

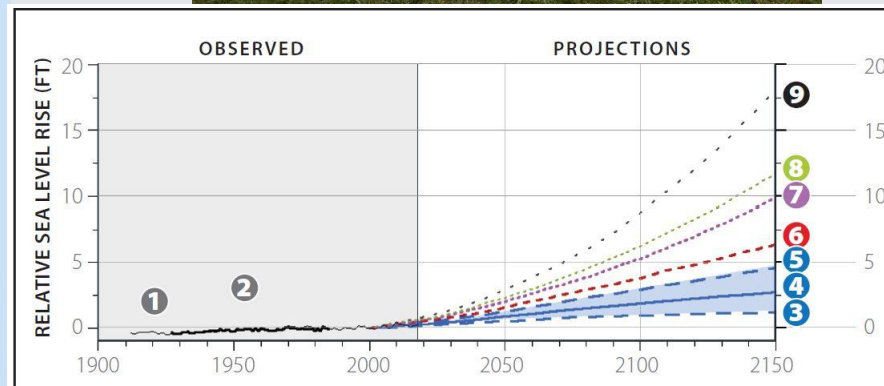
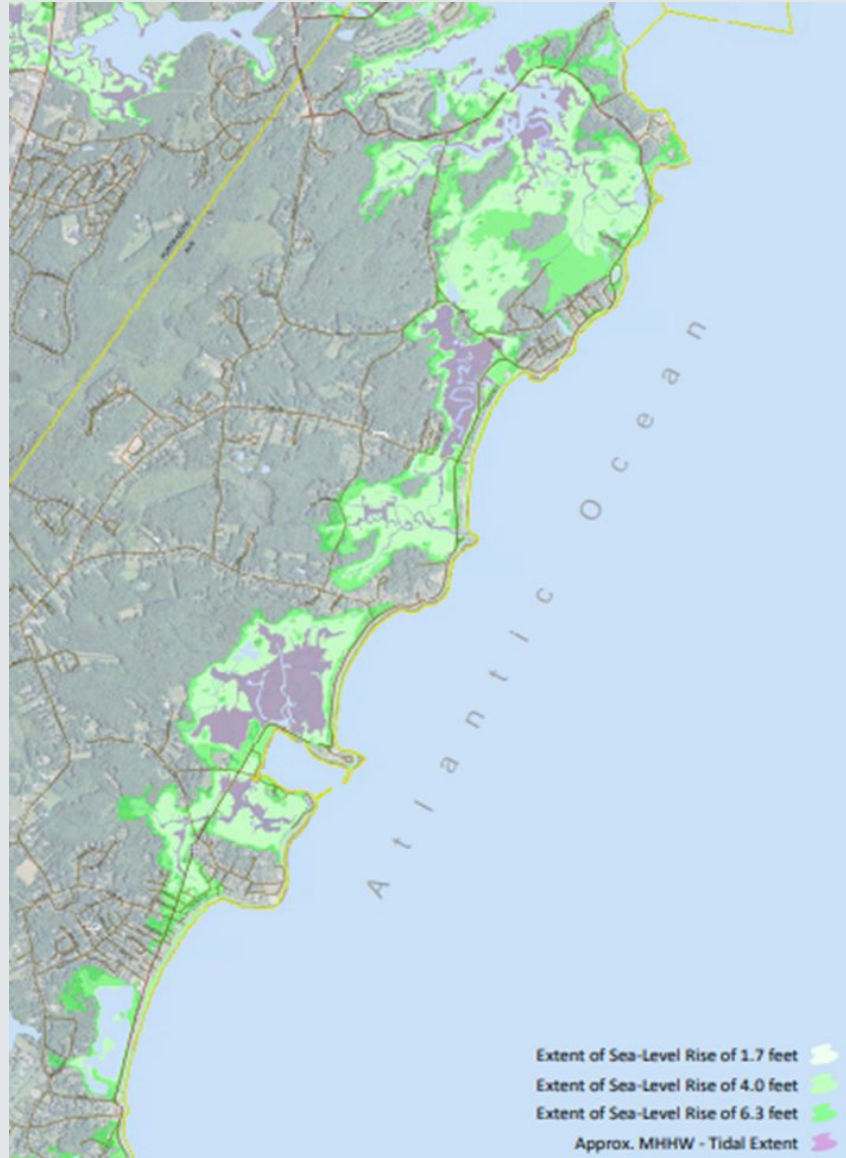
# The Future is Now: Being Resilient to Sea Level Rise and Extreme Weather

Northern New England  
Planning Conference  
November 6 – 8, 2023  
Wentworth by the Sea  
New Castle, NH





# How do we communicate Sea Level Rise?



**Figure 4.5.** Observed and Projected Relative Sea-Level Rise for Seavey Island Tide Gauge K14 Projections | Stabilized Greenhouse Gas Concentrations (RCP 4.5).

- ① Historical data for Portland, ME (1912-2018; thin black line)
- ② Historical data for Seavey Island, ME (1927-1986; thick black line)
- ③ Lower end of "likely range"
- ④ Central estimate
- ⑤ Upper end of "likely range"
- ⑥ 1-in-20 chance estimate
- ⑦ 1-in-100 chance estimate
- ⑧ 1-in-200 chance estimate
- ⑨ 1-in-1000 chance estimate





**High Tide, Swasey Parkway in Exeter.  
December 23, 2067.**



# The Story Map's Purpose

- Document the extent and severity of coastal flooding from the high tide and storm surge
- Provide visual for future Sea Level Rise
- Improve communication for future storm events/ SLR
- Improve flood forecasts products developed by the National Weather Service
- Inform investment in coastal resilience projects.



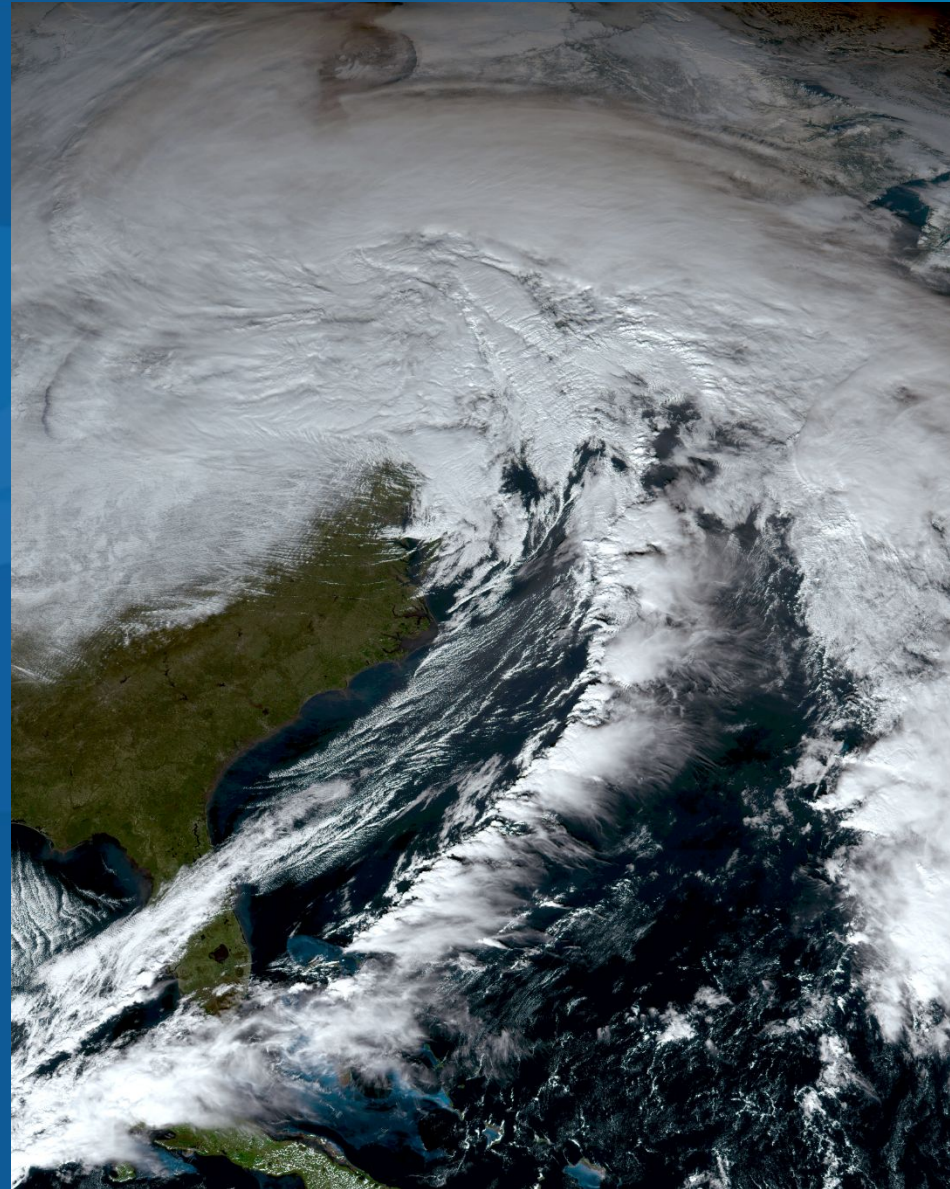




# December 23rd, 2022 “Sou’easter”

11/8/2023

Donny Dumont  
Warning Coordination Meteorologist  
National Weather Service, Gray, ME

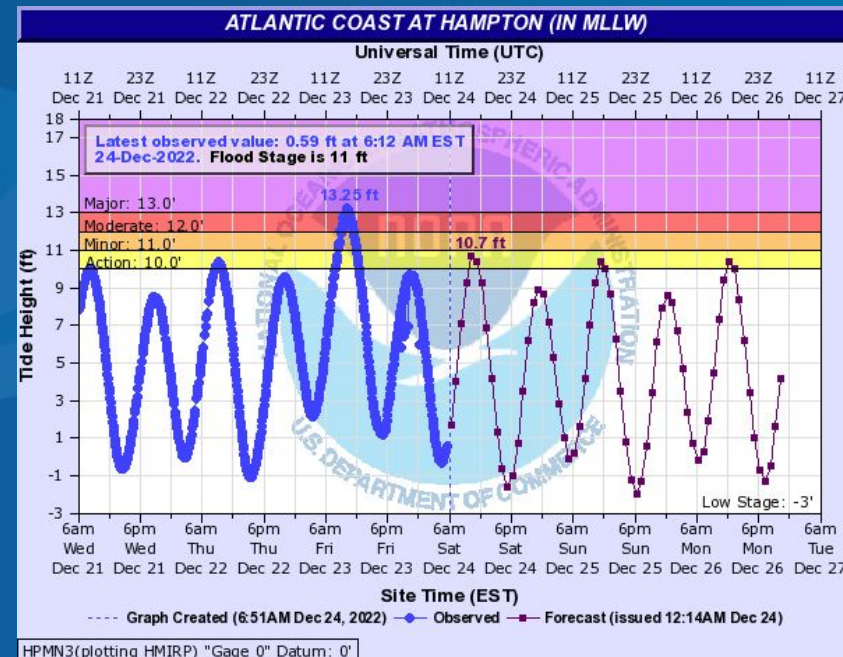
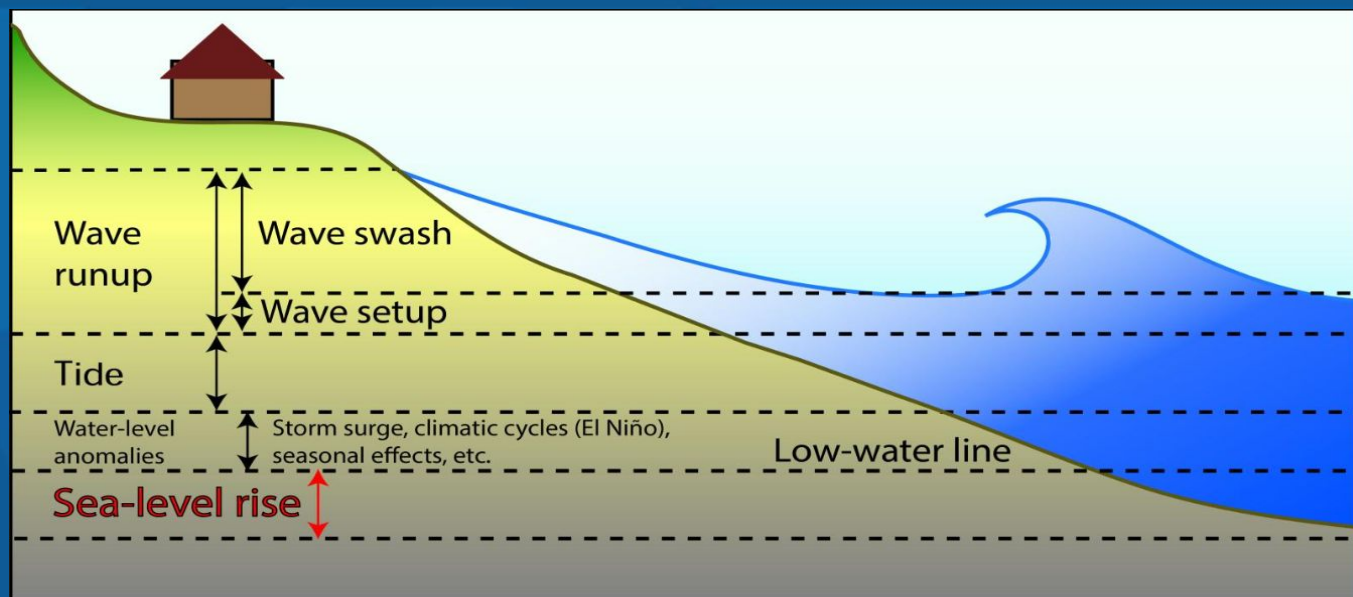






# Coastal Flood Alignment

Major coastal flood events in the Gulf of Maine are all about alignment!!!



