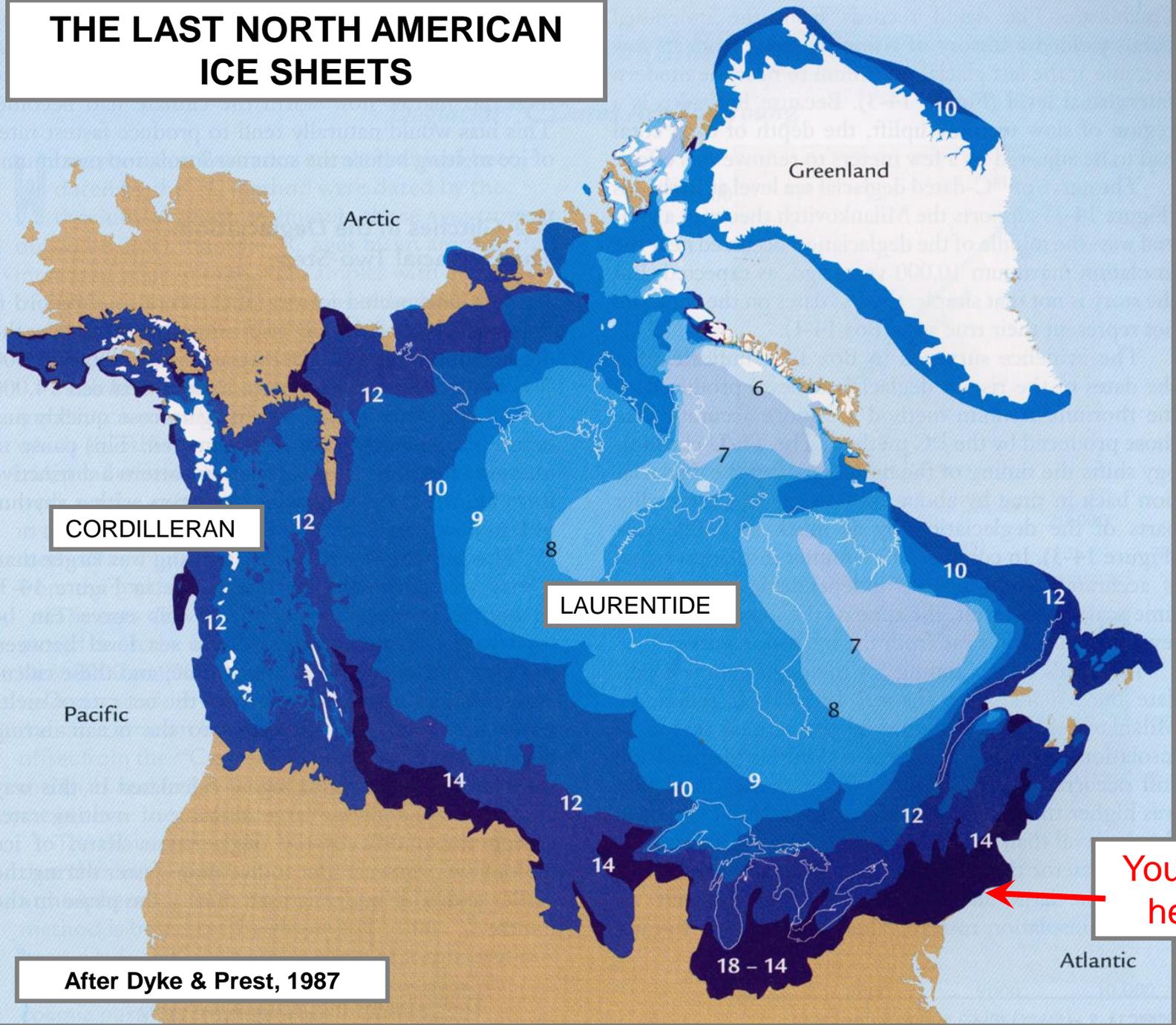


# Phanerozoic Climate Change





# THE LAST NORTH AMERICAN ICE SHEETS



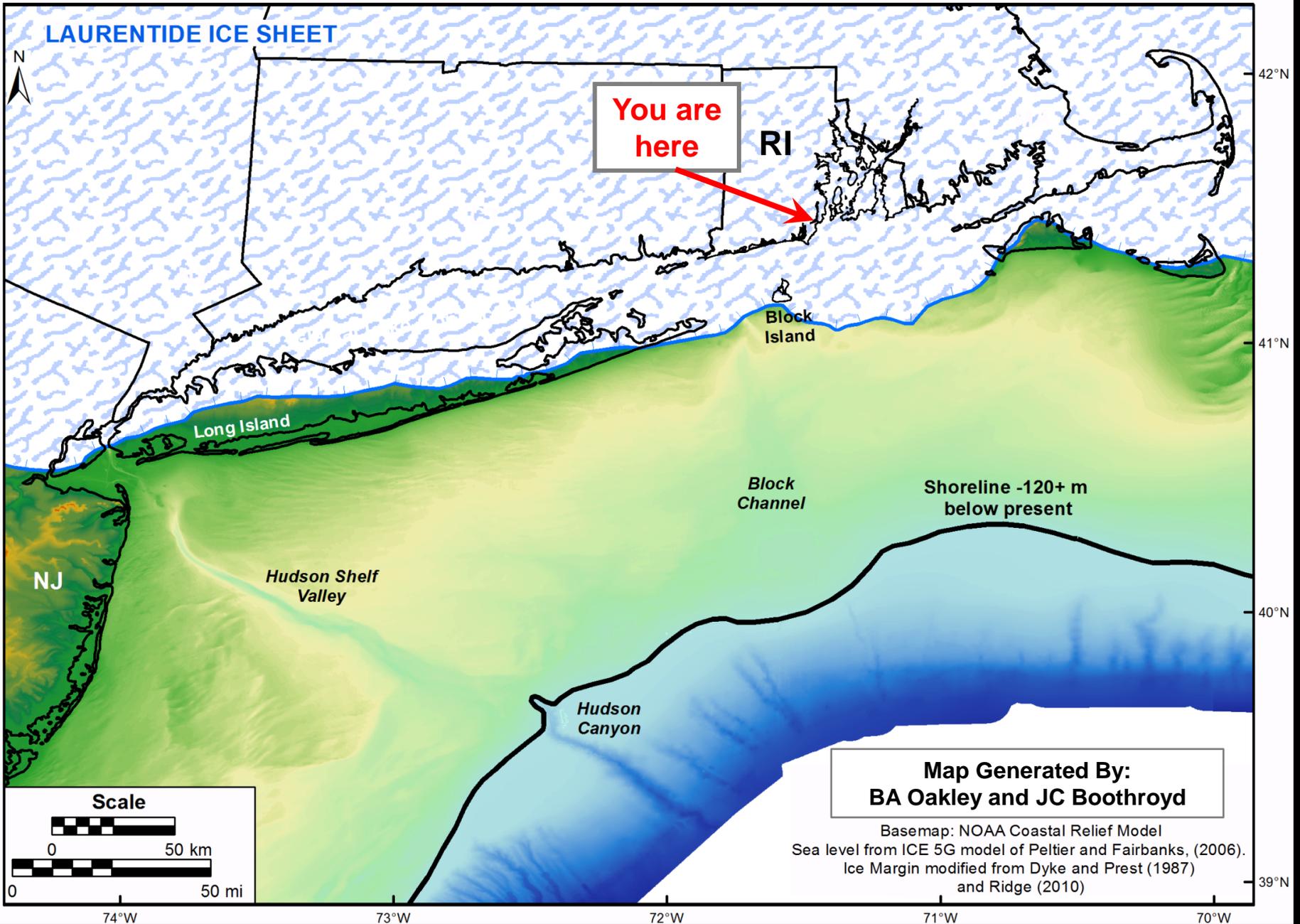
CORDILLERAN

LAURENTIDE

You are here

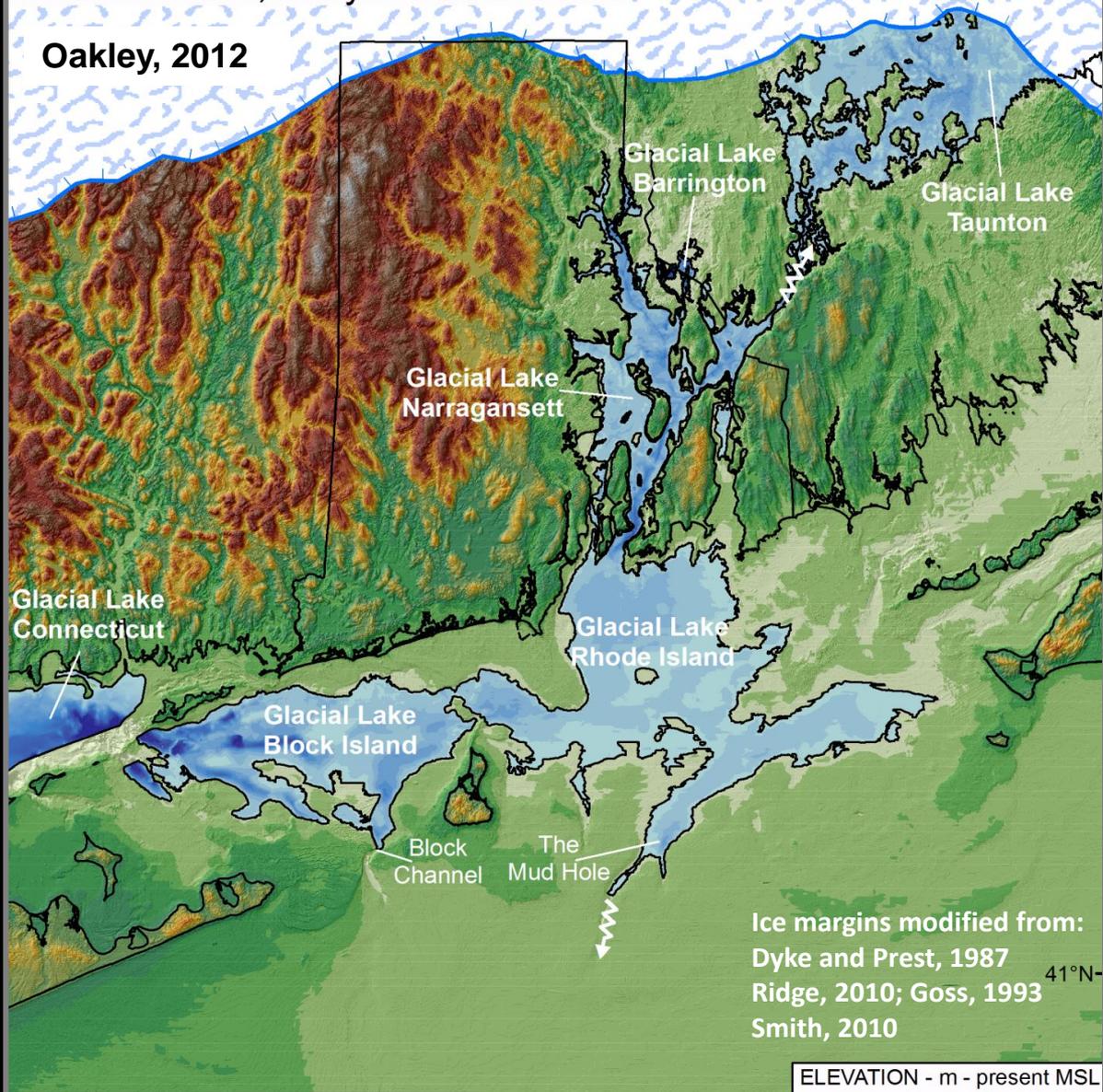
After Dyke & Prest, 1987

# S New England, E New York, Continental Shelf at LGM ~ 26,000 yBP



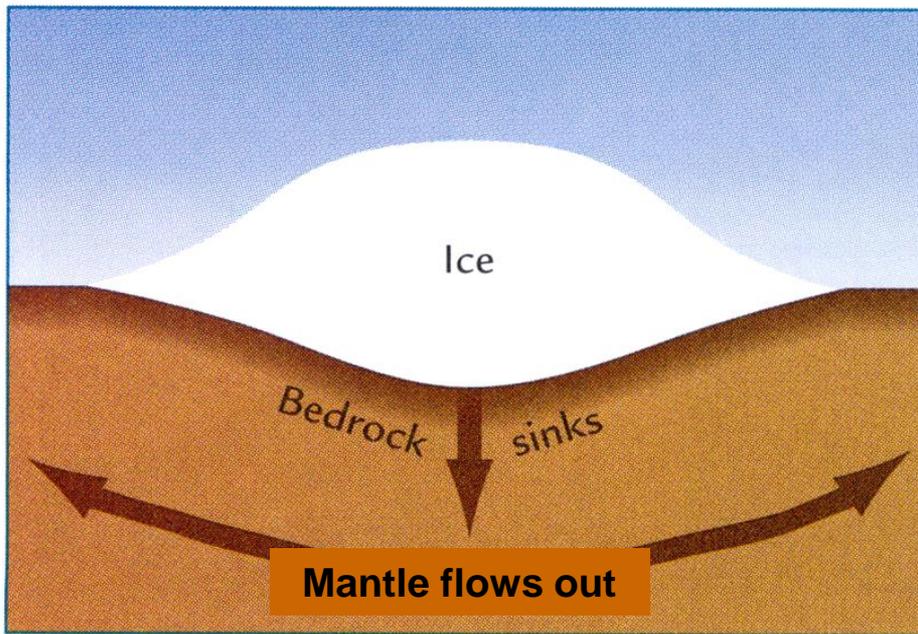
# GLACIAL LAKE NARRAGANSETT: 18,500 yBP

Oakley, 2012

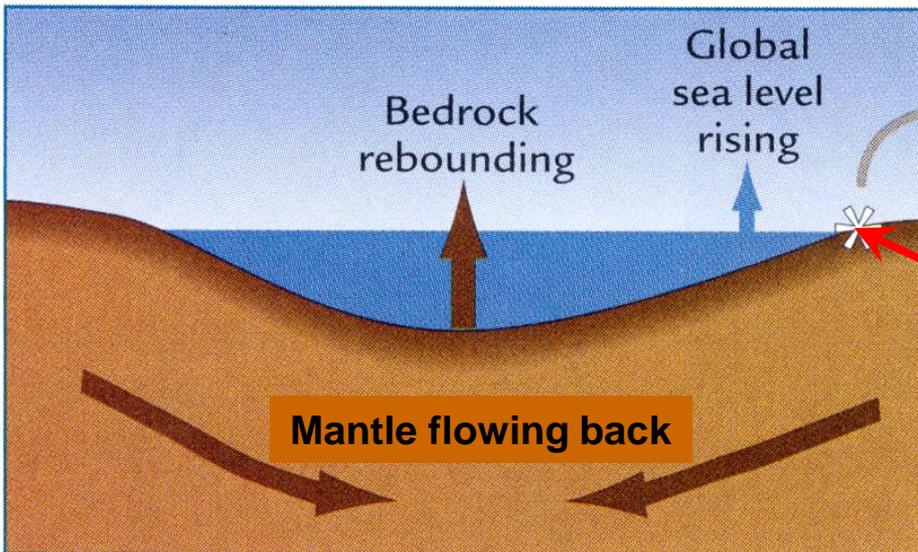


41°N

# Isostatic Rebound

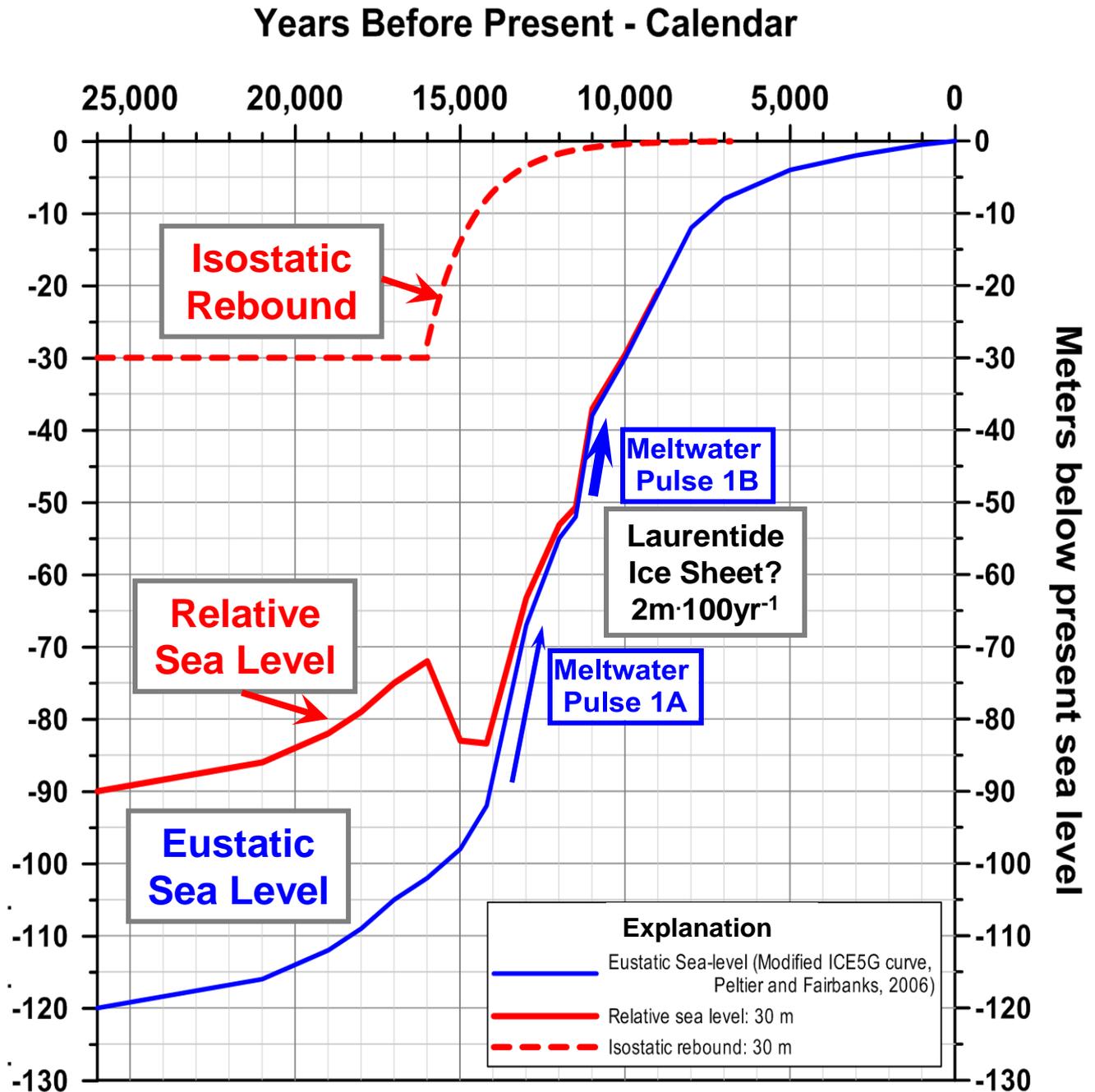


A Last glaciation (21,000 years ago)



B Today

# Eustatic Sea-Level Rise + Isostatic Rebound at Block Island RI

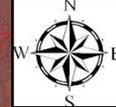


Oakley and Boothroyd,  
July 2012

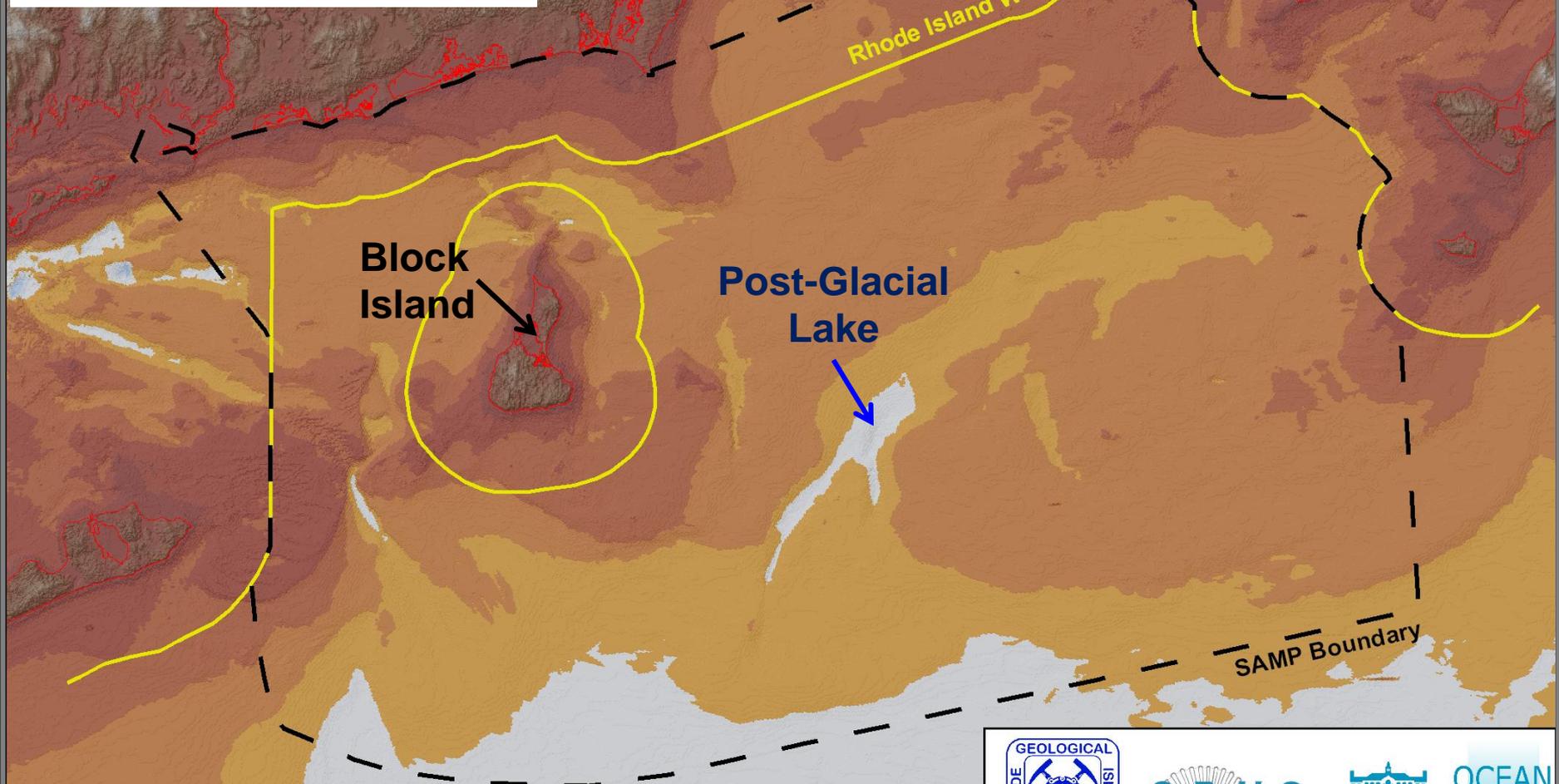
# SEA-LEVEL RISE: OSAMP AREA

- 50 m below present  
~ 11,500 yBP

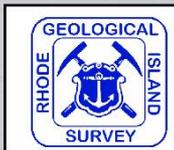
Sea level data from Peltier and Fairbanks, 2006  
Elevation data from P. Jordan, RI DEM  
Map created by B.A. Oakley, URI Geosciences



