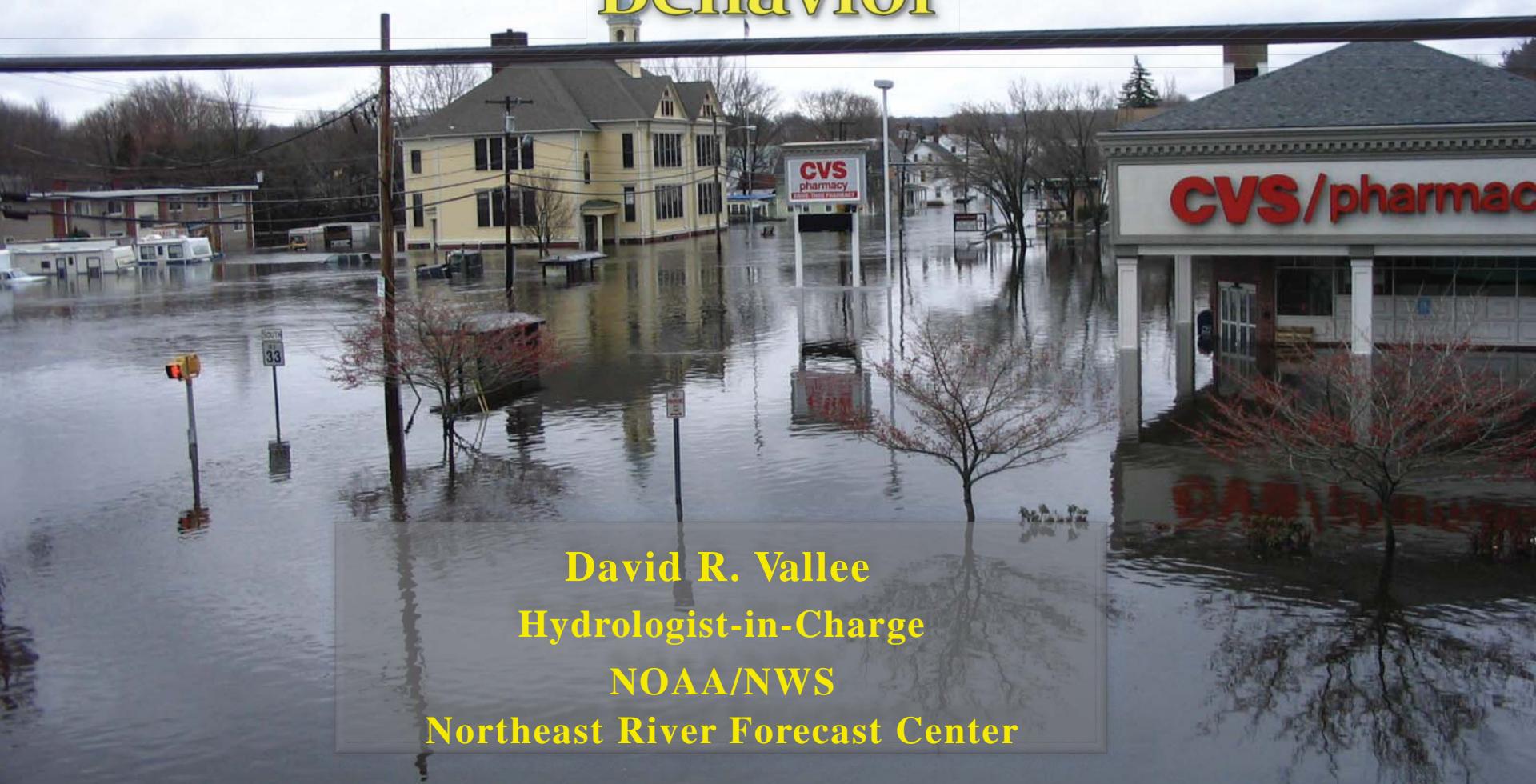


Climate Trends in Rhode Island and Its Impact on Riverine & Coastal Flood Behavior



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

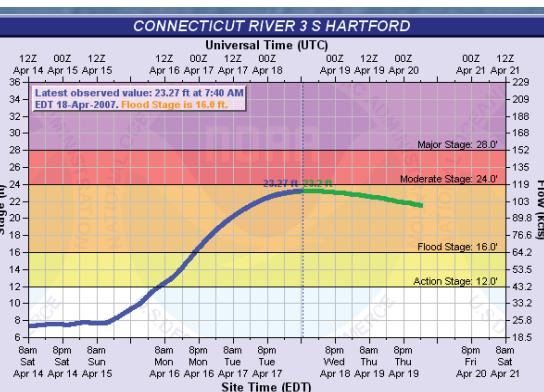
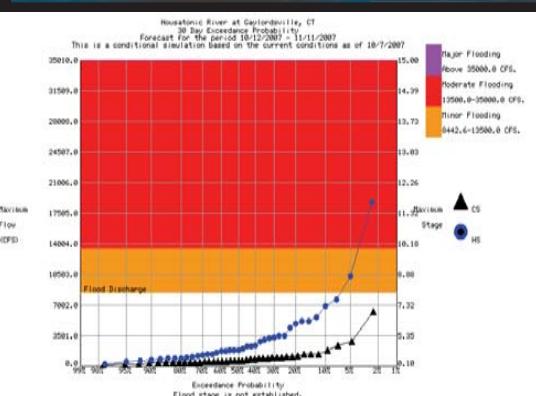
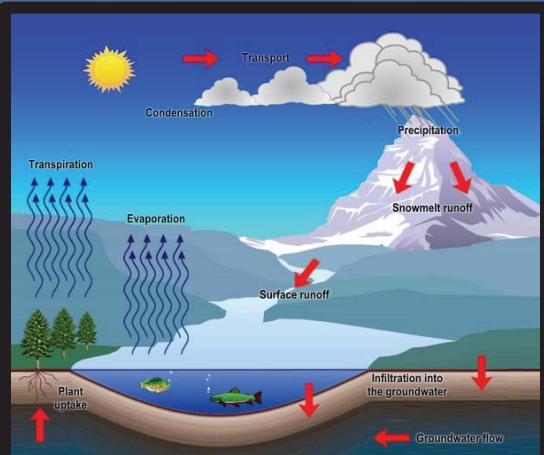
Outline

- From a “Practitioner’s Perspective”
- Two Parts:
 - Part I: Rainfall/Temperature trends and changes in flood behavior
 - Part II: The coastline and its vulnerability; lessons from Sandy
- But first...a bit about NWS services in the basin

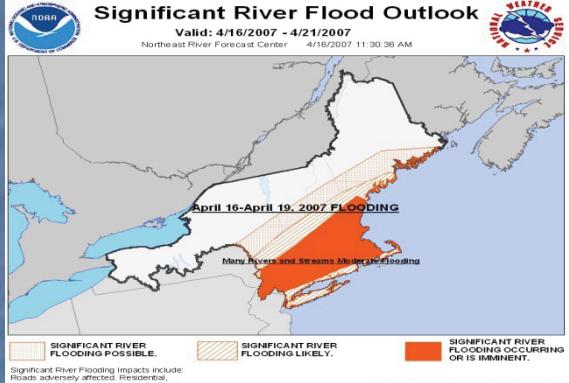
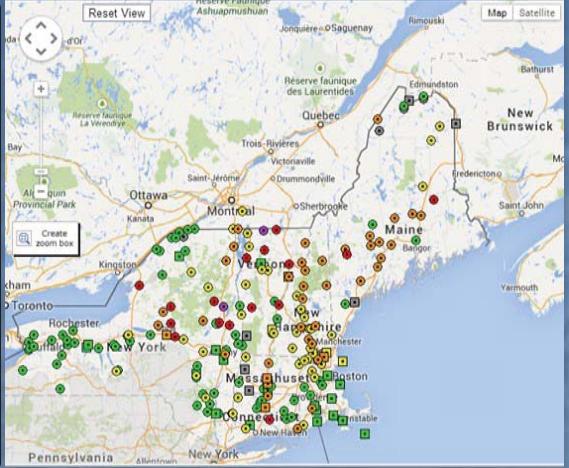
River Forecast Center Responsibilities

- Calibrate and implement variety of hydrologic and hydraulic models and produce temperature and precipitation forecasts to provide:

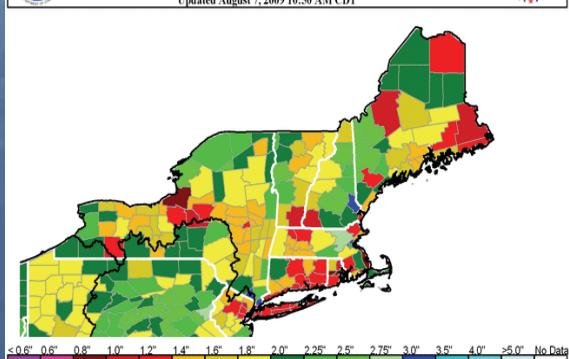
- River flow and stage forecasts at ~ 200 locations
- Guidance on the rainfall needed to produce Flash Flooding
- Ensemble streamflow predictions
- Ice Jam and Dam Break support
- Water Supply forecasts
- Reservoir Inflow Forecasts



HFDC3 (plotting HOFG) *Stage 0* Datum: msl Observations courtesy of the US Geological Survey



National Weather Service
Northeast River Forecast Center
1 Hour Flash Flood Guidance
Updated August 7, 2009 10:50 AM CDT



Partnerships are key

- NWS provides forecasts & warnings
 - Establish flood stages, watch/warning dissemination, AHPS web service, decision support to Federal, State & Local authorities
- NWS relies on other agencies for stream gaging & reservoir data
 - USGS—huge partner—they maintain many of the river/stream gages NWS relies on
 - USACE provides data for their flood control reservoirs
 - Providence Water provides data for Scituate reservoir



US Army Corps of Engineers



Wood-Pawcatuck Watershed Association
Our mission is to promote and protect the integrity of
the lands and waters of the Wood and Pawcatuck watersheds



The Northeast River Forecast Center

<http://www.weather.gov/nerfc>



NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION



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News Headlines

- [NERFC is transitioning our web page to a new format starting on April 9. Info on transitioning to the new page.](#)
- [There is significant flood potential this week from rain and snow melt. Briefing slides are available here.](#)

Northeast River Forecast Center

[Weather.gov](#) > Northeast River Forecast Center

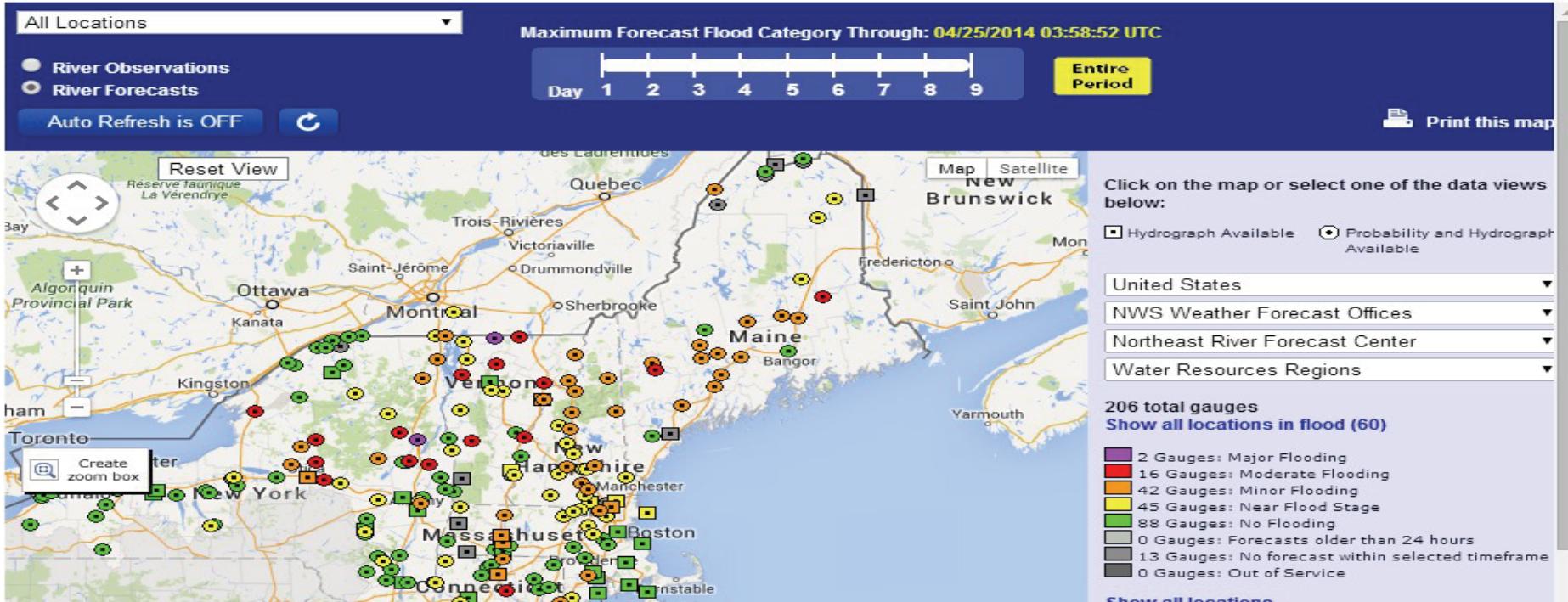
Northeast River Forecast Center

River Forecast Center

[River Observations and Forecasts](#) [Weather Observations and Forecasts](#) [Water Supply](#) [Climate and History](#) [Seasonal Interest](#) [Additional Info](#)

FLOOD STATEMENTS

[Click for details](#)



The Taunton Weather Forecast Office

<http://www.weather.gov/box/>



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Local forecast by
"City, ST" or ZIP code

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News Headlines

- Upcoming SKYWARN Classes - Only 2 Classes Left!
- Check Out our Latest Office Newsletter

Location Help

NWS Weather Forecast Office - Boston / Taunton, MA

[Weather.gov](#) > Boston, MA

Boston, MA
Weather Forecast Office

Current Hazards Current Conditions Radar Forecasts Rivers and Lakes Climate and Past Weather Local Programs