Tide  
(low/high)



Storm  
Surge



Wave  
Runup



HAT

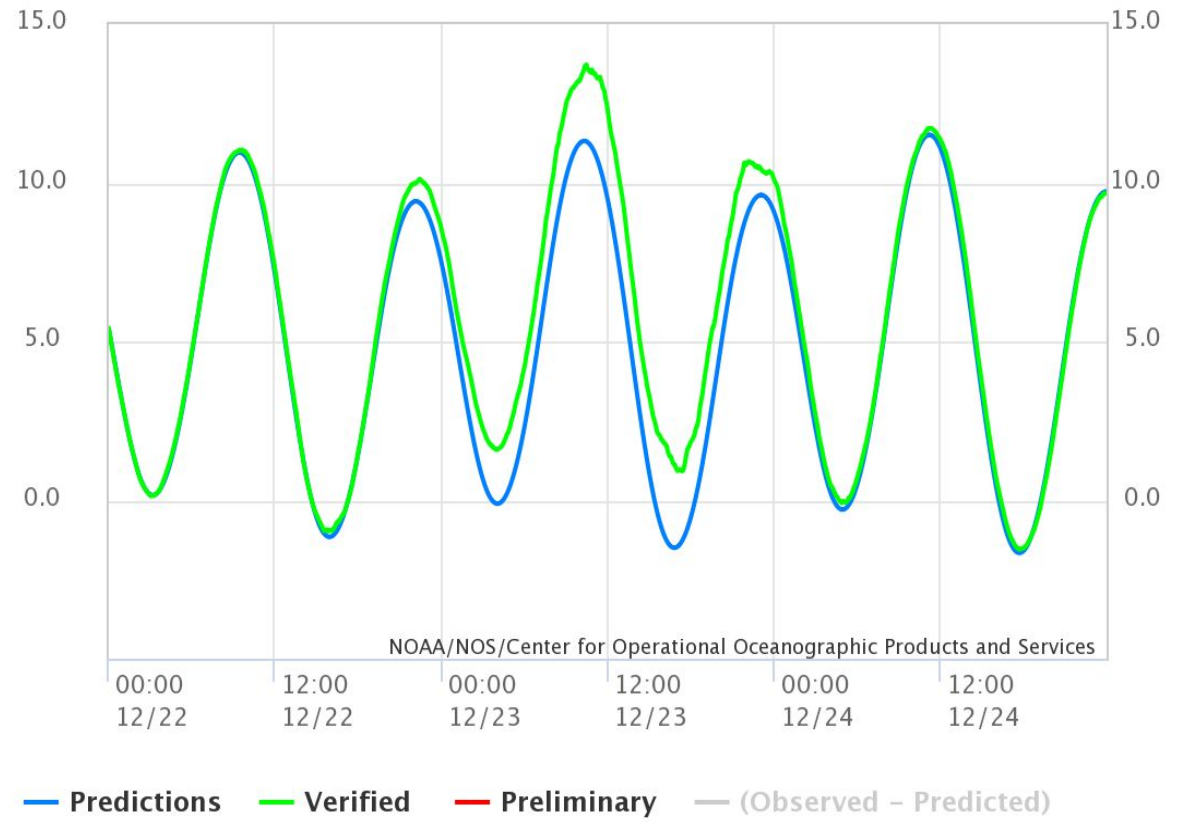




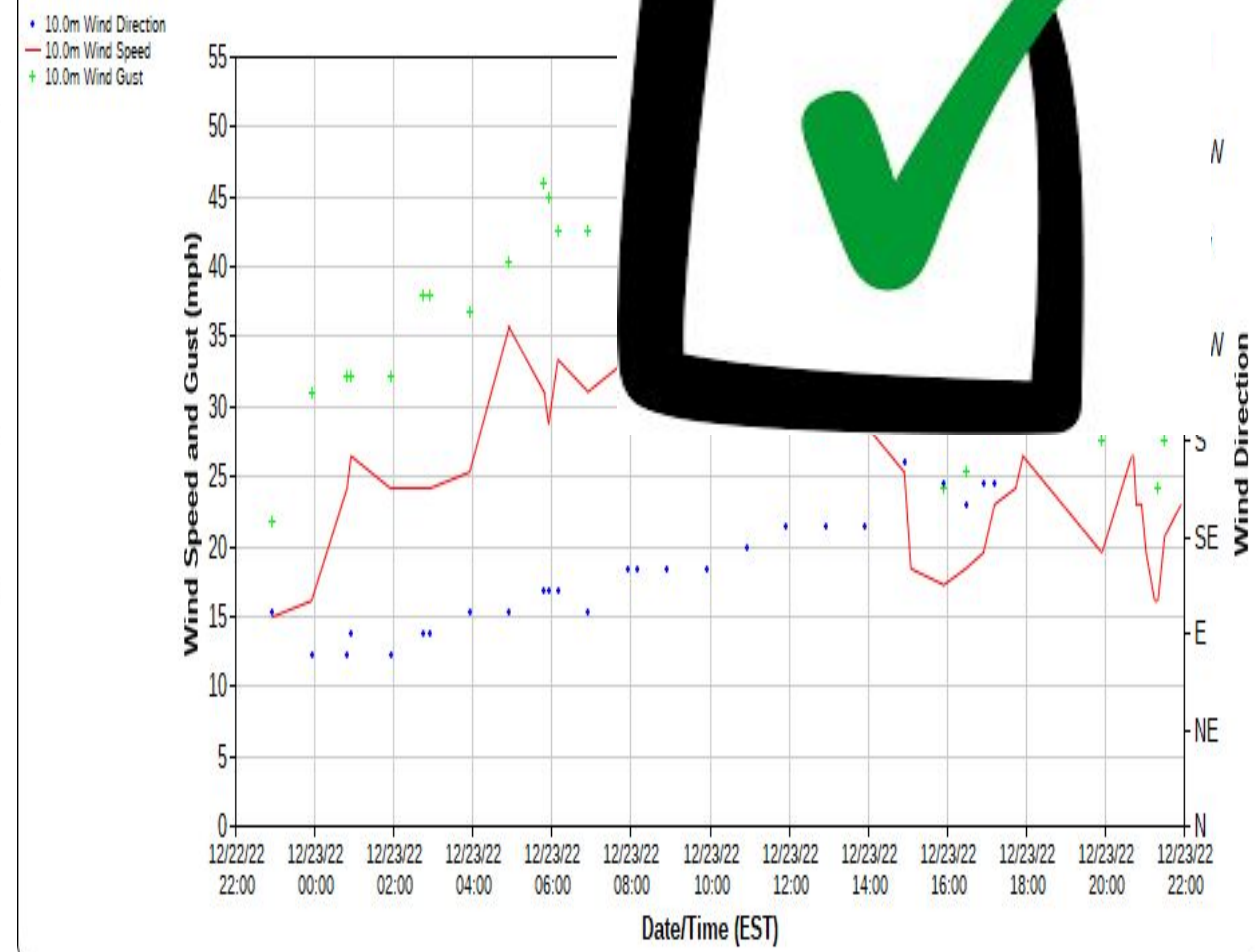
# The Ingredients - Tide

## Did the Storm Peak at High Tide?

NOAA/NOS/CO-OPS  
Observed Water Levels at 8418150, Portland ME  
From 2022/12/22 00:00 LST/LDT to 2022/12/24 23:59 LST/LDT



Pease Air Force Base



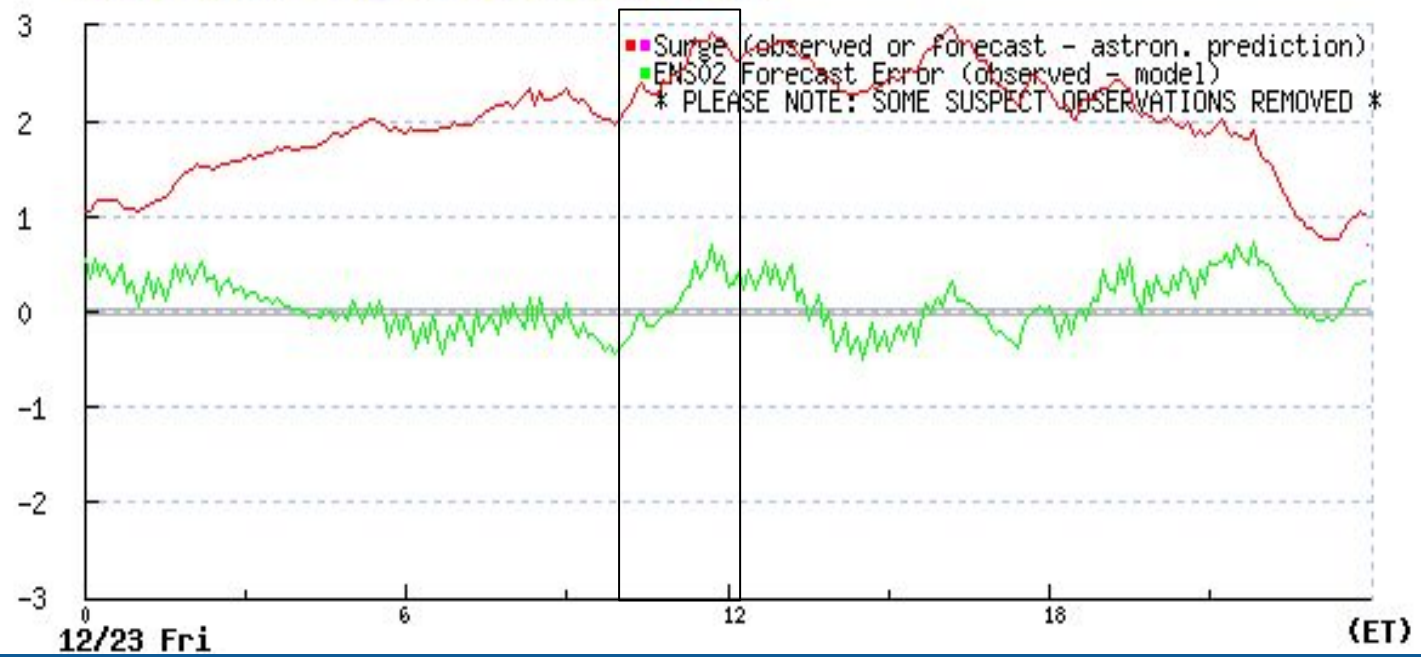




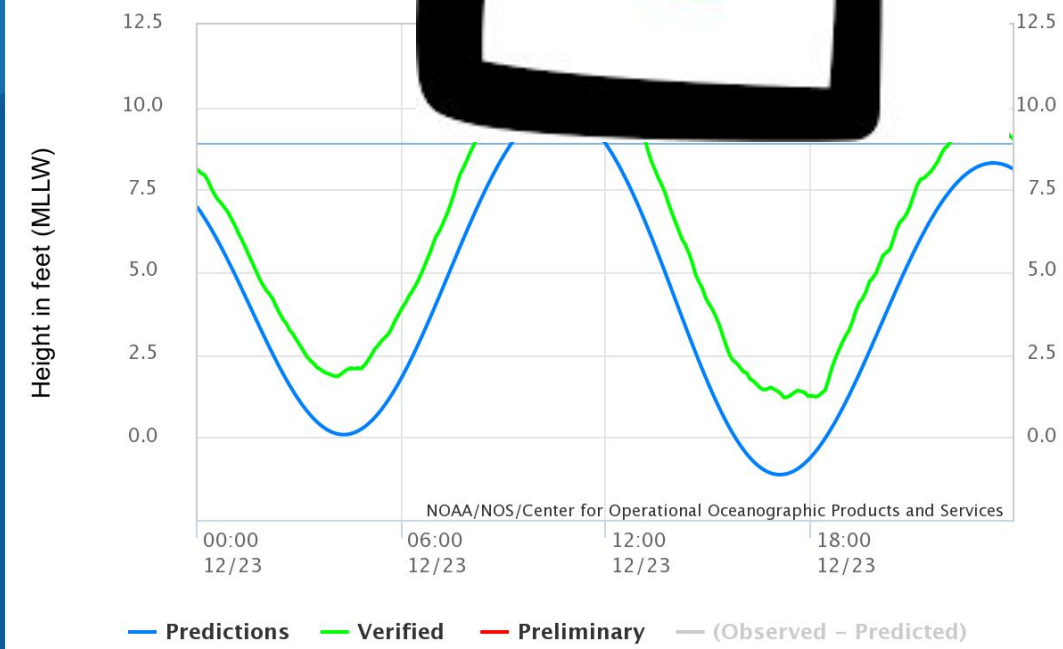
# The Ingredients - Surge

## Did the Storm Surge Occur at High Tide?

Portland ME - Surge and model error (ft)



Observed Water  
From 2022/12

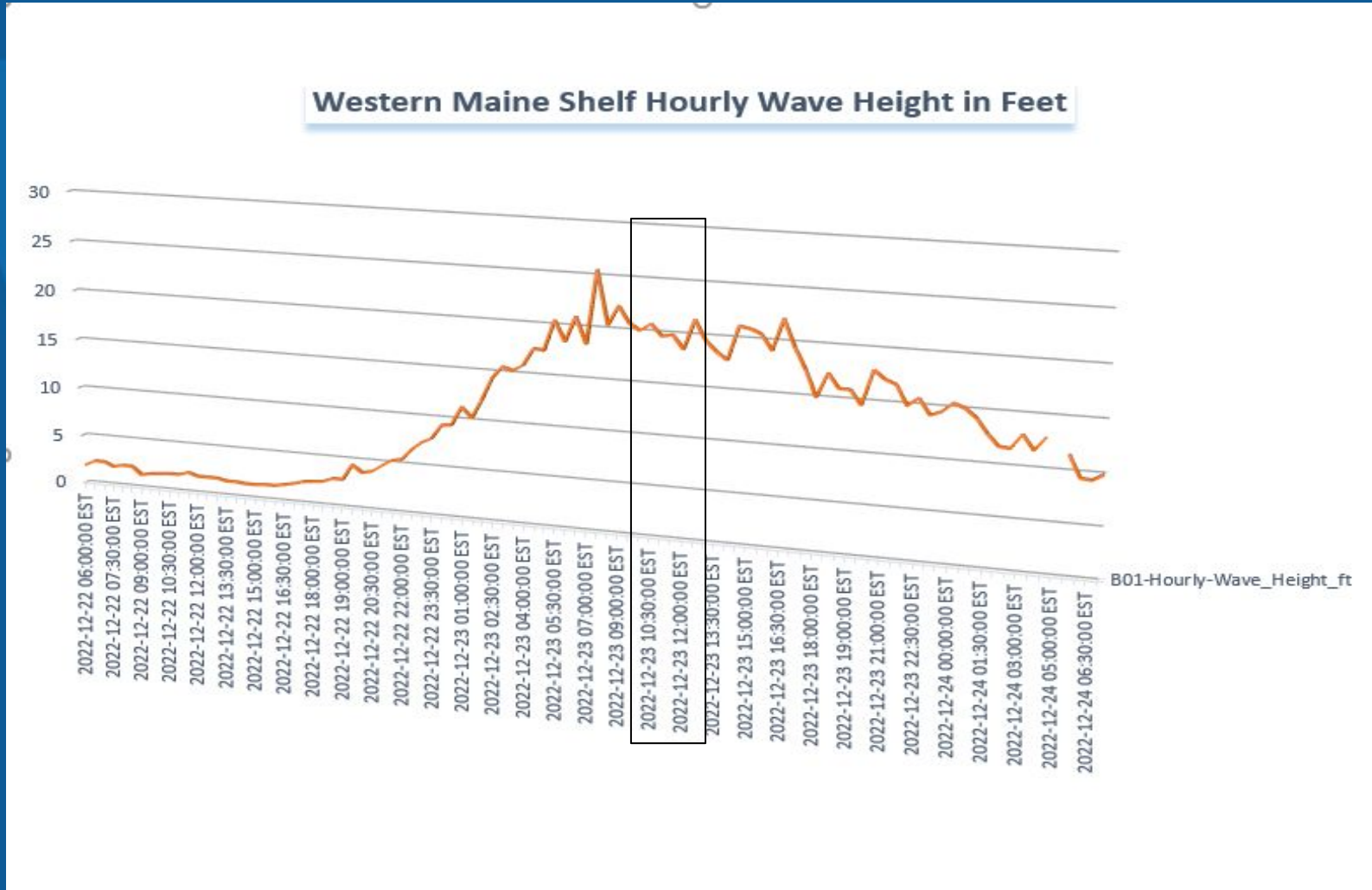






# The Ingredients - Waves

Did the Large Waves Occur at High Tide?







# The Ingredients - HAT

Did the storm occur during a High Astronomical Tide (HAT) Period?

If the same storm hit on Dec 14th, the water level at Hampton would of been around 10.2 feet, barely above action stage.

The HAT variability of 3 feet in the month of December was = to the 2.9 ft of storm surge for the event.