## Begin Meltwater Pulse 1B



Atlantic Ocean



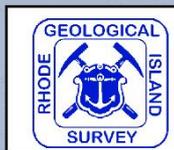
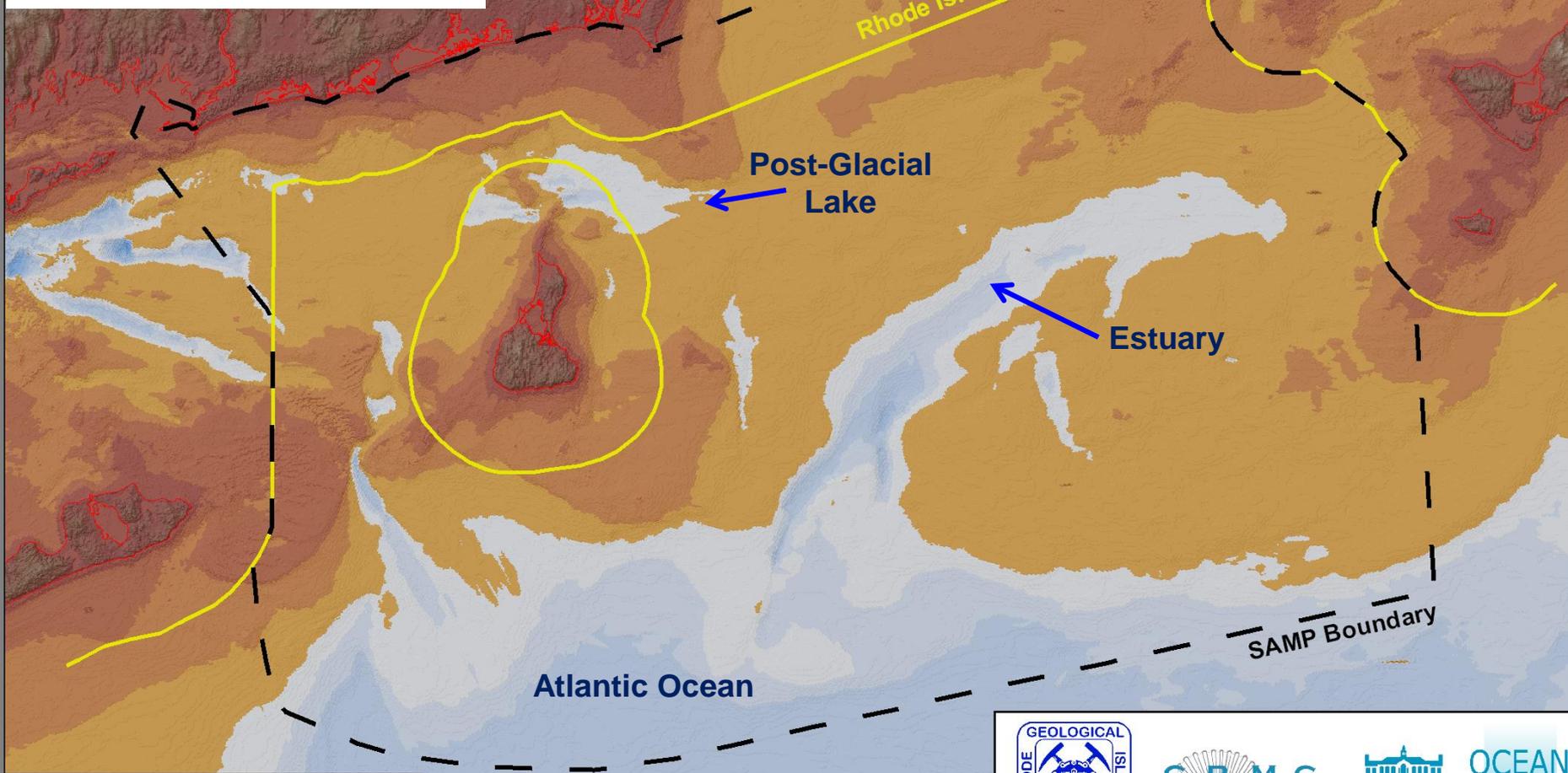
# SEA-LEVEL RISE: OSAMP AREA

- 40 m below present  
11,000 yBP

Sea level data from Peltier and Fairbanks, 2006  
Elevation data from P. Jordan, RI DEM  
Map created by B.A. Oakley, URI Geosciences



## End Meltwater Pulse 1B

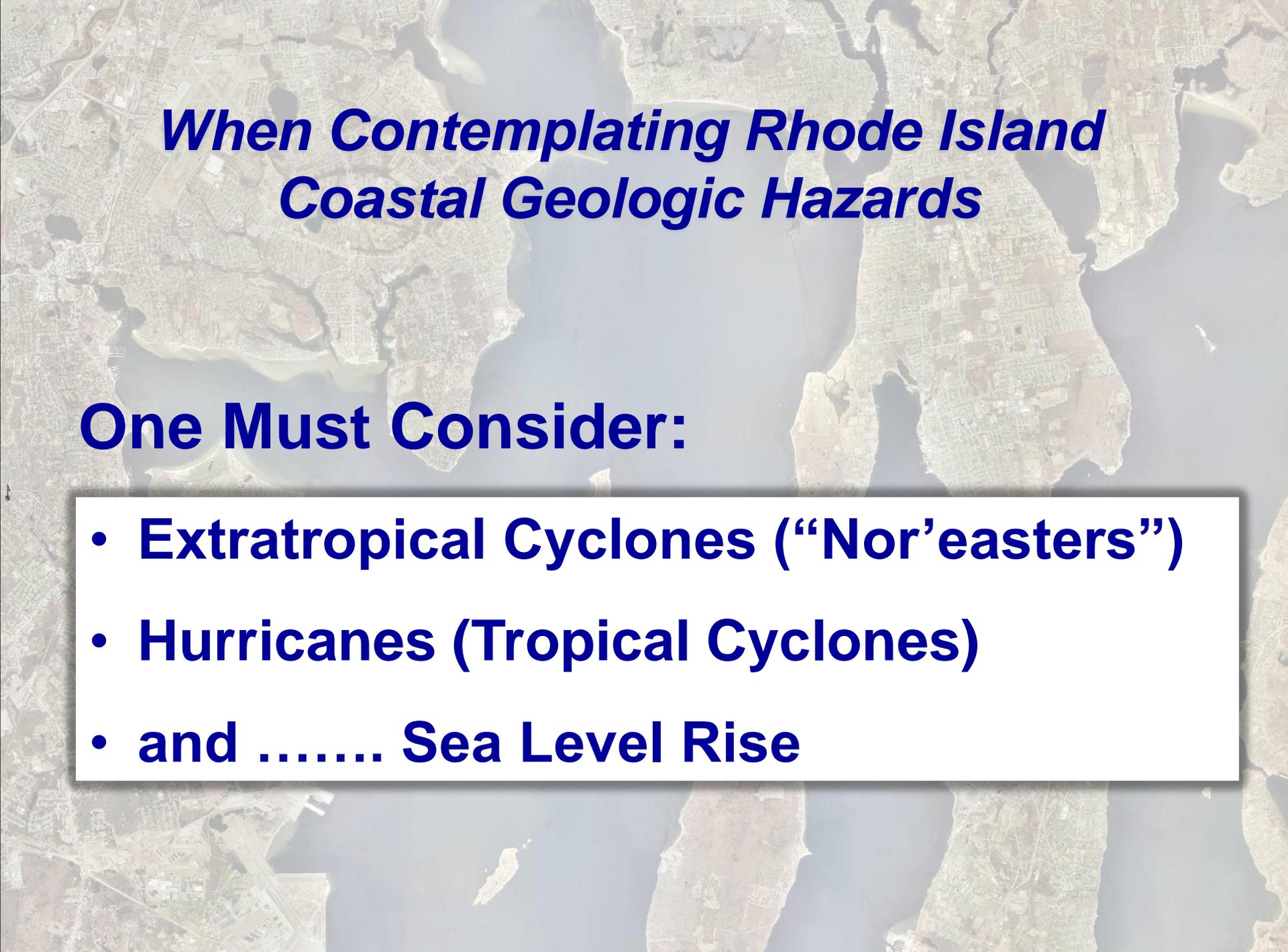


**The Sea May Be Rising Long Term – But.....  
Instantaneous Storm Surges  
Elevate Sea Level Now**

# Narragansett Pier, RI Seawall – Tropical Storm Irene 2011



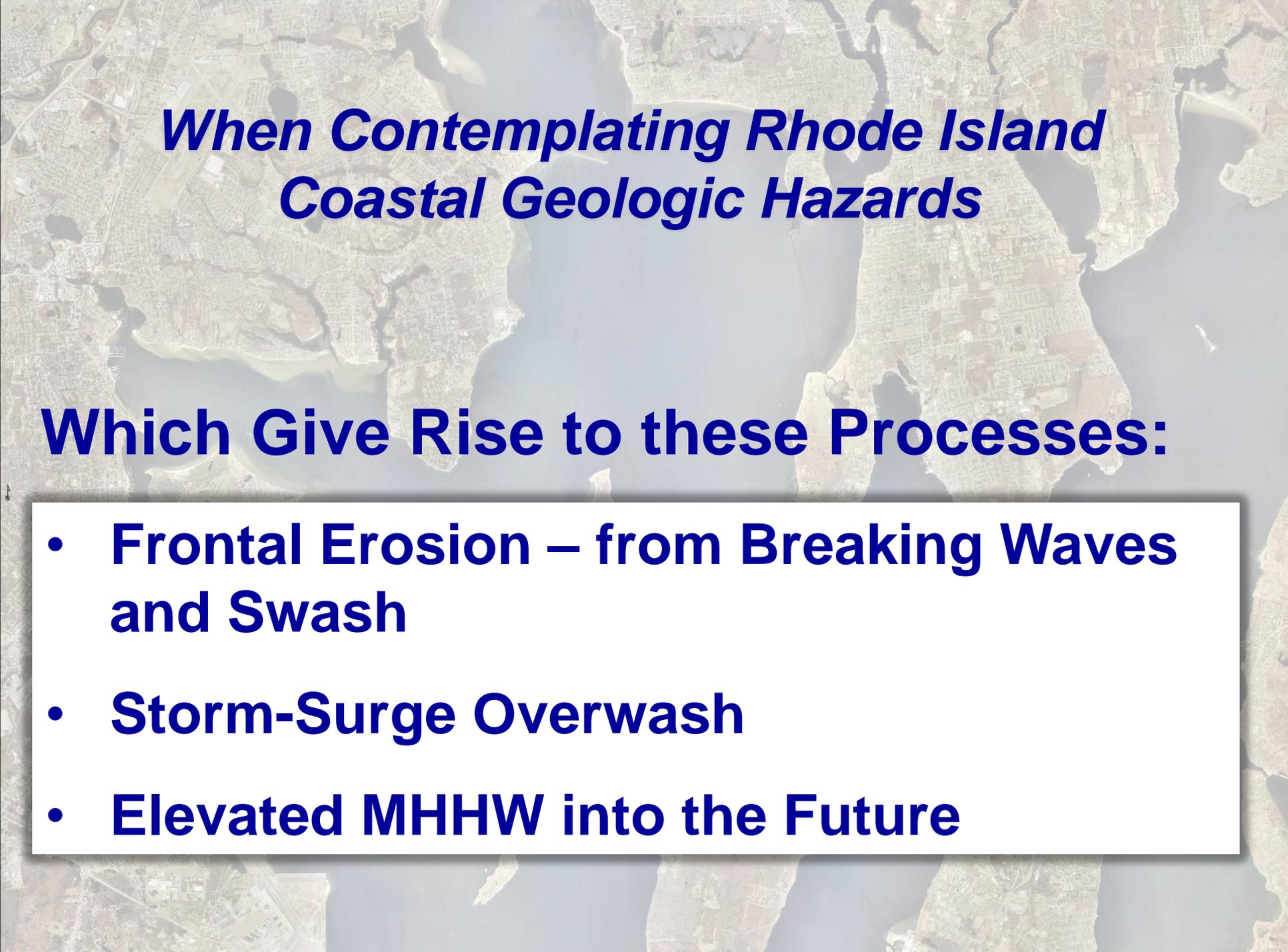
Anonymous via N Vinhateiro, 28 aug 2011



# ***When Contemplating Rhode Island Coastal Geologic Hazards***

## **One Must Consider:**

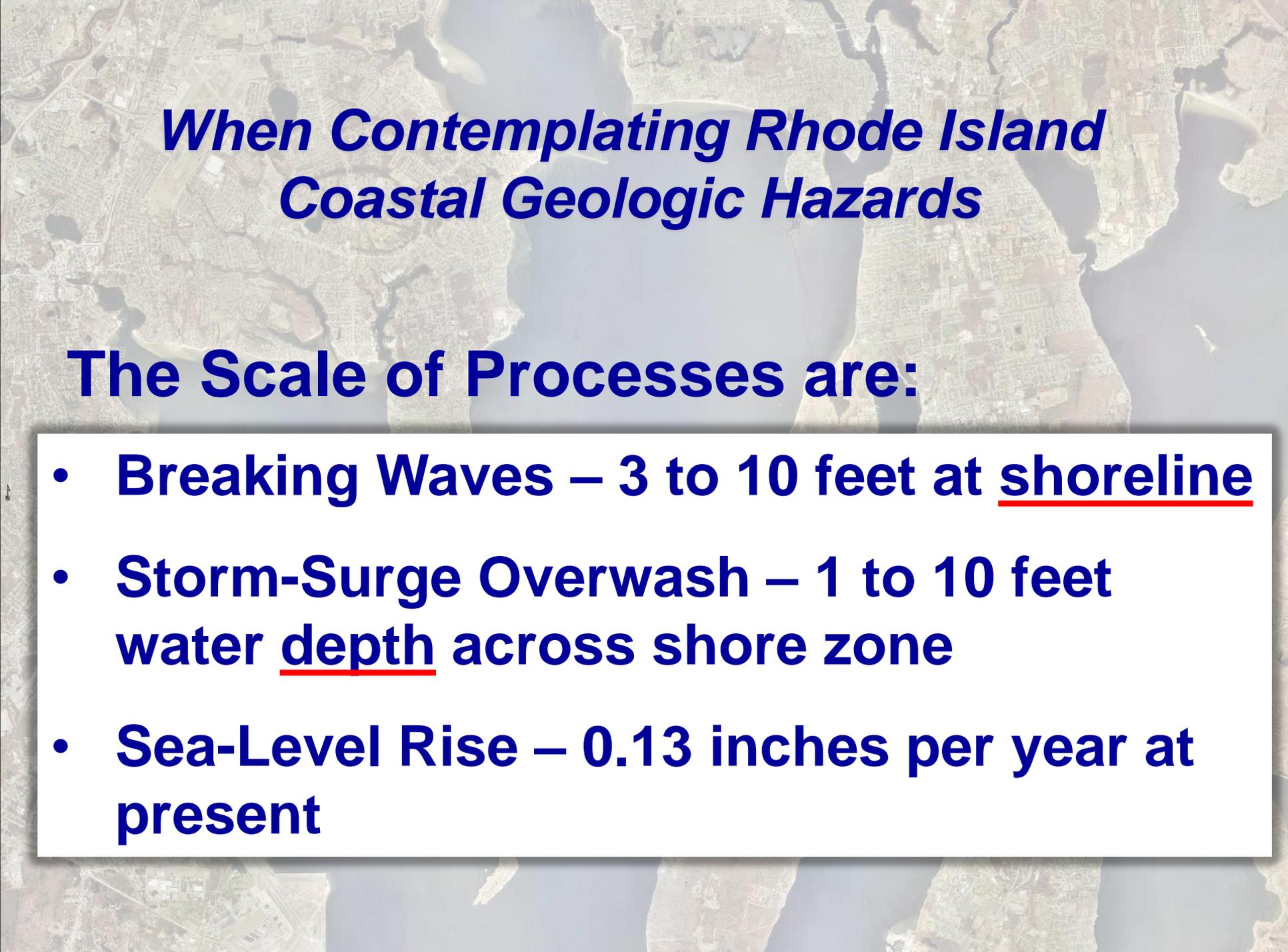
- **Extratropical Cyclones (“Nor’easters”)**
- **Hurricanes (Tropical Cyclones)**
- **and ..... Sea Level Rise**



***When Contemplating Rhode Island  
Coastal Geologic Hazards***

**Which Give Rise to these Processes:**

- **Frontal Erosion – from Breaking Waves and Swash**
- **Storm-Surge Overwash**
- **Elevated MHHW into the Future**

An aerial photograph of the Rhode Island coastline, showing the state's irregular shape and the surrounding water. The land is a mix of urban areas with grid patterns and rural areas with fields and forests. The water is a dark blue-grey color.

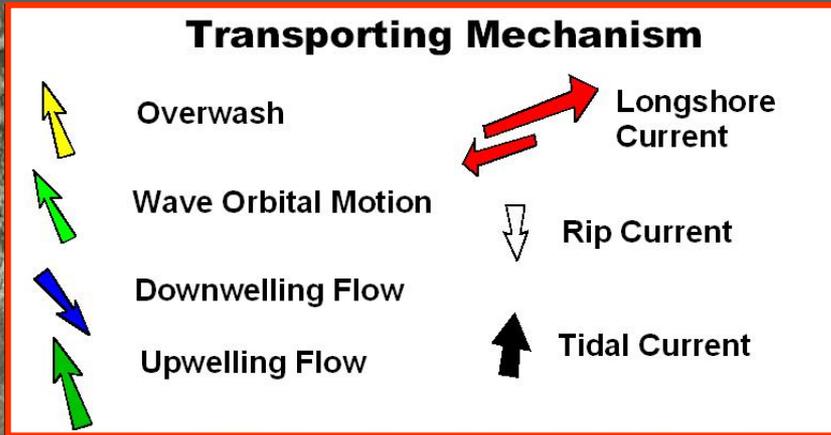
## ***When Contemplating Rhode Island Coastal Geologic Hazards***

### **The Scale of Processes are:**

- **Breaking Waves – 3 to 10 feet at shoreline**
- **Storm-Surge Overwash – 1 to 10 feet water depth across shore zone**
- **Sea-Level Rise – 0.13 inches per year at present**

# Sediment Transport Pathways Charlestown – Green Hill Barrier and Headland

**The Message:**  
**Many  
Directions and  
Processes**



**Storm Surge and Overwash  
Browning Cottages  
Moonstone Beach, RI**



04/16/2007 08:42

RE Hehre

# Frontal Erosion - Browning Cottages



# Superstorm Sandy - Browning Cottages



RI DOT

30 Oct 2012

# Superstorm Sandy - Browning Cottages



30 Oct 2012

<http://fema.maps.arcgis.com/home/webmap/viewer.html?webmap=>

# Superstorm Sandy - Browning Cottages



RI DOT

30 Oct 2012

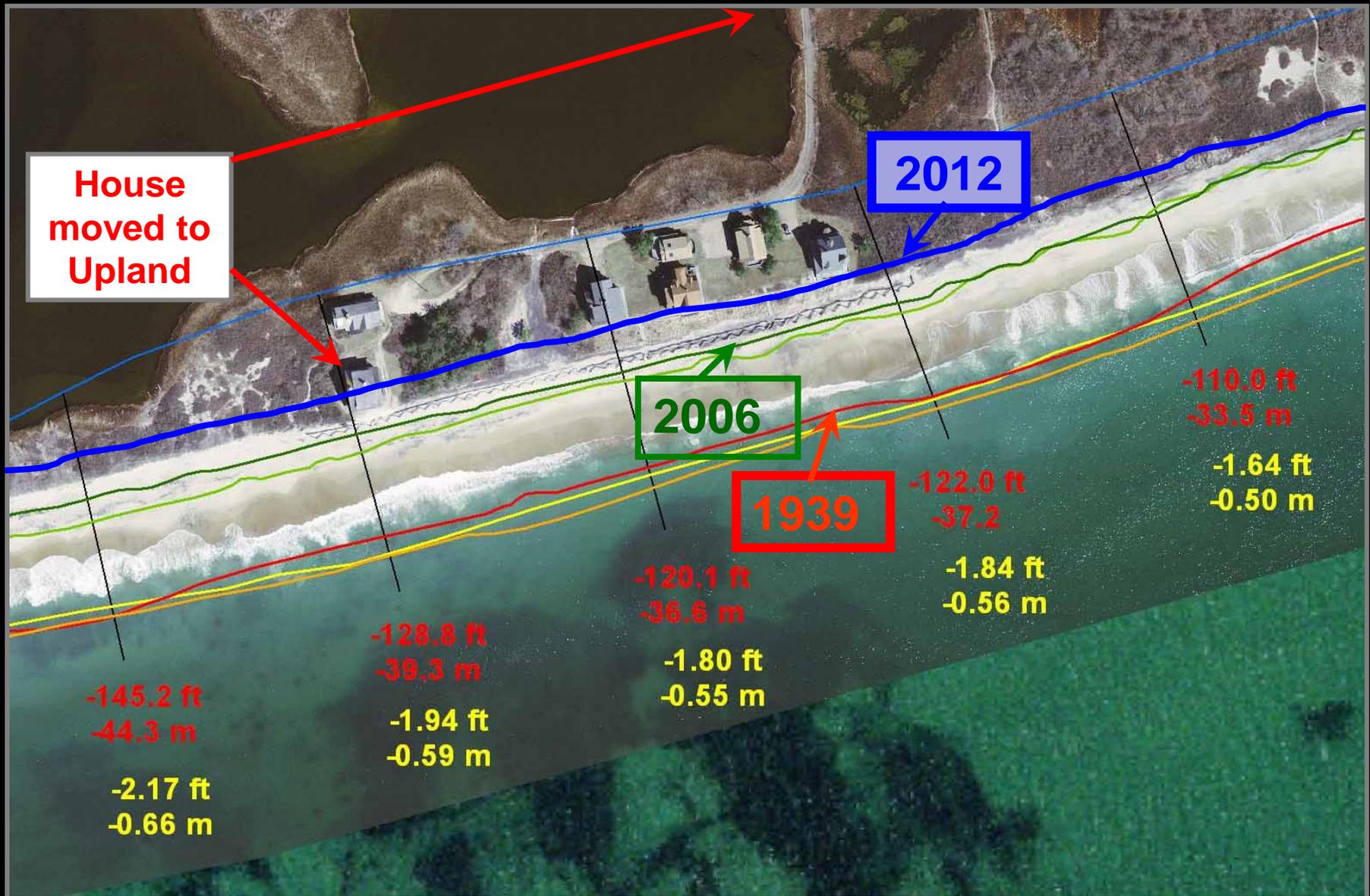
# Superstorm Sandy - Browning Cottages



31 Oct 2012

OAKLEY, 2012

# Frontal Erosion 1939-2012 - Browning Cottages, Moonstone Beach, RI



# “2 Sticks and A String” – or, the Modified Emery Method



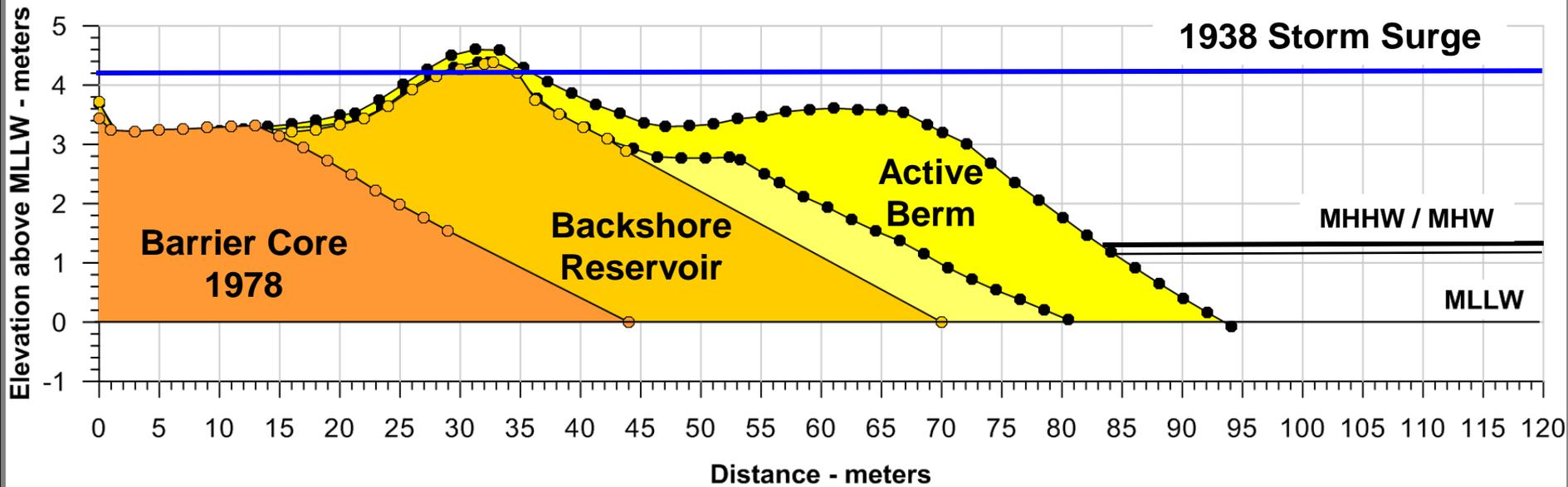
Summer 1983

JC Boothroyd

# CHA-EZ Profile Plot

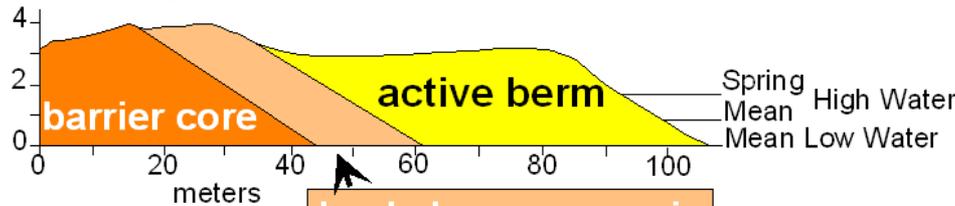
Date	Volume m <sup>3</sup> .m
07 Feb 1978	93.3
11 July 2009	216.1
09 July 2010	288.8