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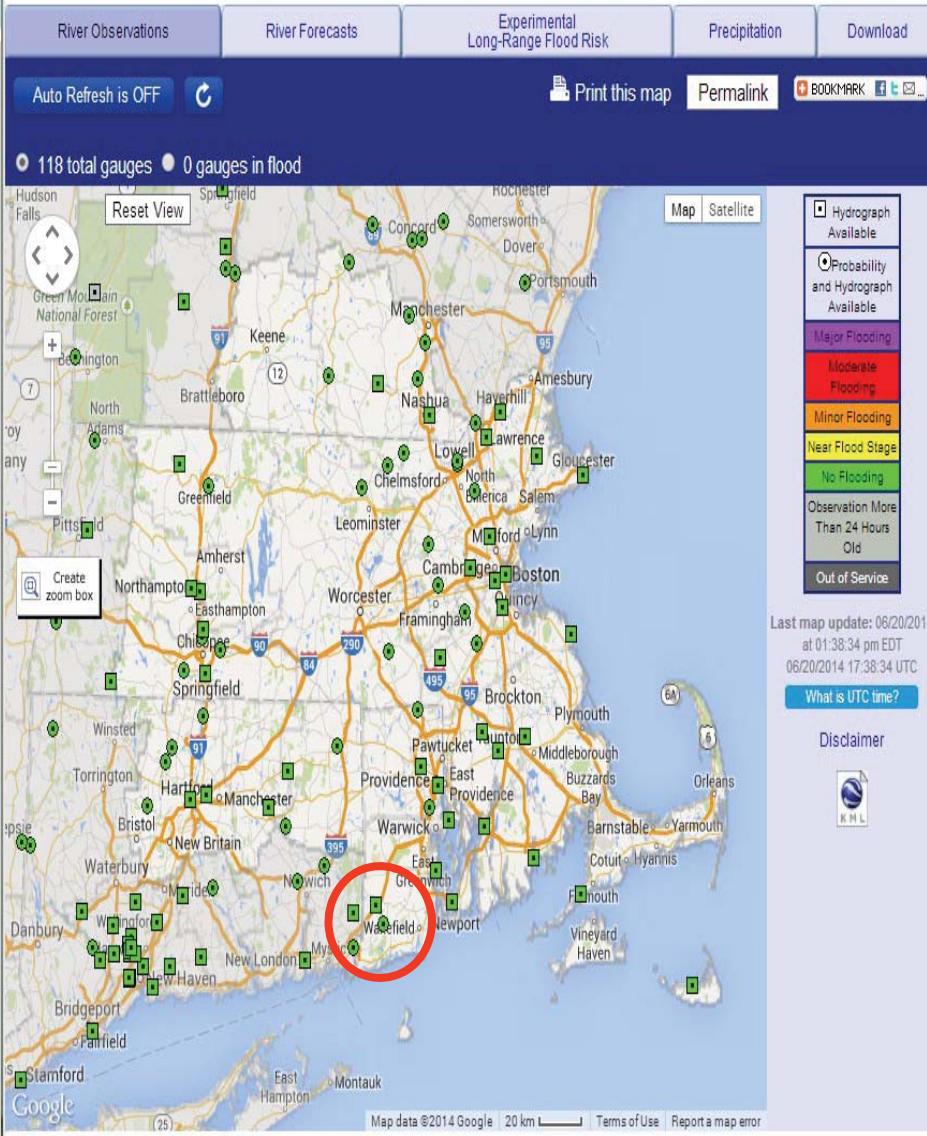
Last Map Update: Wed, Jun. 11, 2014 at 2:43:09 pm EDT



Small Craft Advisory



Weather Forecast Office Boston, MA



The Advanced Hydrologic Prediction Service AHPS

Northeast River Forecast Center

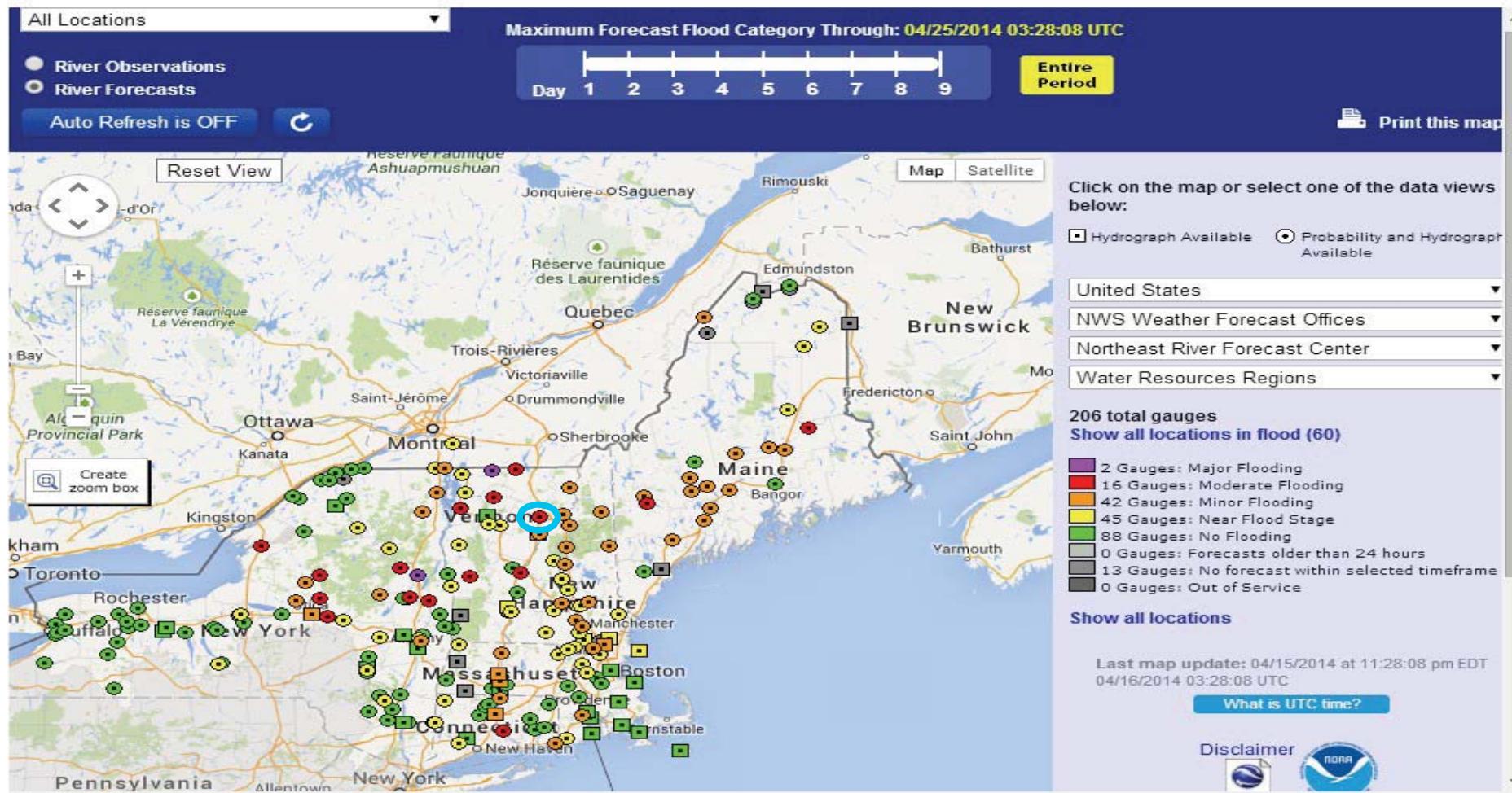
[Weather.gov](#) > Northeast River Forecast Center

Northeast River Forecast Center
River Forecast Center

River Observations and Forecasts Weather Observations and Forecasts Water Supply Climate and History Seasonal Interest Additional Info

FLOOD STATEMENTS

Click for details

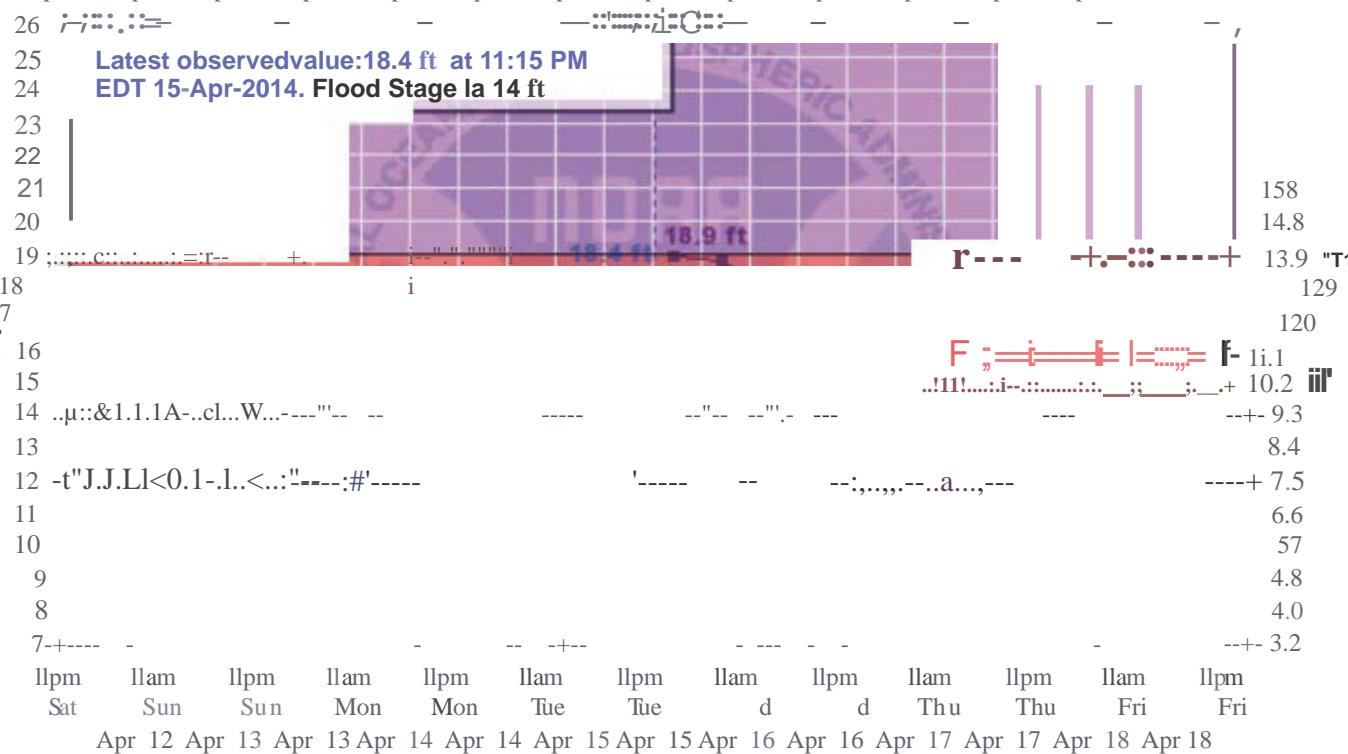


Flood Warning**Flood Watch**[View all valid statements/warnings](#)[Hydrograph](#)[River at a Glance](#)[Download](#)[Probability Information](#)

Auto Refresh is OFF

**PASSUMPS/C RIVER AT PASSUMPS/C****Universal Time (UTC)**

3Z 15Z 3Z 15Z 3Z 15Z 3Z 15Z 3Z 15Z 3Z 15Z 3Z
 Apr 13 Apr 13 Apr 14 Apr 14 Apr 15 Apr 15 Apr 16 Apr 16 Apr 17 Apr 17 Apr 18 Apr 18 Apr 19

**Site Elevation (EDT)**

----- Graph Created (11:31PM Apr 15, 2014) --- Observed ----- Forecast (as of 11:06PM Apr 15)

Text Products

Flood Warning

FLOOD STATEMENT
NATIONAL WEATHER SERVICE BURLINGTON VT PM EDT TUE APR
1140 15 2014

VT C005-009-160945-
/0CON.1<3TV.FA .W .0011.00000TOOOOZ-140416T0945Z/
/00000.0.RS .00000TOOOOZ .00000TOOOOZ .00000TOOOOZ.00/
CALEDONIA VT-ESSEX
1140 PM EDT TUE APR 15 2014

...T::IE FLOOD WARN:::NG REL INS IN EFFECT UNTI-- 545 AM!! EDT WEDNESDAY FOR ORT::!EASTERN
NCaledonia COUNTY IN NORT::!EAST VERMONT ...AND WEST CENTRAL
Essex COUNTY IN NORT::!ERN VERMONT ...

AT 1132 PM EDT ...T3:E EAST 3RANC3 OF T3:E PASSOMPSIC RIVER NEA-"1 EAST
HAVEN 3AS CRESTED. WATER LEVELS WILL SLOWLY FALL AFTER MIDNIG3T IN LYNDON ALONG T:i:E PASSUMPSIC
RIVER. 30MES AND 3USI
ST 3TROUG3 SAINT J03NS3URY WI=-L CONTINUE TO EXPERIENCE FLOOD IMPACTS
T3.ROUG3 MID-MORNING WEDNESDAY UNTIL T:i:E RIVER RECEDES .
SSSES ALONG ROUTE

LOCATIONS IN T3E WARNING INC=-UDE 3UT A-"LE NOT LIMITED TO ST. VOS3URY ...LYNDON
CENTER ...AND LYNDONVILLE .

IF YOU ENCOUNTER FLOODING ...SEEK 3IG3:ER GROUND IMMEDIATELY. WHEN YOU CAN DO SO SAFE LY
P:::..EASE REPORT ANY FLOODING TO T3:E NATIONAL WEATHER SERVICE BY CALLING TOL=- FREE ...1 800 8 6 3 4
2 7 9...OR BY SUBMITTING
A STORM REPORT AT WEATHER.GOV/BURLINGTON .

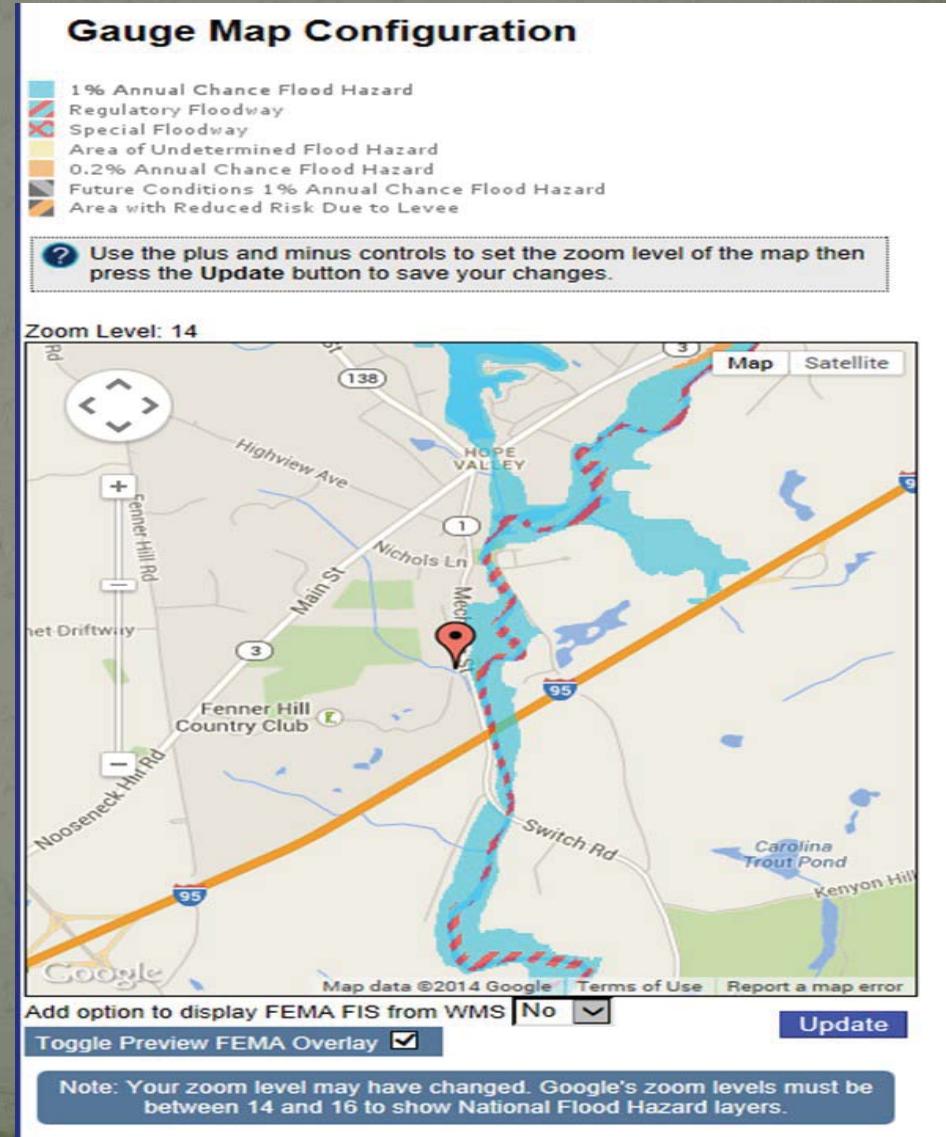
PRECAUTIONA- "LY/PREPARE- "LEDNESS ACTIONS...