Date	High											
	AM	ft										
1	Thu	5:20	8.3									
2	Fri	6:23	8.5									
3	Sat	7:22	8.7									
4	Sun	8:16	9.0									
5	Mon	9:04	9.2									
6	Tue	9:48	9.2									
7	Wed	10:30	9.2									
8	Thu	11:10	9.1									
9	Fri	11:49	9.0									
10	Sat	12:30	7.8									
11	Sun	1:09	7.7									
12	Mon	1:49	7.5									
13	Tue	2:31	7.4	2:28	8.2	8:35	1.6	9:13	0.7	7:04	4:06	☾
14	Wed	3:15	7.3	3:15	8.0	9:21	1.7	9:57	0.8	7:05	4:06	☾
15	Thu	4:01	7.4	4:05	7.8	10:12	1.7	10:43	0.9	7:05	4:06	☾
16	Fri	4:48	7.5	4:57	7.6	11:04	1.6	11:29	1.0	7:06	4:06	☾
17	Sat	5:35	7.7	5:52	7.6	11:59	1.4			7:07	4:07	☾
18	Sun	6:23	8.1	6:49	7.6	12:18	1.0	12:55	1.0	7:07	4:07	☾
19	Mon	7:13	8.5	7:45	7.8	1:10	0.9	1:51	0.5	7:08	4:07	☾
20	Tue	8:02	9.0	8:39	8.0	2:01	0.7	2:45	0.0	7:09	4:08	☾
21	Wed	8:50	9.5	9:31	8.3	2:52	0.4	3:36	-0.6	7:09	4:08	☾
22	Thu	9:39	10.0	10:22	8.6	3:42	0.1	4:26	-1.1	7:10	4:09	☾
23	Fri	10:30	10.3	11:14	8.8	4:32	-0.1	5:17	-1.4	7:10	4:09	☾
24	Sat	11:22	10.5			5:24	-0.3	6:09	-1.5	7:10	4:10	☾
25	Sun	12:07	8.9	12:15	10.5	6:17	-0.3	7:02	-1.5	7:11	4:10	☾
26	Mon	1:00	8.9	1:10	10.3	7:12	-0.3	7:55	-1.3	7:11	4:11	☾
27	Tue	1:55	8.8	2:07	9.9	8:09	-0.1	8:51	-1.0	7:11	4:12	☾
28	Wed	2:53	8.7	3:08	9.4	9:10	0.1	9:49	-0.6	7:12	4:12	☾
29	Thu	3:54	8.7	4:12	8.8	10:14	0.3	10:48	-0.2	7:12	4:13	☾
30	Fri	4:54	8.6	5:17	8.3	11:21	0.5	11:47	0.3	7:12	4:14	☾





# Unique Aspect of Storm

- Majority of notable coastal flood storms are usually large Nor'easters.
- This storm was unique due to the quick hitting westward track it took and the southeast wind direction.
  - Single tide cycle flooding would be similar to a tropical cyclone
  - The longevity of a constant wind fetch was favorable for large nearshore waves

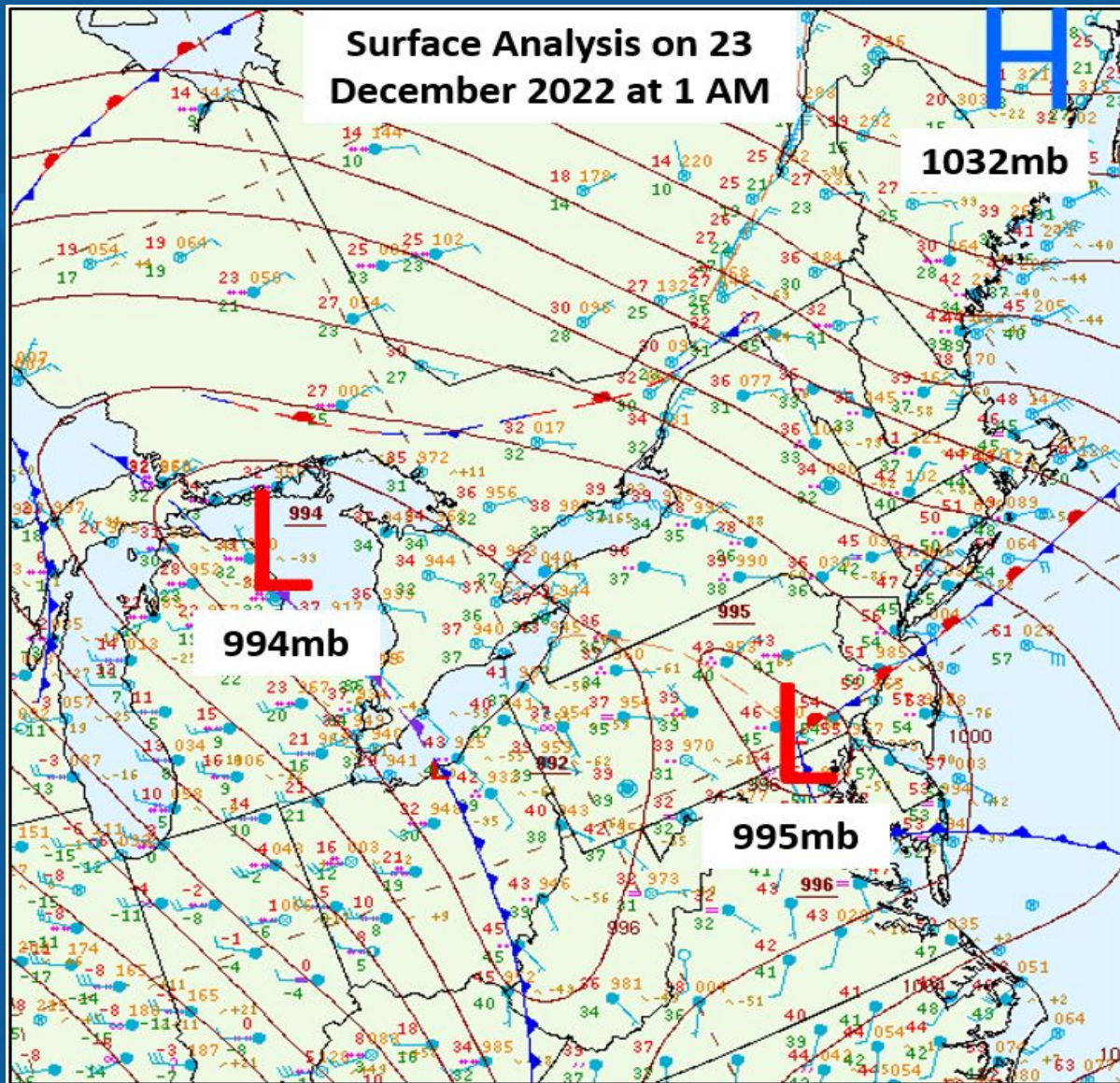
ALL TIME HIGHEST STORM TIDES (HIGH TIDE) AT PORTLAND, ME 1912-2022 (MLLW)		
Rank	Height (MLLW)	Date
1	14.17'	February 7, 1978
2	13.98'	January 9, 1978
3	13.79'	Jan 4, 2018
4	13.72'	Dec 23, 2022
5	13.40'	Dec 4, 1990
6	13.31'	Mar 16, 1976
7	13.29'	Nov 20, 1945
	13.29'	Nov 30, 1945
9	13.28'	Apr 16, 2007
10	13.18'	Jan 2, 1987
	13.18'	Oct 30, 1991
12	13.17'	Mar 2, 2018
13	13.09'	Apr 7, 1978
	13.09'	Dec 29, 1959
	13.09'	Feb 19, 1972
16	13.07'	Jan 28, 1979
17	13.03'	Jun 3, 2012
18	13.00'	Jun 4, 2012
19	12.96'	May 25, 2017
20	12.92	January 2, 2010