1938 Storm Surge + Waves



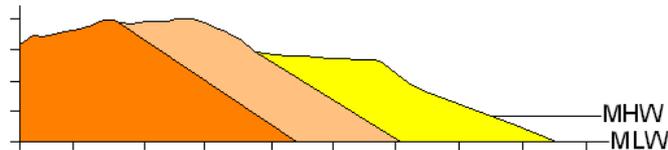
# Beach Cycles – RI Shore

## Long-Term Depositional



Hrs-10's Hrs

## Moderate Storm

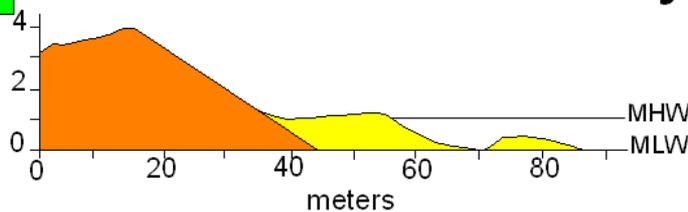


## Severe Storm

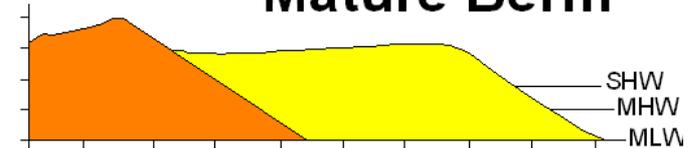


10's Hrs-Days

## Post-Storm Recovery



## Mature Berm



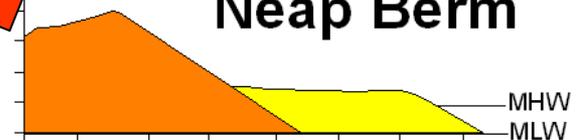
Months

## Spring Berm



2 - 4 Weeks

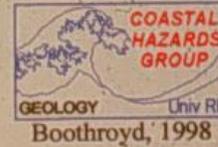
## Neap Berm



4-7 Days

# Charlestown Beach – Blizzard 1978 – No Berm

CHARLESTOWN BEACH  
7 February 1978



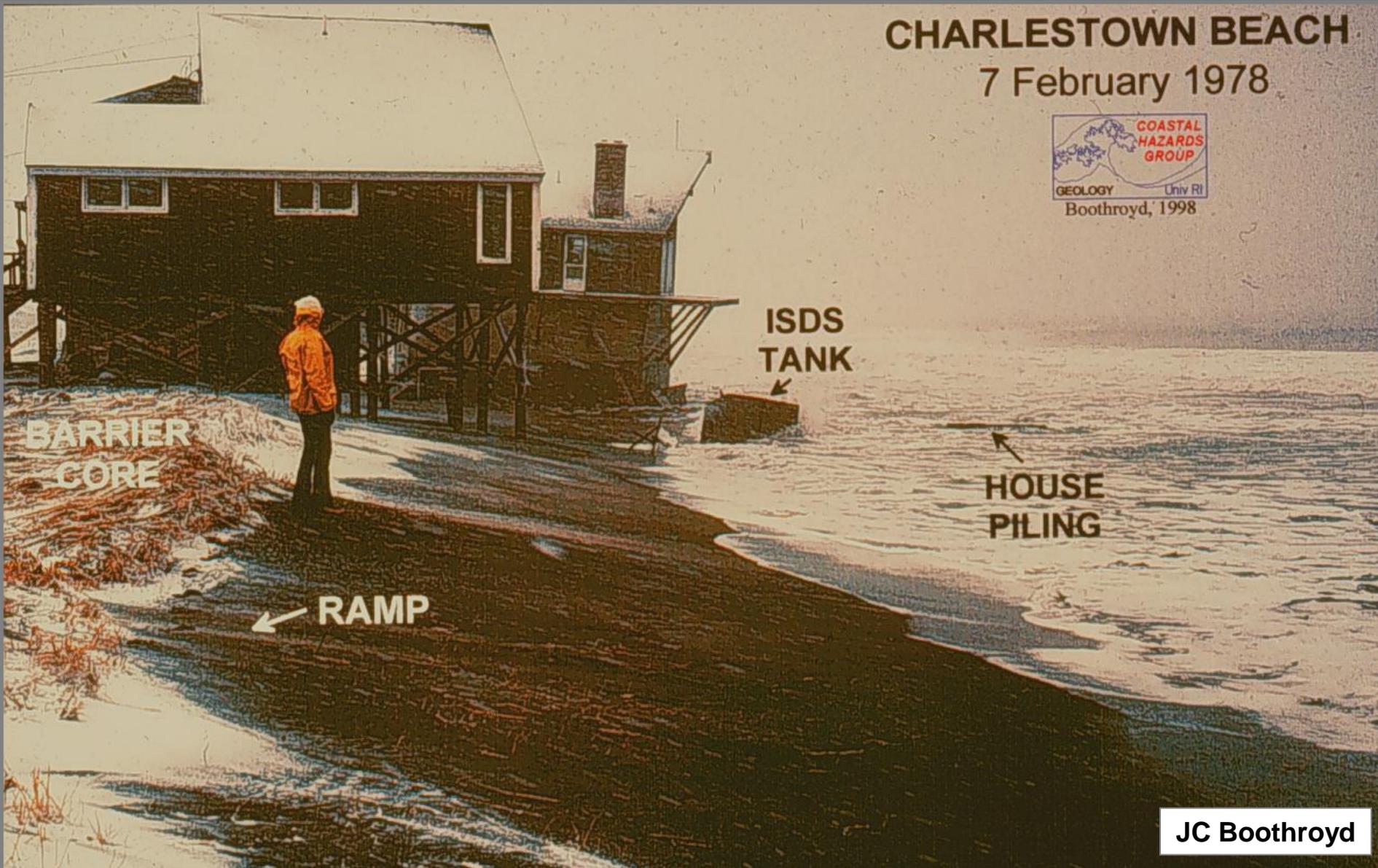
BARRIER  
CORE

ISDS  
TANK

HOUSE  
PILING

RAMP

JC Boothroyd



# Charlestown Beach – Superstorm Sandy



RI DOT

30 Oct 2012

# Charlestown Beach – Superstorm Sandy



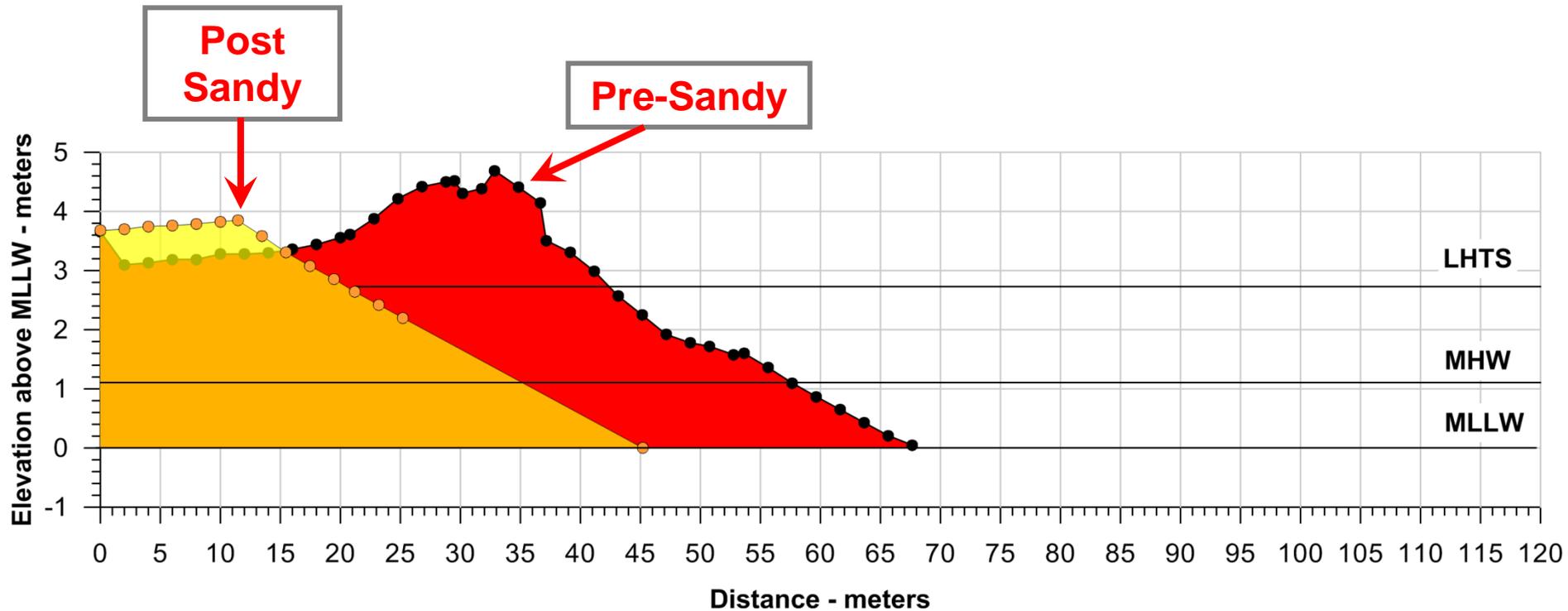
2 Nov 2012

OAKLEY, 2012

# CHA-EZ Profile Plot

Date      Volume m<sup>3</sup>·m

- 27 Oct 2012      188.3
  - 30 Oct 2012      106.2
- Volume change: -82.1



# Washover Fan Deposition Misquamicut Barrier - Westerly



Atlantic Ave

Washover Fan

RI DOT

30 Oct 2012

# Washover Fan Deposition Misquamicut Headland - Westerly

Washover Fan



Andrea  
Hotel

RI DOT

30 Oct 2012

# Washover Fan Deposition Beach St - Narragansett

Washover Fan



RI DOT

30 Oct 2012

# Washover Fan Deposition - Charlestown Beach



31 Oct 2012

<http://fema.maps.arcgis.com/home/webmap/viewer.html?webmap=>

# Charlestown Beach, RI – Hurricane Bob 1991 Washover Fan Deposition

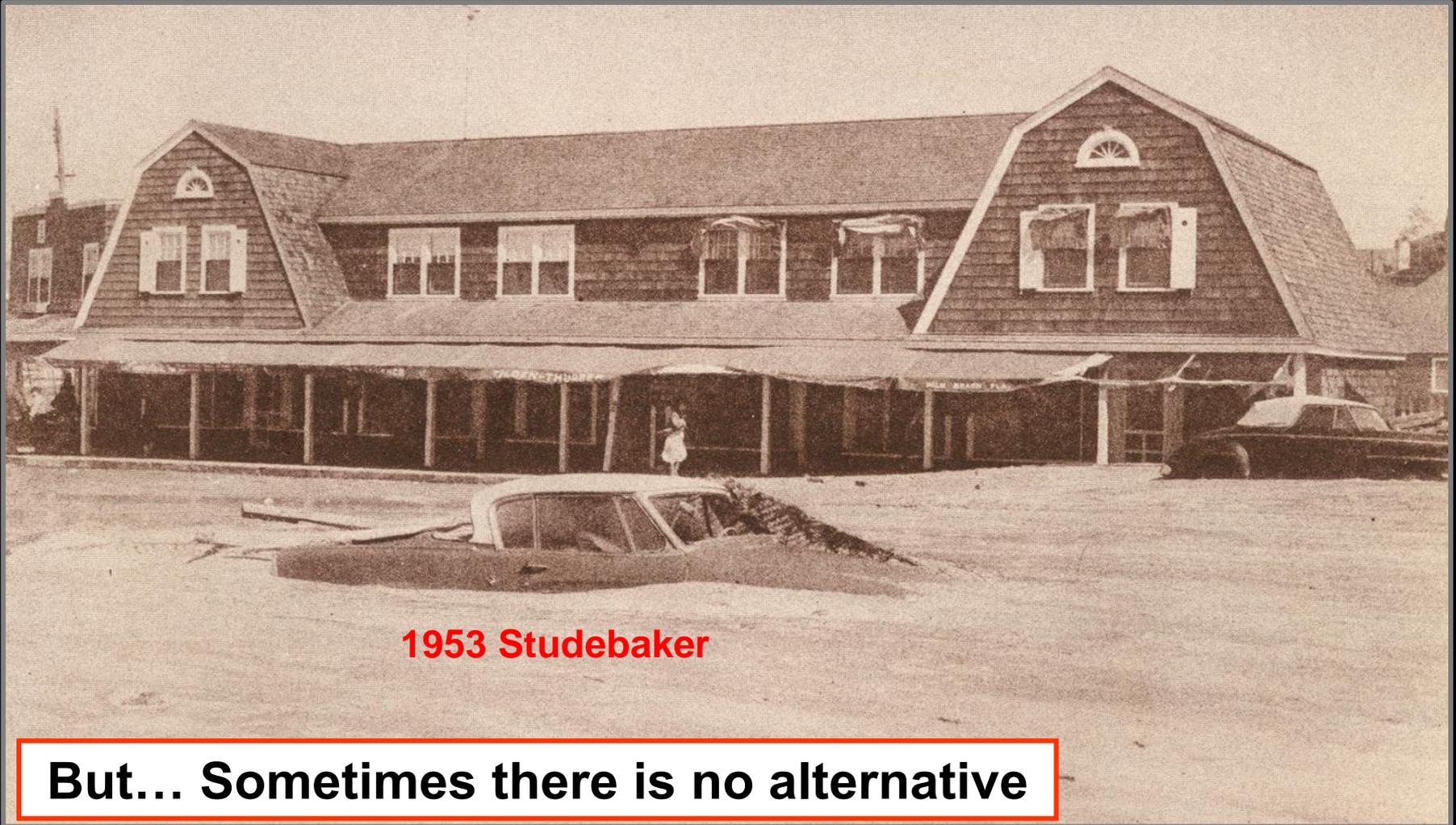


**Removal is a Bad Idea .....**  
**Barriers Naturally Retreat**  
**Landward and Upward**

Aug 1991

JC Boothroyd

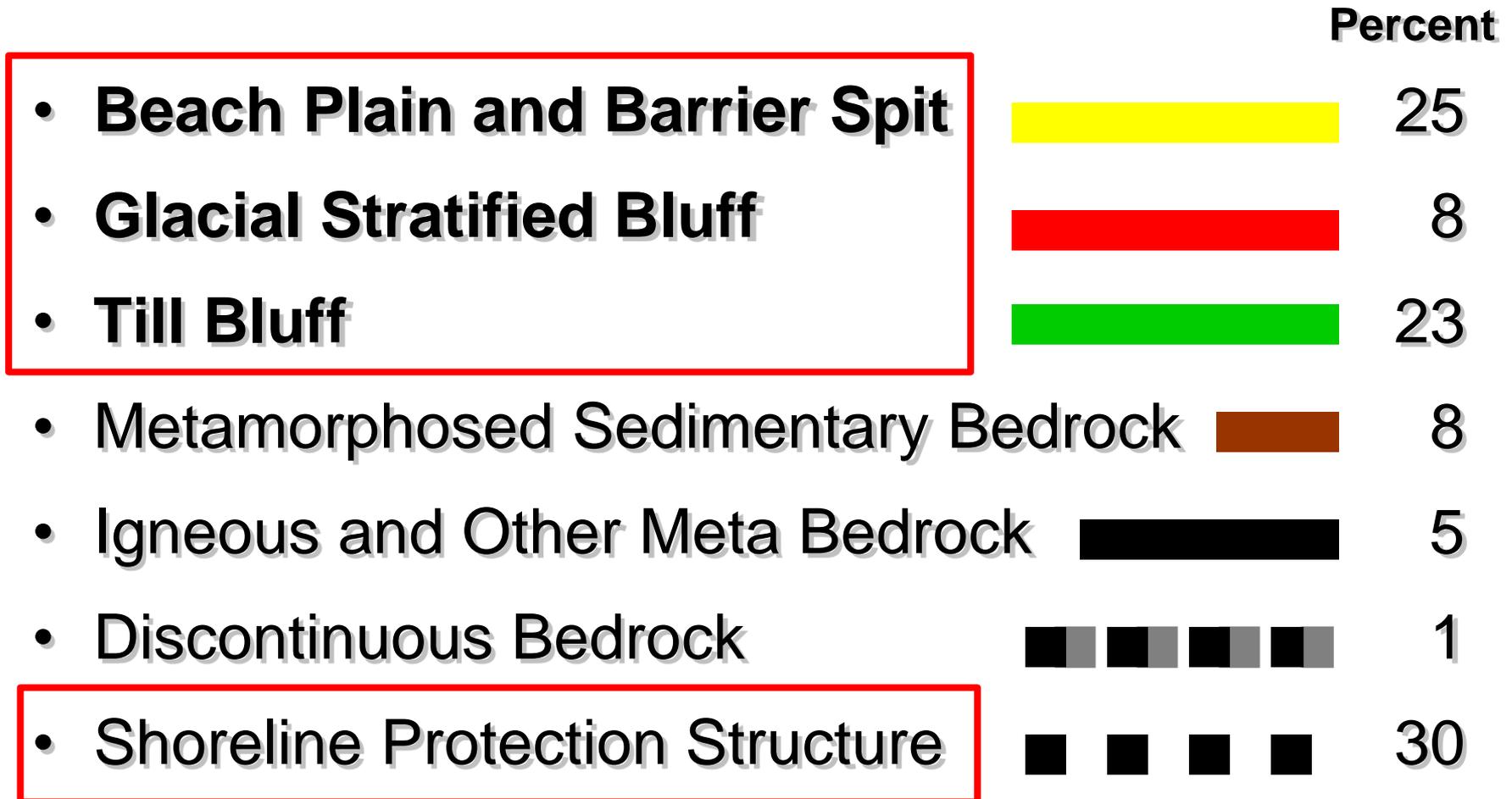
# Watch Hill, RI – Hurricane Carol, 1954



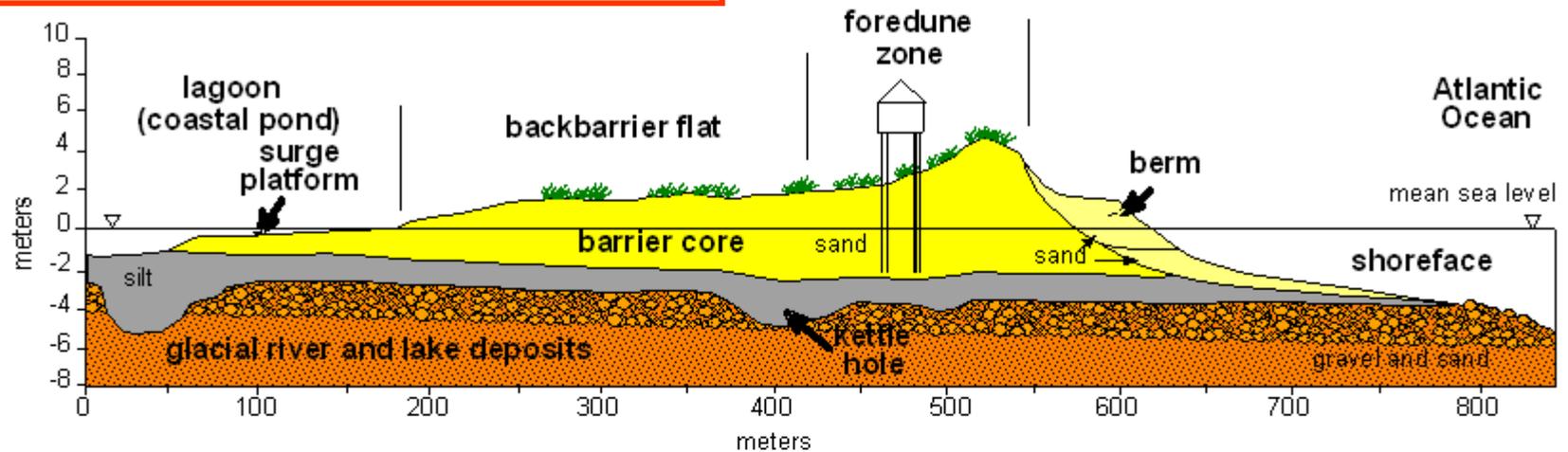
1953 Studebaker

**But... Sometimes there is no alternative**

# GEOLOGIC SHORE ZONE TYPES



## Barrier Geologic Cross-Section



## Headland Geologic Cross-Section

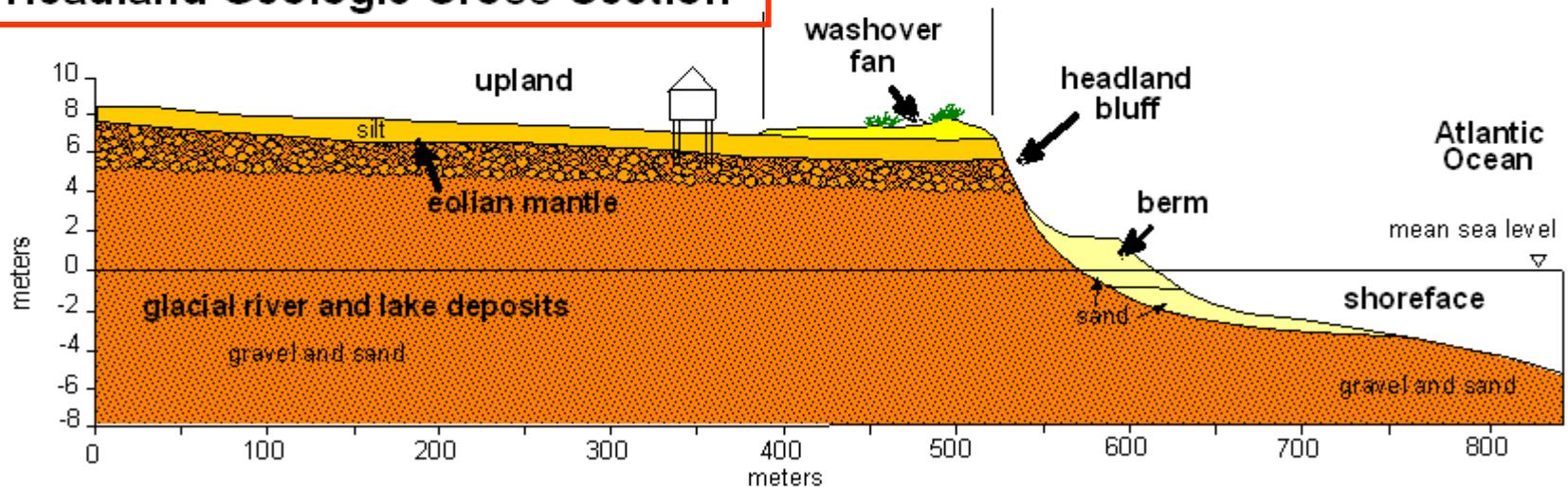
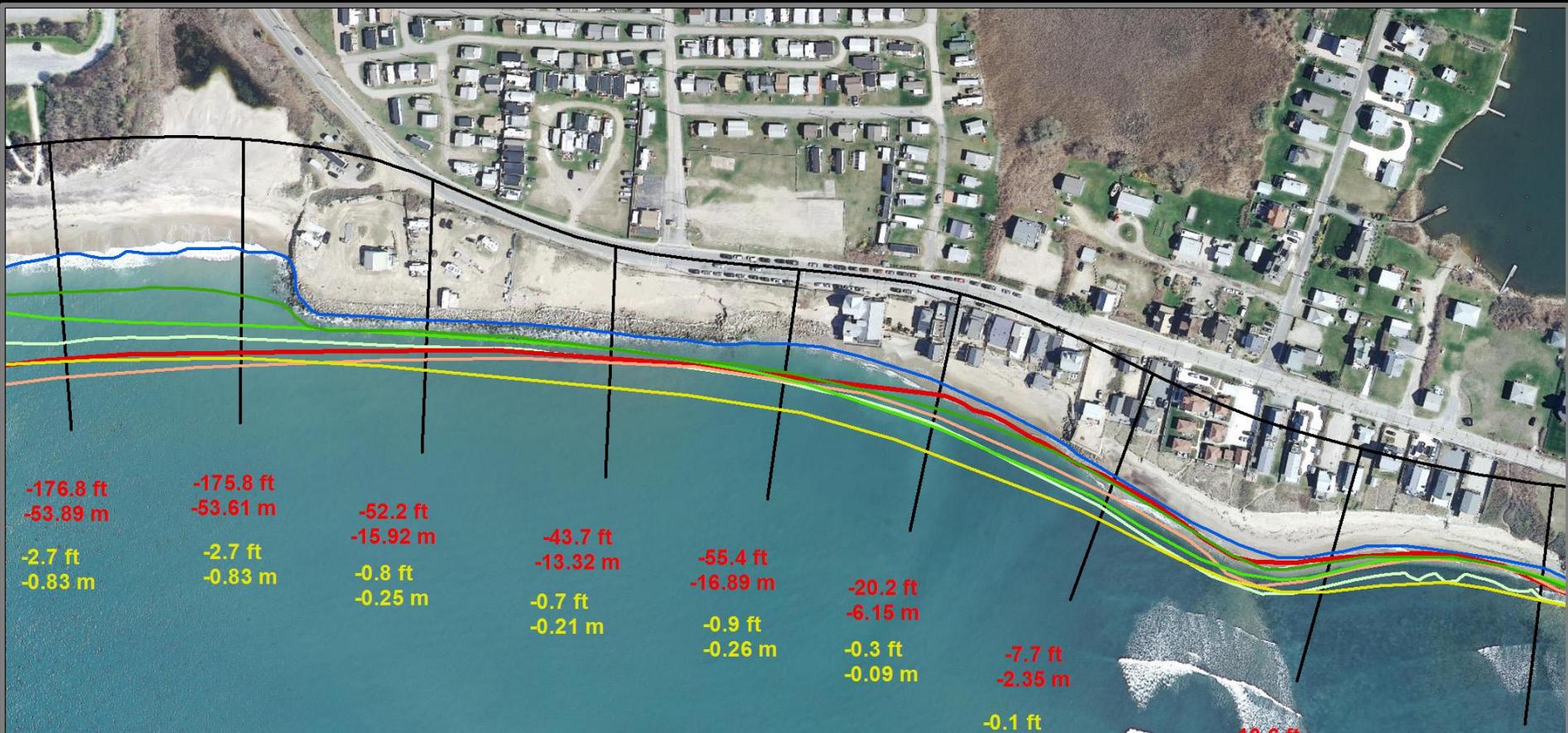