BE ESPECIALLY CAUTIOUS AT NIGHT WHEN IT IS HARDER TO RECOGNIZE THE DANGERS OF FLOODING .

DO ON...IN...OR NEAR RIVERS AND STREAMS. T3:E 3IG3 WATER LEVELS & FAST FLOWS CAN
CREATE DEADLY CONSEQUENCES FOR PERSONS WHO VENTURE
AN TOO CLOSE AND BECOME CAUGHT IN FLOODWATERS BY ACCIDENT ...OR
TO INTENTIONALLY TRY TO SWIM OR BATHE ON FLOODED WATERWAYS. WHEN YOU PUT OURSELF IN 3ARMS WAY T3:E LIFE
IN YOU RISK IS NOT ONLY YOUR OWN ...YOU
YO SO RISK TO T3:E LIVES OF RESCUE PERSONNEL.
AL

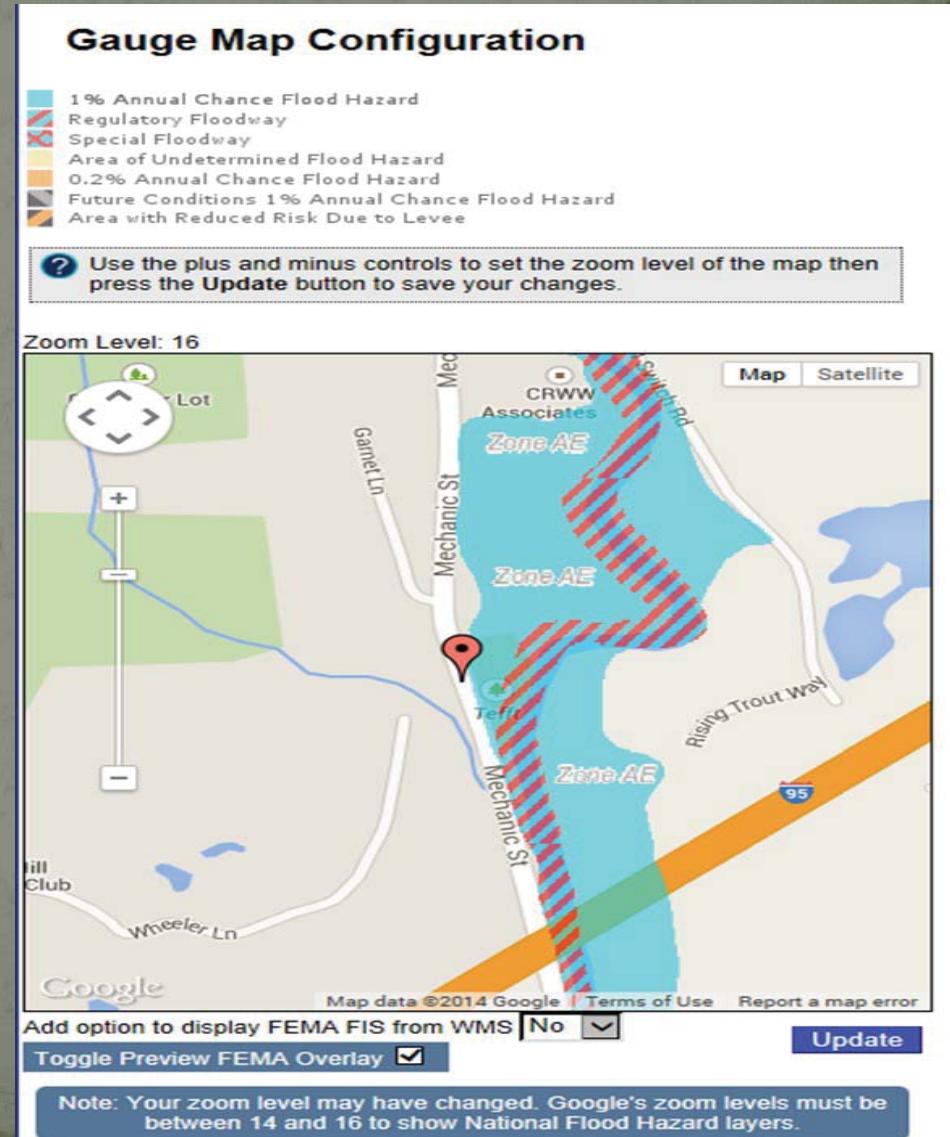
Current & future service locations in RI and a new AHPS capability

- Pawcatuck River
 - Wood River Junction
 - Westerly
- Pawtuxet River
 - Cranston
- Blackstone River
 - Woonsocket
- Later this summer we add the Wood River!
 - At Hope Valley



Current & future service locations in RI and a new AHPS capability

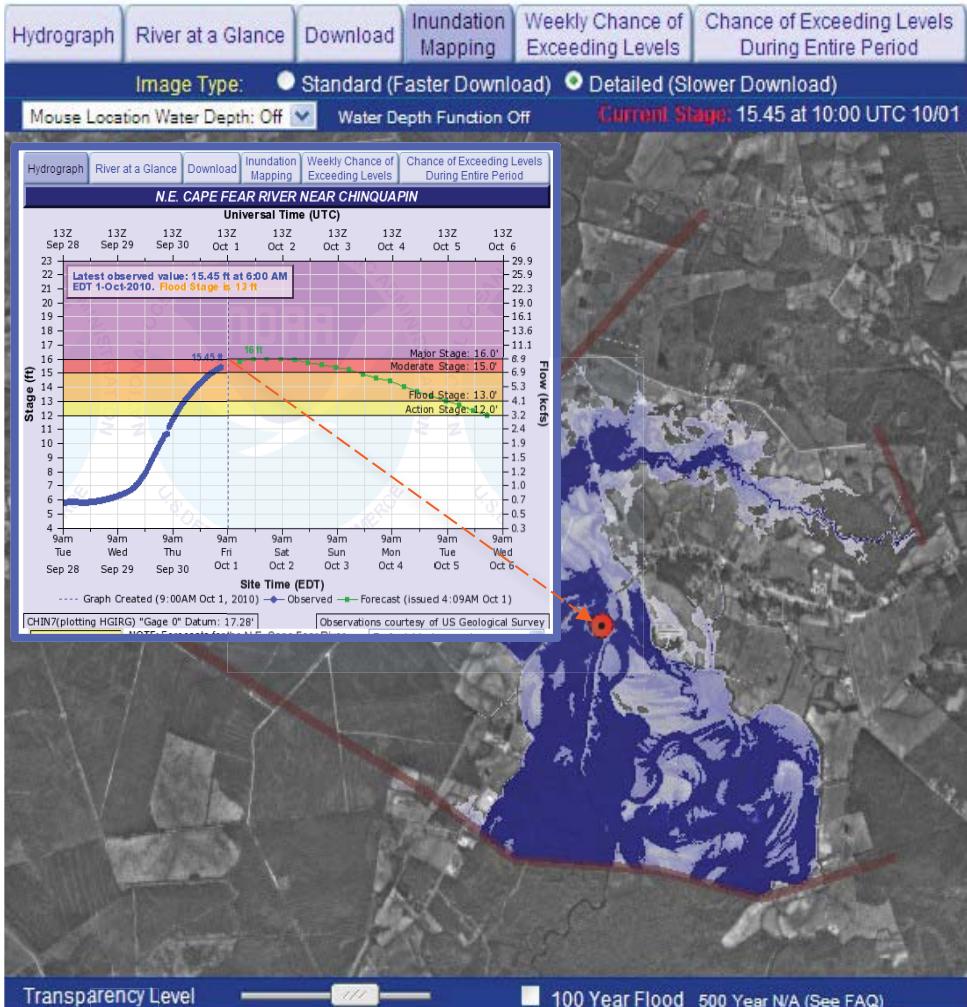
- Pawcatuck River
 - Wood River Junction
 - Westerly
- Pawtuxet River
 - Cranston
- Blackstone River
 - Woonsocket
- Later this summer we add the Wood River!
 - At Hope Valley



Enhancing Hydrologic Decision Support Inundation Mapping

Flood Inundation Mapping

- Provide spatial extent & depth of flood waters
- Display inundation maps for levels from minor flooding through flood of record
- Better mitigate impacts of flooding and build more resilient communities
- Libraries include NWS flood severity categories and regulatory FEMA flood frequency maps
- Integrated Water Resource Science & Services (IWRSS) initiative – a tri-agency effort (NOAA, USGS, USACE) working collaboratively to share resources and move this type of mapping forward
- NERFC participates on a QA/QC regional team for inundation map validation



I've been a little busy these past 7 years! *Job Security in 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. Remoiz



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

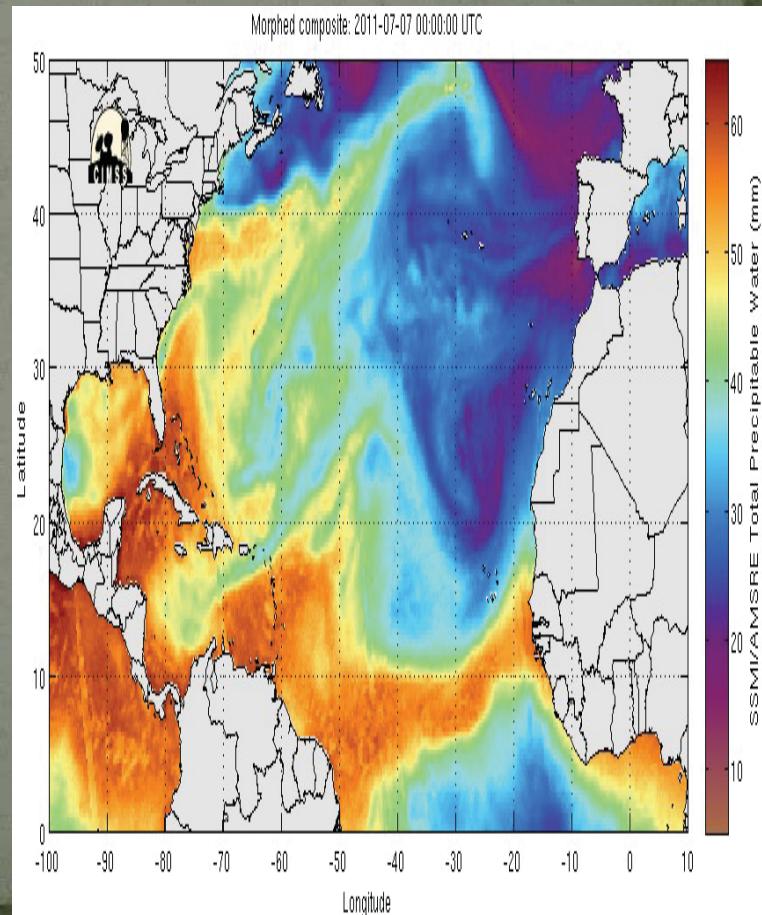
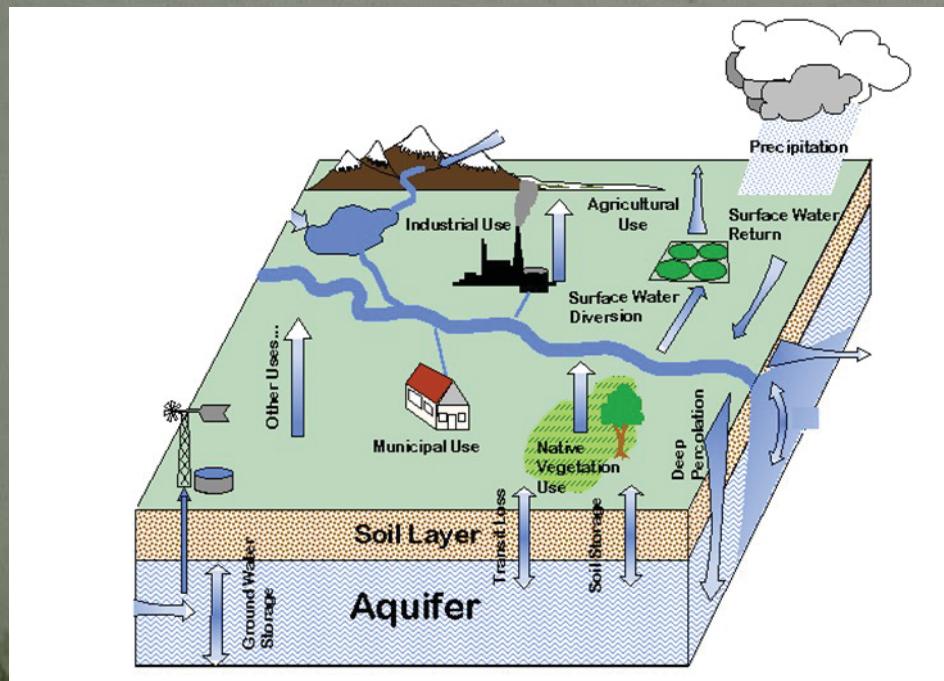


Home washed off its foundation along the Schoharie Creek, Prattsville, NY – Tropical Storm Irene

Is there a common theme to recent?