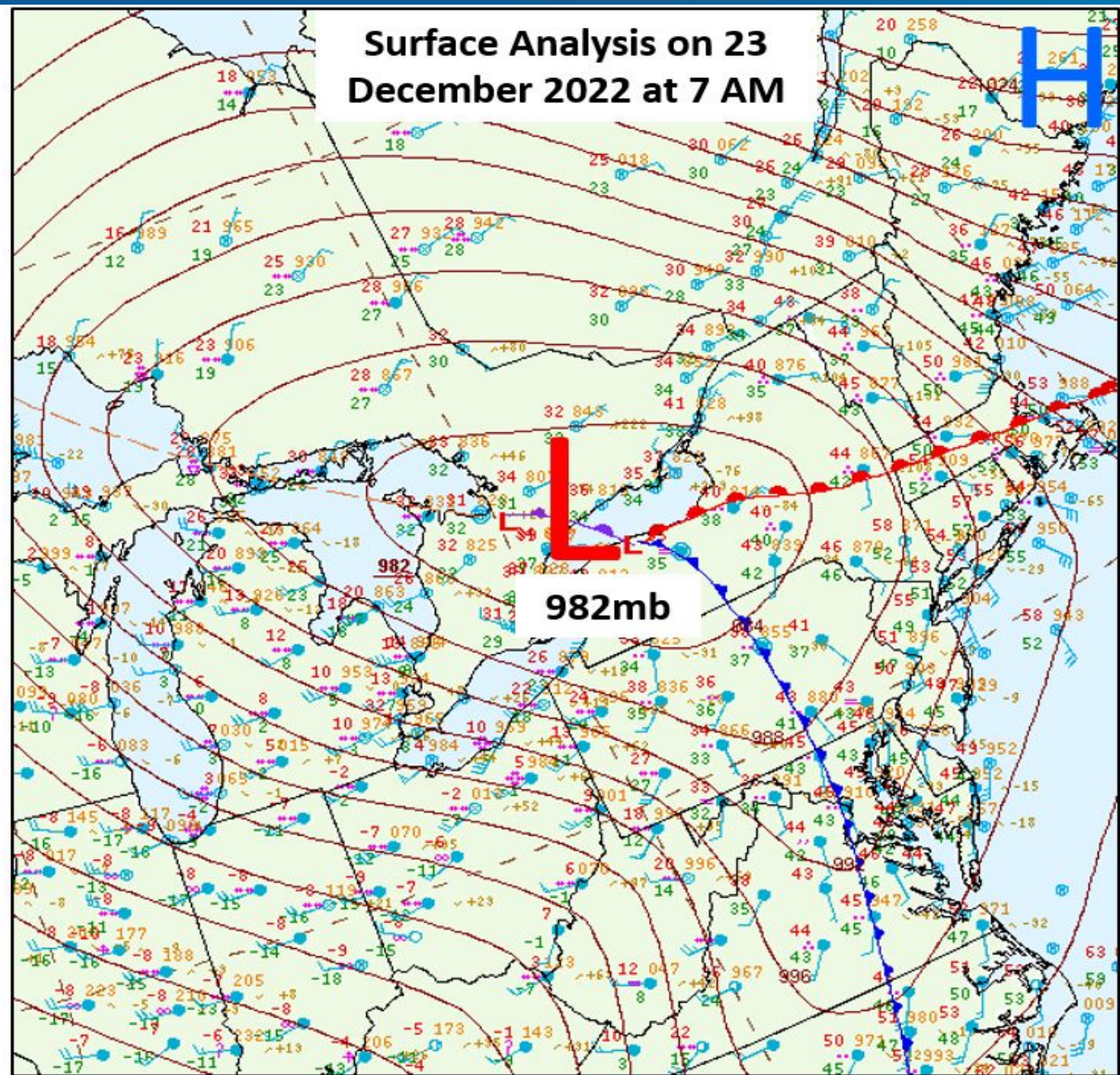


# The Storm Track

Surface Analysis on 23  
December 2022 at 1 AM



Surface Analysis on 23  
December 2022 at 7 AM

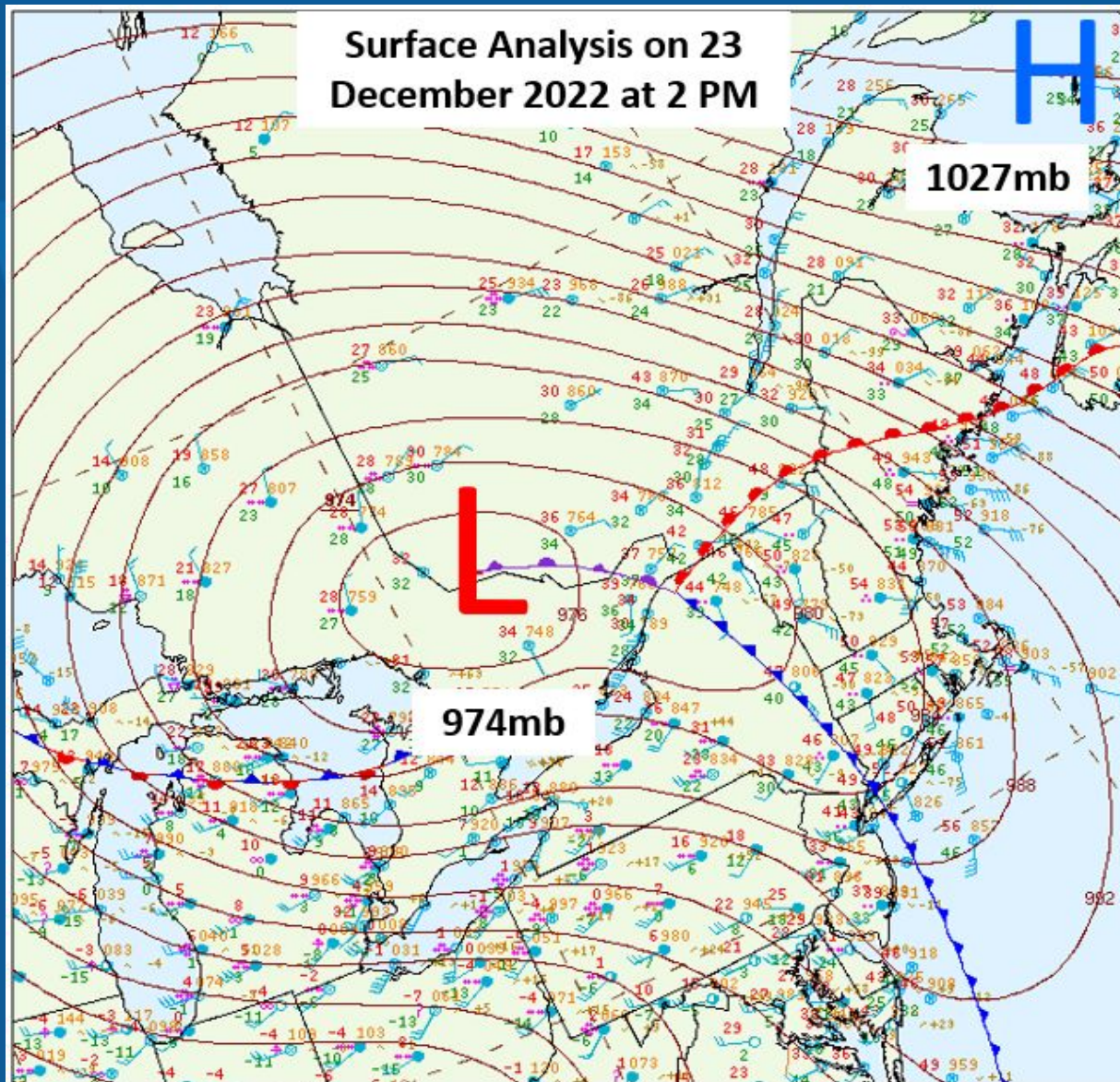




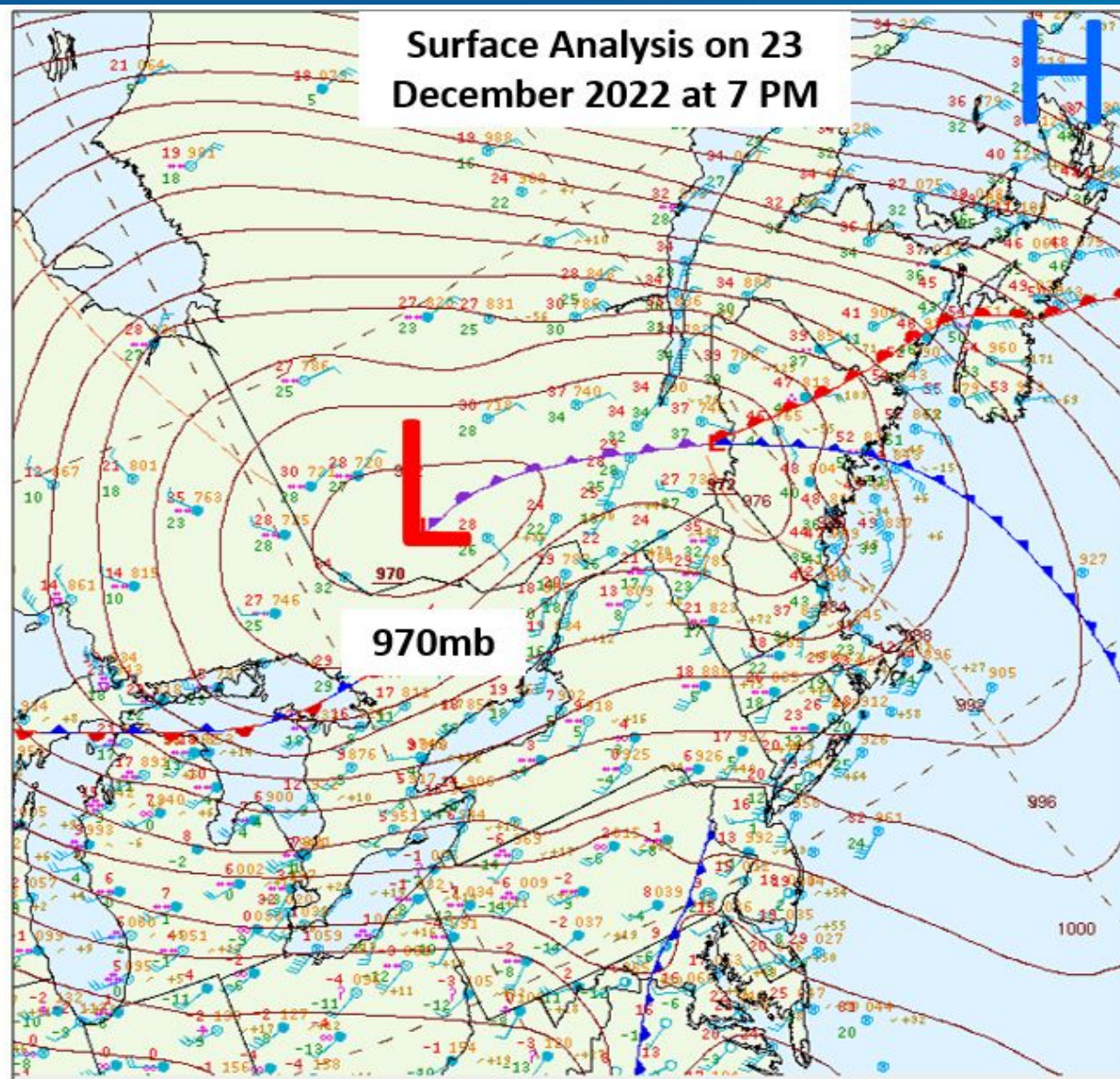


# The Storm Track

Surface Analysis on 23  
December 2022 at 2 PM



Surface Analysis on 23  
December 2022 at 7 PM

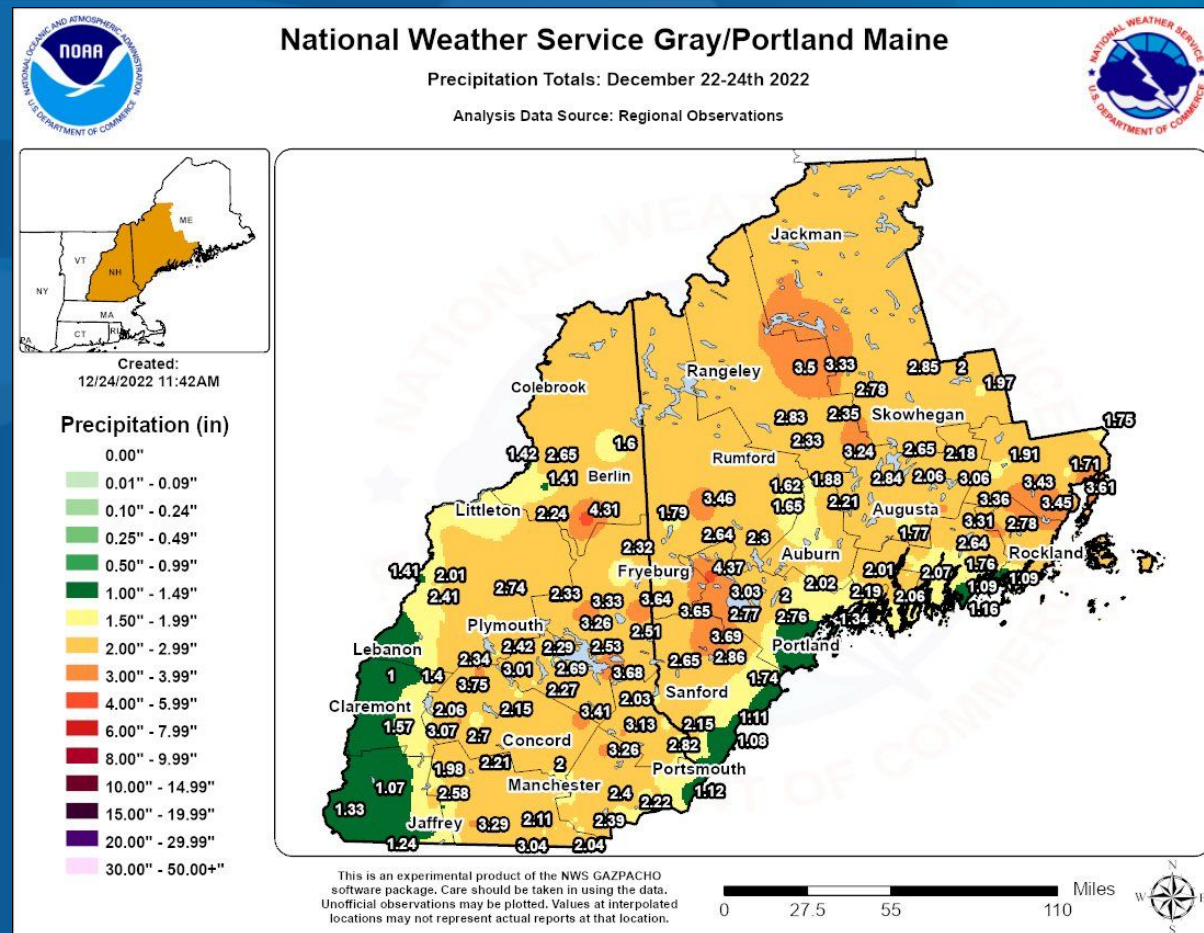






# Rain and Freshwater Factors

Fortunately the heavy rain rates and amounts didn't align with the high tide for this event!

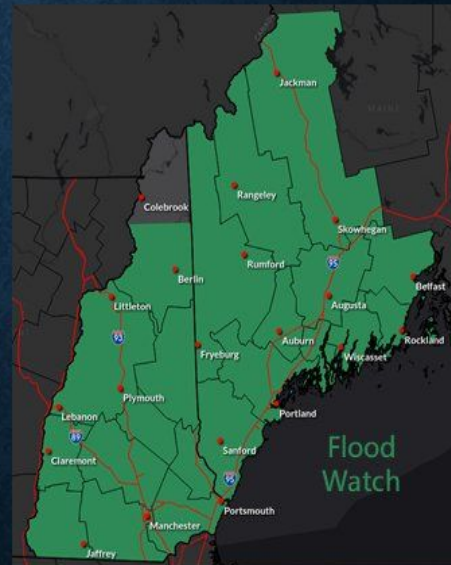
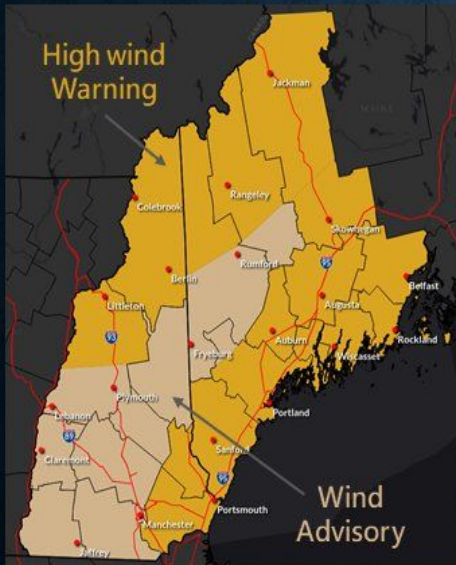






# NWS Coastal Flood Headlines

## Multi-Impact Major Holiday Storm



Coastal flooding can be predicted and normally **is not** a surprise.

Why? Our tide cycle





# Product Timeline (Ready, Set, Go)

## Hazardous Weather Outlook

Hazardous Weather Outlook  
National Weather Service Gray ME  
333 AM EST Sun Dec 18 2022

MEZ023>028-NHZ014-190845-  
Coastal York-Coastal Cumberland-Sagadahoc-Lincoln-Knox-Coastal Waldo-  
Coastal Rockingham-  
333 AM EST Sun Dec 18 2022

This Hazardous Weather Outlook is for south central Maine,  
southwest Maine and southern New Hampshire.

.DAY ONE...Today and tonight.

Hazardous weather is not expected at this time.

.DAYS TWO THROUGH SEVEN...Monday through Saturday.

A large and strong low pressure system will likely impact the  
Northeast late Thursday through Friday bringing the threat of heavy  
precipitation and strong winds. At this time the track of this  
system and resultant precipitation types are uncertain, although  
travel impacts will be possible going into the Holiday Weekend.  
Astronomical tides will be high also. A risk for coastal flooding  
will exist if strong onshore winds develop along with high seas.



## Coastal Flood Watch

URGENT - IMMEDIATE BROADCAST REQUESTED  
Coastal Hazard Message  
National Weather Service Gray ME  
318 AM EST Wed Dec 21 2022

MEZ023>028-NHZ014-211830-  
/O.NEW.KGYX.CF.A.0002.221223T1300Z-221223T1800Z/  
Coastal York-Coastal Cumberland-Sagadahoc-Lincoln-Knox-  
Coastal Waldo-Coastal Rockingham-  
318 AM EST Wed Dec 21 2022

...COASTAL FLOOD WATCH IN EFFECT FROM FRIDAY MORNING THROUGH  
FRIDAY AFTERNOON...

- \* WHAT...Some areas may have moderate flooding around the time of the Friday morning high tide with a foot or more water in some areas. Flooding may continue into the early afternoon hours. Large, battering waves may lead to splash-over and beach erosion.
- \* WHERE...In Maine, Coastal York, Coastal Cumberland, Sagadahoc, Lincoln, Knox and Coastal Waldo Counties. In New Hampshire, Coastal Rockingham County.
- \* WHEN...From Friday morning through early Friday afternoon.
- \* IMPACTS...Numerous roads may be closed. Low lying property including homes, businesses, and some critical infrastructure may be inundated. Some shoreline erosion may occur.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

If travel is required, allow extra time as some roads may be closed. Do not drive around barricades or through water of unknown depth. Take the necessary actions to protect flood-prone property.



## Coastal Flood Warning

URGENT - IMMEDIATE BROADCAST REQUESTED  
Coastal Hazard Message  
National Weather Service Gray ME  
424 AM EST Thu Dec 22 2022

MEZ023>028-NHZ014-221730-  
/O.UPG.KGYX.CF.A.0002.221223T1300Z-221223T1800Z/  
/O.NEW.KGYX.CF.W.0002.221223T1200Z-221223T1900Z/  
Coastal York-Coastal Cumberland-Sagadahoc-Lincoln-Knox-  
Coastal Waldo-Coastal Rockingham-  
424 AM EST Thu Dec 22 2022

...COASTAL FLOOD WARNING IN EFFECT FROM 7 AM TO 2 PM EST FRIDAY...

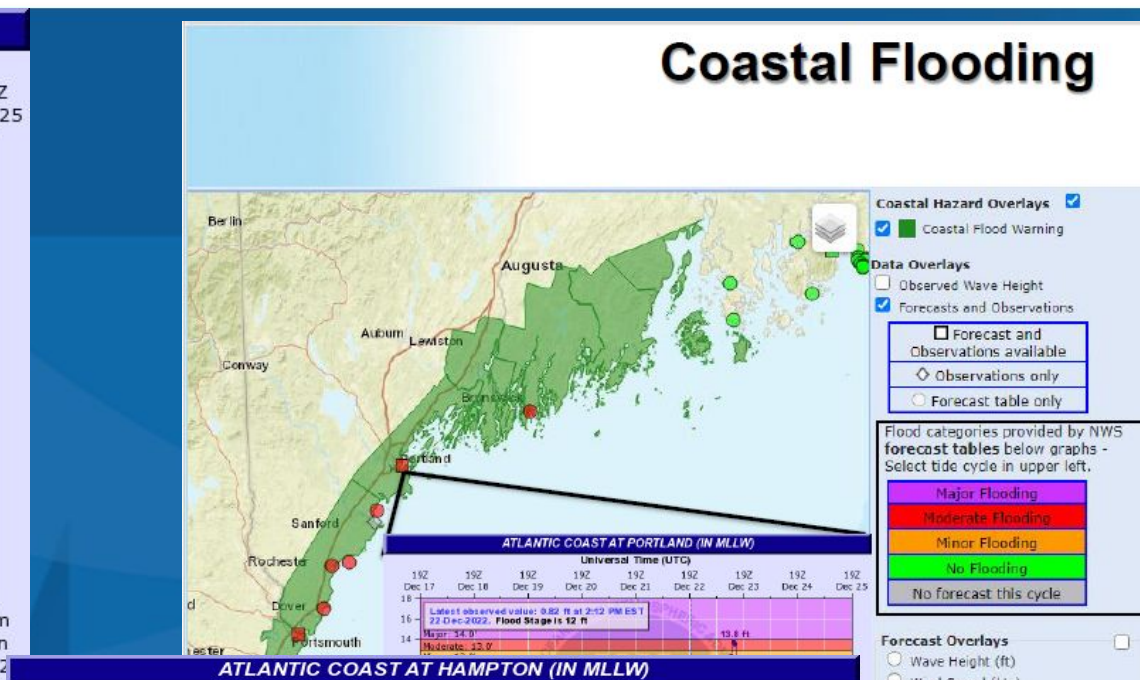
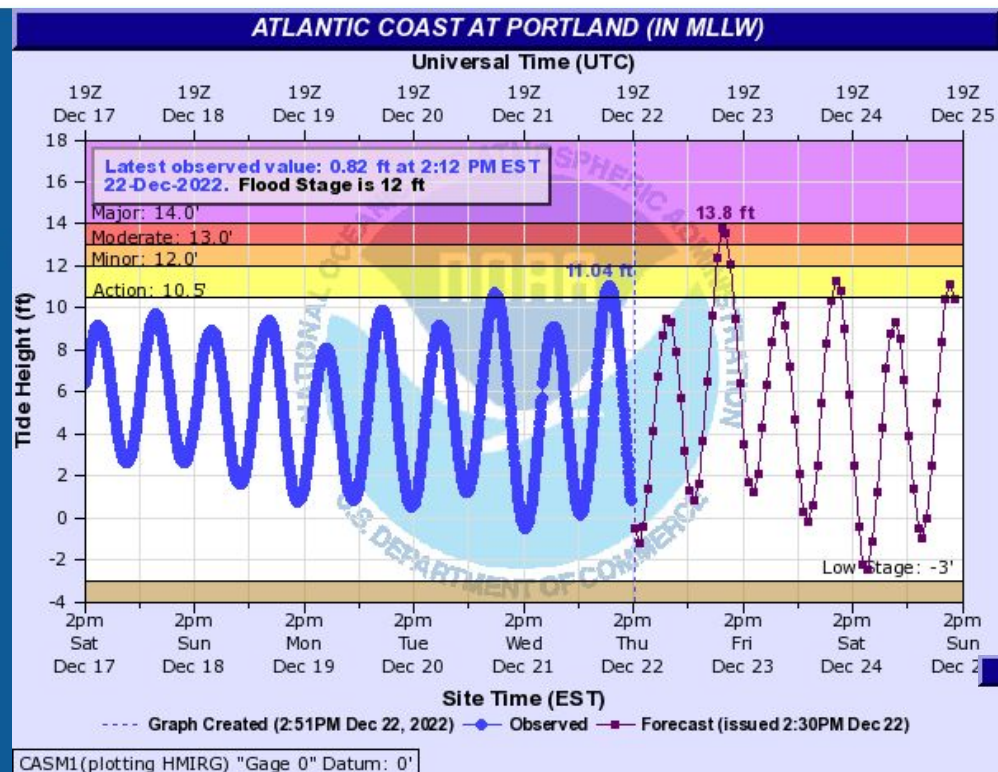
- \* WHAT...Some areas may have moderate flooding around the time of the Friday morning high tide with one to two feet water in some locations. Pockets of major flooding are possible with up to three feet of water in some areas. Flooding may be prolonged and continue into the early afternoon hours. Large, battering waves driven by storm force southeasterly winds will lead to significant splash-over and beach erosion.
- \* WHERE...In Maine, Coastal York, Coastal Cumberland, Sagadahoc, Lincoln, Knox and Coastal Waldo Counties. In New Hampshire, Coastal Rockingham County.
- \* WHEN...From Friday morning through early Friday afternoon.
- \* IMPACTS...Numerous roads may be closed. Low lying property including homes, businesses, and some critical infrastructure may be inundated and damaged. Shoreline erosion will occur with damage to dune systems.
- \* ADDITIONAL TIDAL FLOOD IMPACTS...Widespread flooding of locations near the waterfront expected, including some damage to vulnerable structures. Numerous road closures expected. A few locations could become isolated due to the flooding of roads. Vehicles parked in vulnerable areas near the waterfront will likely become flooded. A few evacuations may be needed in the most vulnerable areas. There is significant threat to property. Many coastal communities will experience damage. Numerous structures will flood. Flood waters will extend well inland in riverine tidal areas.
- \* WAVE IMPACTS...Expect moderate to locally significant beach erosion with considerable erosion of protected dune structures due to large breaking waves. Splash-over may lead to ponding of water behind dune structures and result in flooding of roads and vulnerable structures. Small rocks associated with splash-over may result in damage to passing vehicles or pedestrians.