Figure 4-2



## RHODE ISLAND SOUTH SHORE: Matunuck headland

**SHORELINE CHANGE 1939-2004**  
Rachel E. Hehre and Jon C. Boothroyd

### EXPLANATION

<p><b>DIGITAL SHORELINE ANALYSIS</b></p> <p>— DSAS Transect</p> <p>— Baseline</p>	<p><b>SHORELINE CHANGE</b></p> <p>End Point Distance <b>27.5 ft</b> <b>8.4 m</b></p> <p>End Point Rate <b>0.4 ft</b> <b>0.13 m</b></p>	<p><b>SHORELINE Wet/Dry Lines</b></p> <p>1939 1975</p> <p>1951 1985</p> <p>1963 1995</p> <p>2004</p>
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**Scale**

0 150 300 ft      0 50 100 m

**RHODE ISLAND SURVEY**

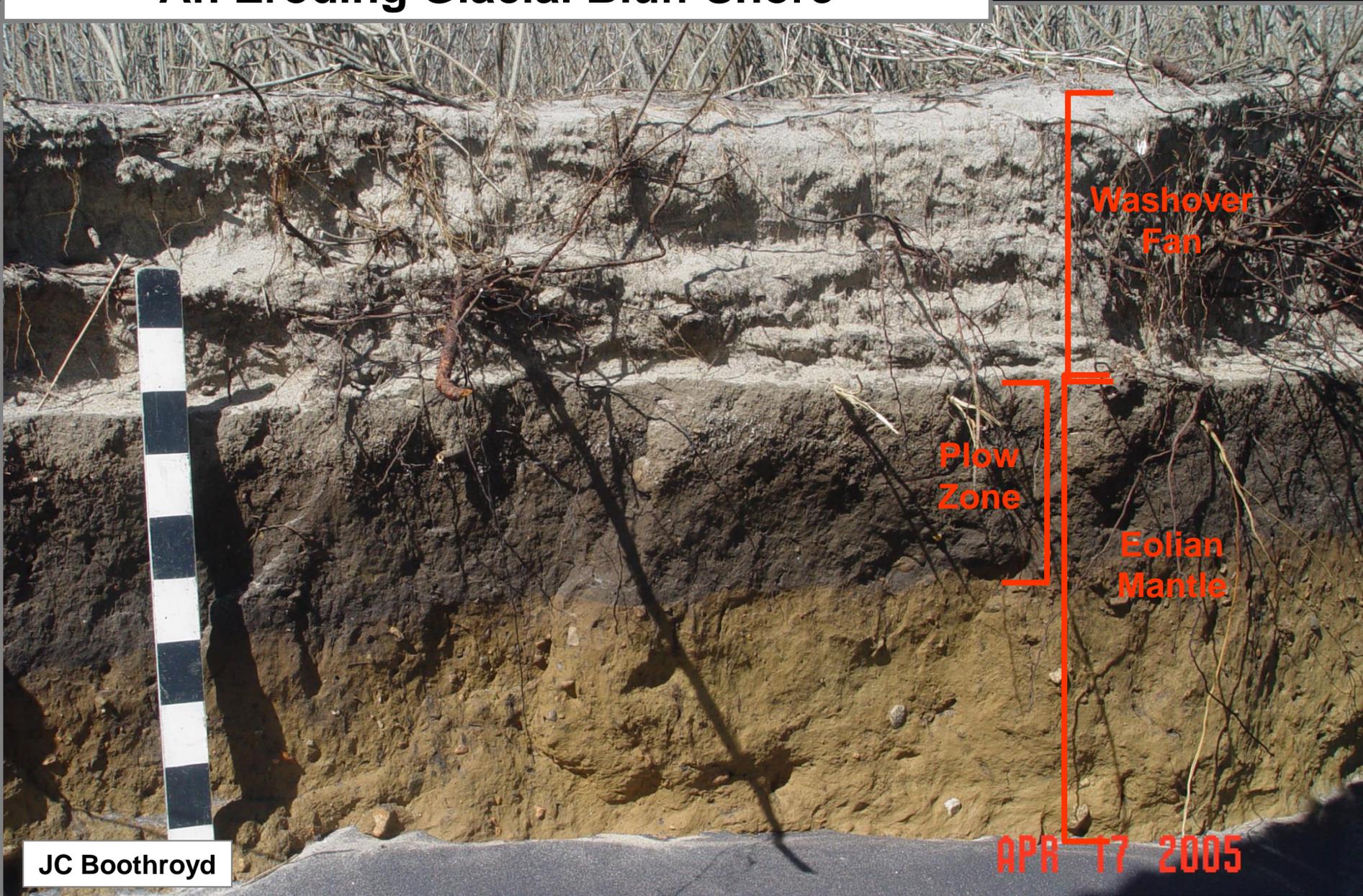
**UNIVERSITY OF Rhode Island**

**CRMC**  
Coastal Resource Management Council

**RIGIS**

# South Kingstown, RI – Town Beach

## An Eroding Glacial Bluff Shore



JC Boothroyd

APR 17 2005

# South Kingstown, RI – Town Beach

## An Eroding Glacial Bluff Shore



BA Oakley

25 Oct 2005

# South Kingstown, RI – Town Beach

## An Eroding Glacial Bluff Shore

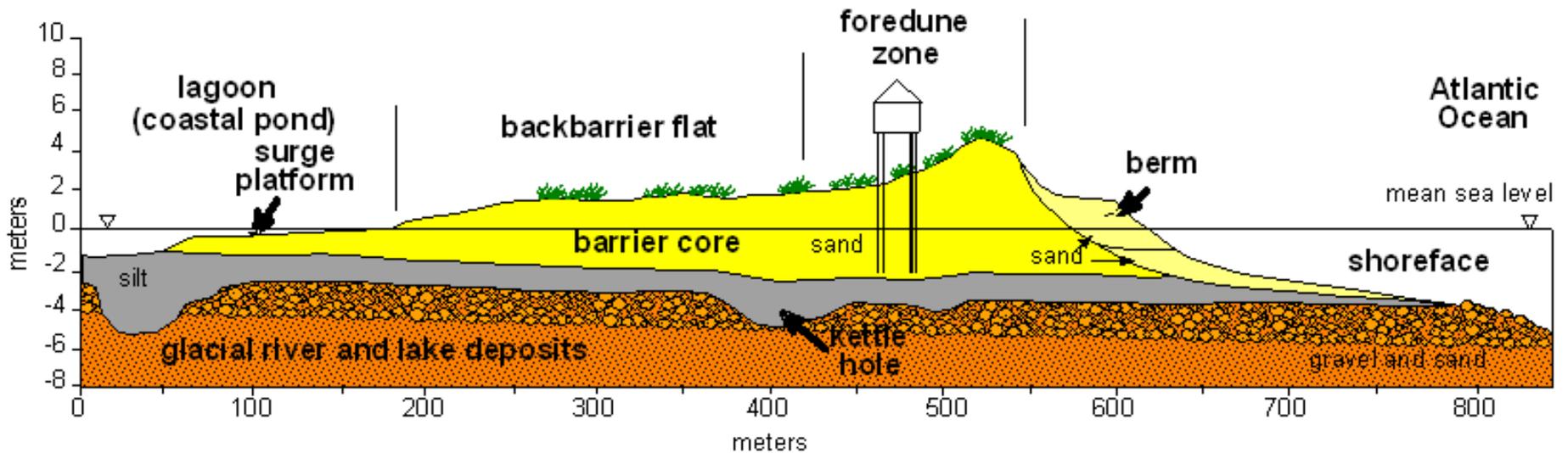


RI DOT

30 Oct 2012

# A General Coastal Barrier Model for Rhode Island

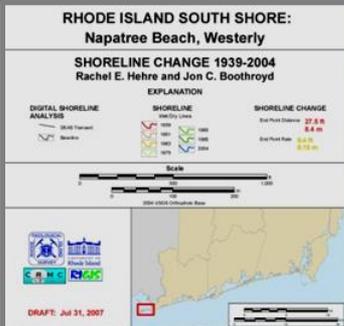
Very Transgressive



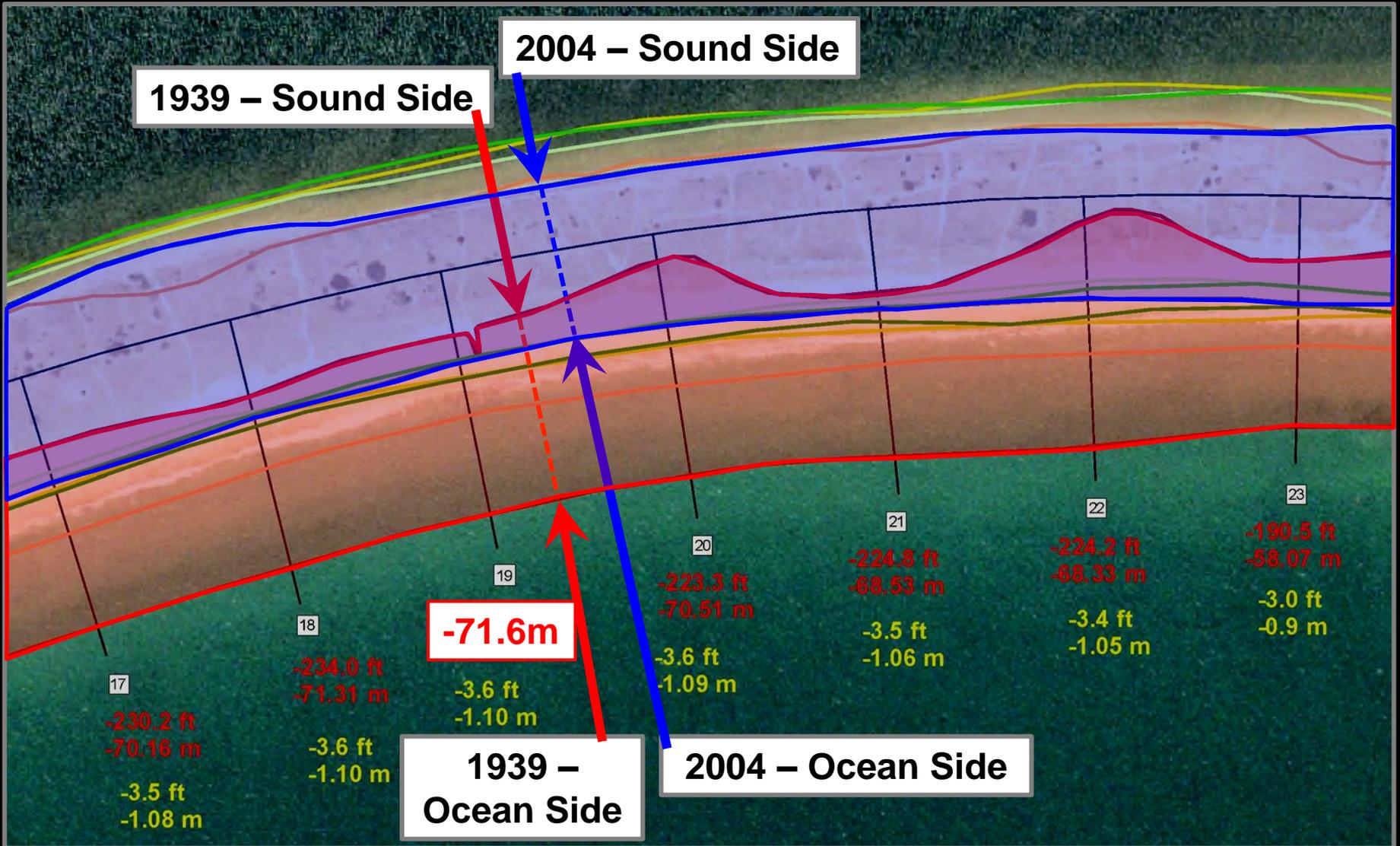
# Napatree Barrier – Westerly, RI

Little Narragansett Bay

Watch Hill

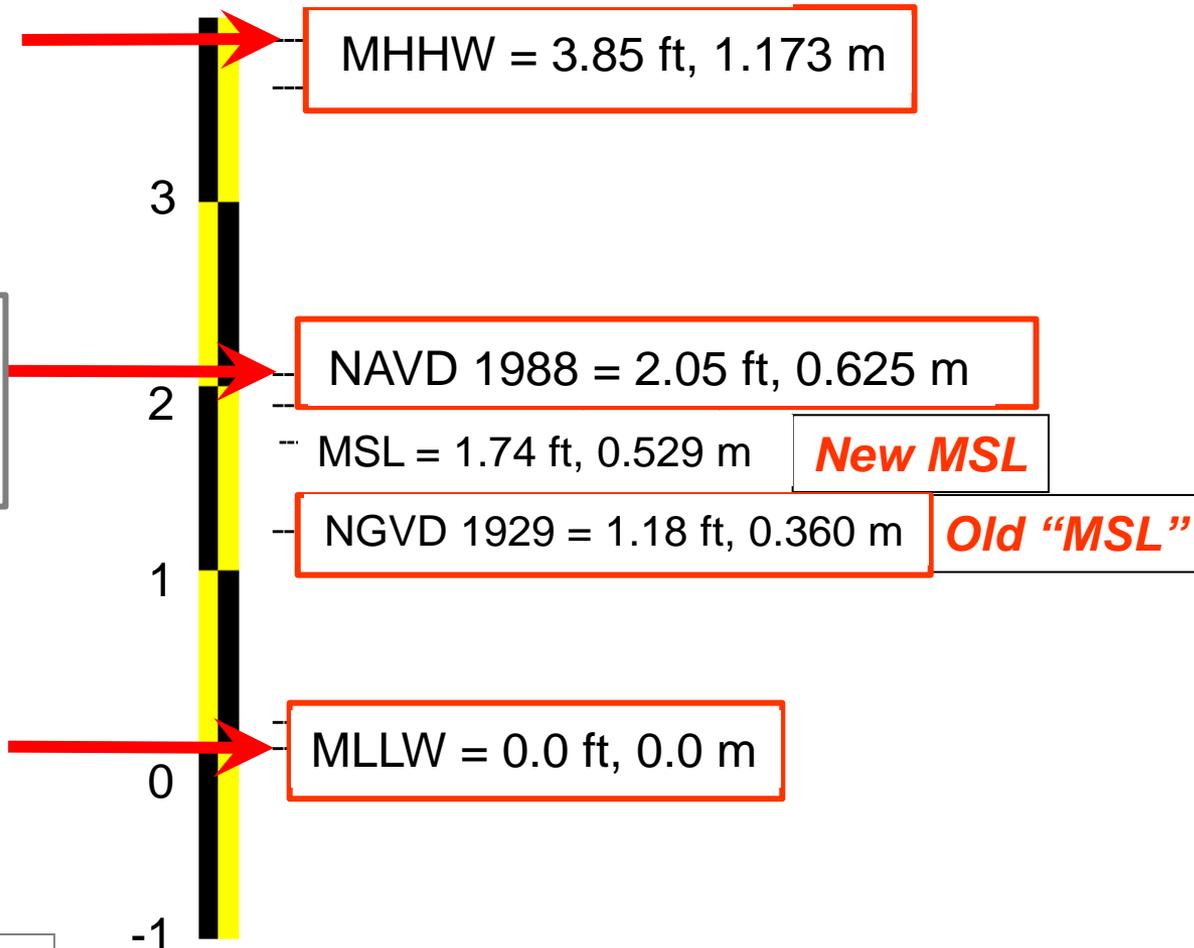


# Napatree Barrier – Shoreline Change Map



# Tidal Datums Newport, RI

## How High will the Water Be?



“Zero” in some  
data sets  
and on maps

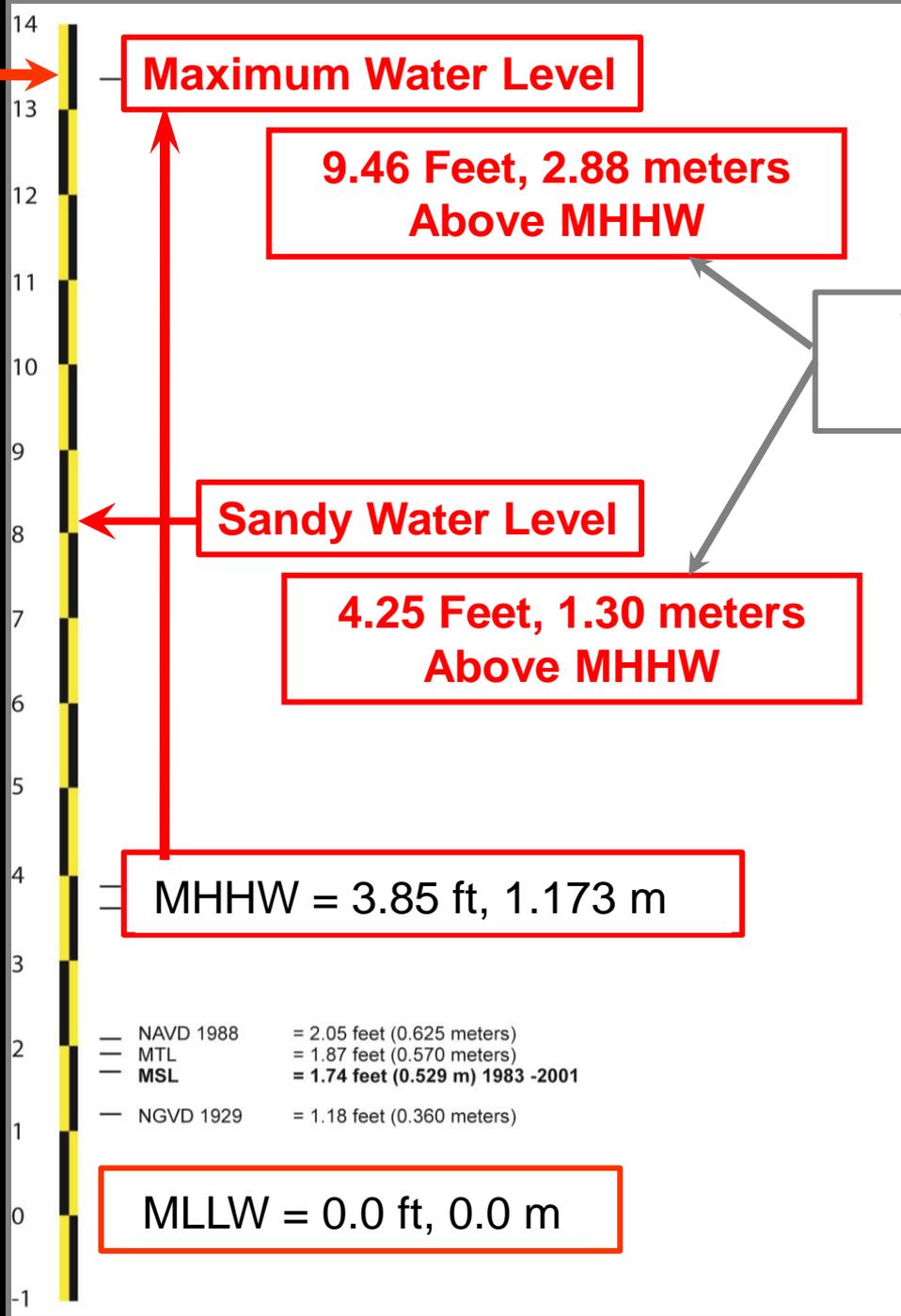
Adapted from:  
[www.ngs.noaa.gov/newsys-cgi-bin/ngs\\_opsd.pr?PID=LW0493&EPOCH=1983-2001](http://www.ngs.noaa.gov/newsys-cgi-bin/ngs_opsd.pr?PID=LW0493&EPOCH=1983-2001)

The NAVD 1988 and NGVD 1929 elevations related to MLLW were computed from Bench Mark, 845 2660 TIDAL 6, at the station.

Displayed tidal datums are MEAN HIGHER HIGH WATER (MHHW), MEAN HIGH WATER (MHW), MEAN TIDE LEVEL (MTL), MEAN LOW WATER (MLW), AND MEAN LOWER LOW WATER (MLLW) referenced on 1983-2001 Epoch.

**How High  
will the  
Water Be?**

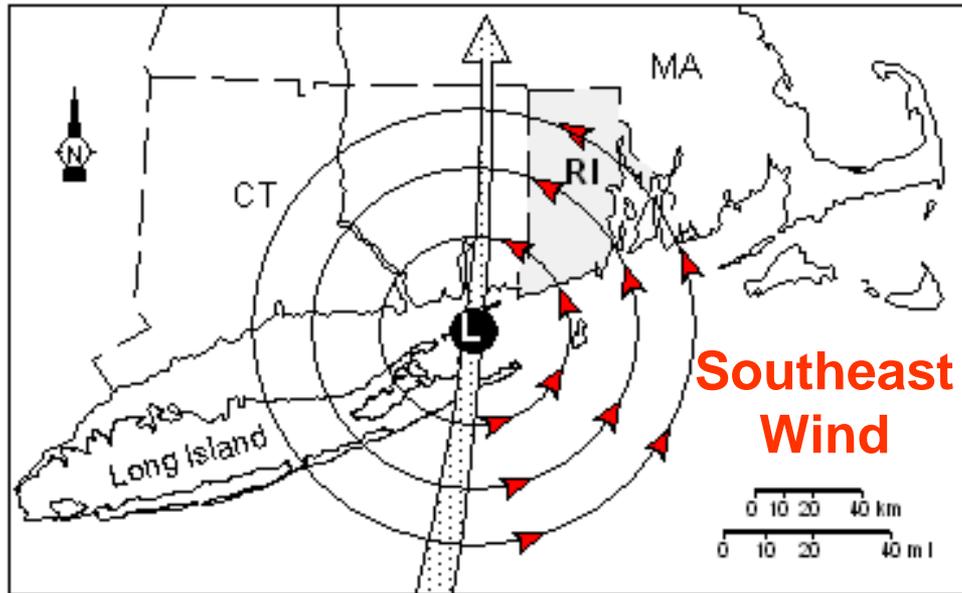
**Tidal  
Heights  
Newport, RI**



**Why above  
MHHW?**

Adapted from:  
[www.ngs.noaa.gov/newsys-cgi-bin/ngs\\_opsd.pr1?PID=LW0493&EPOCH=1983-2001](http://www.ngs.noaa.gov/newsys-cgi-bin/ngs_opsd.pr1?PID=LW0493&EPOCH=1983-2001)

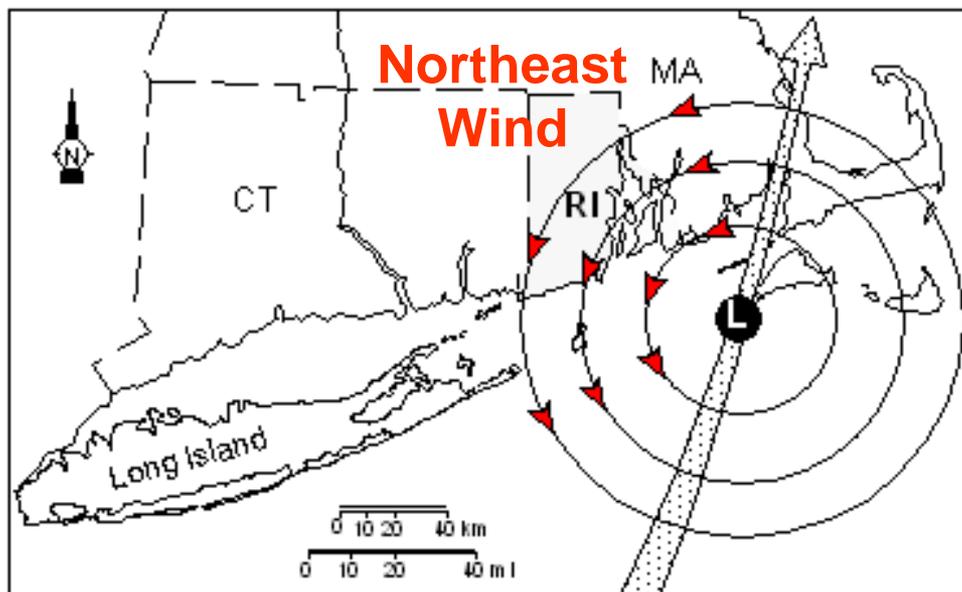
# HURRICANE and EXTRATROPICAL STORM PATHS and ASSOCIATED WIND PATTERNS