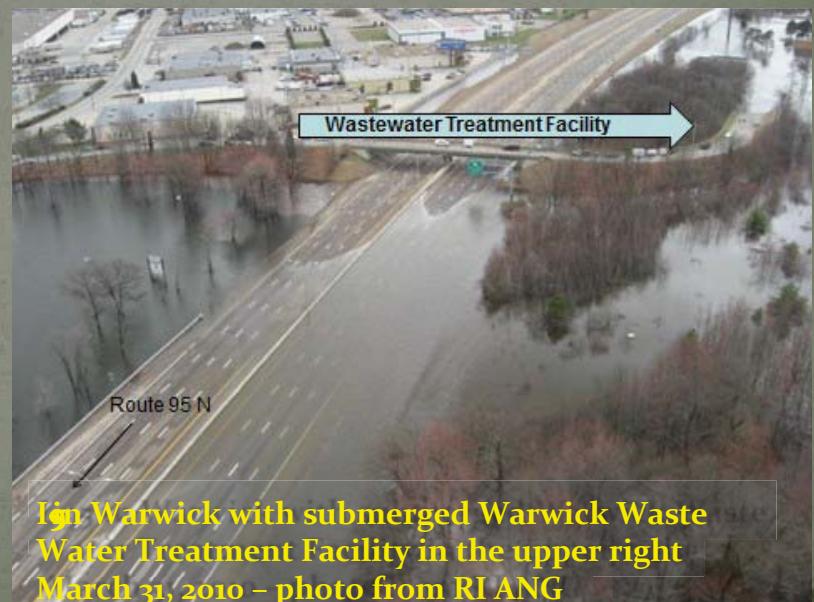
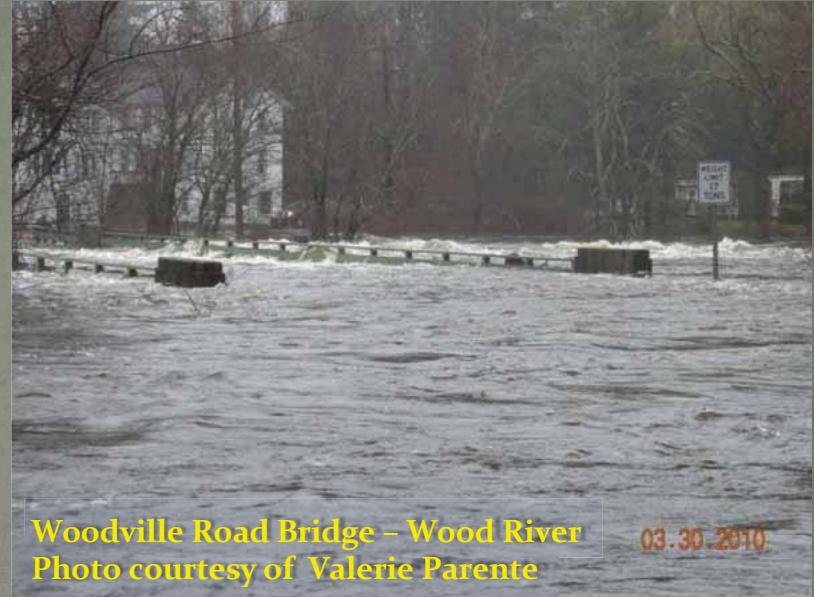
- Several:

- Slow moving weather systems – a blocked up atmosphere
- Multiple events in close succession or 1 or 2 slow movers
- Resulted in saturated antecedent conditions before “main event”
- Each fed by a “tropical connection”
 - Plumes of deep moisture



The Changing Climate

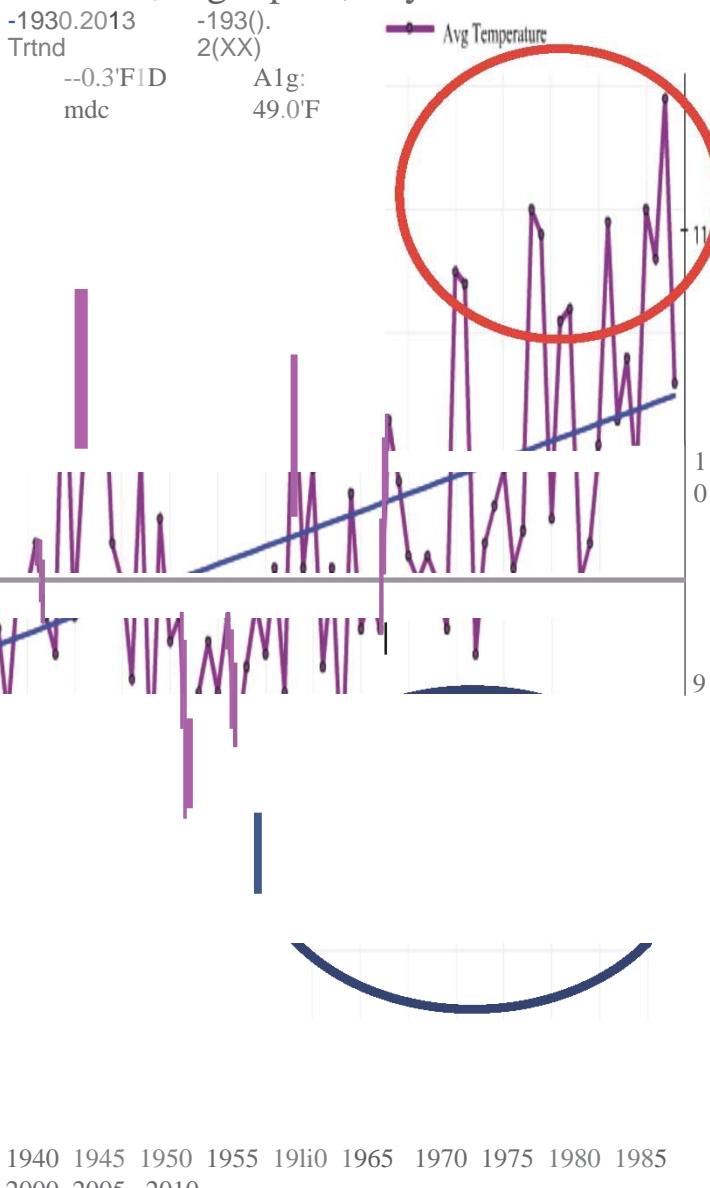
- Common themes across New England:
 - Increasing annual precipitation
 - Increasing frequency of heavy rains
 - Warming annual temperatures
 - Wildly varying seasonal snowfall
- Shift in precipitation frequency (50, 100 yr – 24 hr rain)
- For smaller (<800 sq mi) basins – trend toward increased flood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



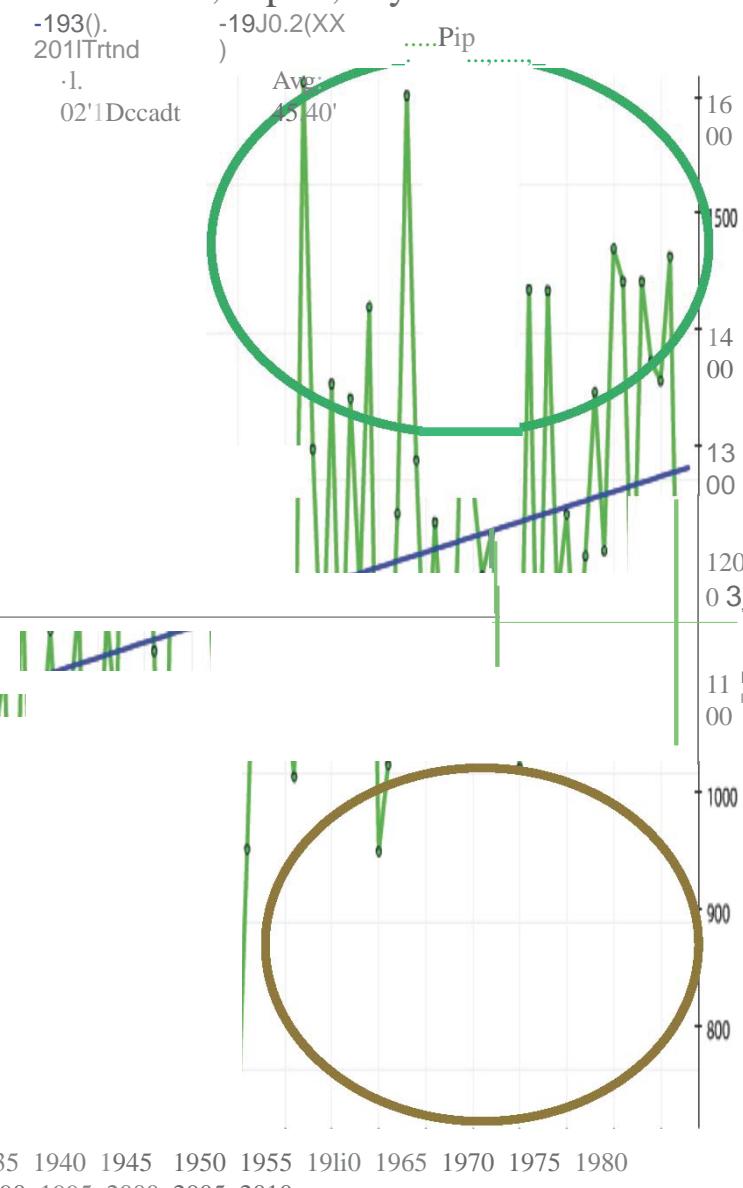
A Look at Temperature and Precipitation Trends

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

Rookland,Average Temperature,January-December

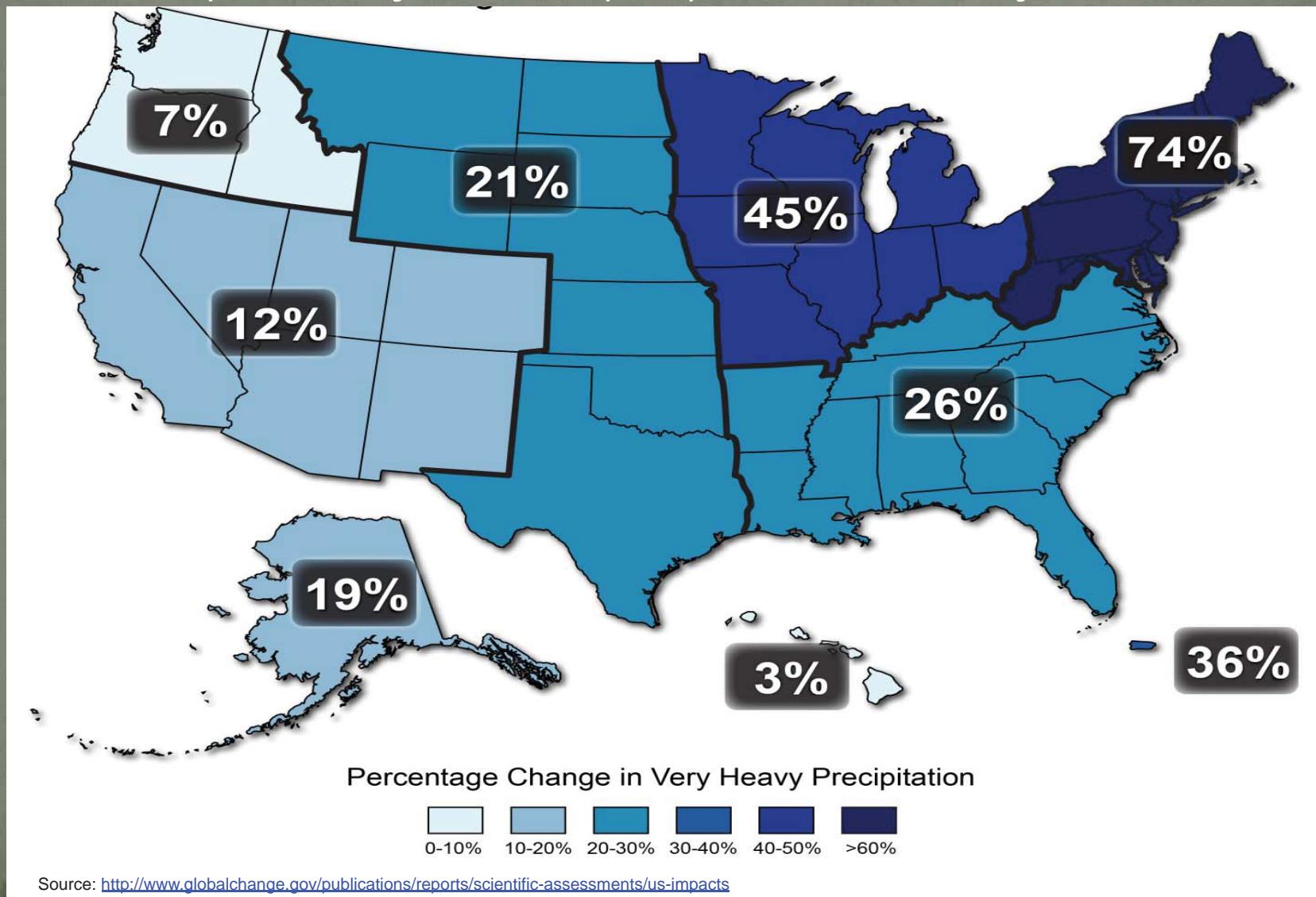


Rookland,Precipitation,January-December

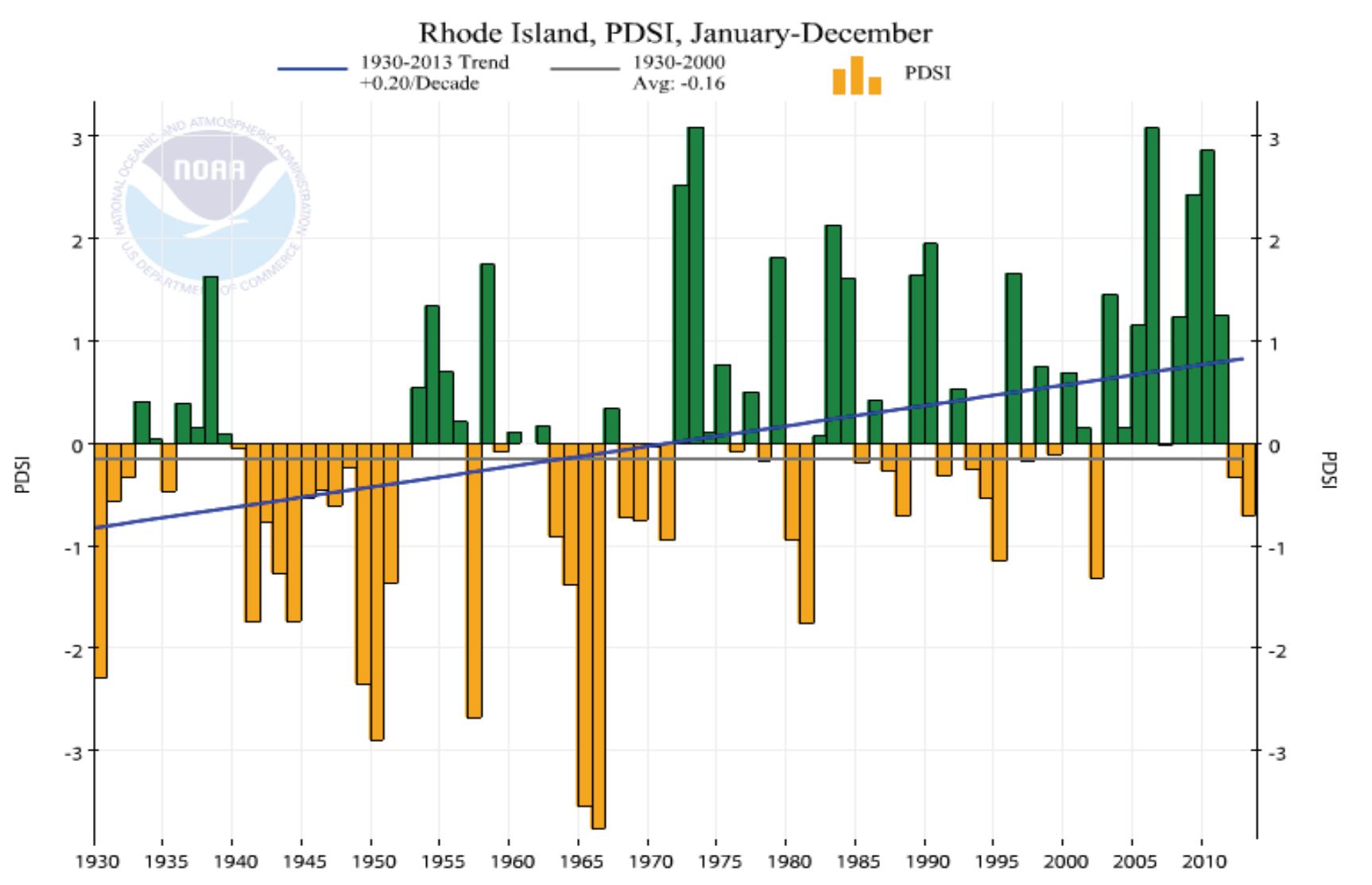


Change in Precipitation Patterns

Intense precipitation events (the heaviest 1%) in the continental U.S. increased by 20% over the past century while total precipitation increased by 7%.