PRECAUTIONARY/PREPAREDNESS ACTIONS...



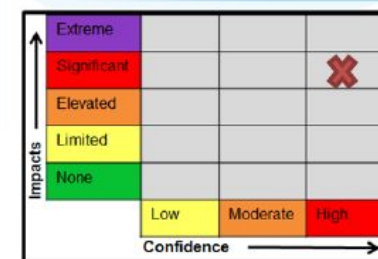


# Product Messaging



## Key Information:

- ✓ Storm surge 2-3'
- ✓ 15-20 ft waves peak Friday.
- ✓ Moderate with some areas of major coastal flooding will bring coastal erosion and 1 to 3 feet of inundation.
- ✓ Friday AM tide is the greatest tide of concern.

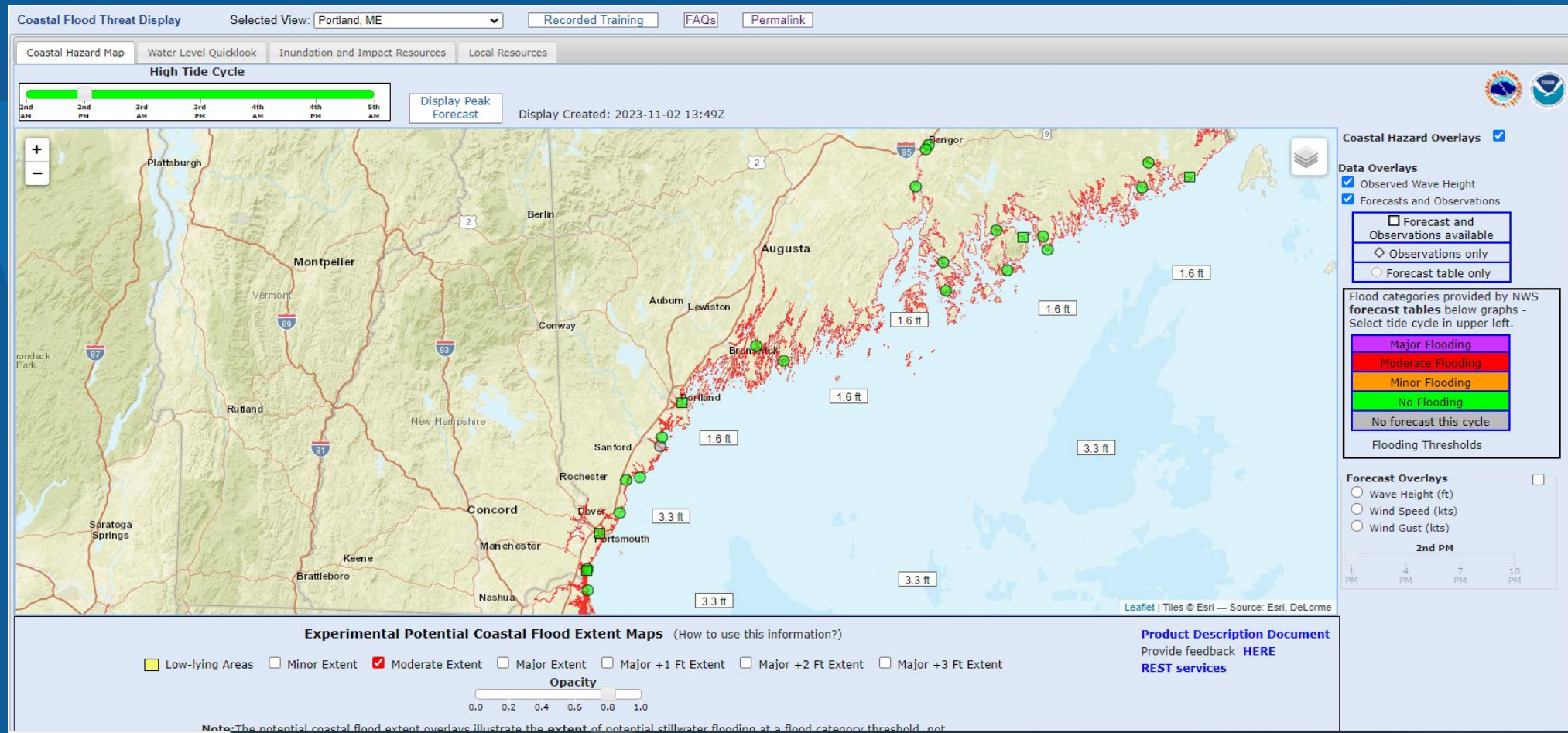






# Resources

<https://www.weather.gov/erh/coastalflood>



[Coastal Flooding](#)

Contact: [Donald.Dumont@noaa.gov](mailto:Donald.Dumont@noaa.gov)





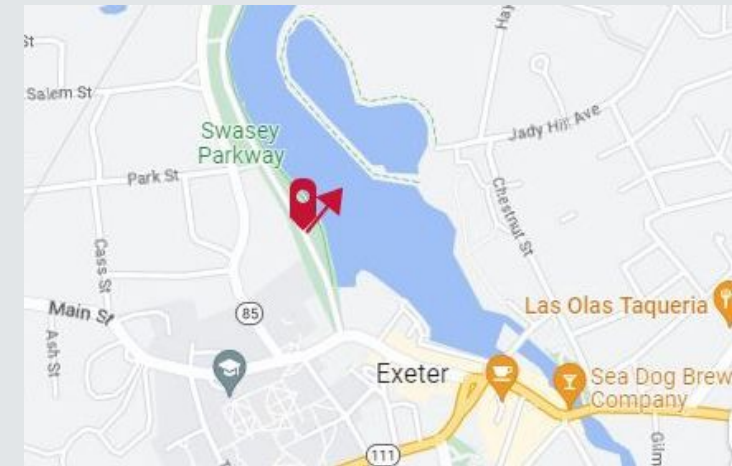
# Examining the Impacts: Making SLR Relatable





## Exeter:

High water levels flooded Swasey Parkway, with at least 18 inches of water.

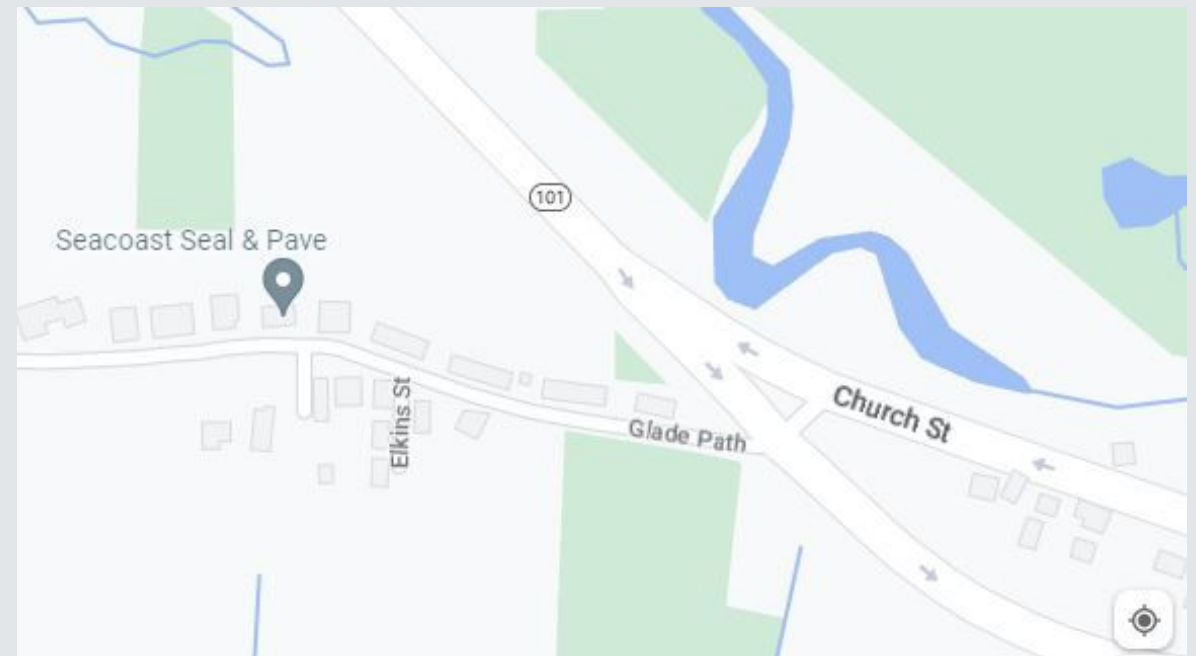






# Hampton:

Residences on Glade Path and Island Path were cut off from rest of the community as these dead-end roads were flooded, preventing safe travel to the connecting road network.





# North Hampton:

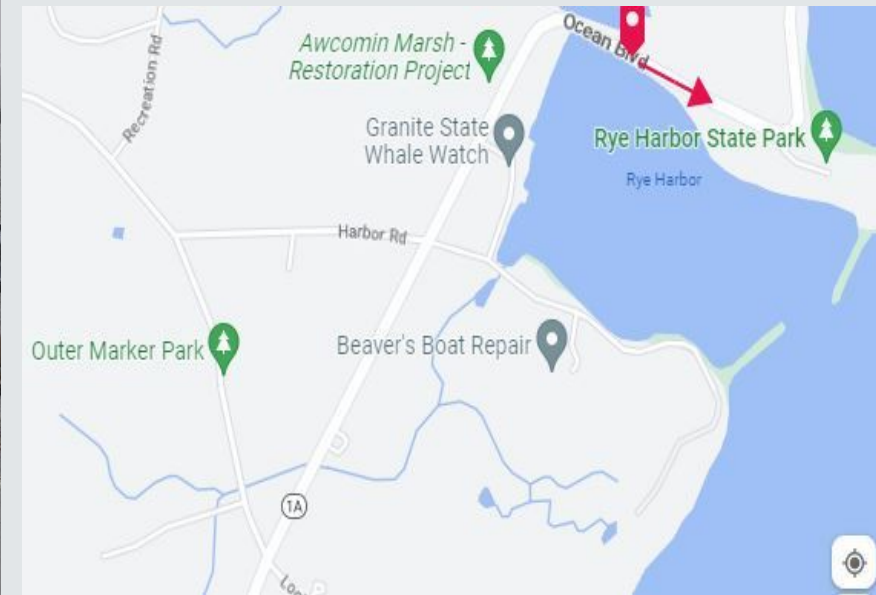
Route 1A north of Little Boars Head





# Rye Harbor:

At the Harbor entrance northward to Rye Harbor State Park, NH 1A was inundated by an estimated 2 to 3 feet in some areas.

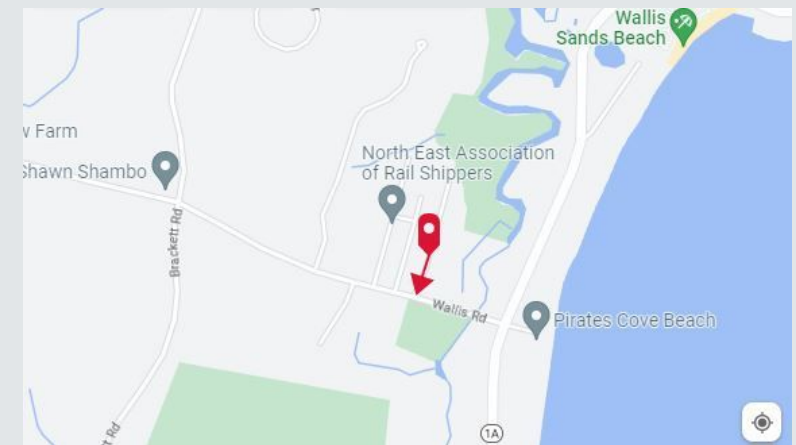






## Rye / Wallis Rd:

Wallis Road at Appledore Road was submerged under more than 1.5 feet of water. The marsh area flooded and cut off access to residents on Appledore Ave.



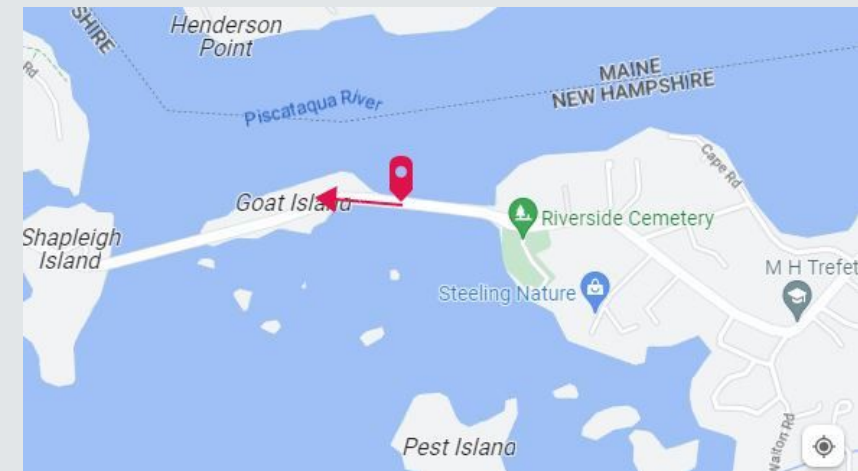




## New Castle:

Both island access points were cut off by flooding.

The Causeway was overtopped east of Goat Island and the Kittery Point Yacht Club.





# New Castle:

NH 1B near Sagamore Creek is also vulnerable to Sea Level Rise.

Flood water over topped 1B east of BG's Boat House.