## PASSAGE TO THE WEST

- Maximum Onshore Wind
- Severe Storm-Surge Flooding

***The Message:  
Pay Attention  
to Storm Track***



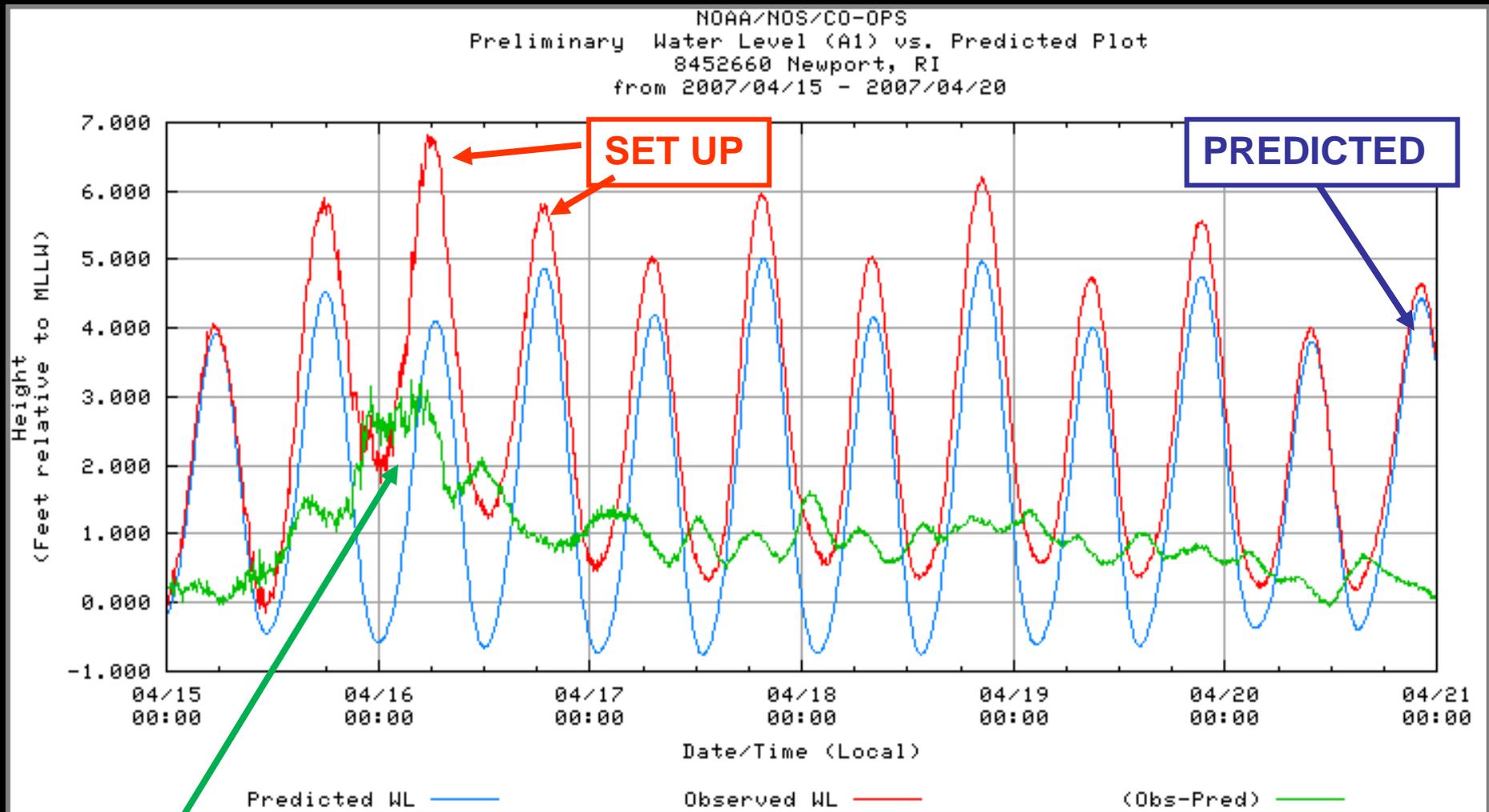
## PASSAGE TO THE EAST

- Offshore Wind
- Minimum Storm-Surge Flooding

From Wright and Sullivan

# Patriots Day Extratropical Storm – April 2007

## Newport Tide Gauge

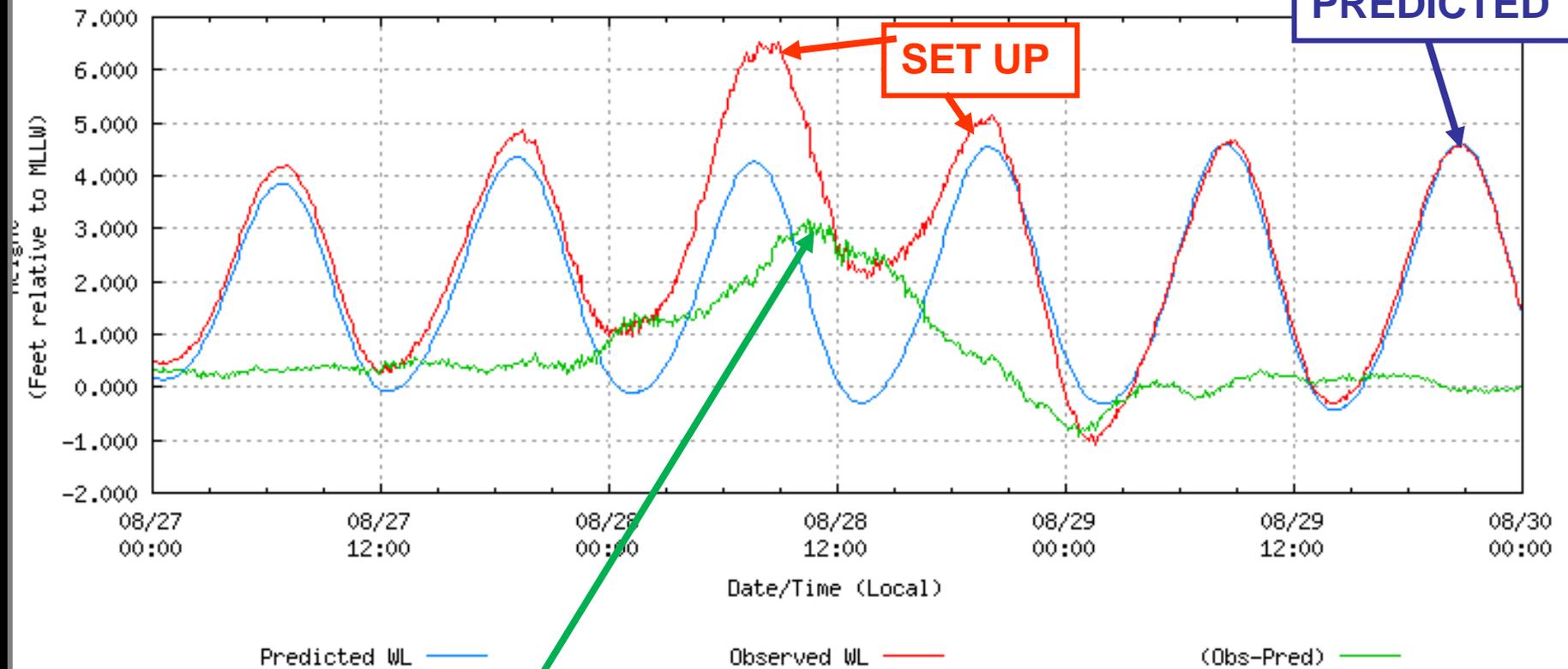


[http://tidesandcurrents.noaa.gov/  
data\\_menu.shtml?stn=8452660%20Newport,%20RI&type=Tide+Data](http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=8452660%20Newport,%20RI&type=Tide+Data)

# Tropical Storm Irene– Aug 2011

## Newport Tide Gauge

NOAA/NOS/CO-OPS  
Preliminary Water Level (A1) vs. Predicted Plot  
8452660 Newport, RI  
from 2011/08/27 - 2011/08/29

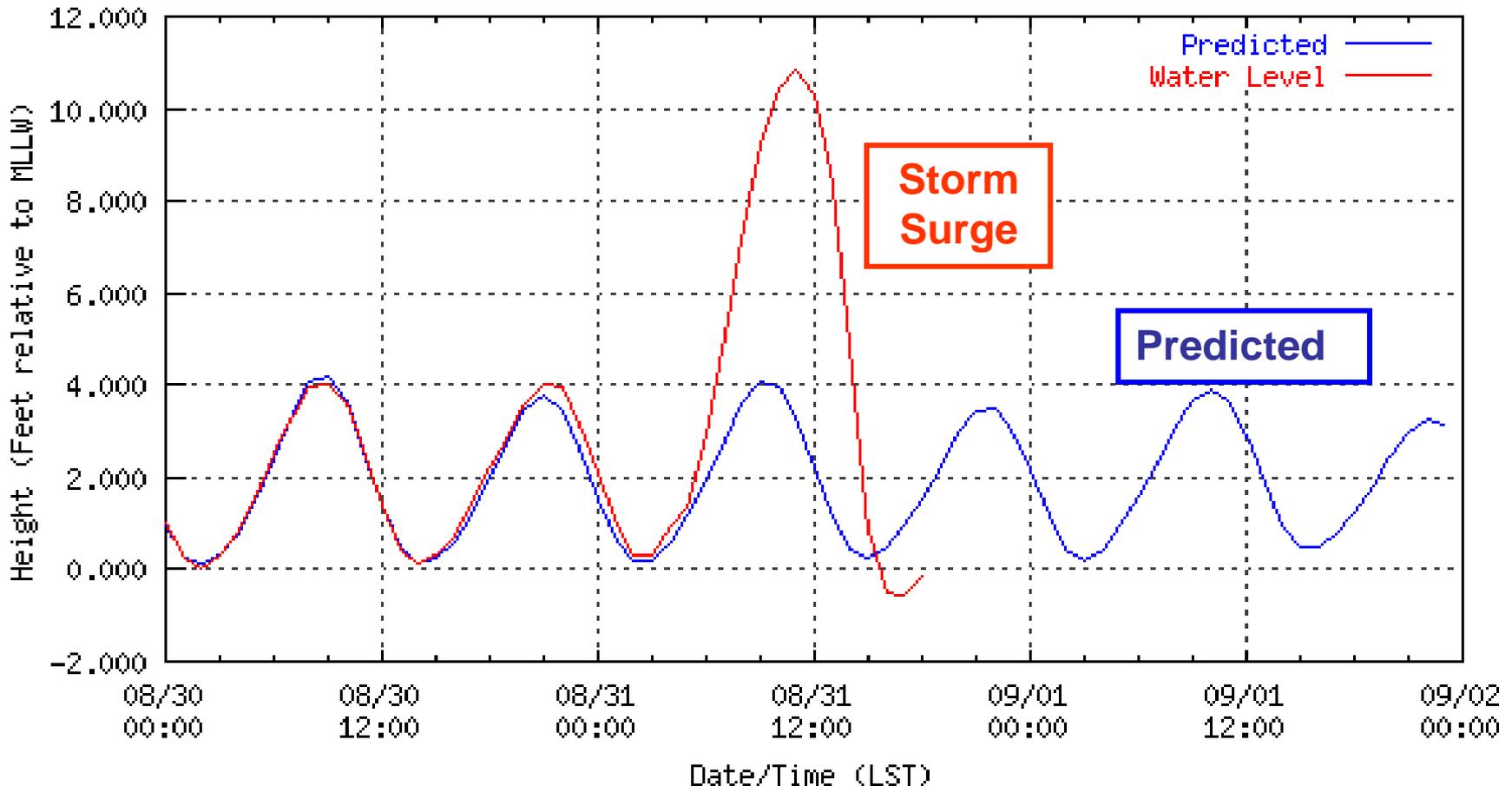


**STORM SURGE**

[http://tidesandcurrents.noaa.gov/  
data\\_menu.shtml?stn=8452660%20Newport,%20RI&type=Tide+Data](http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=8452660%20Newport,%20RI&type=Tide+Data)

# Hurricane Carol - 1954

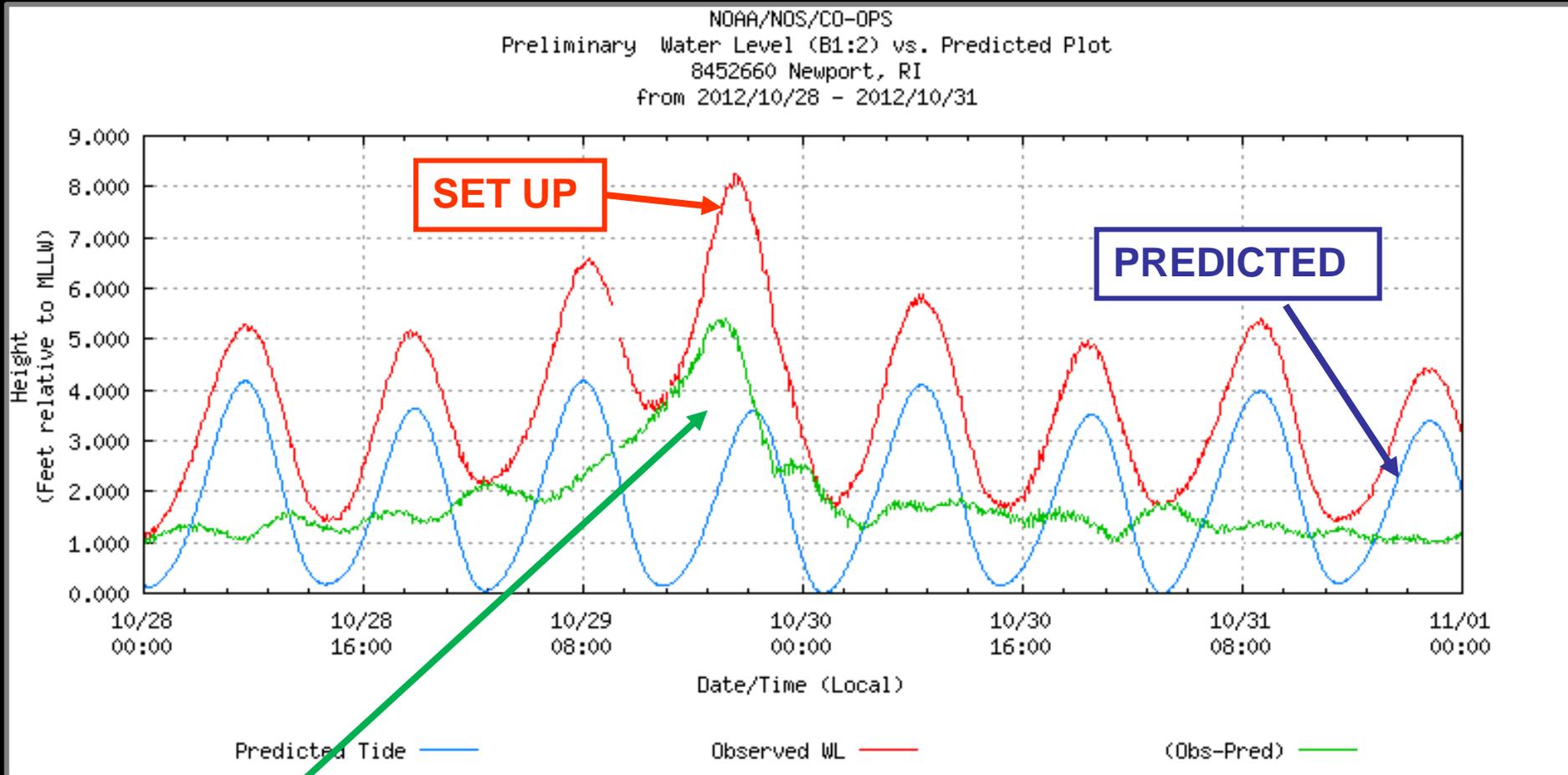
NOAA/NOS/CO-OPS  
Verified Hourly Height Water Level Plot  
8452660 NEWPORT, NARRAGANSETT BAY, RI  
from 08/30/1954 - 09/01/1954



# Superstorm Sandy – Tropical-Extratropical Hybrid

## 29 October 2012

### Newport Tide Gauge

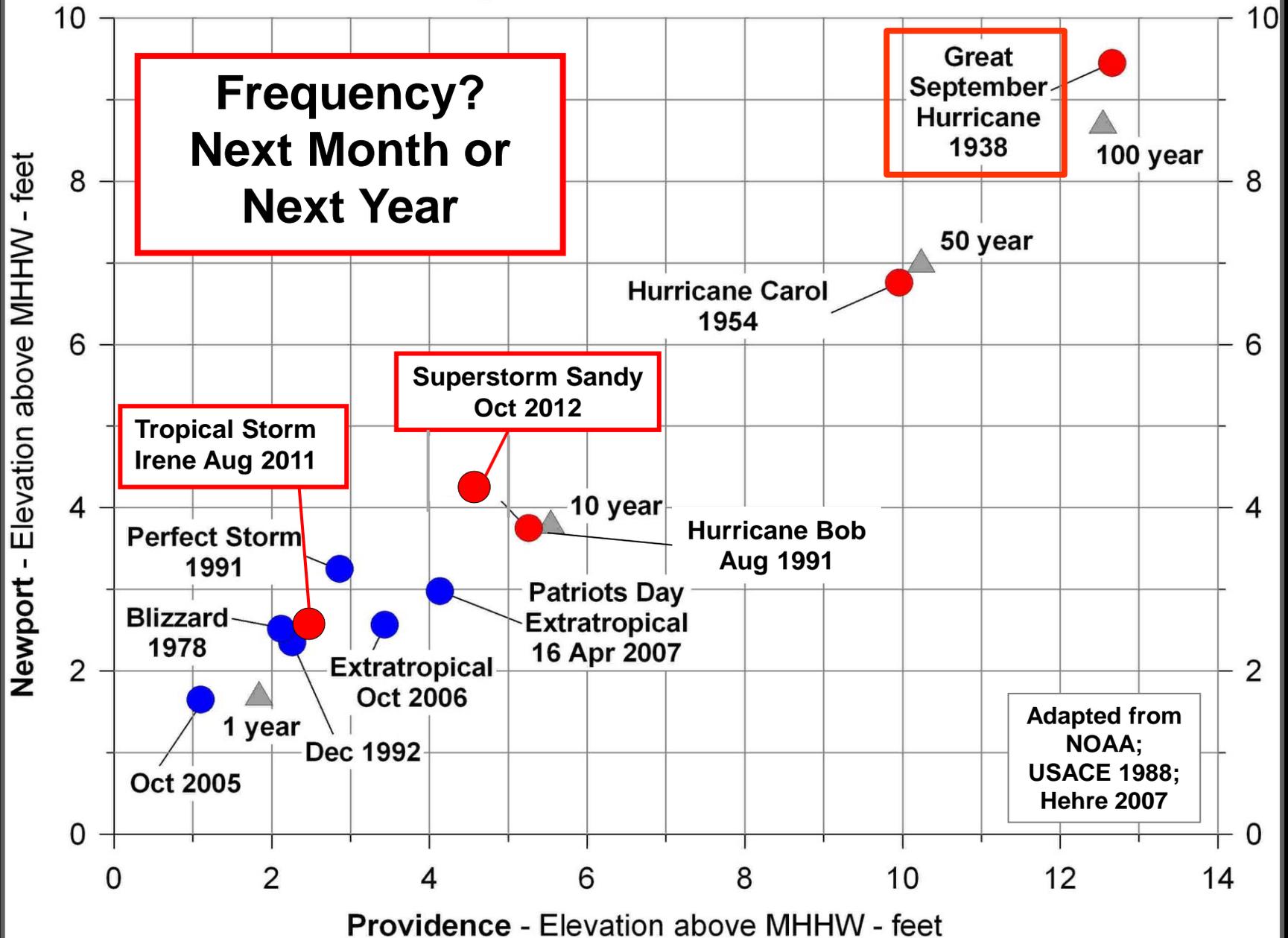


**STORM SURGE**

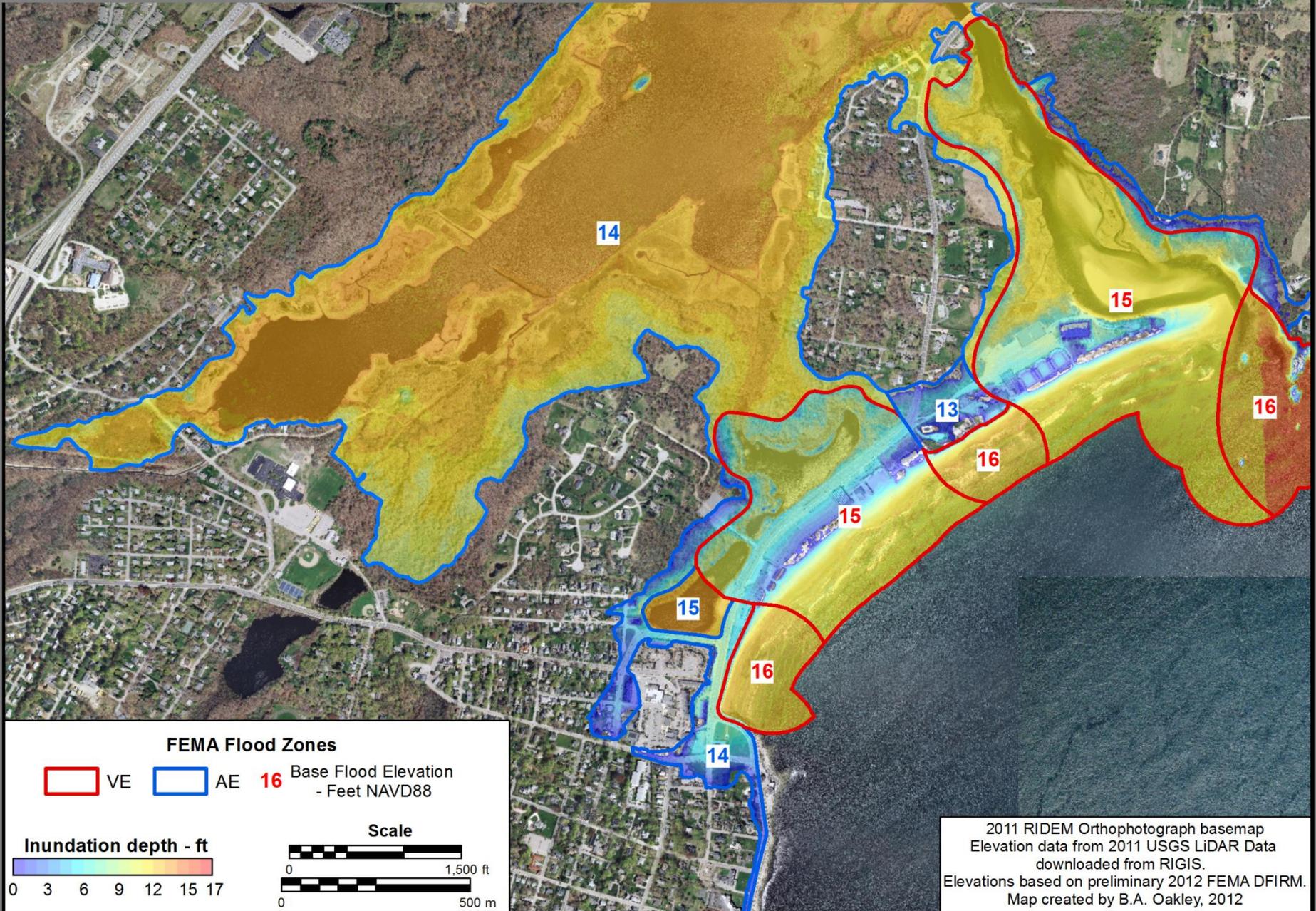
[http://tidesandcurrents.noaa.gov/  
data\\_menu.shtml?stn=8452660%20Newport,%20RI&type=Tide+Data](http://tidesandcurrents.noaa.gov/data_menu.shtml?stn=8452660%20Newport,%20RI&type=Tide+Data)

# STORM-SURGE ELEVATION

## Newport - Providence, RI



# Narrow River and Narragansett Barrier Area

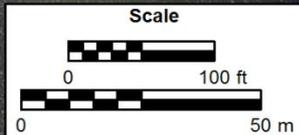
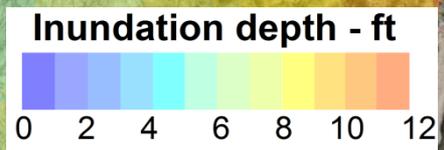