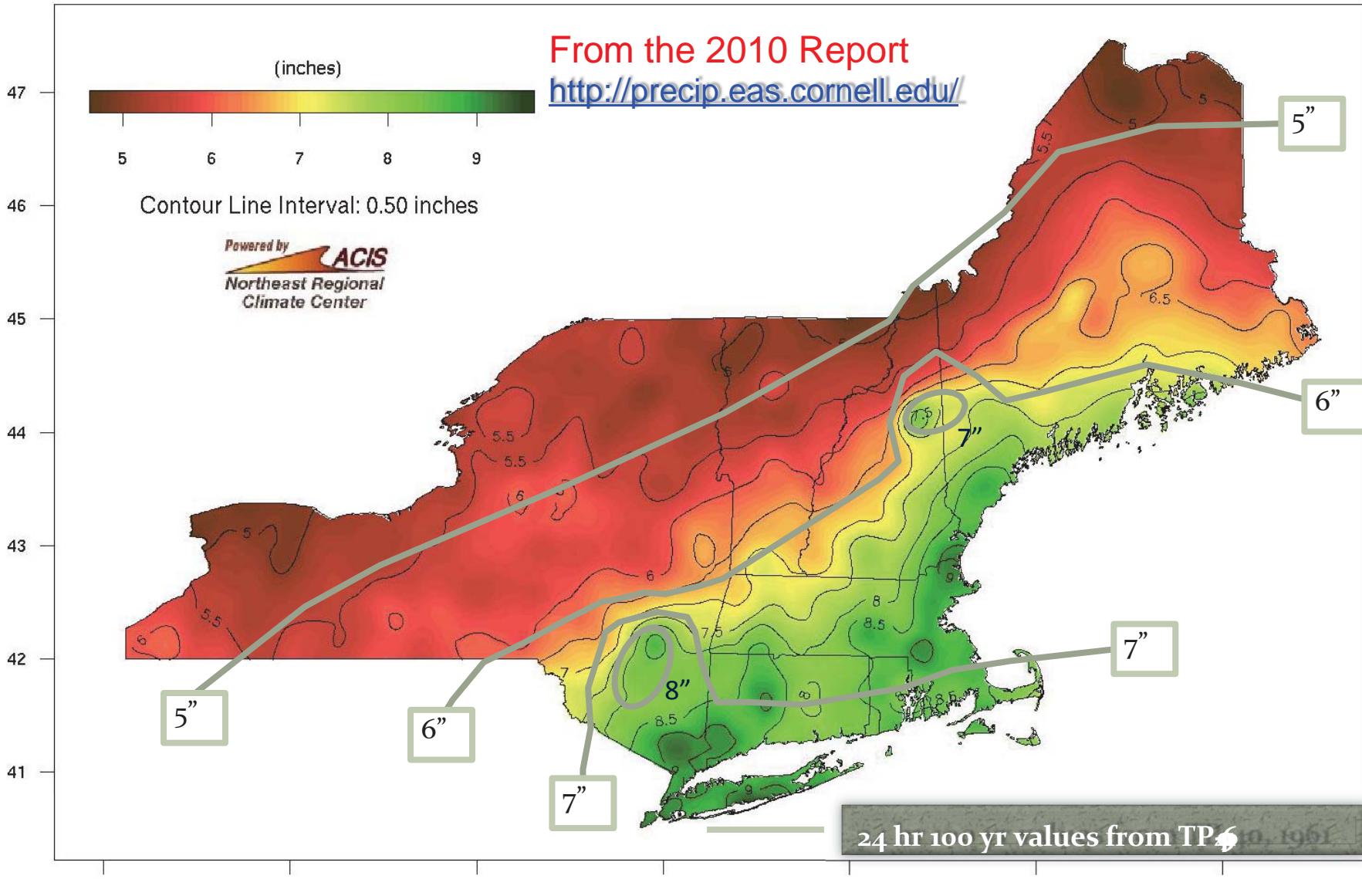


Changes in the Palmer Drought Index



Since the late 60s, similar signature of much shorter, less intense dry periods and longer higher amplitude wet periods

Extreme Precipitation Estimates 24hr 100yr



Southeast ½ of NE experience a 1 to 2 inch upward shift!

Trends in Flood Frequency: *From the Practitioner's perspective*

- Small watersheds feeling the effects
 - Changes in frequency/magnitude
 - Part land use/urbanization
 - Compounded by encroachment in the floodplain
 - Part changing climate
- Larger basins with flood control haven't seen as noticeable a shift
 - Most USACE reservoirs are built for 6-8 inch runoff events
 - Greater capacity to handle more rain



Dow Baseball Field, Main Street – Hope Valley
Photo: C. Fox



Kenyon Industries, Pawcatuck River
Photo: C. Fox



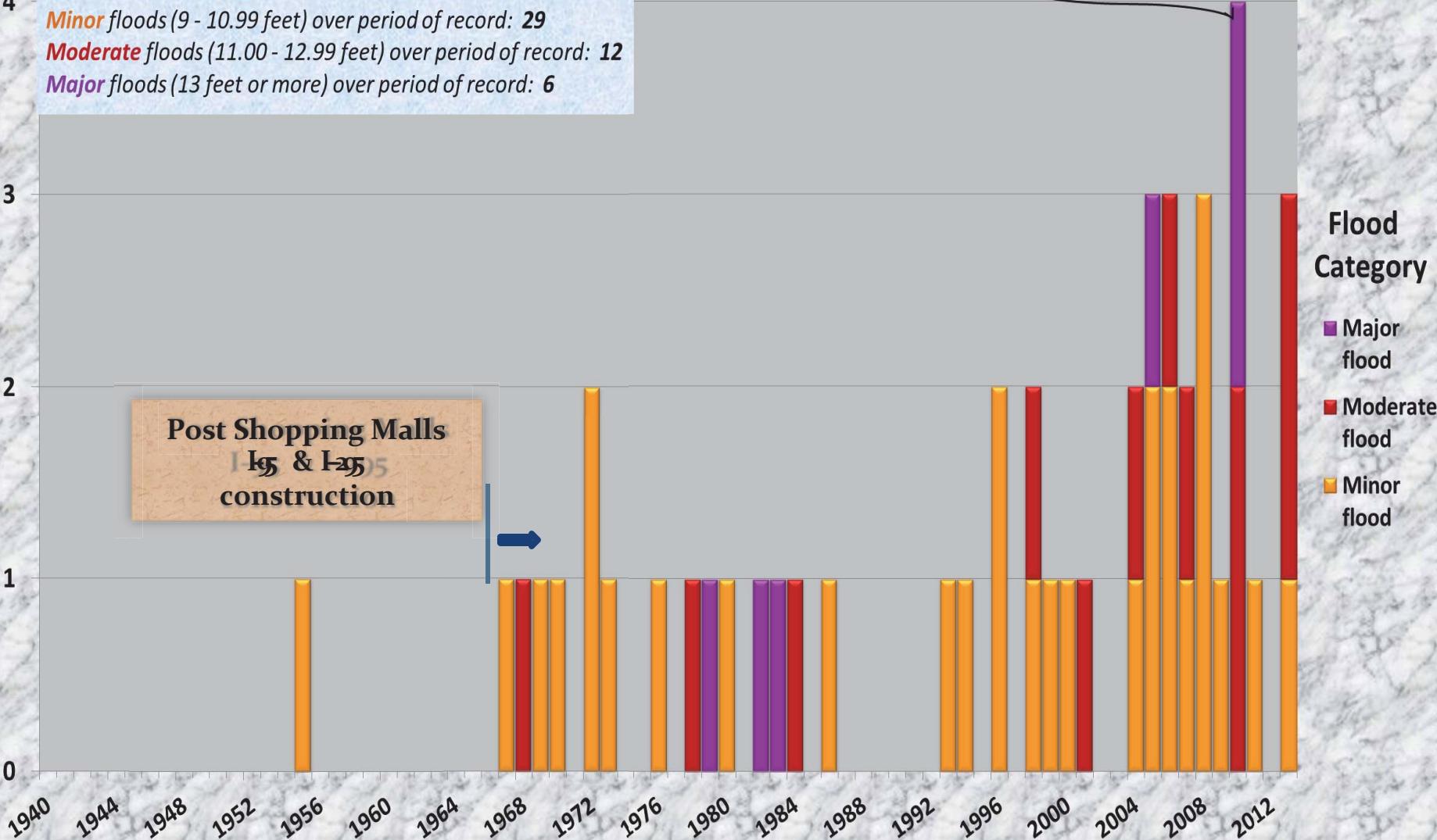
Number of Floods per Year by Flood Category for the Pawtuxet River at Cranston, RI

1940 - 2013

Data provided by
USGS
science for a changing world

Flood of record: 20.79 feet
on March 31, 2010

Minor floods (9 - 10.99 feet) over period of record: 29
Moderate floods (11.00 - 12.99 feet) over period of record: 12
Major floods (13 feet or more) over period of record: 6

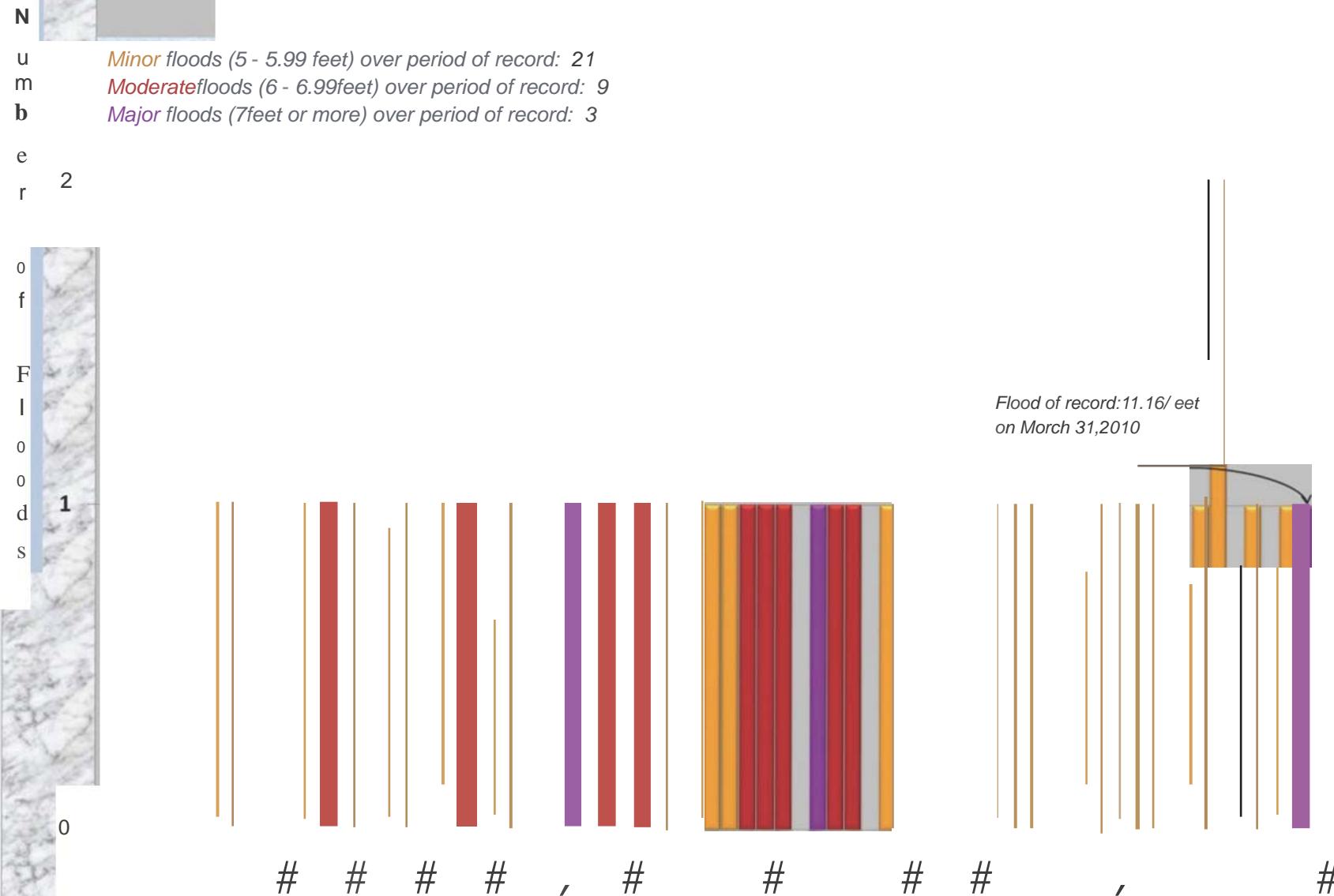




Number of Floods per Year by Flood Category for the Pawcatuck River at Wood River Junction, RI 1941 - 2013