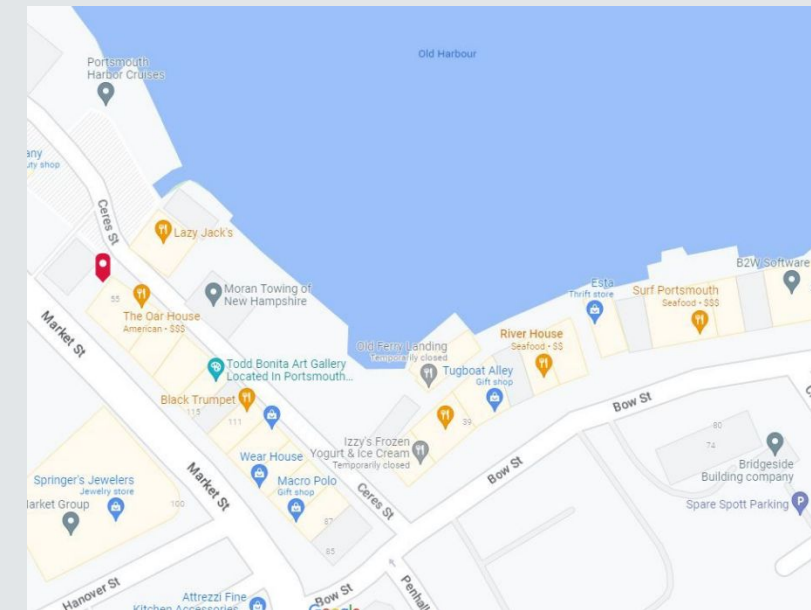






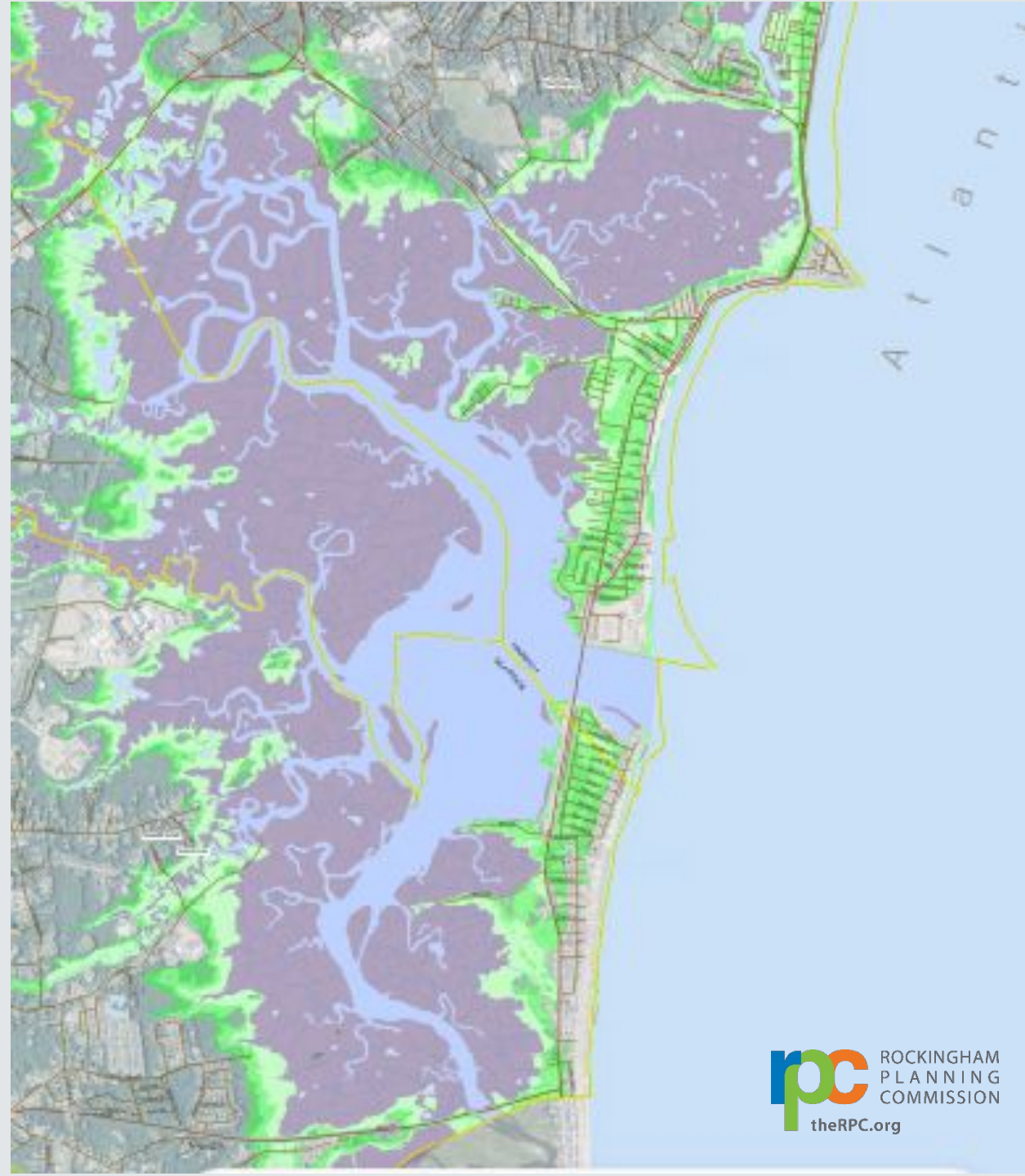
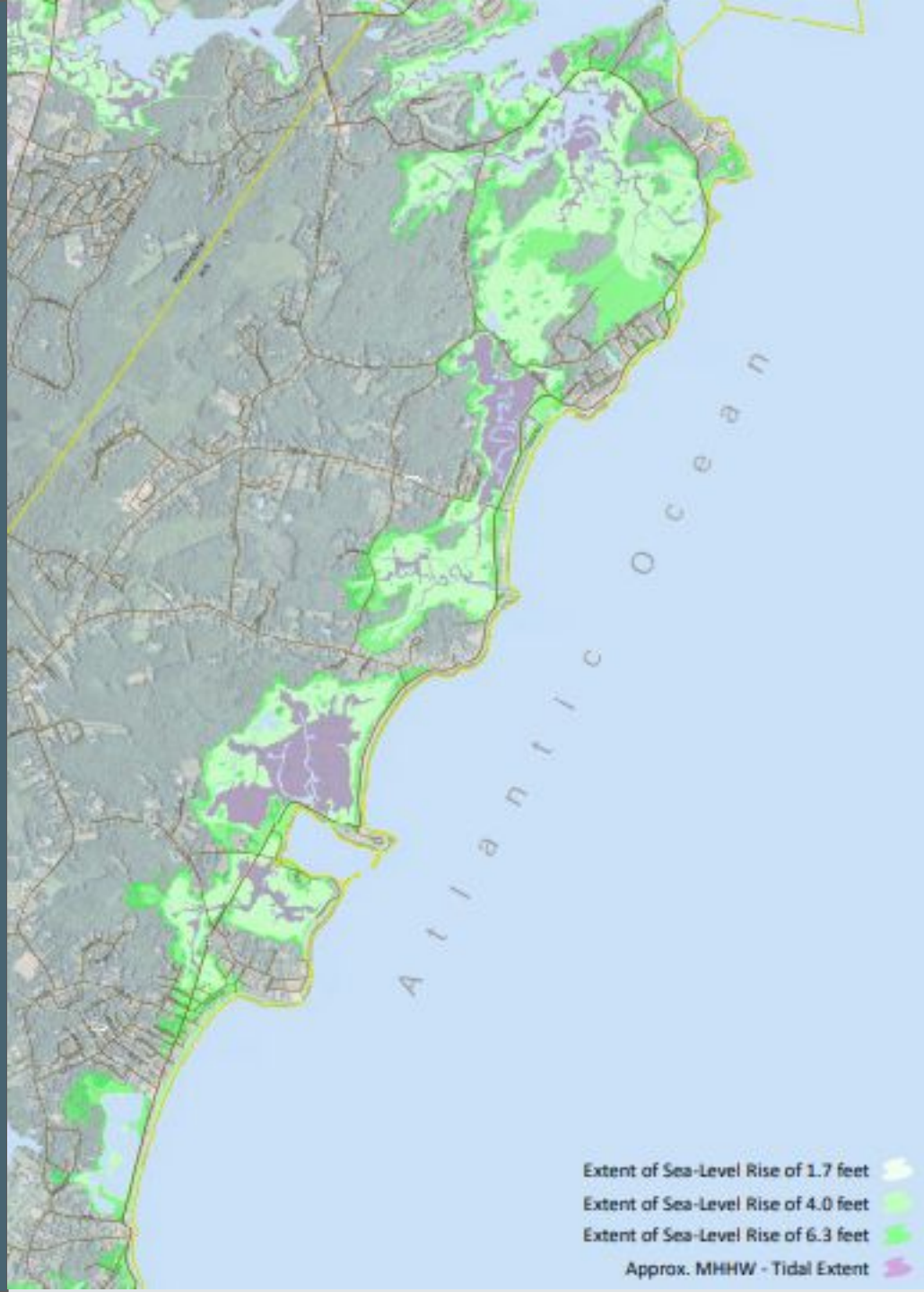
# Portsmouth:

Ceres Street near the Tugboats. Picture taken just after High Tide.





# 4 Feet SLR



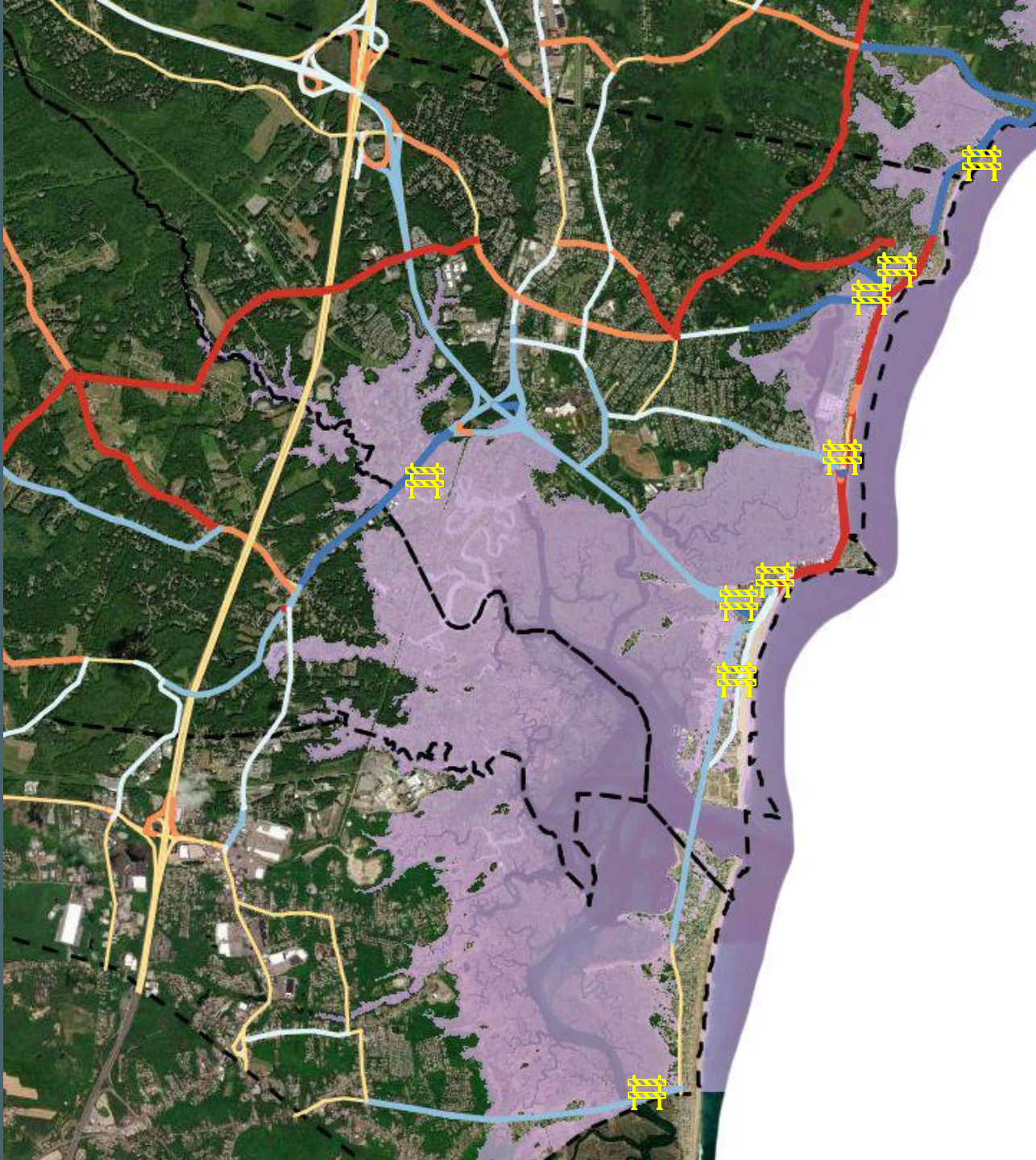




# STCVA Goals

- Assess the impacts of projected sea-level rise on the seacoast transportation network under 1', 1.7', 4', and 6.3' sea-level rise (SLR) scenarios.
- Evaluate changes in traffic volume, travel patterns, road capacity, road conditions due to SLR
- Identify & prioritize sites impacted by flooding for further evaluation
- Identify adaptation and resilience strategies for priority sites
- Improve RPC/MPO decision making processes