# Middlebridge Area Narrow River South Kingstown

Inundation Depths  
based on  
2012 DFIRMs

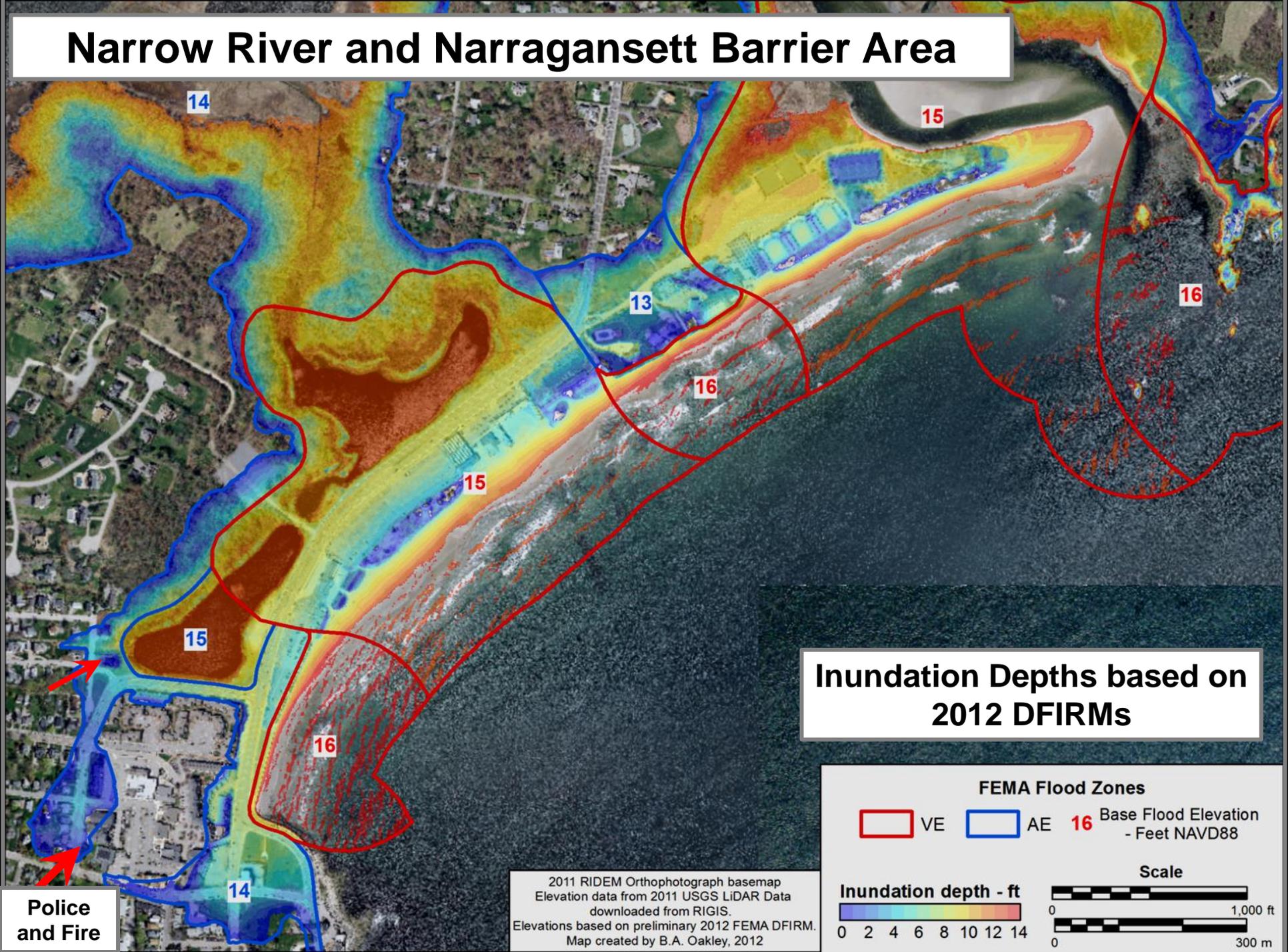
Colors  
cropped

Wastewater  
Pump  
Station

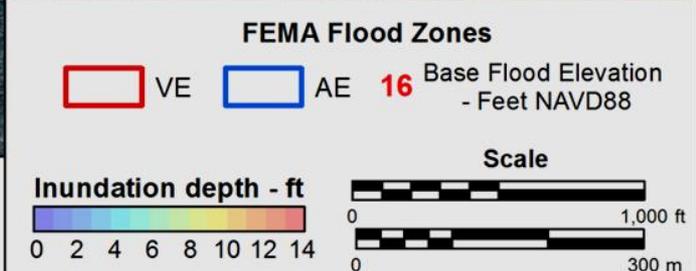


2011 RIDEM Orthophotograph basemap  
Elevation data from 2011 USGS LiDAR Data downloaded from RIGIS.  
Elevations based on preliminary 2012 FEMA DFIRM.  
Map created by B.A. Oakley, 2012

# Narrow River and Narragansett Barrier Area



## Inundation Depths based on 2012 DFIRMs



2011 RIDEM Orthophotograph basemap  
Elevation data from 2011 USGS LiDAR Data  
downloaded from RIGIS.  
Elevations based on preliminary 2012 FEMA DFIRM.  
Map created by B.A. Oakley, 2012

**Police  
and Fire**

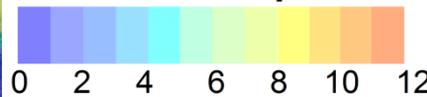
# Narragansett Pier Area

Inundation Depths based on  
2012 DFIRMs

Wastewater  
Pump  
Station



Inundation depth - ft



Scale



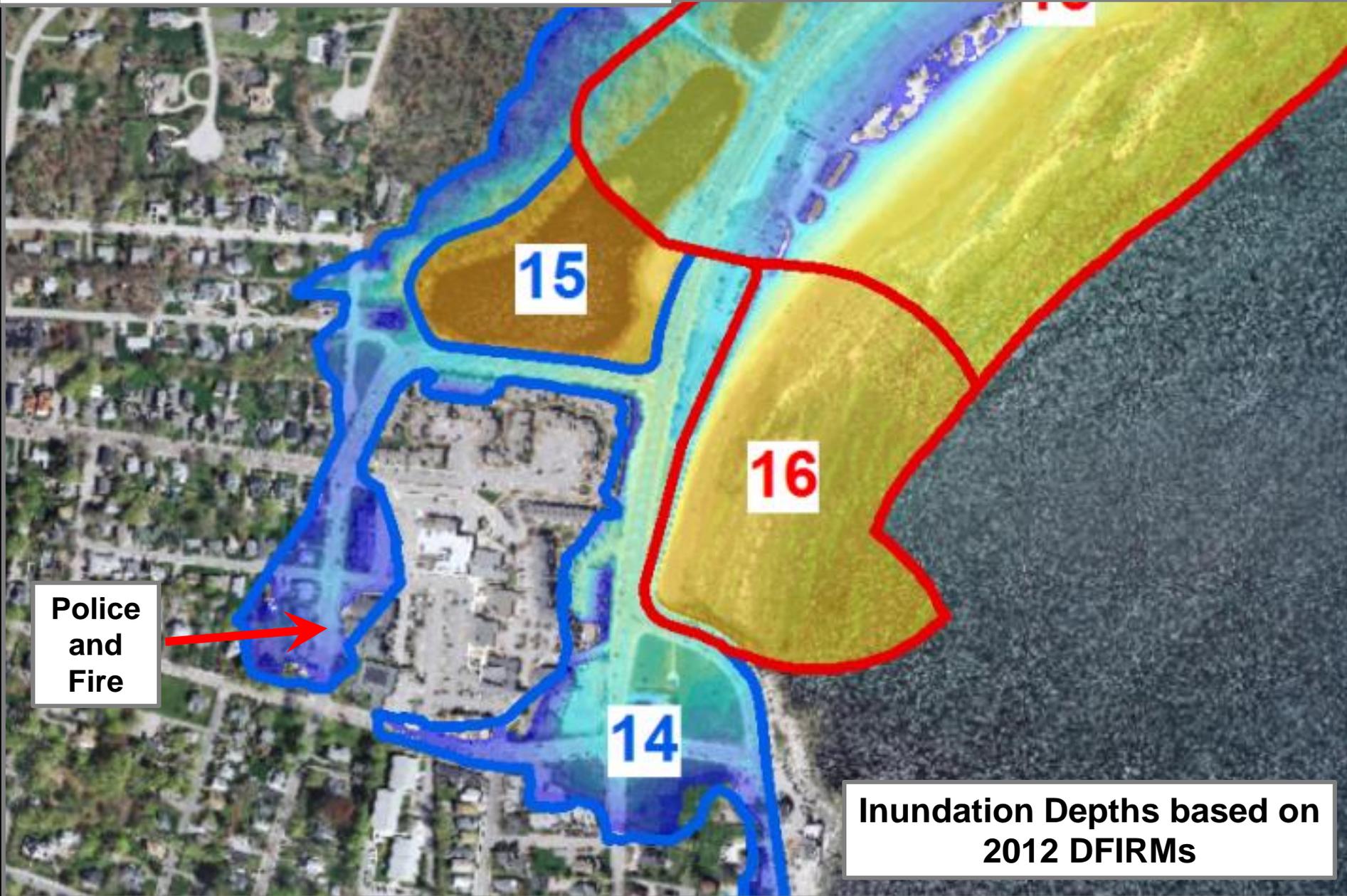
2011 RIDEM Orthophotograph basemap

Elevation data from 2011 USGS LiDAR Data downloaded from RIGIS.

Elevations based on preliminary 2012 FEMA DFIRM.

Map created by B.A. Oakley, 2012

# Narragansett Pier Area



Police  
and  
Fire

15

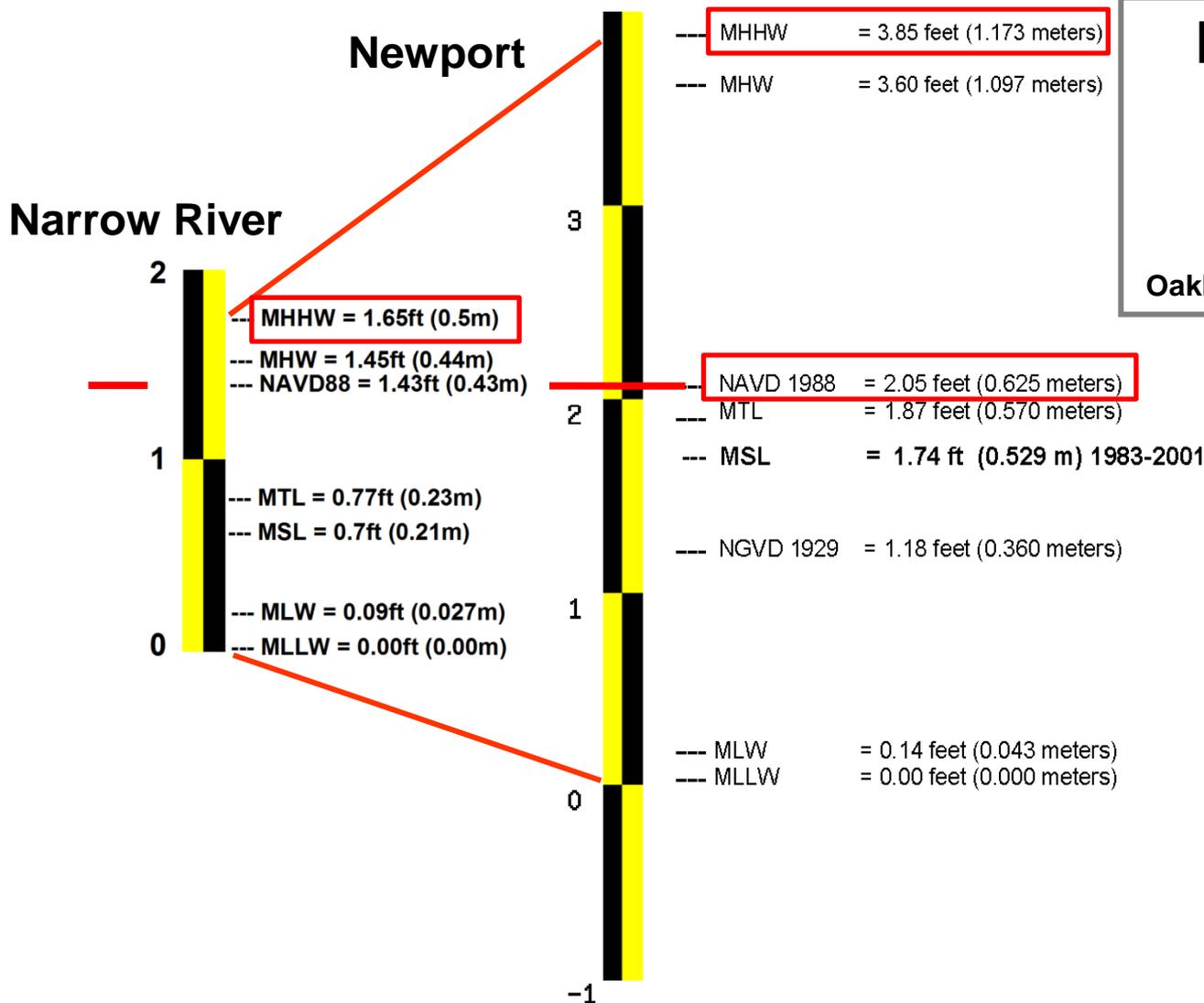
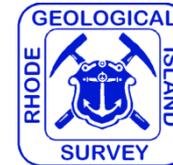
16

14

Inundation Depths based on  
2012 DFIRMs

# Narrow River – Newport Tidal Datums

Oakley, Alvarez and Boothroyd, 2008

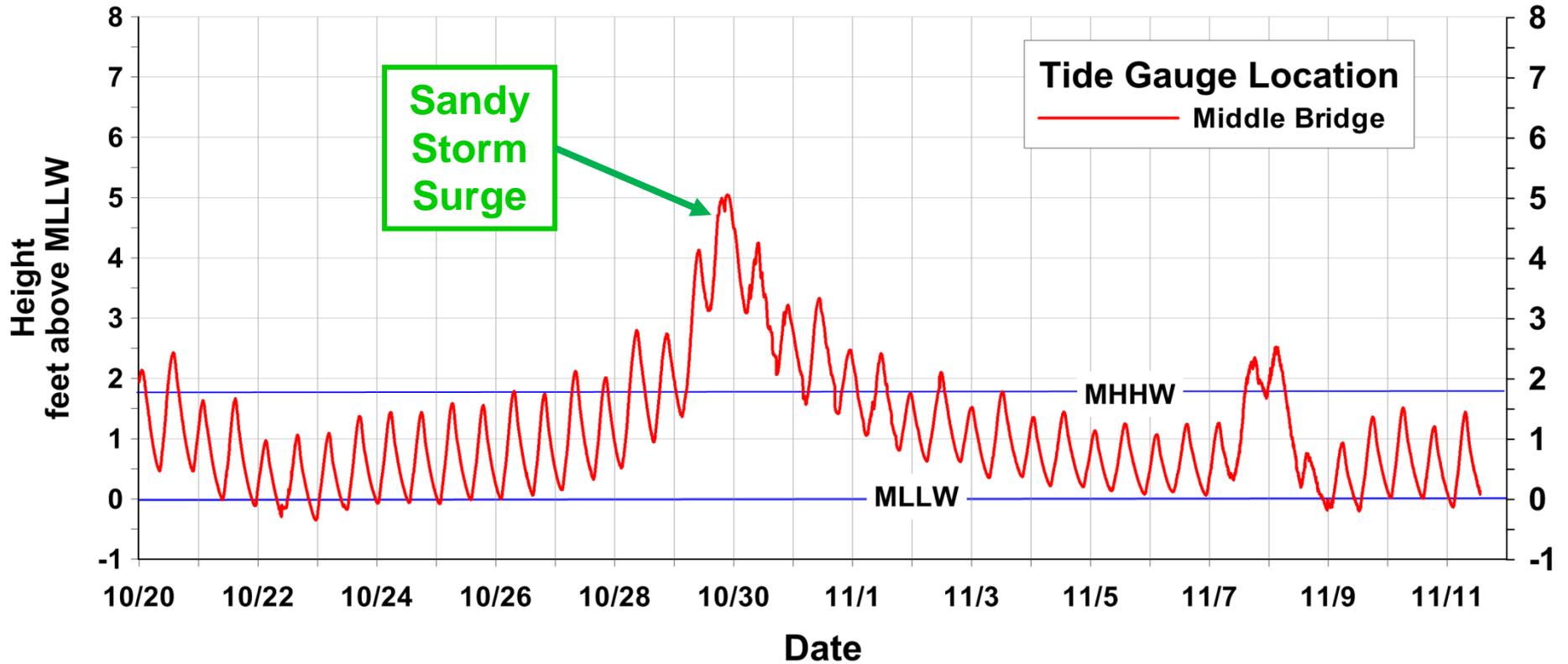


The NAVD 1988 and NGVD 1929 elevations related to MLLW were computed from Bench Mark, 845 2660 TIDAL 6, at the station.

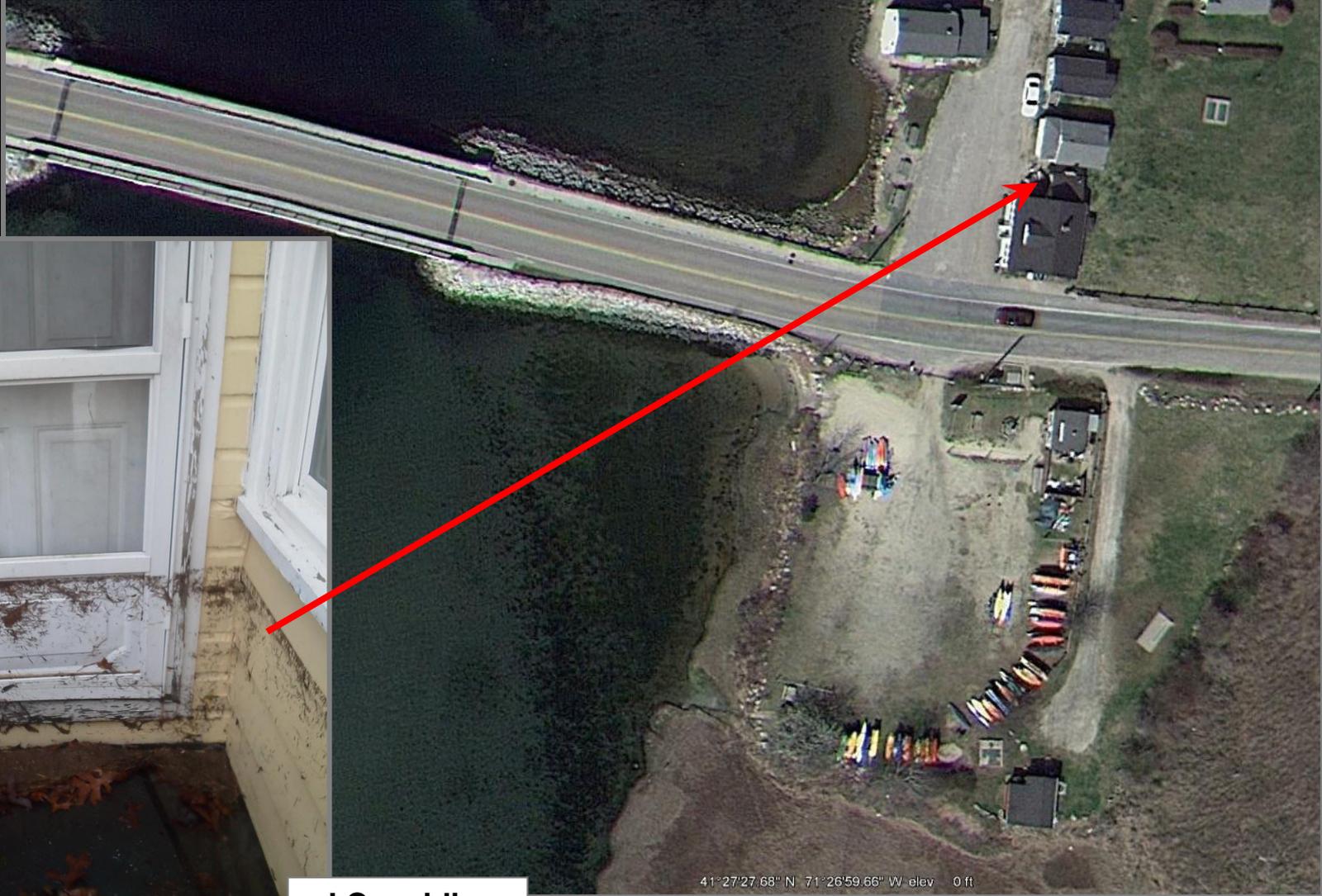
Displayed tidal datums are MEAN HIGHER HIGH WATER (MHHW), MEAN HIGH WATER (MHW), MEAN TIDE LEVEL (MTL), MEAN LOW WATER (MLW), AND MEAN LOWER LOW WATER (MLLW) referenced on 1983-2001 Epoch.

Newport datum adapted from [www.ngs.noaa.gov/cgi-bin/ngs\\_opsd?PID=LW0493](http://www.ngs.noaa.gov/cgi-bin/ngs_opsd?PID=LW0493)

# Narrow River Tidal Range



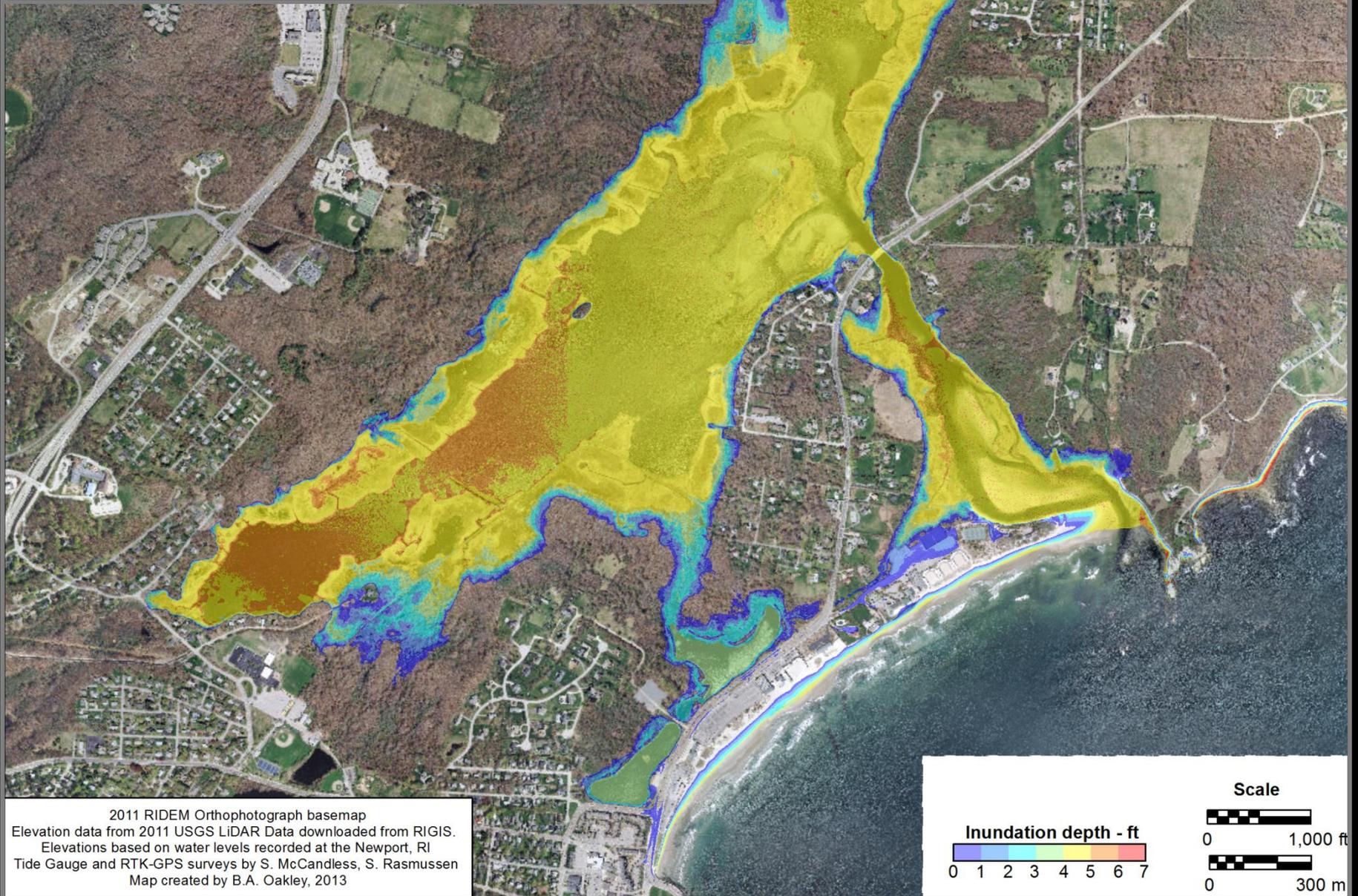
# Narrow River Kayaks – Middlebridge Sandy Storm Surge