Data provided by
 USGS
 science for a changing world

Minor floods (5 - 5.99 feet) over period of record: 21
 Moderate floods (6 - 6.99feet) over period of record: 9
 Major floods (7feet or more) over period of record: 3



Number of Floods per Year by Flood Category for the Wood River at Hope Valley, RI

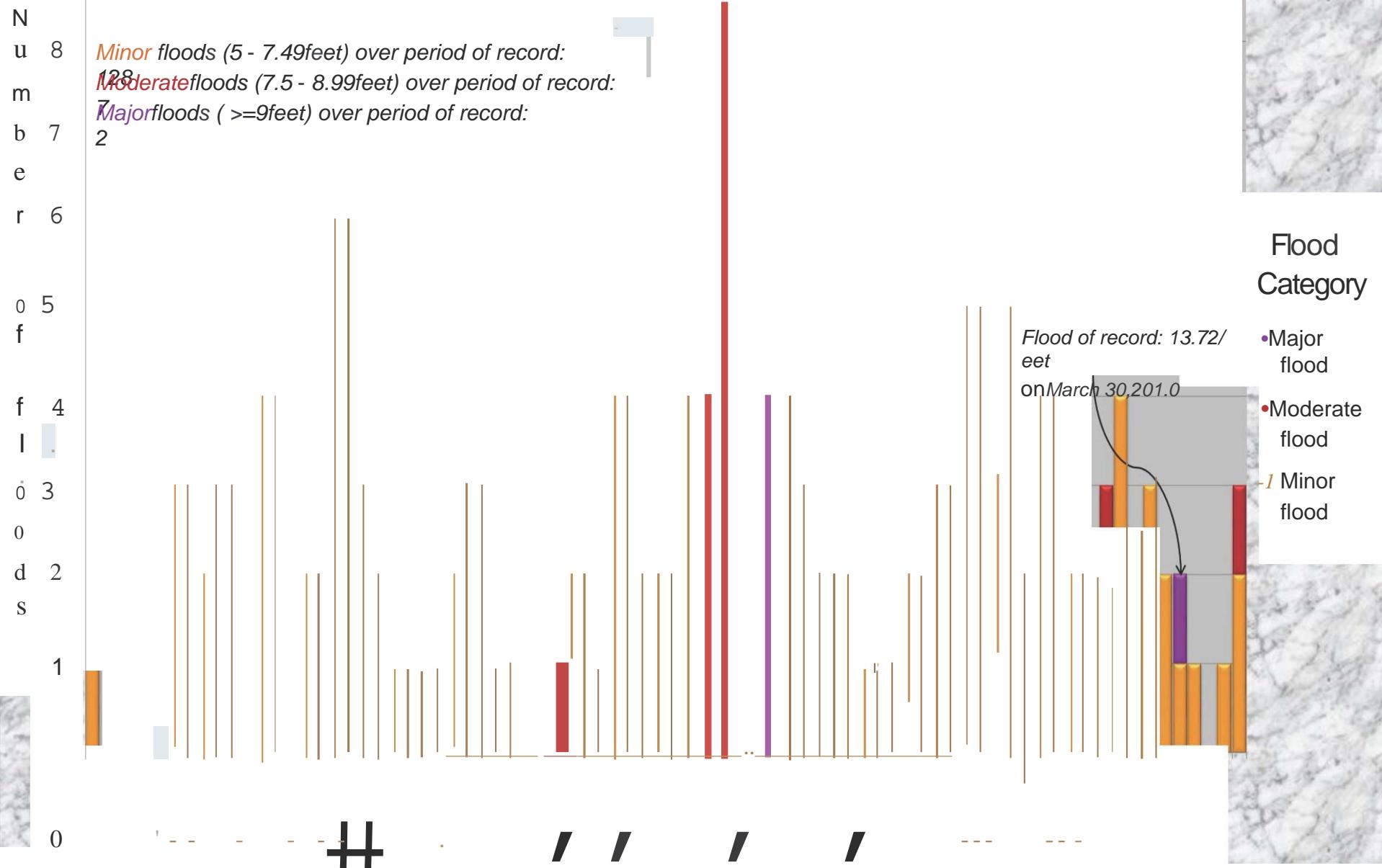
1936 - 2014

- Minor* floods (5 - 7.49feet) over period of record:
128
- Moderate*floods (7.5 - 8.99feet) over period of record:
7
- Major*floods (>=9feet) over period of record:
2

Flood
Category

- Major flood
- Moderate flood
- Minor flood

Flood of record: 13.72/
feet
on March 30, 2010.

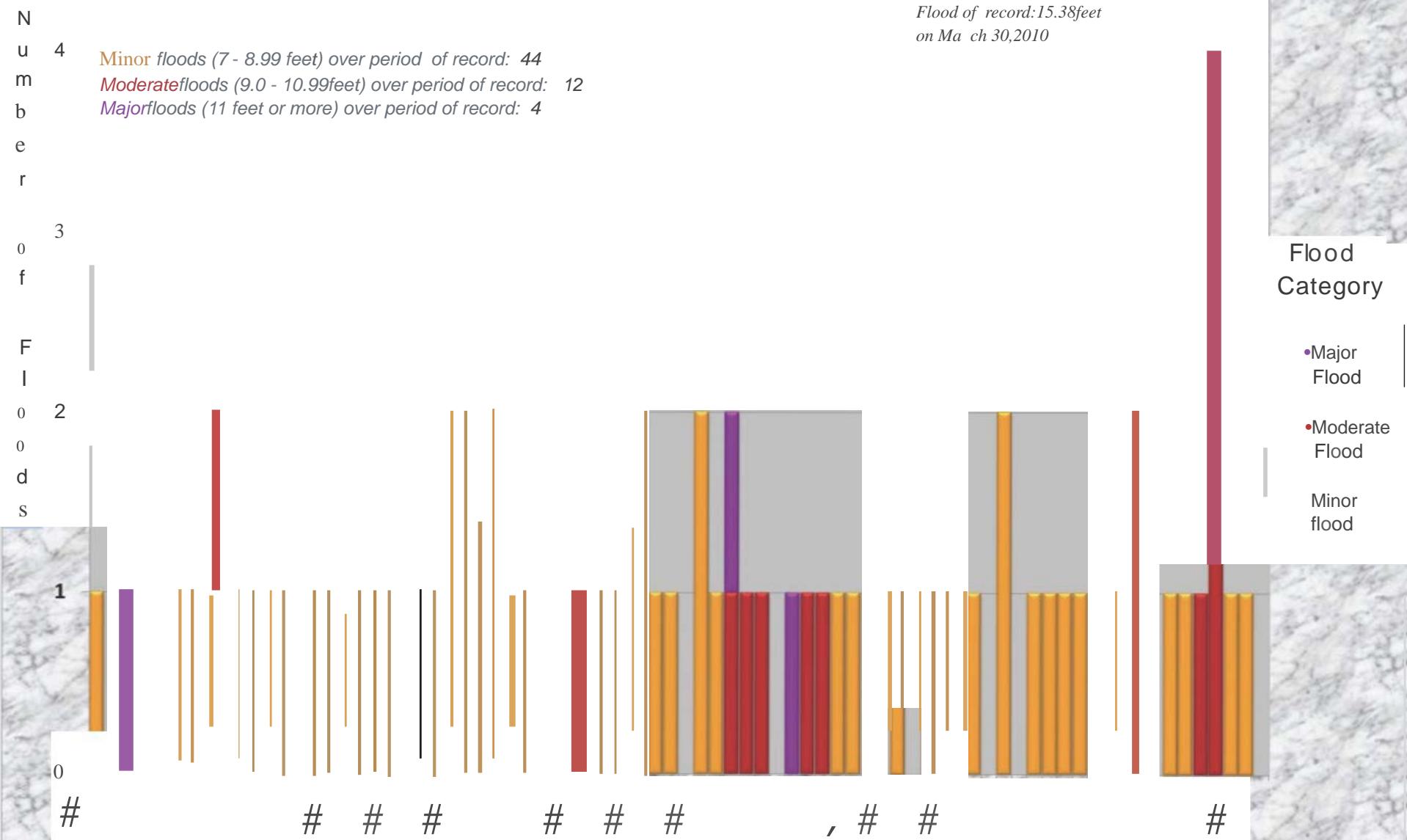




t j!}!}

Number of Floods per Year by Flood Category for the Pawcatuck River at Westerly, RI 1936 - 2013

*Flood of record: 15.38feet
on March 30, 2010*



Normalized Flood Frequency

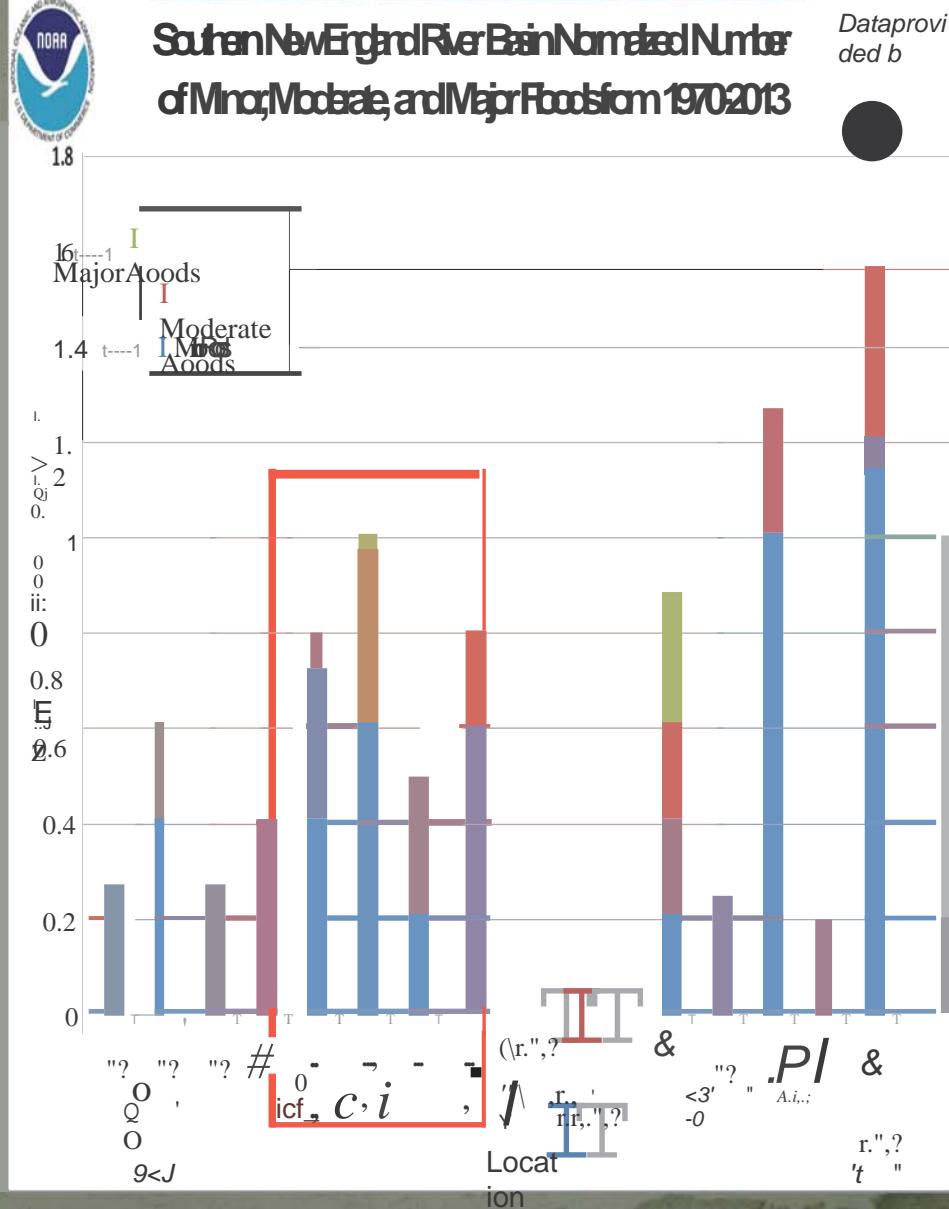
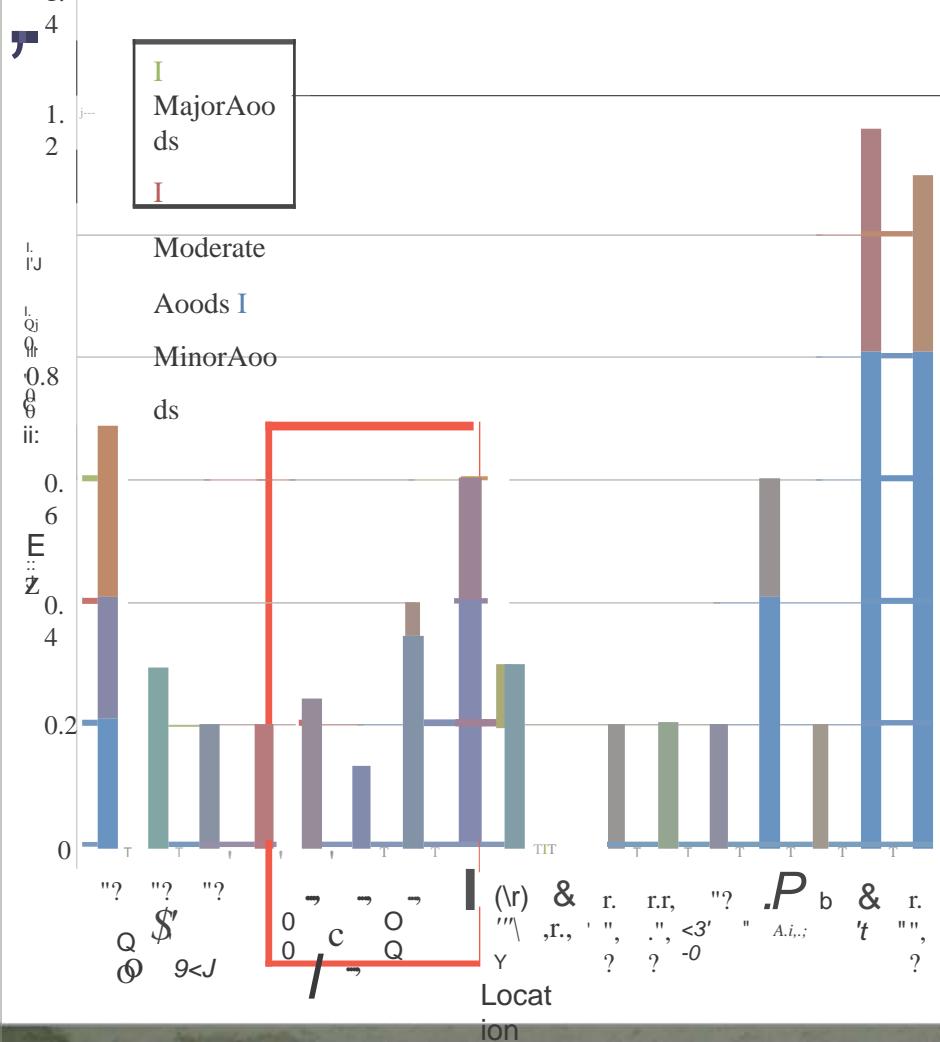
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i

Southern New England River Basin Normalized Number of Minor, Moderate, and Major Floods Prior to 1970



Southern New England River Basin Normalized Number of Minor, Moderate, and Major Floods from 1970-2013

Data provided by



Summary

- The Northeast has become a “hot spot” for record floods & heavy rainfall in the past 10 years
- Noticeable trends include increased yearly rainfall and increased annual temperatures
 - Southeast New England has experienced a 1 to 2 inch shift upwards in the 100 yr – 24 hour rainfall
- Smaller watersheds & those with significant urbanization are most vulnerable to increased river & stream flooding

Part II: Coastal Vulnerability– Lessons to learn from Sandy



IRENE



SANDY

- Irene: Widespread wind damage & power disruption in the east & devastating flooding rains in the west
 - “It’s all about the wind and rain!”
- Sandy: Significant coastal flooding but with less wind and little if any rain
 - “It’s all about the coastal flooding!”