# Traffic Impacts 4.0' SLR

25 Sites inundated – Approximately 108,000 trips/day

Winnacunnet Rd Inundated

No access to coast in Seabrook

Hampton access limited to North Shore Road

Inland impacts in Exeter and Stratham

Impacts to North-South Travel

- Two locations on US 1 and multiple spots on NH 1A

NH 1B – No access to New Castle Island

Portsmouth city streets around South Mill Pond

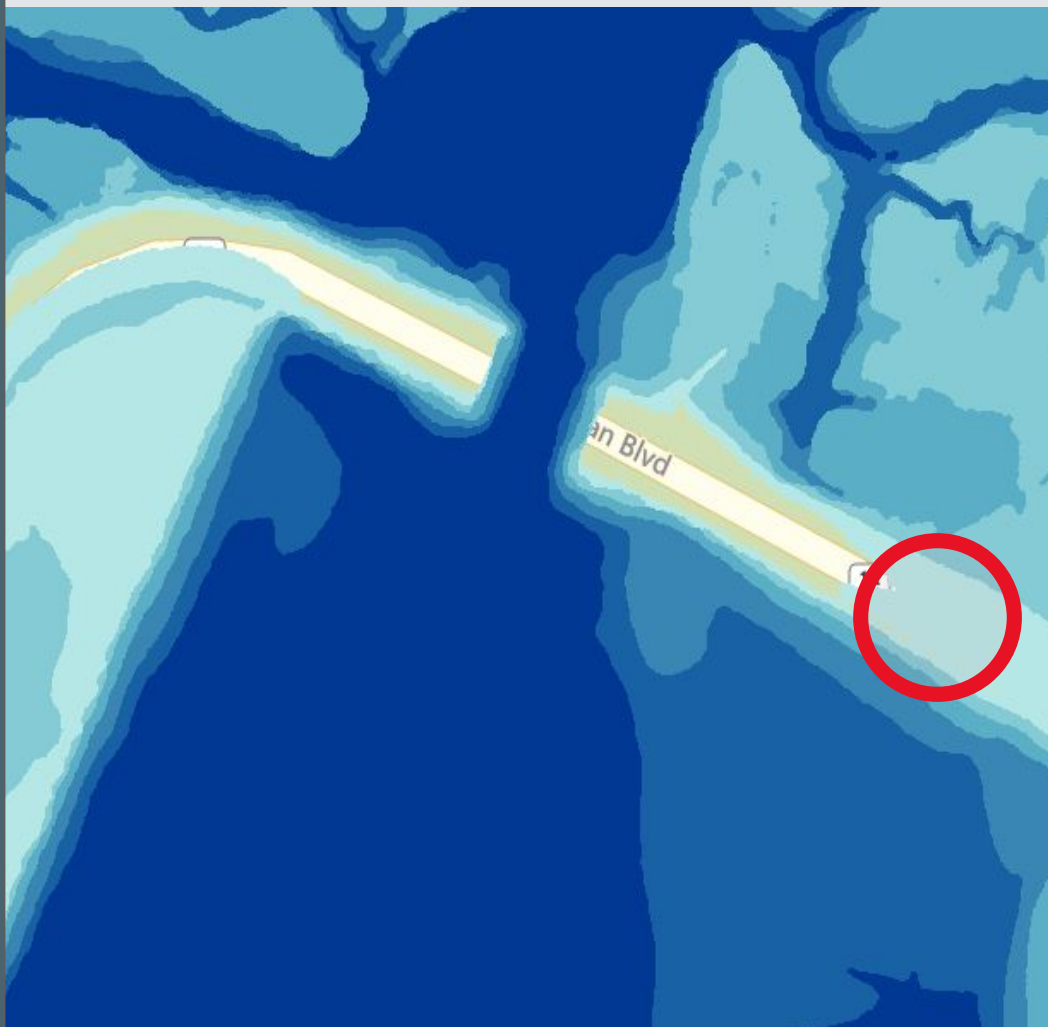


Site #4 of the STCVA is along NH 1B New Castle



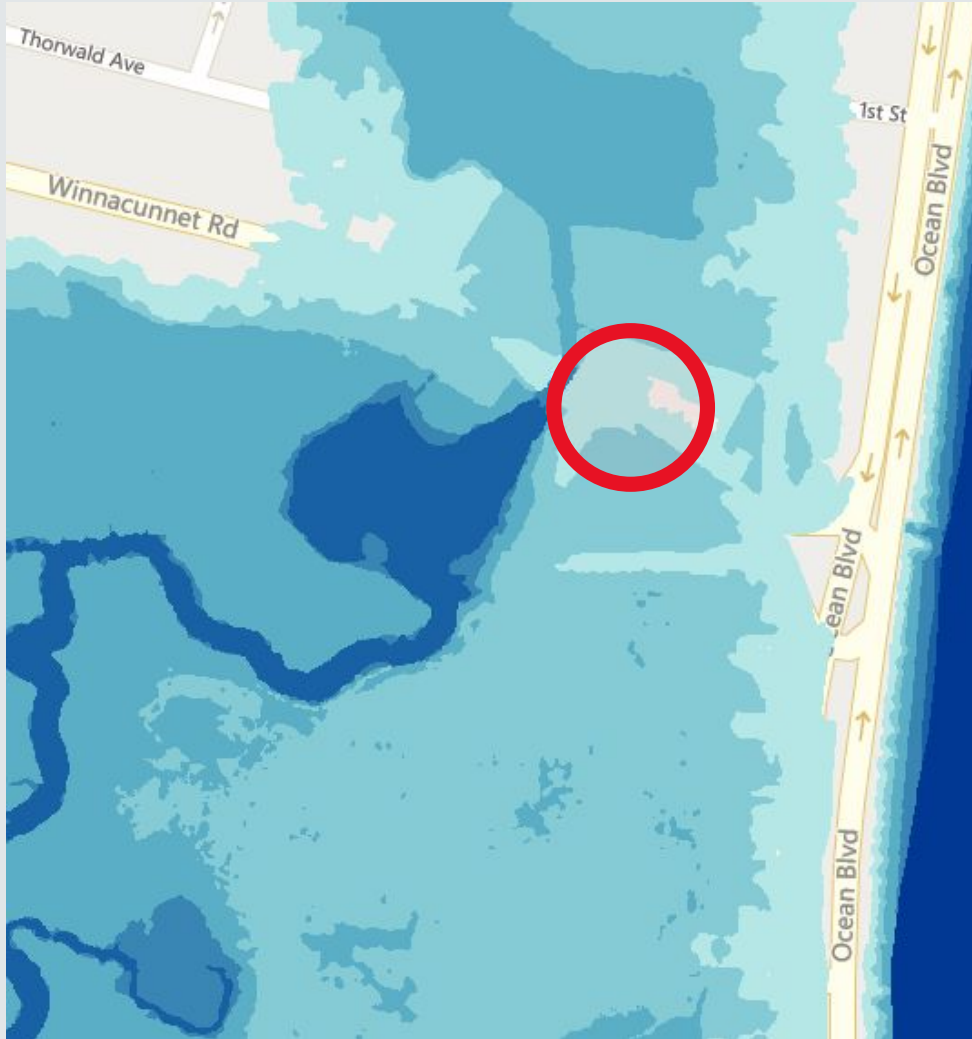


Site #13 of the STCVA is along Ocean Boulevard near Rye Harbor





Site #17 of the STCVA is along Ocean Boulevard near Winnacunnet Road in Hampton







# How do we make our transportation infrastructure more resilient?

---



# *How do we make our transportation infrastructure more resilient?*

## ***Advancing Science: Nature Based Solutions to Protect Transportation Infrastructure from Sea Level Rise and Flooding***





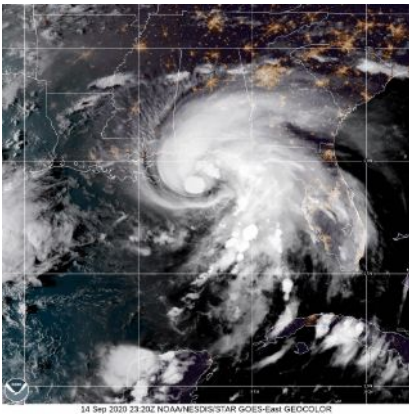
# Research Site: New Hampshire and Alabama Coastlines



## Our approach to Adaptation Guidance: Multi-disciplinary and holistic

### Stressor

- Sea Level Rise
- Groundwater
- Coastal Storms



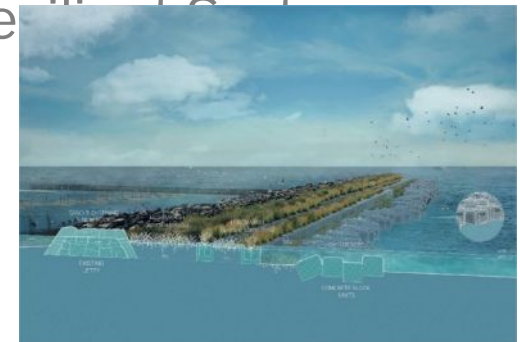
### Infrastructure

- Asphalt Pavements
- Coastal Roads
- Multiple

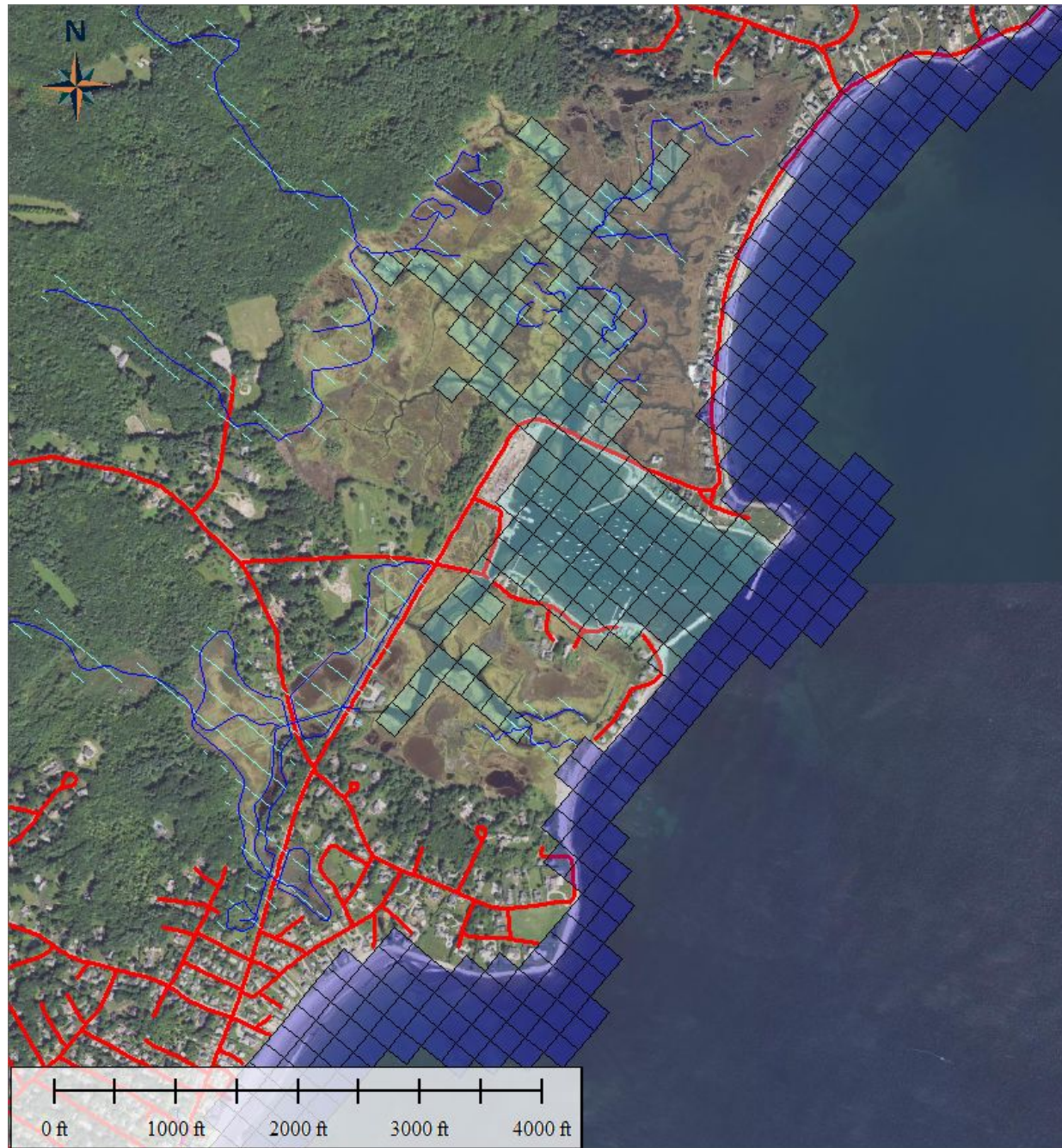


### Socioecological

- Natural and Nature Based Feature Alternatives
- Costs & Benefits
- Resilient







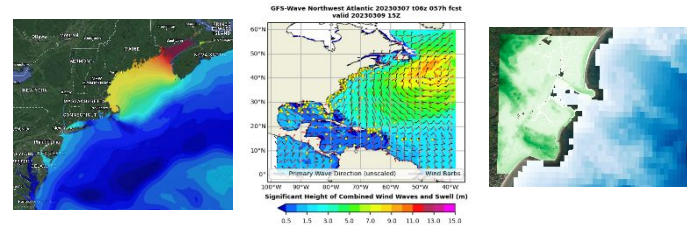
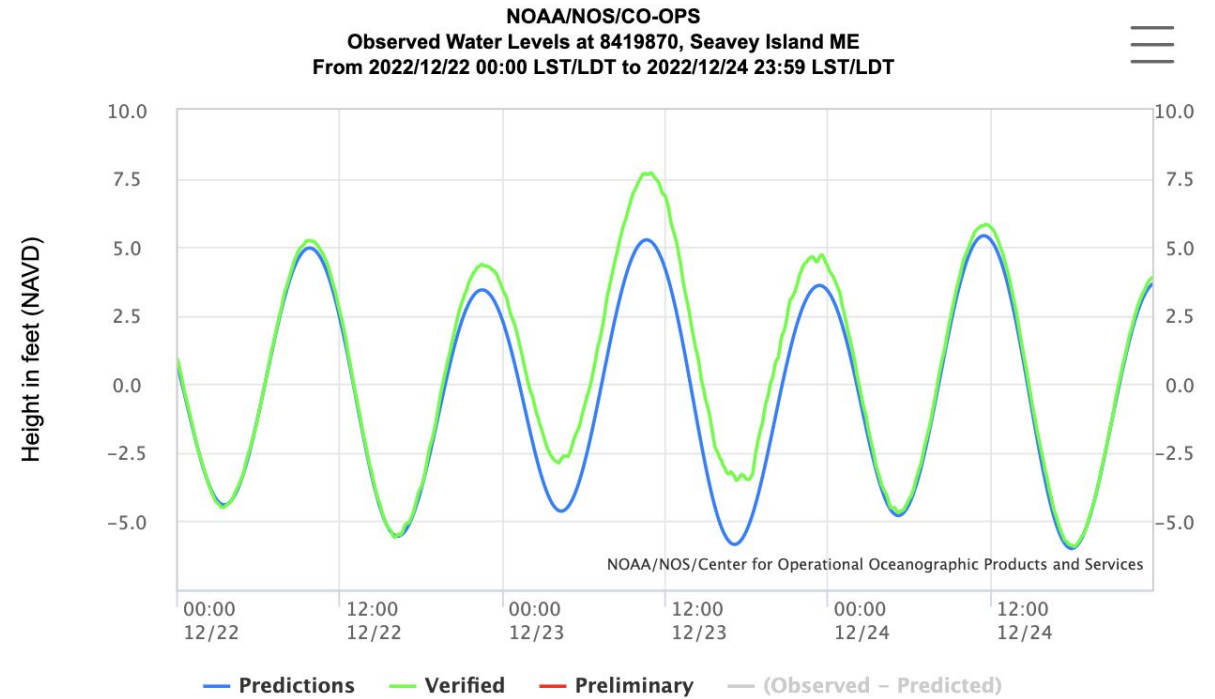
## Closeup of NH study area for hydrodynamic and groundwater modeling in Rye Harbor

200' x 200' cell size will be reduced to  
50' x 50' cell size in this area for better  
resolution.



# Hydrodynamic Modeling

- Dec 2022 Winter Storm
  - Elevated water levels
  - Wave action
  - Observed road damage



STOFS  
Hindcast

WaveWatch  
III

Model  
Grids

XBeach  
Hindast

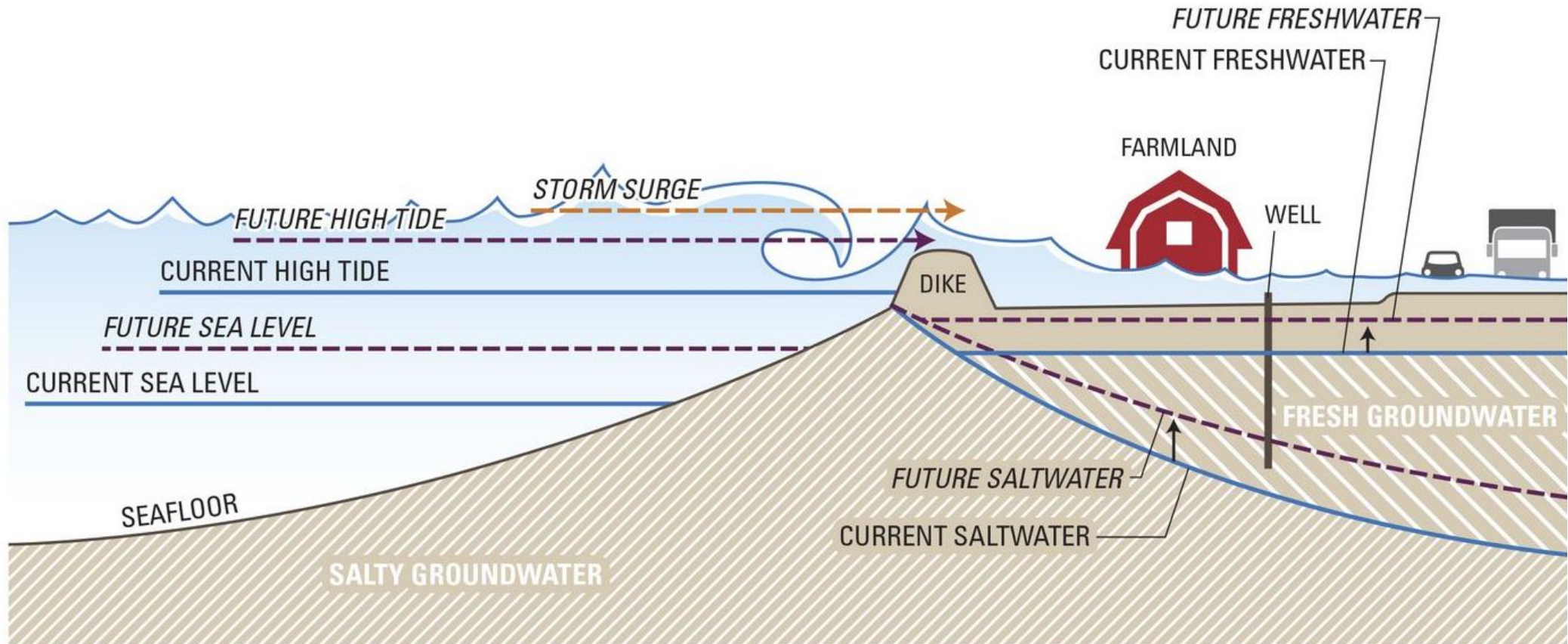
Data  
Extraction

Damage  
Calibration



# Groundwater Modeling

## *What's happening underground?*



NOTE: Sea, tide, and storm surge levels, depth of groundwater, and location of saltwater lens are for illustrative purposes only and do not depict actual or projected levels.