**J Considine**  
**30 Oct 2012**

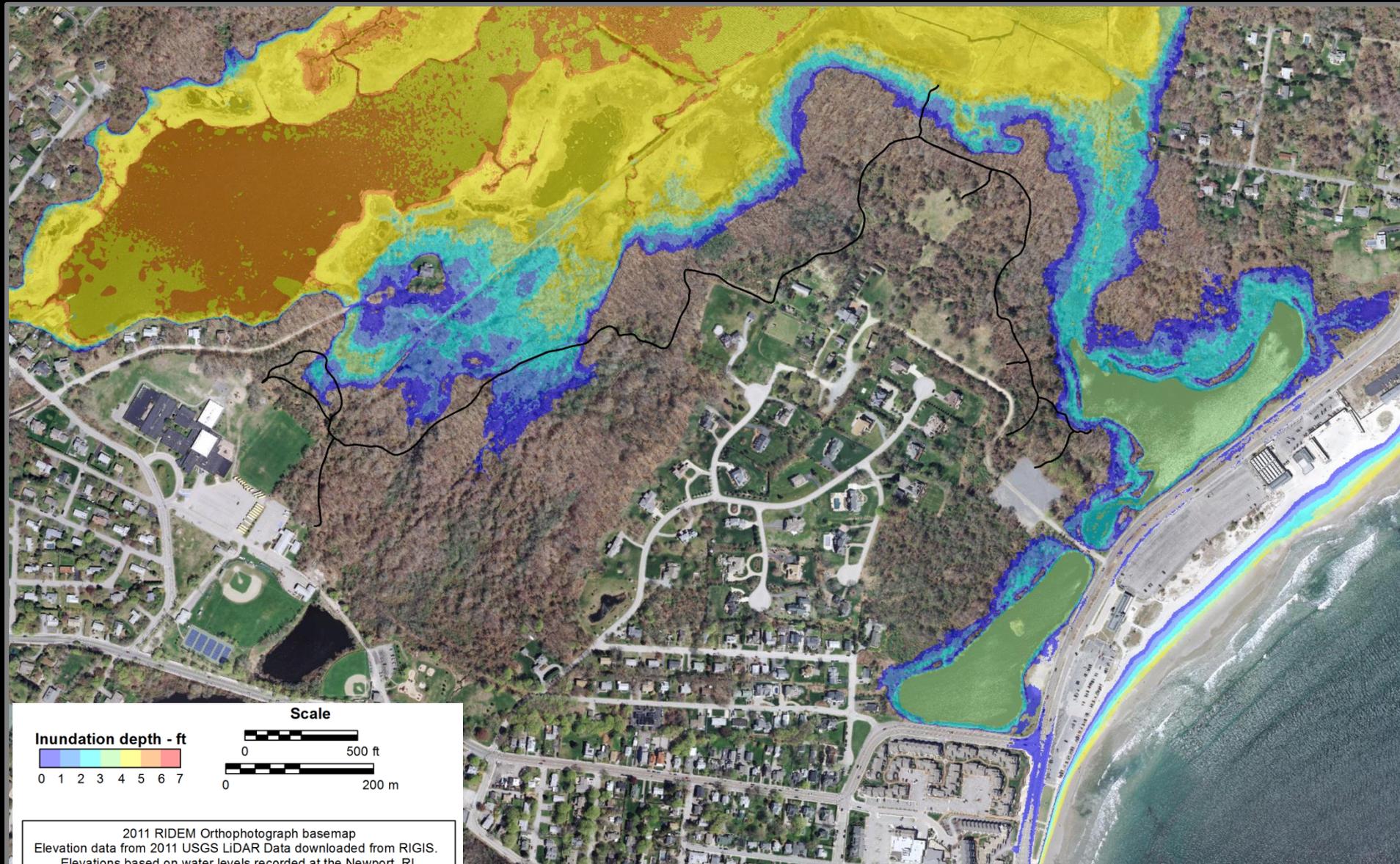
41°27'27.68" N 71°26'59.66" W elev 0 ft

# Superstorm Sandy Surge - Narragansett



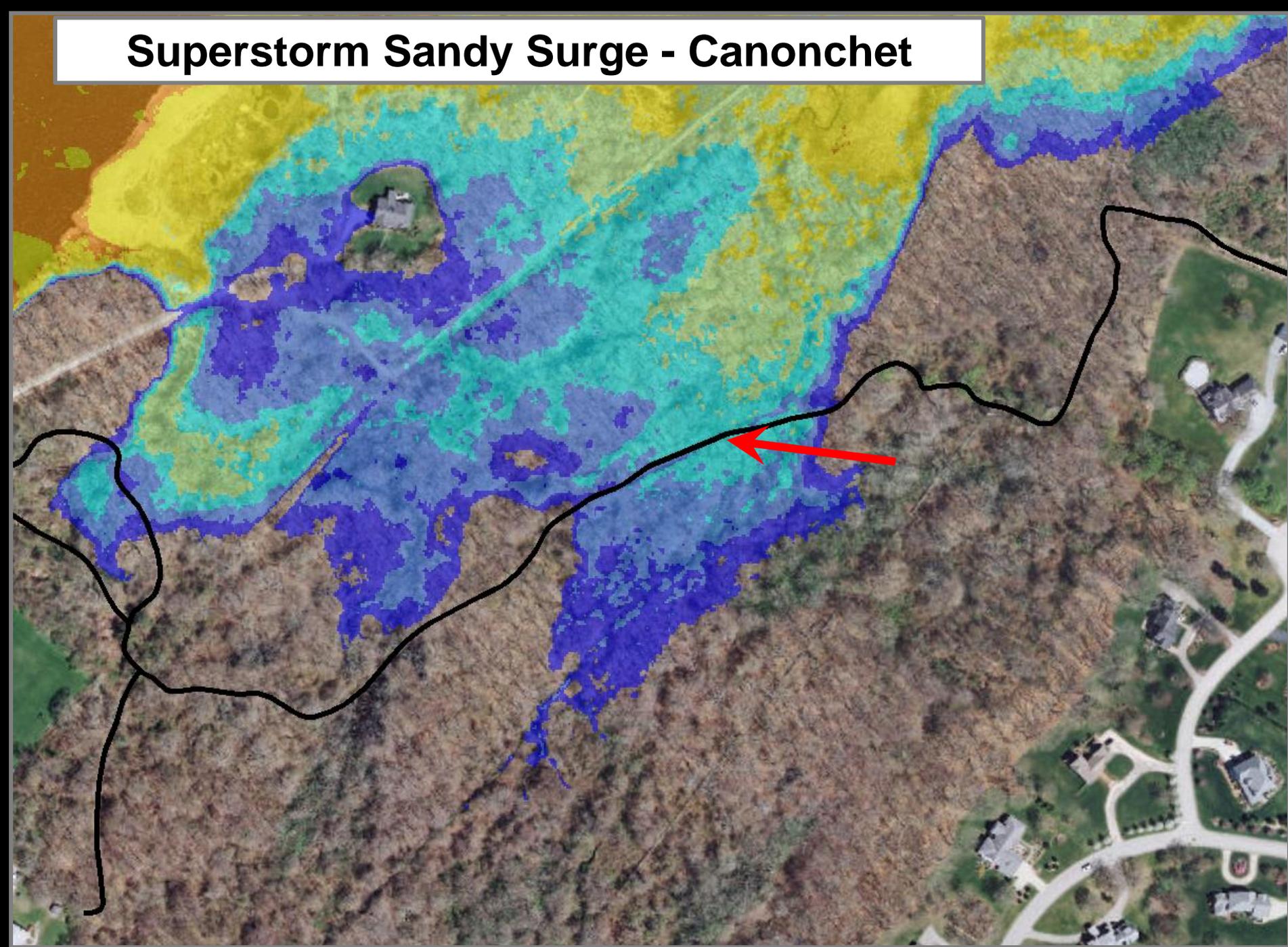
2011 RIDEM Orthophotograph basemap  
Elevation data from 2011 USGS LiDAR Data downloaded from RIGIS.  
Elevations based on water levels recorded at the Newport, RI  
Tide Gauge and RTK-GPS surveys by S. McCandless, S. Rasmussen  
Map created by B.A. Oakley, 2013

# Superstorm Sandy Surge - Narragansett

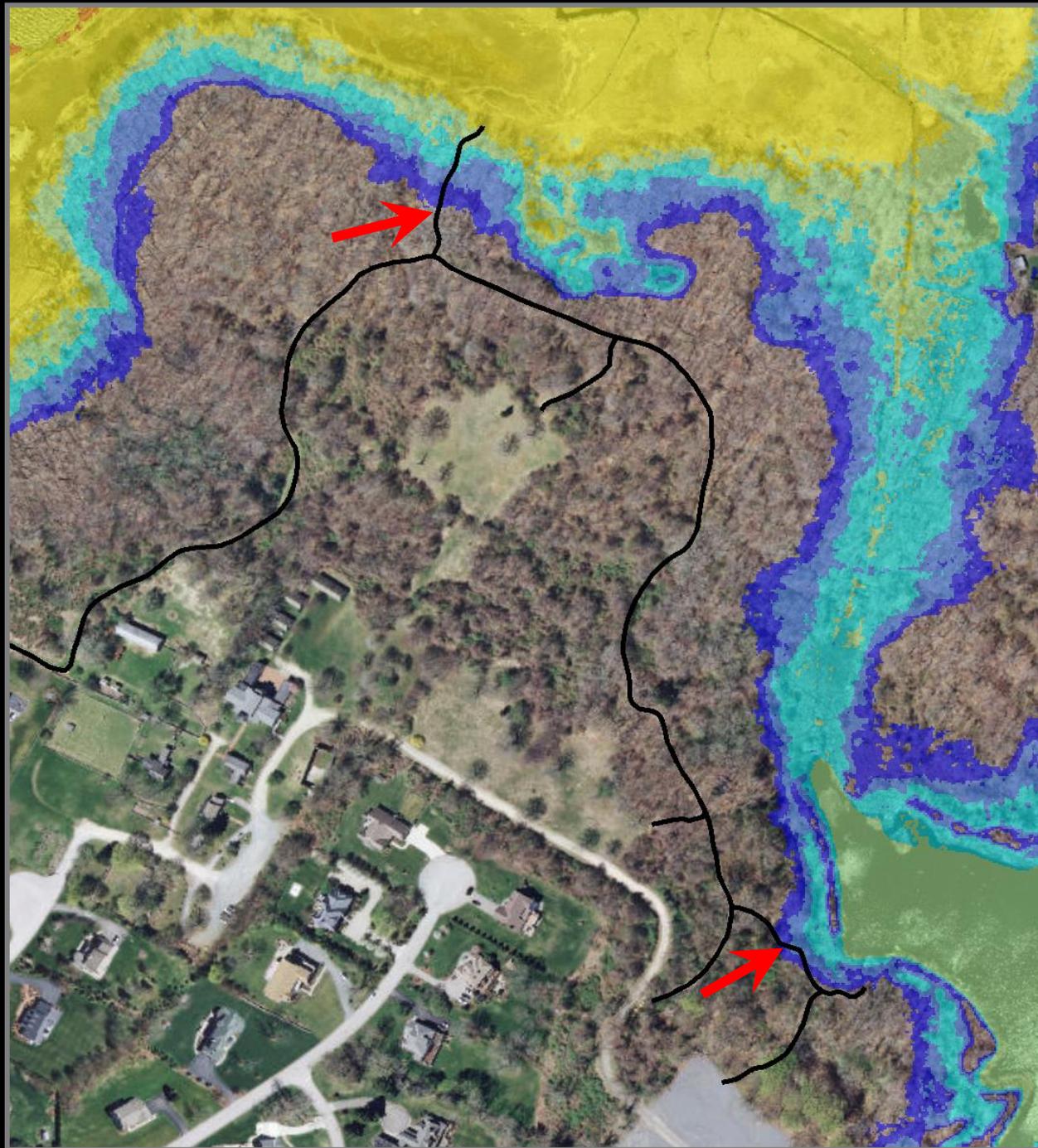


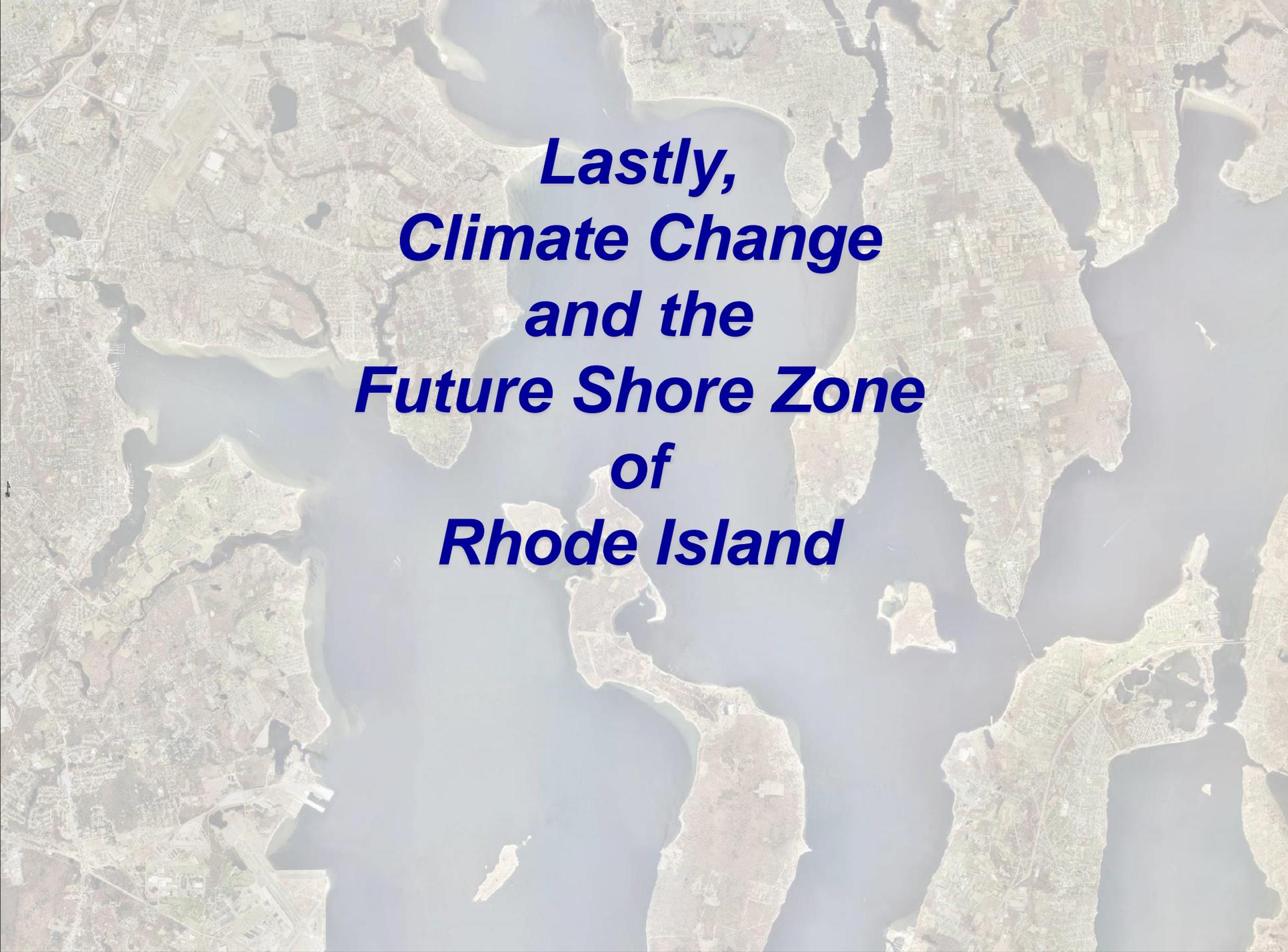
2011 RIDEM Orthophotograph basemap  
Elevation data from 2011 USGS LiDAR Data downloaded from RIGIS.  
Elevations based on water levels recorded at the Newport, RI  
Tide Gauge and RTK-GPS surveys by S. McCandless, S. Rasmussen  
Map created by B.A. Oakley, 2013

# Superstorm Sandy Surge - Canonchet



**Superstorm  
Sandy Surge -  
Canonchet**





***Lastly,  
Climate Change  
and the  
Future Shore Zone  
of  
Rhode Island***

# Carbon Dioxide - CO<sub>2</sub> Levels

## A Cause for Concern

Now 394+ ppm

Carbon Dioxide Levels Today are Higher than over the Past 650,000 Years

Atmospheric carbon dioxide record data sources: Keeling and Whorf (2004), Petit et al. (1999), IPCC (2001), Ahn et al. (2004).

Industrial CO<sub>2</sub> Levels

Pre-industrial CO<sub>2</sub> Levels

First Moon Landing

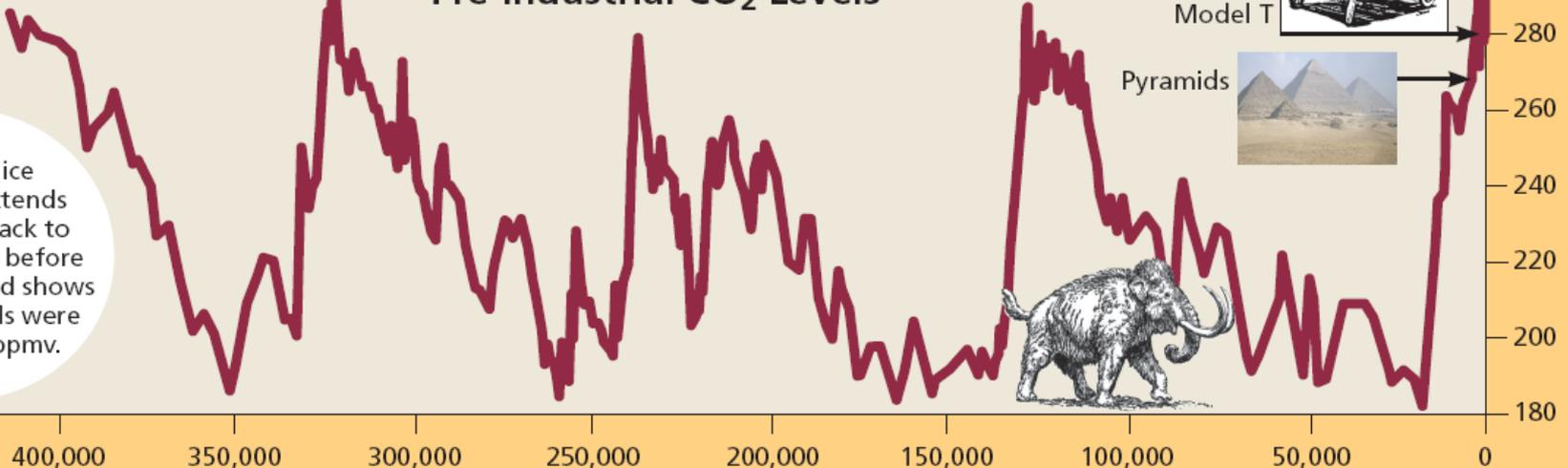


First Production Model T

Pyramids

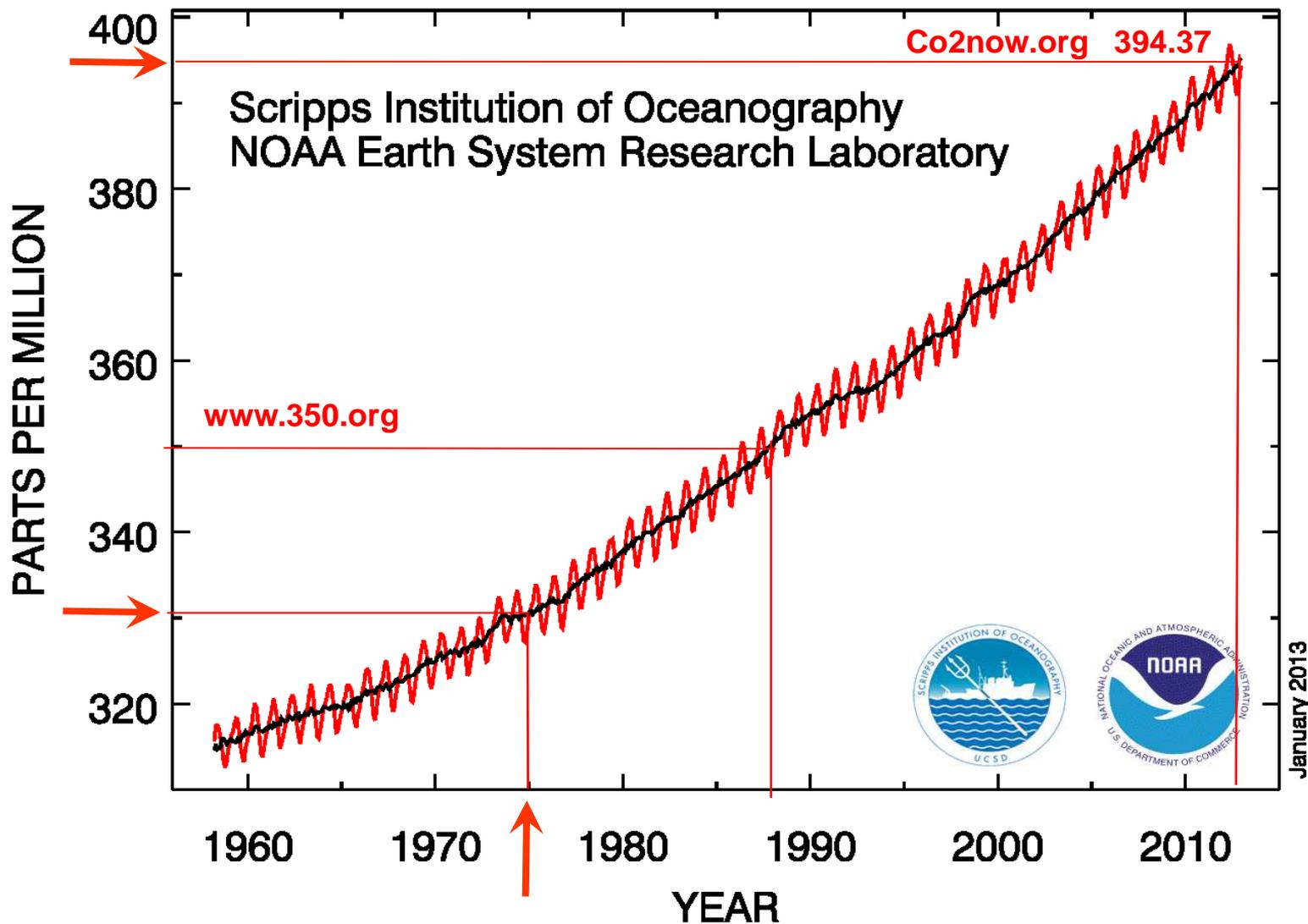


New Antarctic ice core data extends the record back to 650,000 years before the present and shows that CO<sub>2</sub> levels were below 300 ppmv.