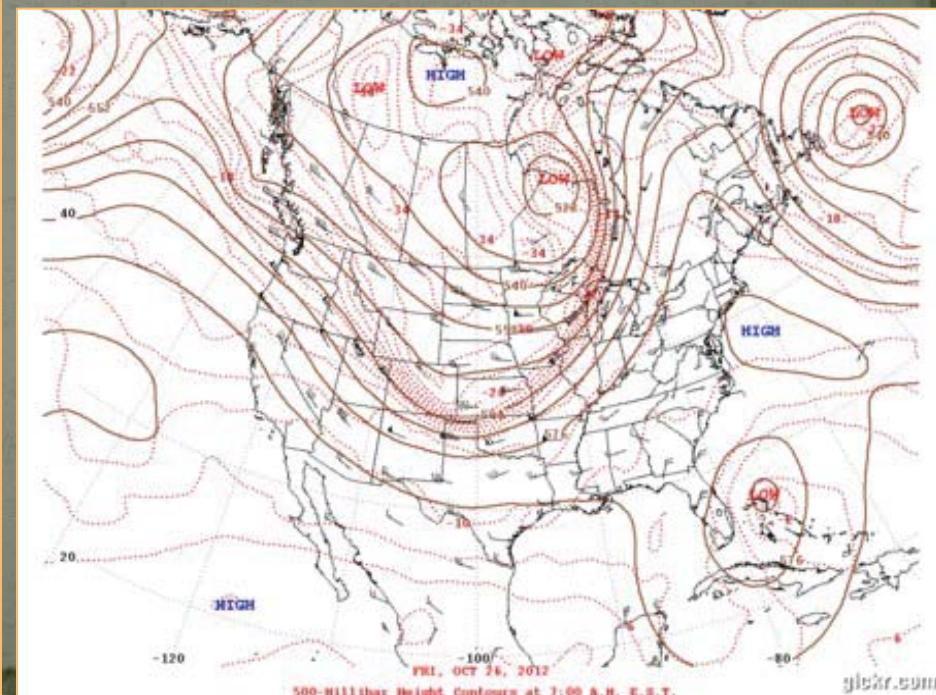
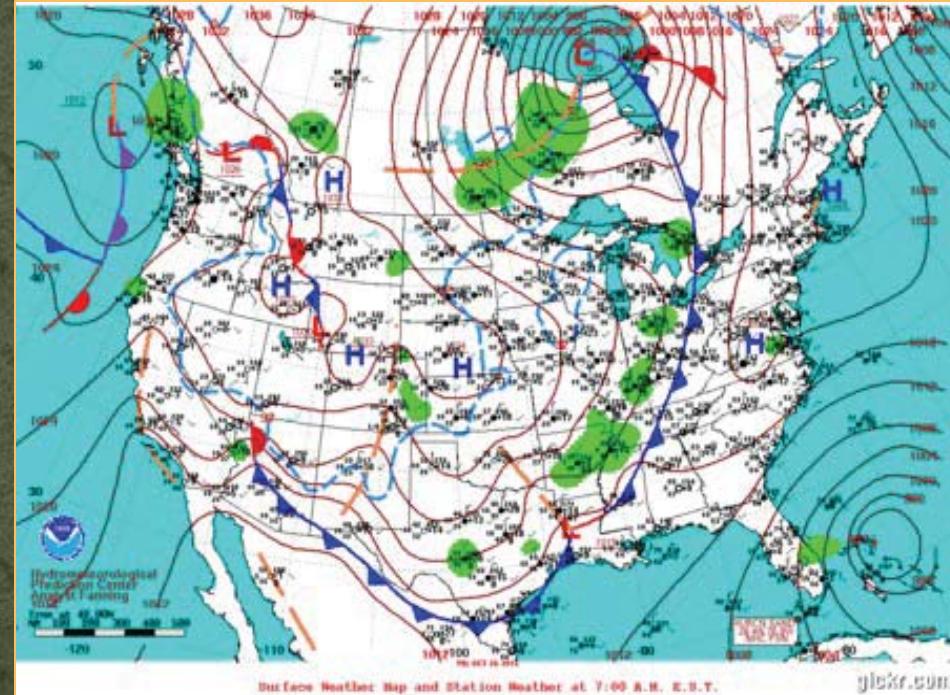
Sandy: A Perfect Storm of Sorts

- Formed in the western Caribbean

- Not at all unusual for late October

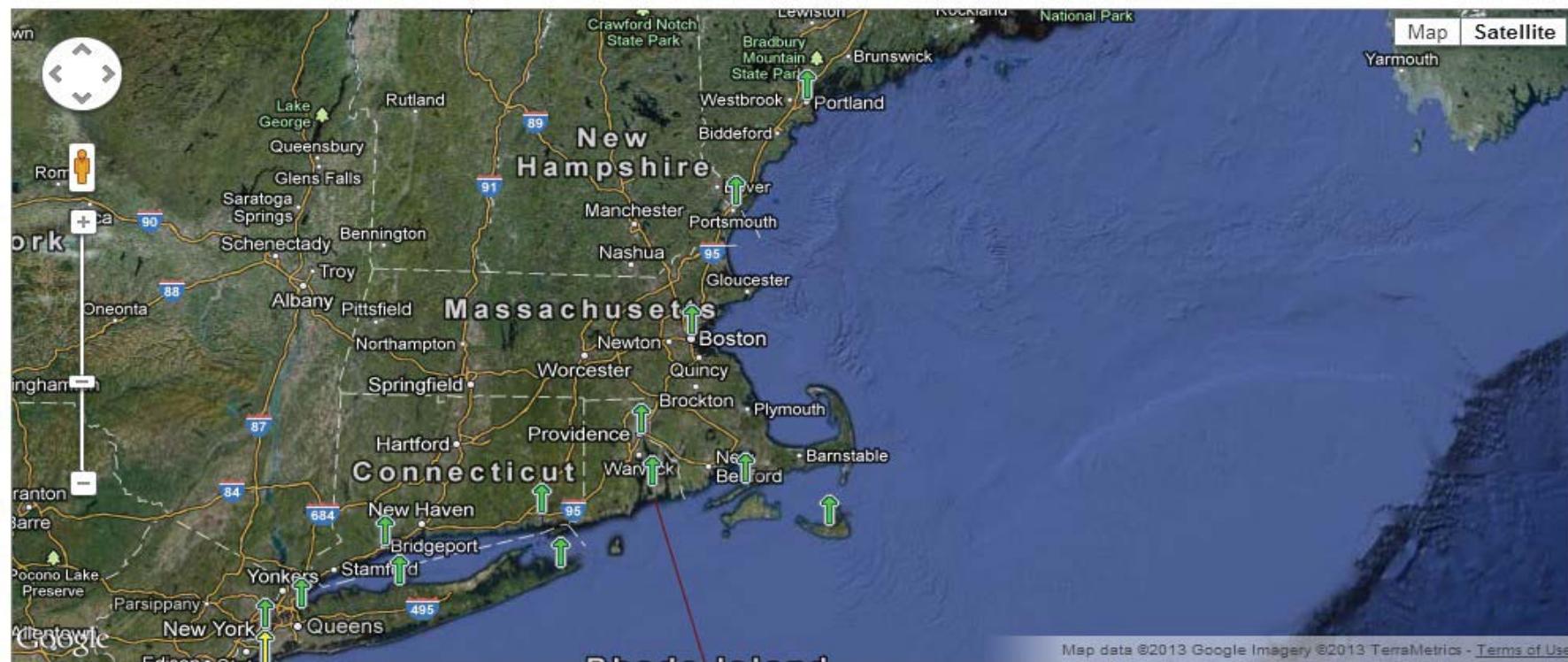
- Encountered a very deep trough of Low Pressure in the eastern United States and very strong High Pressure moving southward from the Canadian Maritimes

- A winter-like dual jet stream set up (classic for a New England Hurricane)
 - Captured Sandy & blocked her attempt to race out to sea



Sea Levels Online

East Coast West Coast Gulf Coast Alaska Hawaii Global



The map above illustrates regional trends in sea level, with arrows representing the direction and magnitude of change. Click on an arrow to access additional information about that station.

Sea Level Trends mm/yr (feet/century)

15 to 21 (5 to 7)	6 to 9 (2 to 3)	-3 to 0 (-1 to 0)	-12 to -9 (-4 to -3)
12 to 15 (4 to 5)	3 to 6 (1 to 2)	-6 to -3 (-2 to -1)	-15 to -12 (-5 to -4)
9 to 12 (3 to 4)	0 to 3 (0 to 1)	-9 to -6 (-3 to -2)	-18 to -15 (-6 to -5)

<http://tidesandcurrents.noaa.gov/slrends/index.shtml>



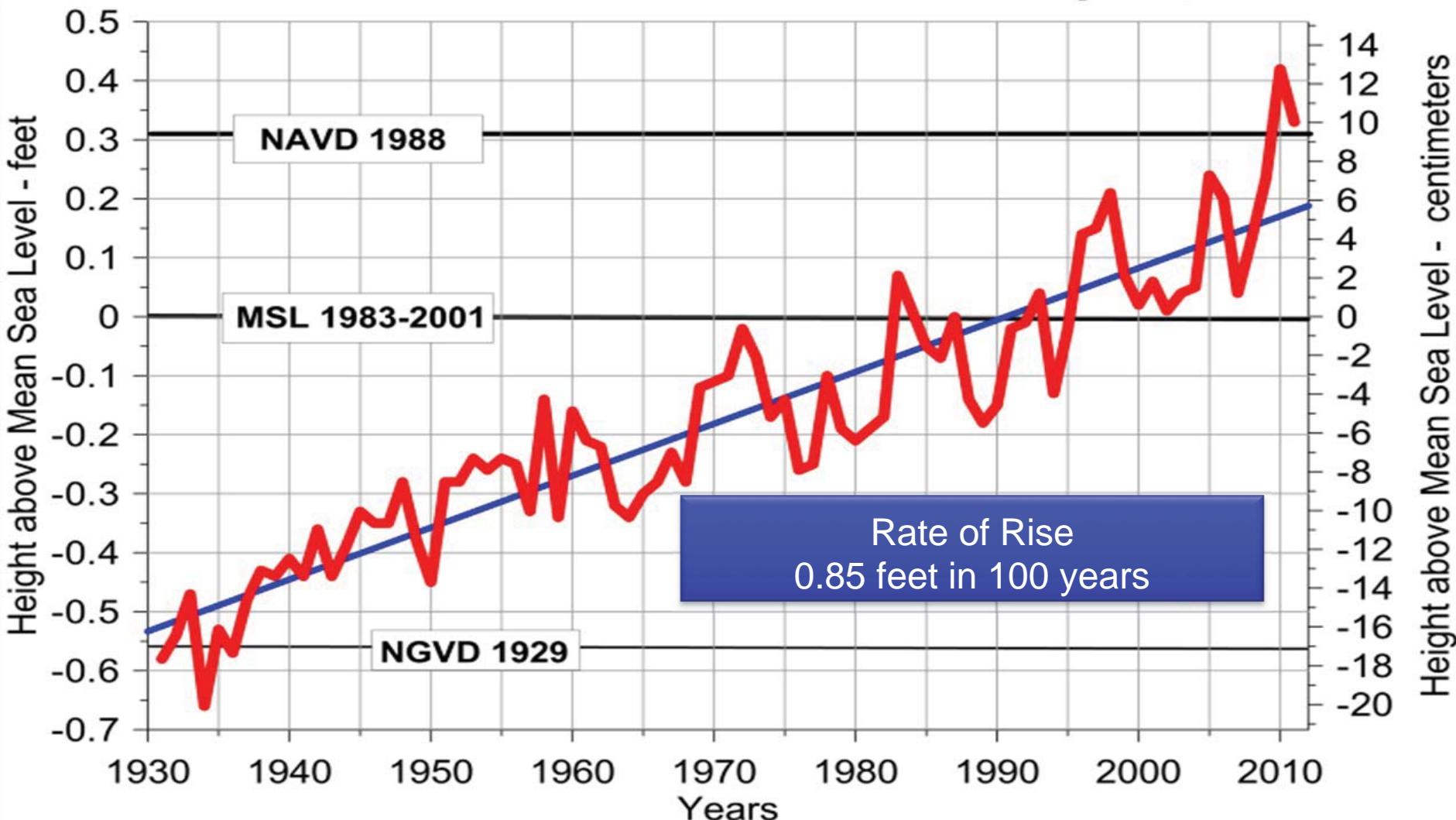
National Oceanic and Atmospheric Administration's
National Weather Service