Years Before the Present

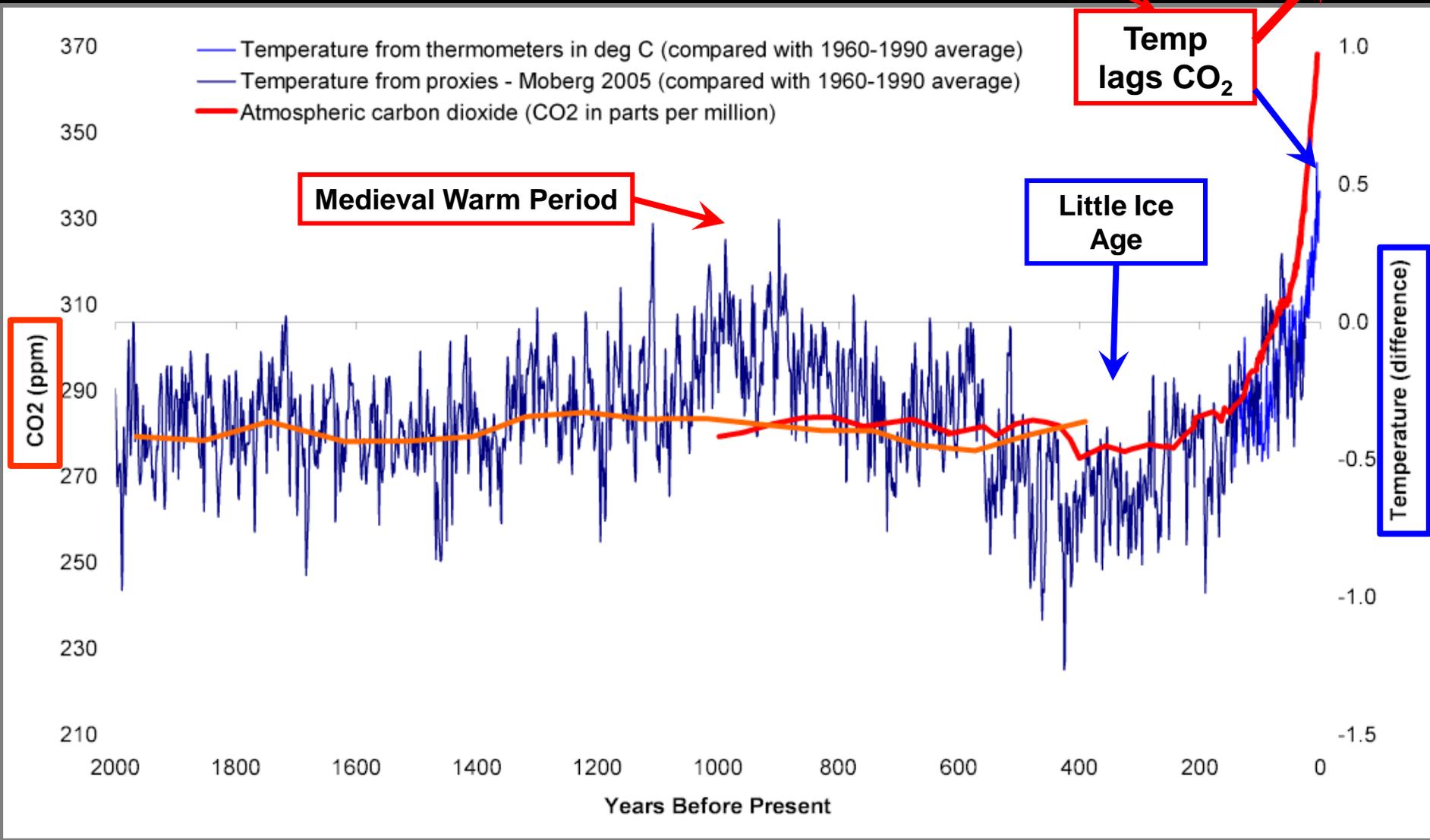
# Atmospheric CO<sub>2</sub> at Mauna Loa Observatory



[http://www.esrl.noaa.gov/gmd/ccgg/trends/co2\\_data\\_mlo.html](http://www.esrl.noaa.gov/gmd/ccgg/trends/co2_data_mlo.html)

# THE HOCKEY STICK

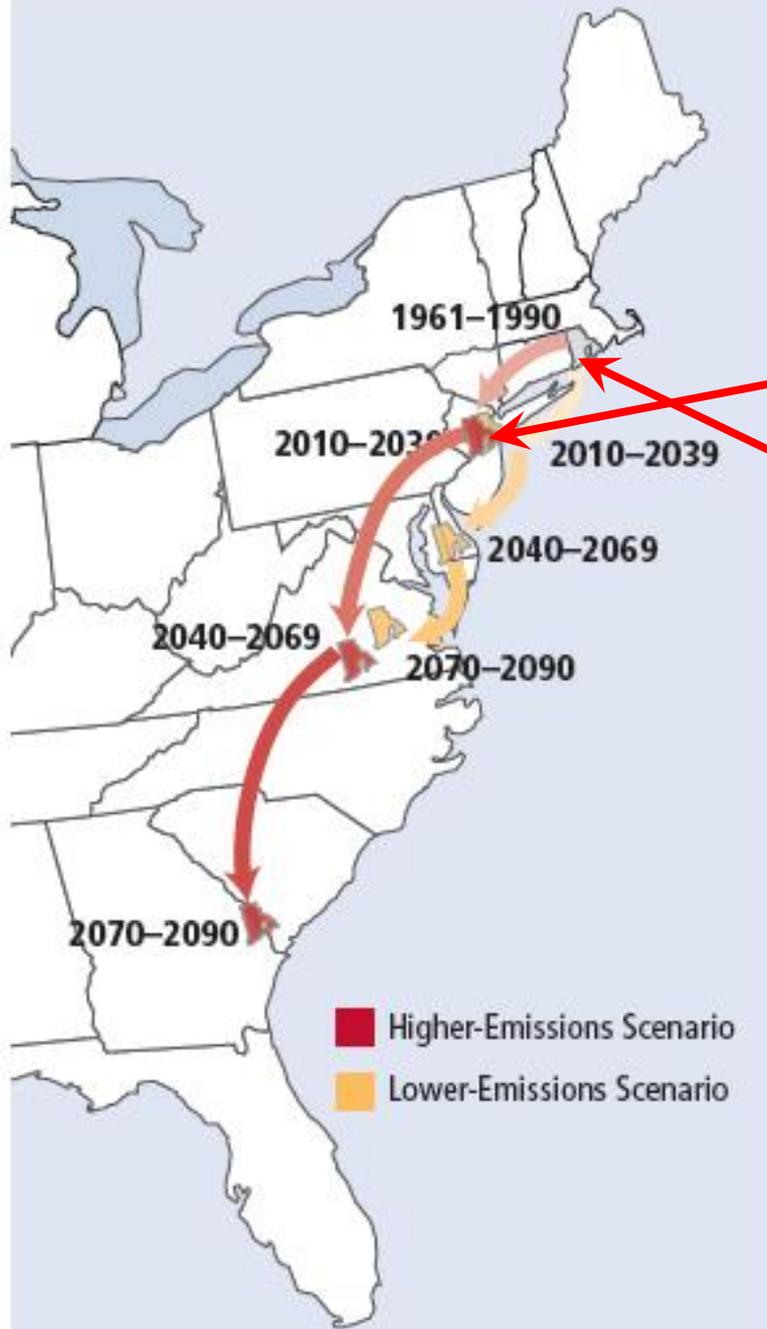
## The Message



# Rhode Island Possible Future Climate

North Jersey – Now Already ???

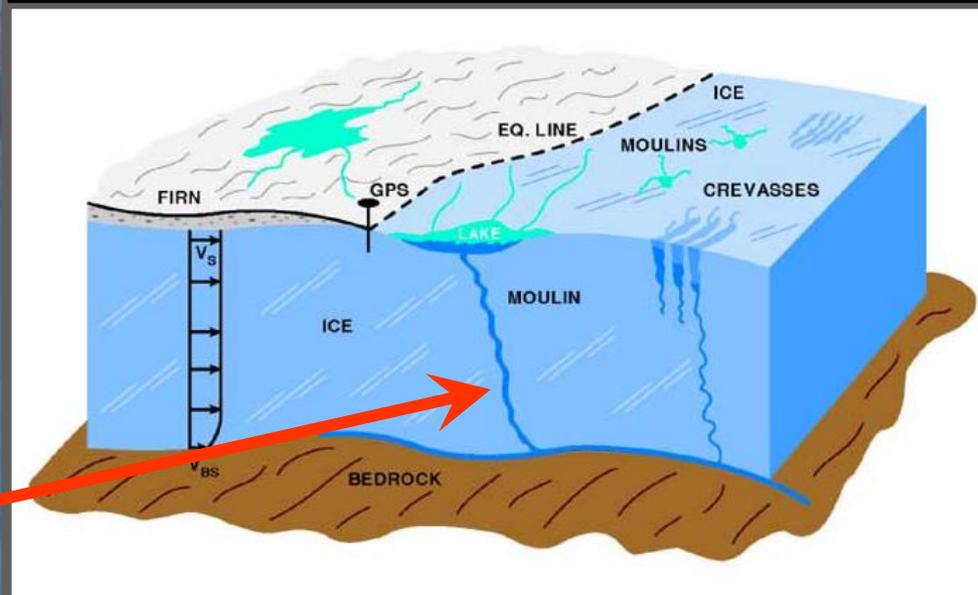
Rhode  
Island



Confronting Climate Change in the  
U.S. Northeast: Climate, Impacts,  
and Solutions, NECIA, 2007

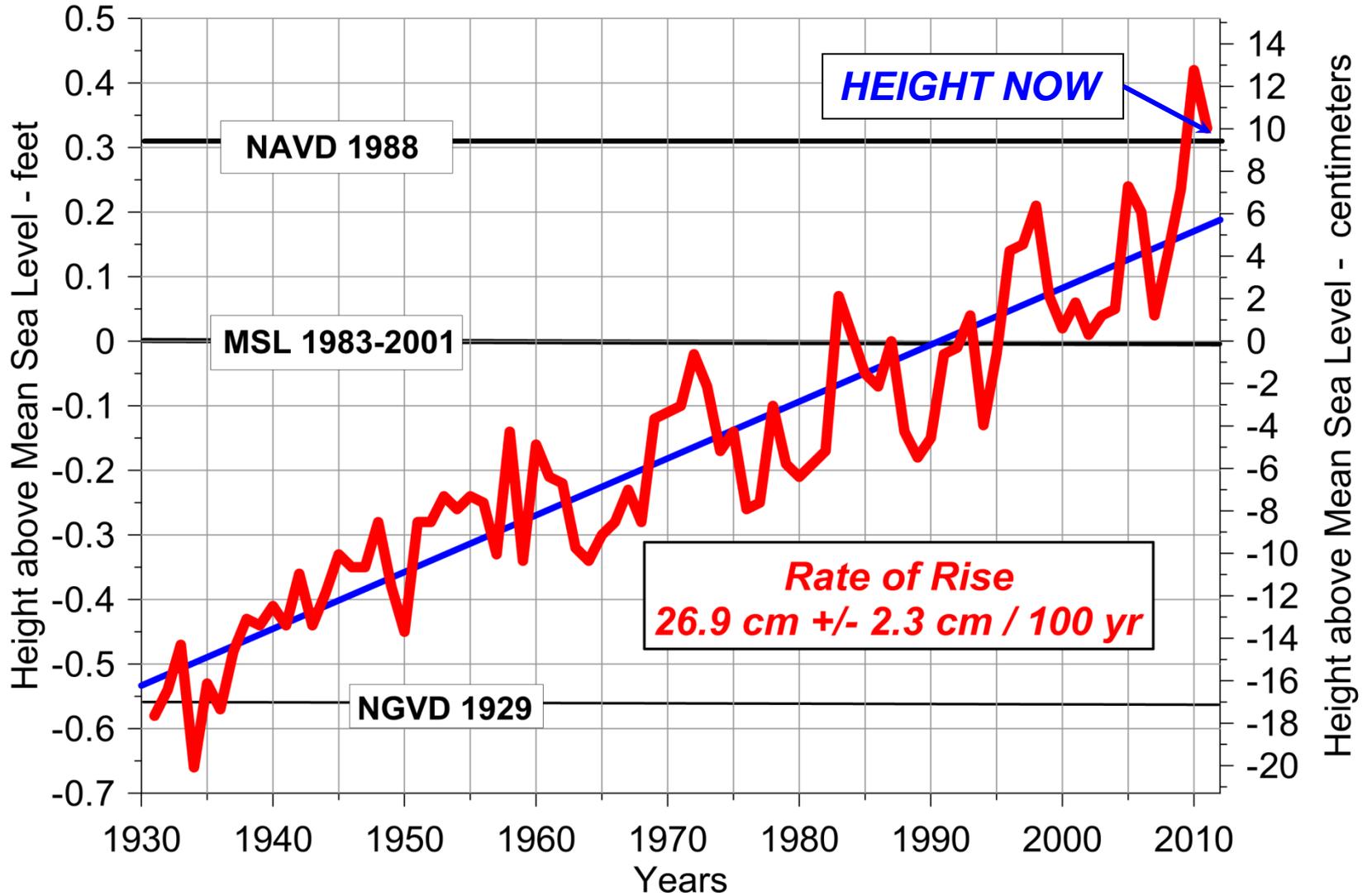
<http://www.northeastclimateimpacts.org/>

**Greenland Outlet Glaciers**  
**Change from Polythermal to Warm Based**  
**A Key to Future Sea-Level Rise**

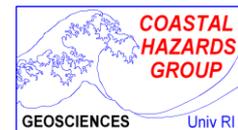


Brathwaite, 2002

# HISTORIC SEA-LEVEL RISE - Newport, RI



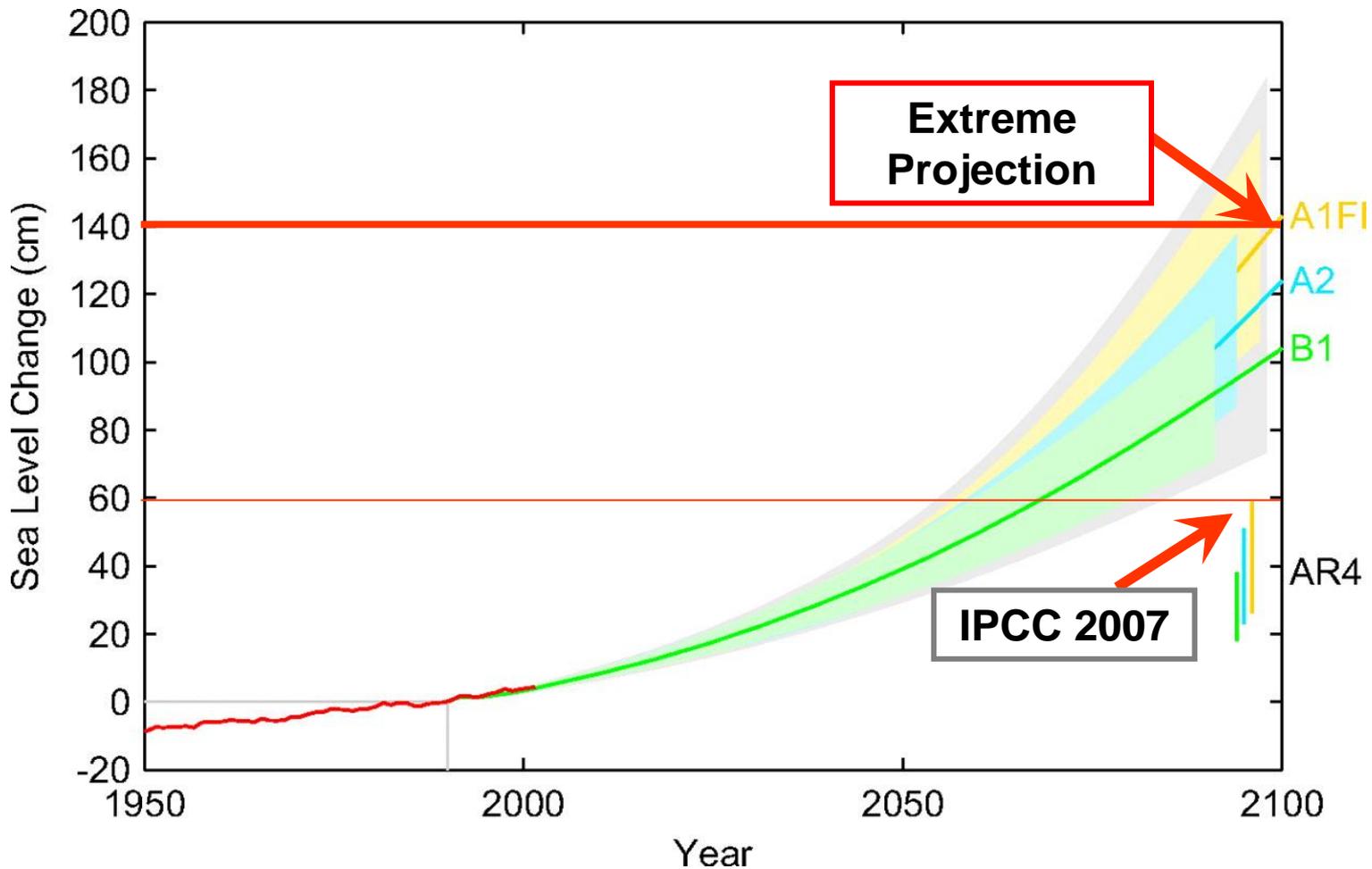
Adapted from:  
[http://tidesandcurrents.noaa.gov/sltrends/sltrends\\_station.shtml?stnid=8452660%20Newport,%20RI](http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8452660%20Newport,%20RI)



Boothroyd 2012

# Global Sea Level Linked to Global Temperature

## Projection of Sea-Level Rise 1990 - 2100 Using IPCC 2007 Temperature Projections



6.1 ft

VR Max

185 cm

4.5 ft

VR A1F1

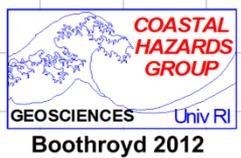
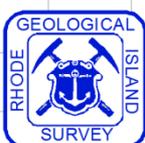
137 cm

# ACCELERATED SEA-LEVEL RISE Newport RI

VR B1

100 cm

IPCC 2001  
Land Ice



Height above NOW

IPCC 2007  
Model Avg

1.4 ft

41

HEIGHT NOW

MSL 1983-2001

NGVD 1929

2010

HISTORIC TREND

1990-2009 TREND

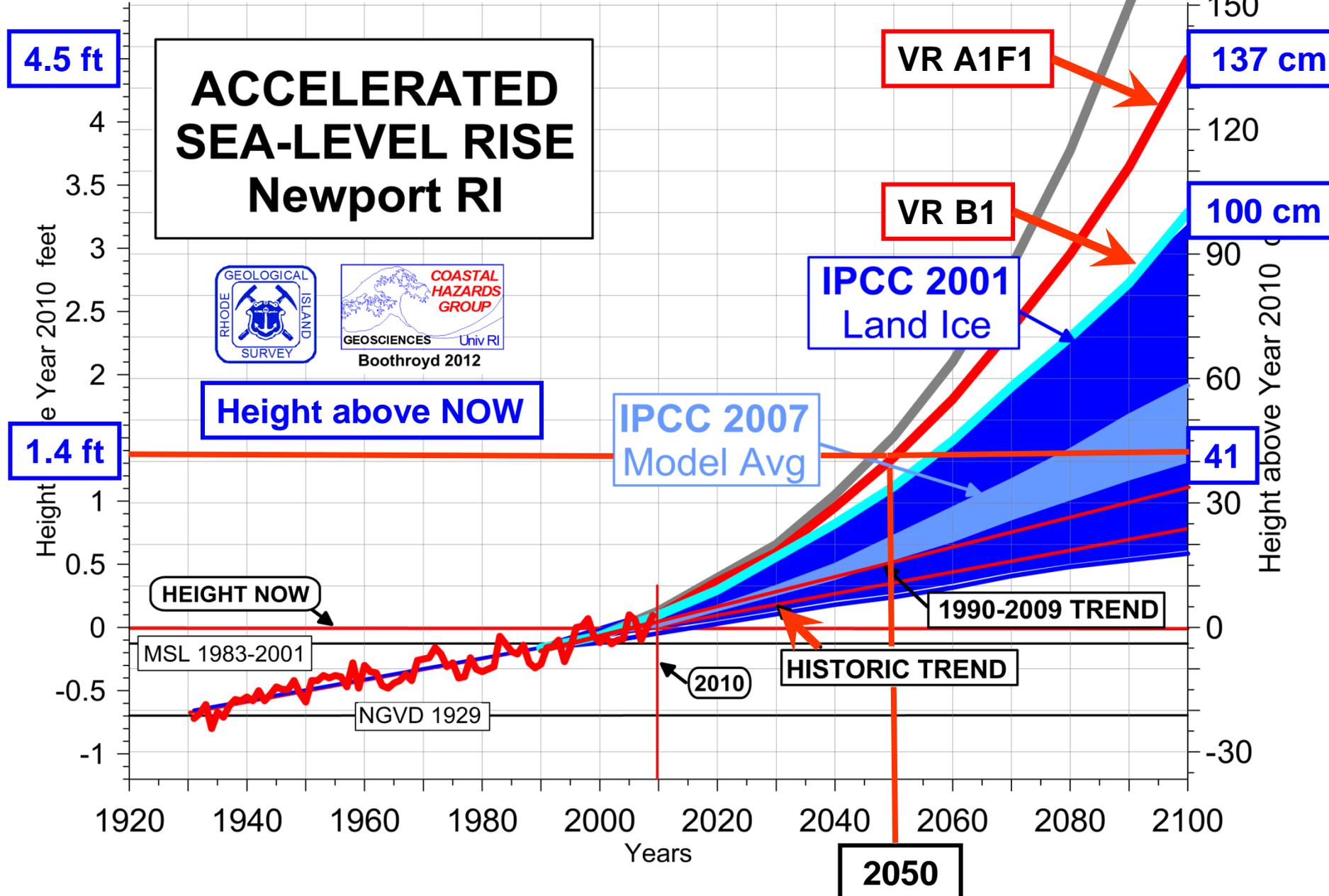
2050

Height above Year 2010 feet

Height above Year 2010 cm

1920 1940 1960 1980 2000 2020 2040 2060 2080 2100

Years



# Ninigret – Green Hill Lagoons

2003 – 2004 Orthophoto

Today

Elevations from USACE Bathymetry LiDAR and Terrain model from 2006  
Charlestown - South Kingstown Orthophotography  
Base Imagery: RIDOT 2003-2004  
Shoreline migration from Boothroyd and Hehre, 2007

Scale



0 5,000 ft



0 2,000 m



# Ninigret – Green Hill Lagoons

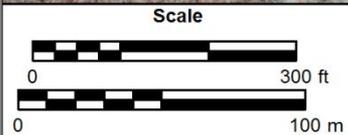
2100 Inundation – 5 ft  
200 ft Barrier Migration

**Projected**



# Narragansett Circuit Drive Detention Pond System

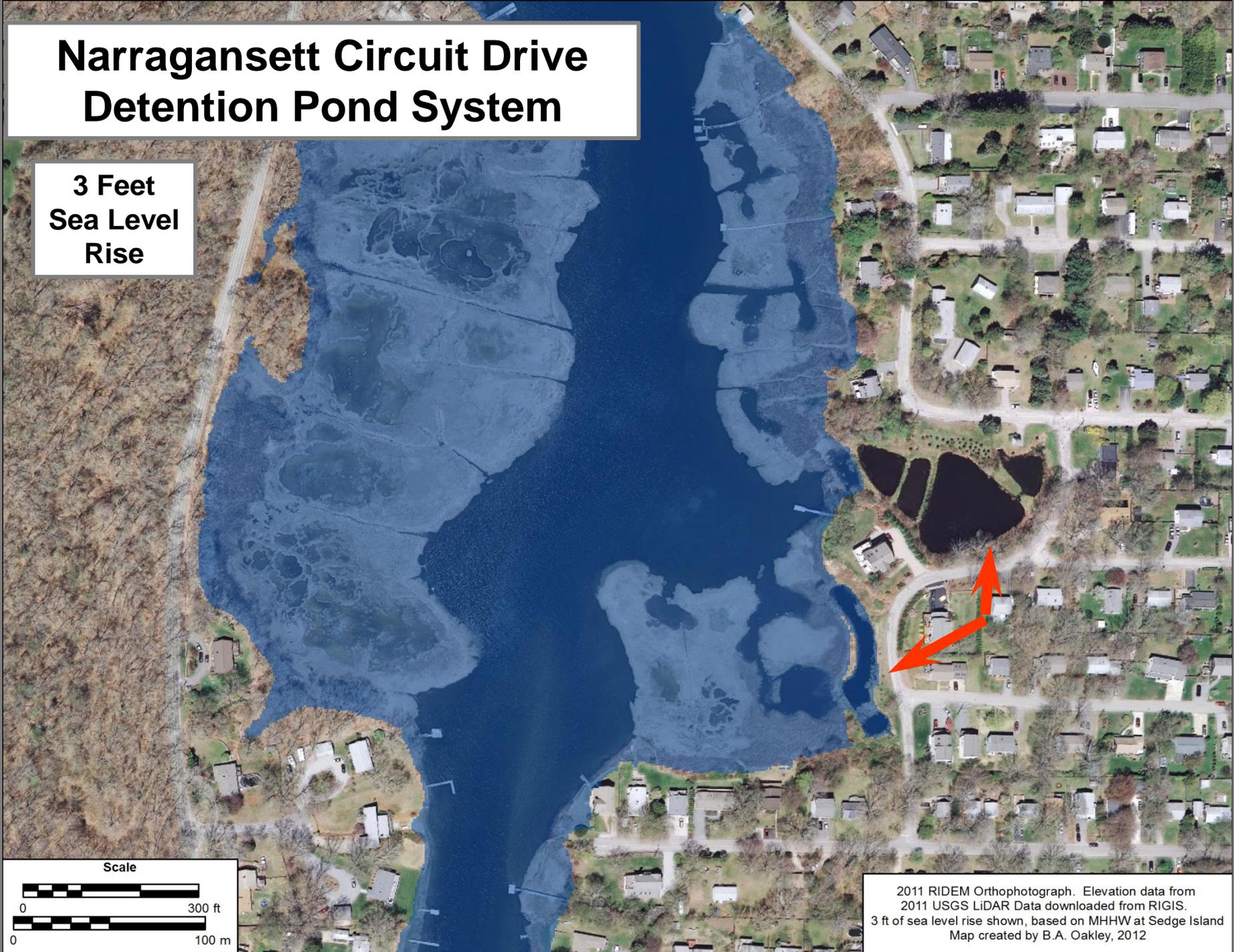
1.4 Feet  
Sea Level  
Rise



2011 RIDEM Orthophotograph. Elevation data from  
2011 USGS LiDAR Data downloaded from RIGIS.  
41 cm of sea level rise shown, based on MHHW at Sedge Island  
Map created by B.A. Oakley, 2012

# Narragansett Circuit Drive Detention Pond System

3 Feet  
Sea Level  
Rise



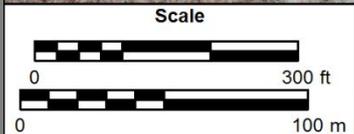
Scale



2011 RIDEM Orthophotograph. Elevation data from  
2011 USGS LiDAR Data downloaded from RIGIS.  
3 ft of sea level rise shown, based on MHHW at Sedge Island  
Map created by B.A. Oakley, 2012

# Narragansett Circuit Drive Detention Pond System

5 Feet  
Sea Level  
Rise



2011 RIDEM Orthophotograph. Elevation data from  
2011 USGS LiDAR Data downloaded from RIGIS.  
5 ft of sea level rise shown, based on MHHW at Sedge Island  
Map created by B.A. Oakley, 2012

# Middlebridge, South Kingstown RI 2.5' Storm Surge from Extratropical Storm

A Common View of the Future

Today



JC Boothroyd

OCT 28 2006

# Wickford Marketplace – In-Place Inundation “The Bathtub Ring”

Today



28 Oct 2011

MelissaDevine9

**End of Presentation**