Northeast River Forecast Center



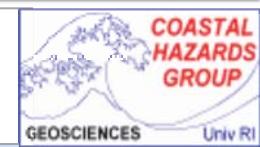
Sea Levels Are Increasing

HISTORIC SEA-LEVEL RISE - Newport, RI

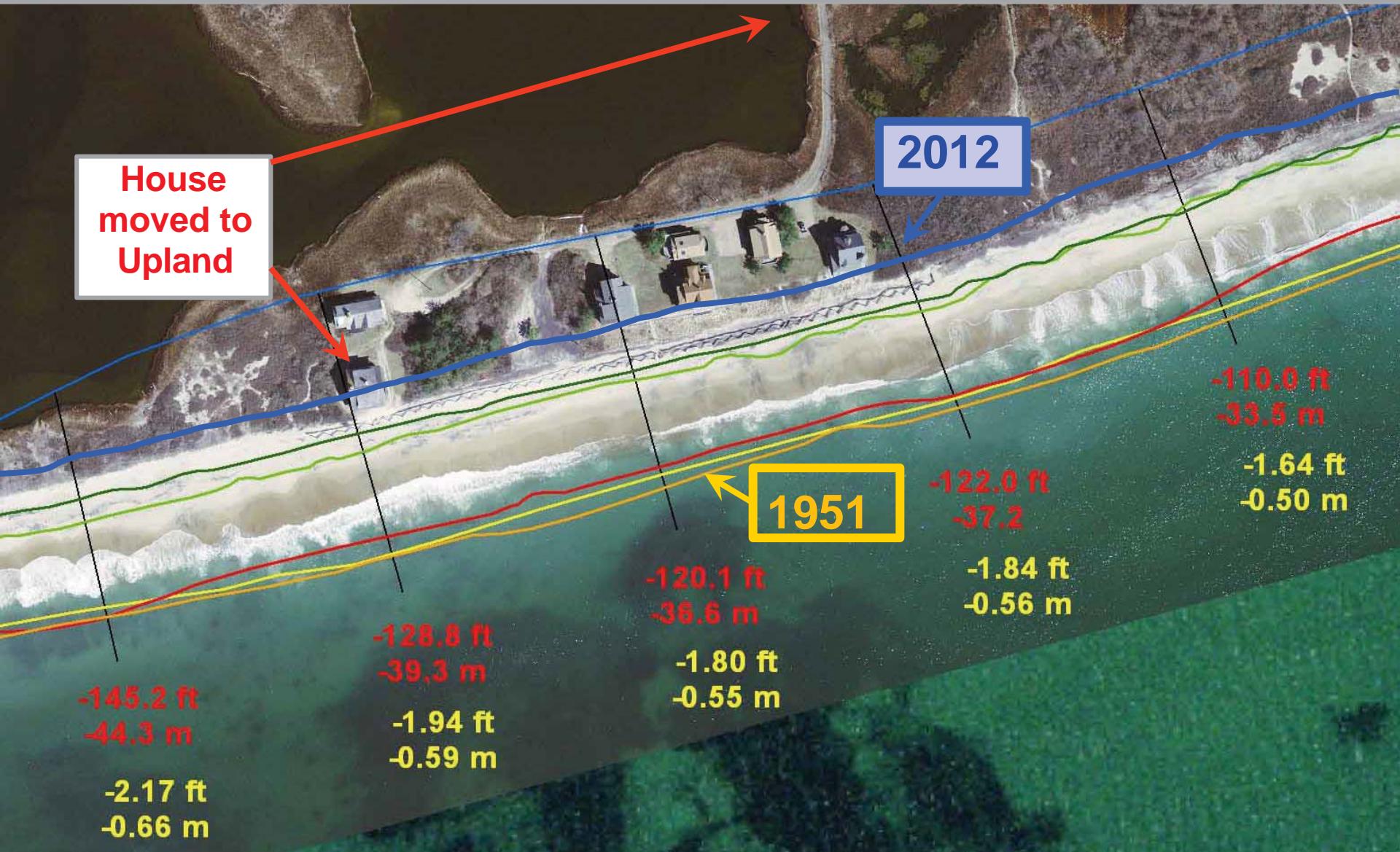


Adapted from:

[http://tidesandcurrents.noaa.gov/slrends/
slrends_station.shtml?stnid=8452660%20Newport,%20RI](http://tidesandcurrents.noaa.gov/slrends/slrends_station.shtml?stnid=8452660%20Newport,%20RI)



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



Superstorm Sandy - Browning Cottages



30 Oct 2012

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

Misquamicut Before Sandy



Misquamicut After Sandy



Damage along Atlantic Avenue

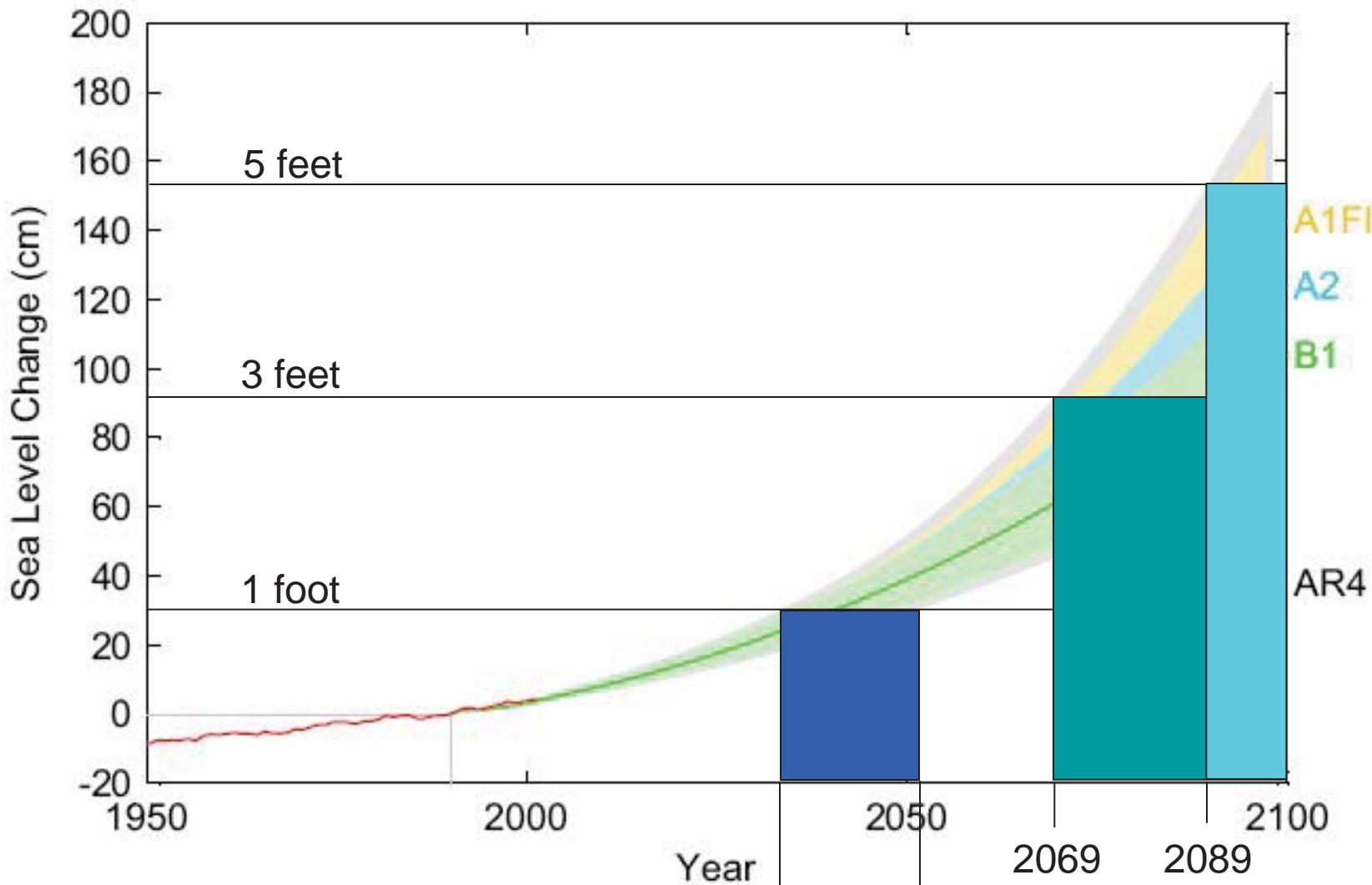
What went in the ocean side – came out the street side!



What did it look like?



Future Sea level Rise



Vermeer and Rahmstorf, 2009

National Oceanic and Atmospheric Administration's
National Weather Service





Imagery

Streets

Share Map

Zoom to: State or Territory



▼



Imagery

Streets

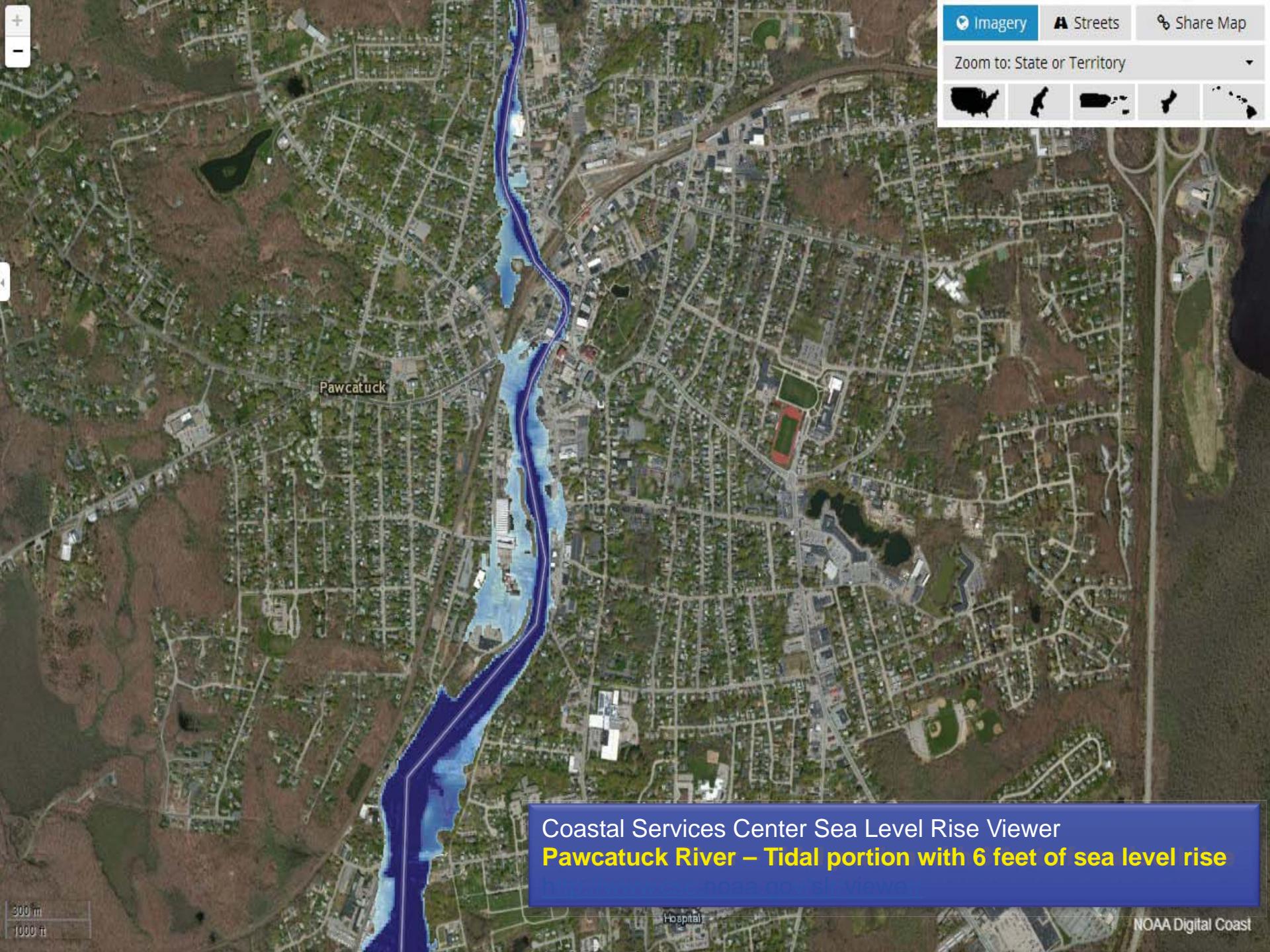
Share Map

Zoom to: State or Territory



+ -

500 m
2000 ft



Summary



IRENE

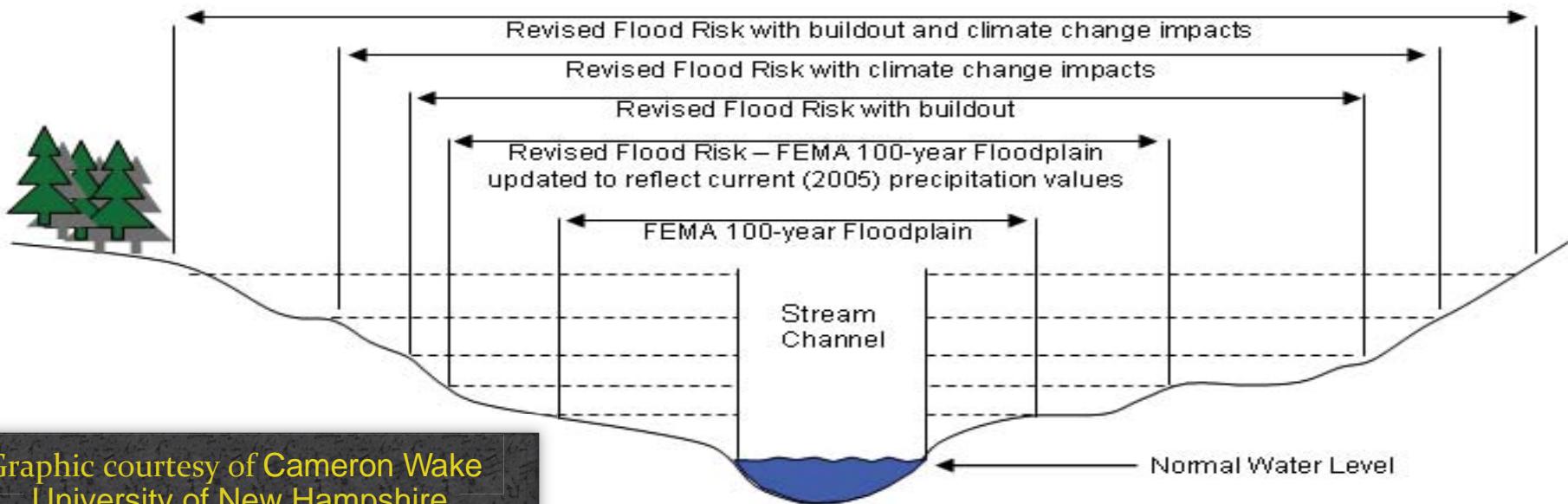


SANDY

- We are a tremendously vulnerable region
 - Planning is of the utmost importance – it must reflect storm events that will undoubtedly far exceed the damage from Irene & Sandy
- Shifts in precipitation frequency & inland flood behavior
 - Expect heavier rain events and an increase in flood events
- Impacts of Sea Level Rise and Erosion
 - Consider: Category 2 Hurricane producing inundation & damage comparable to what a Category 3 would have done 50 years ago!

Far reaching implications: *Protect, Adapt or Retreat???*

- Floodplain, land use, infrastructure, dam spillway requirements, drainage requirements, nonpoint source runoff, bridge clearances, “hardening” of critical facilities in the floodplain, property values etc...
- Flood Insurance – work to increase participation
- How much risk are we willing to insure and accept?



Graphic courtesy of Cameron Wake
University of New Hampshire

Climate Trends in Rhode Island and Its Impact on Riverine & Coastal Flood Behavior

THANK YOU!

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