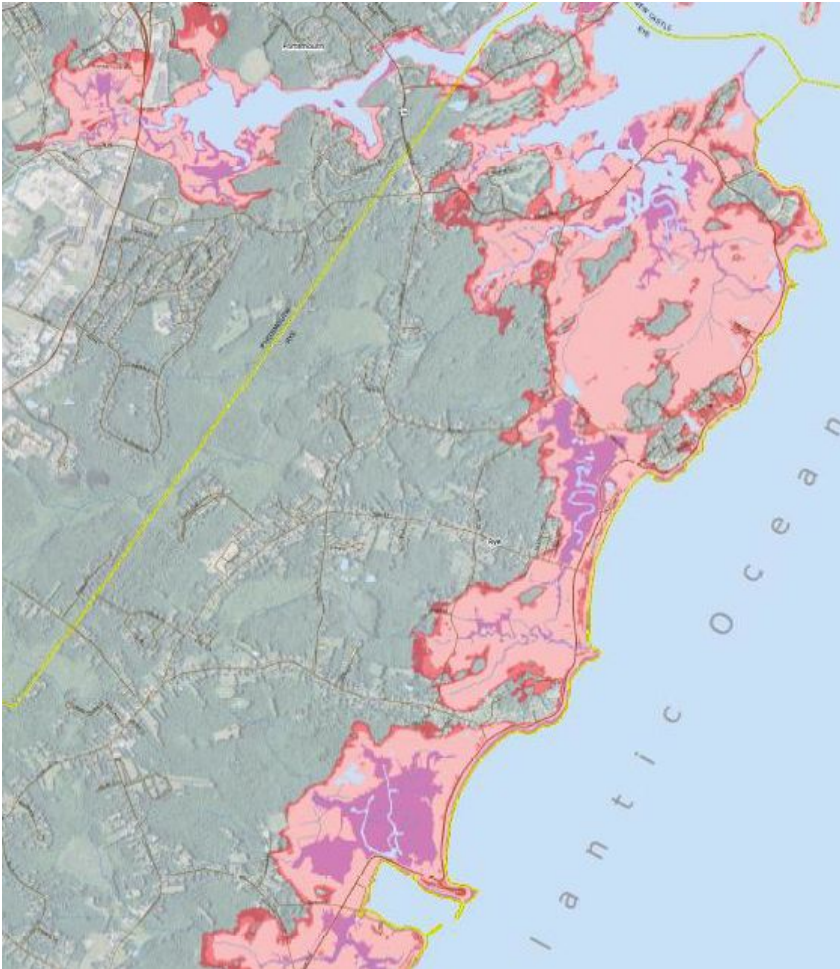
<http://www.skagitclimatescience.org/skagit-impacts/sea-level-rise/>  
Seattle, Washington



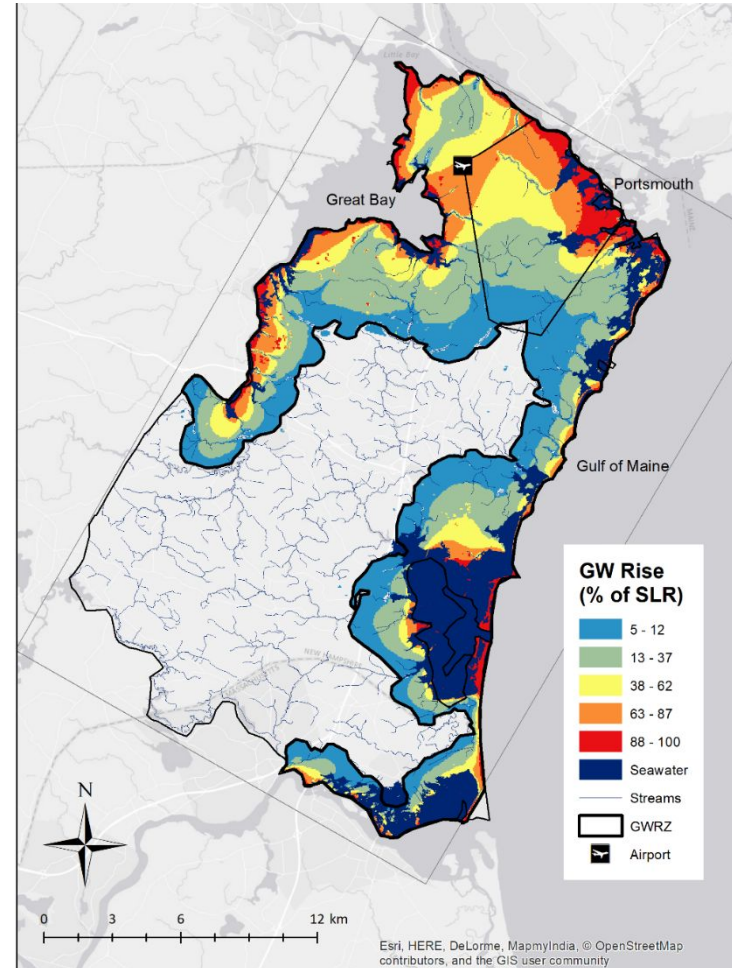
# NH Sea-Level Rise – Projected Flooding

Tidal water inundation with SLR and storm surge

Pink shading = 0.5 m, 1.2 m, and 1.9 m of SLR



Note: Storm surge = flood extent from a 100-year/1% chance storm event



Groundwater rise (% of sea-level rise):

Tidal surface-water flooding: 0.9 miles inland

GW Rise: 2 - 3 miles inland

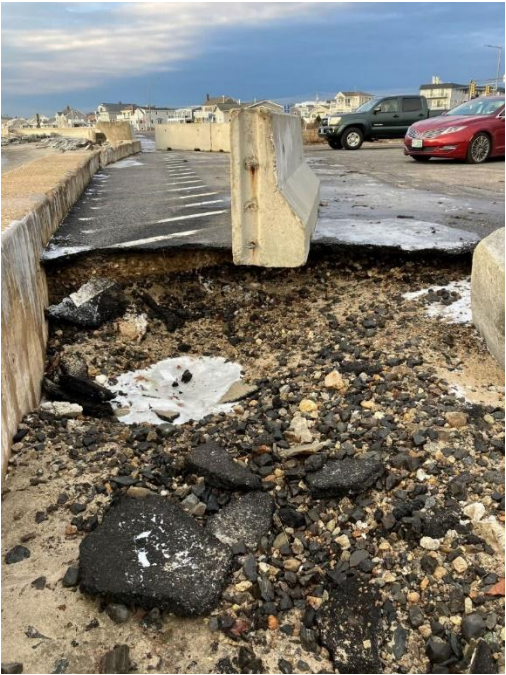
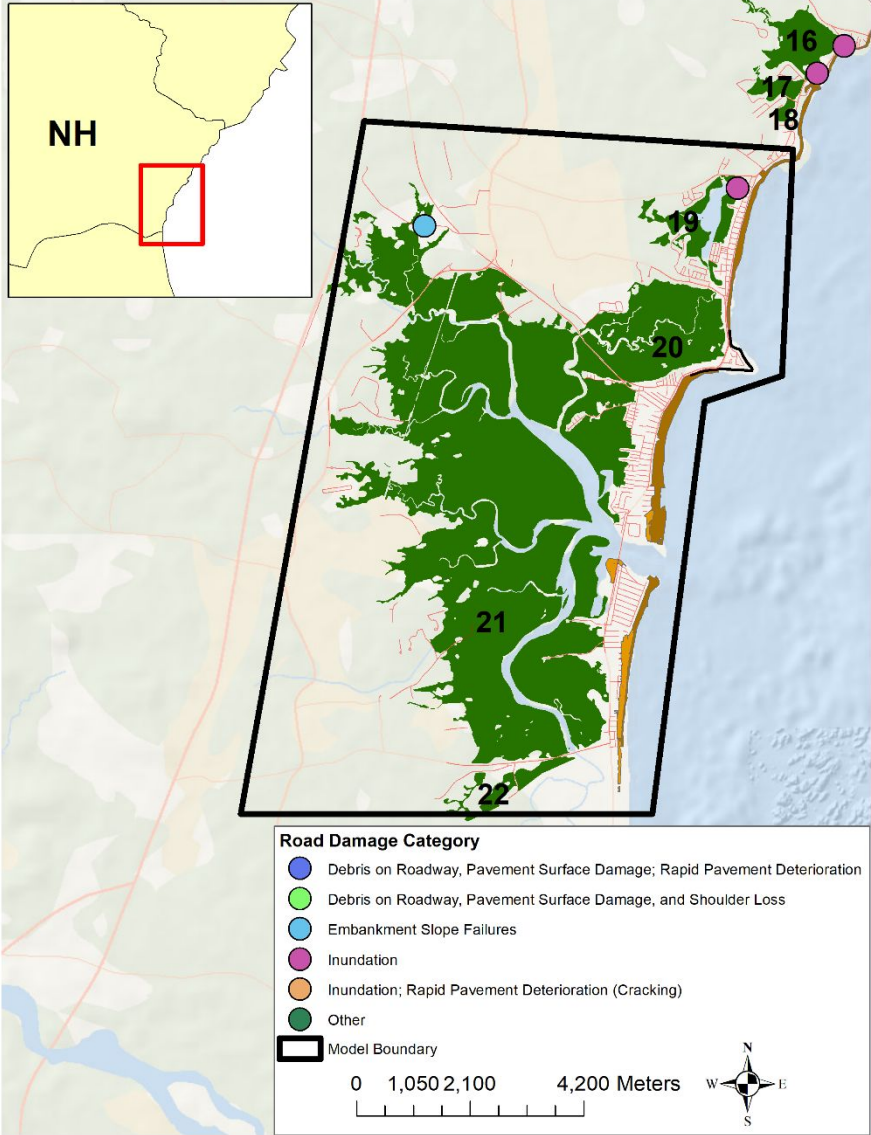
GW Rise is reduced near streams

SLR Map credit: Tides to Storms, Rockingham Planning Commission (2015)





# Pavement Damage from the Dec 2022 storm event





# ***Resilience is Not Just Hard Infrastructure: Natural and Nature-Based Features (NNBF)***

US Army Corps of Engineers (USACE) Definition: “Natural and Nature Based Features are landscape features that are used to provide **engineering functions** relevant to **flood risk management**, while producing additional **economic, environmental, and/or social** benefits”

NNBF utilizes the properties and mechanisms performed by ecosystems for engineering and flood protection solutions

Credit: USACE  
Engineering  
with Nature

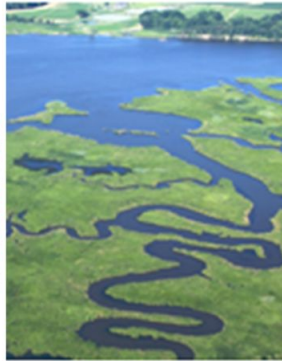
Artificial Reefs



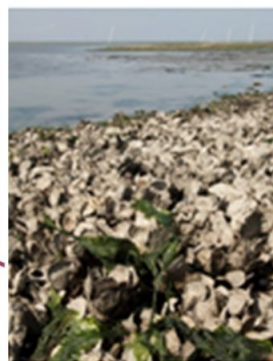
Living Shorelines



Wetlands



Oyster Reefs



Beaches/Dunes





# Natural Feature Mapping

Salt Marsh at Moody Point in NH



Credit: [Jerry Monkman](#)

## Natural and Nature Based Features in Coastal NH:

- Salt Marshes
- Beaches
- Dunes

Beach and Dune System in Hampton, NH



Credit: [Cathy Coletti](#)

## Flood Protection provided by these ecosystems:

Buffer zone between ocean and inland infrastructure

Wave attenuation

Sediment deposition and elevation gain

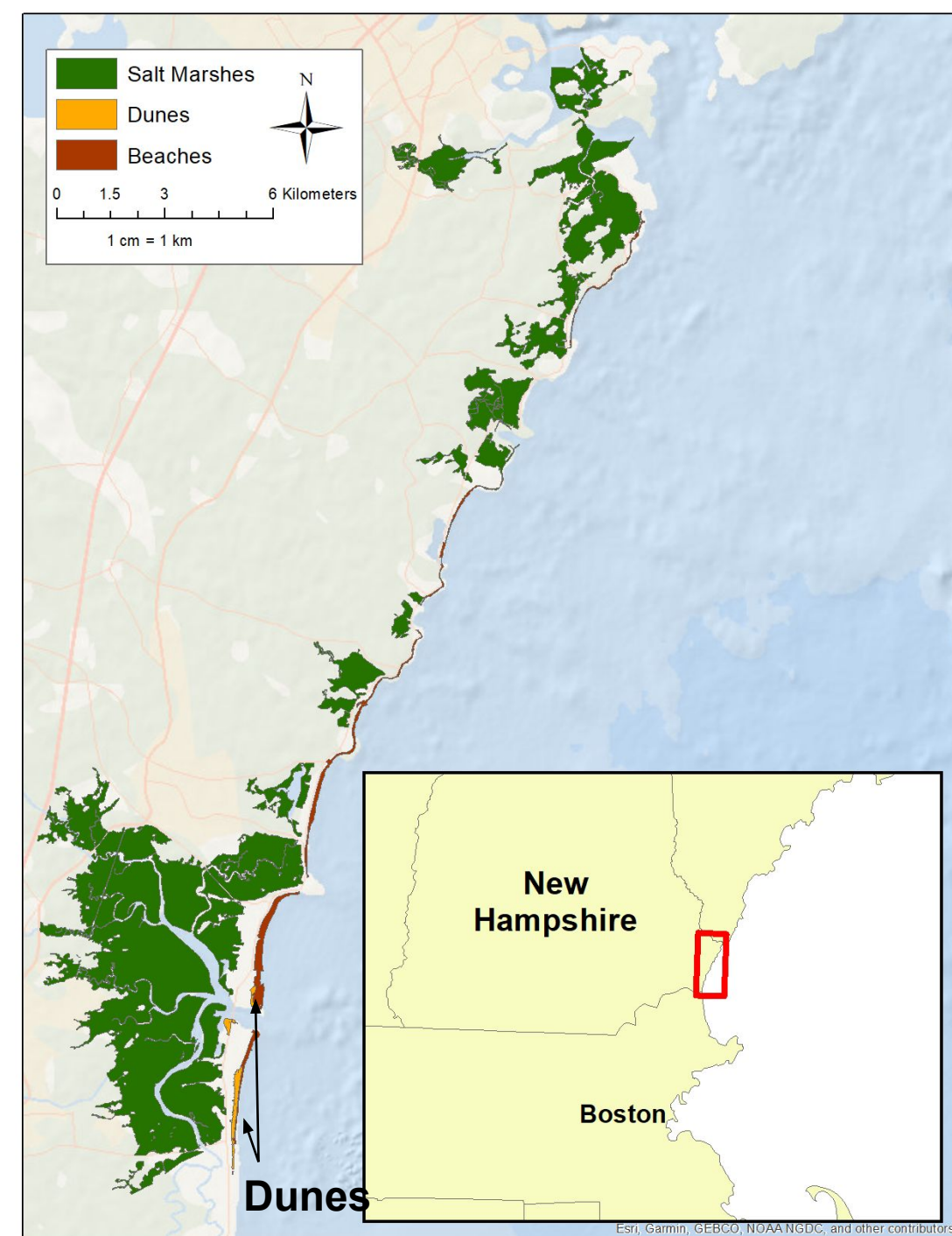
Erosion reduction



# Natural Feature Mapping

Purpose: Determine where and how existing natural features protect coastal roads from SLR and storm surge now and in the future

- Map salt marsh, beach, dune using National Inventories
  - National Wetland Inventory
  - National Land Cover dataset
- Identify natural feature indicators of road protection





# Natural Feature Metrics and Properties that Protect Roads

## Salt Marshes:

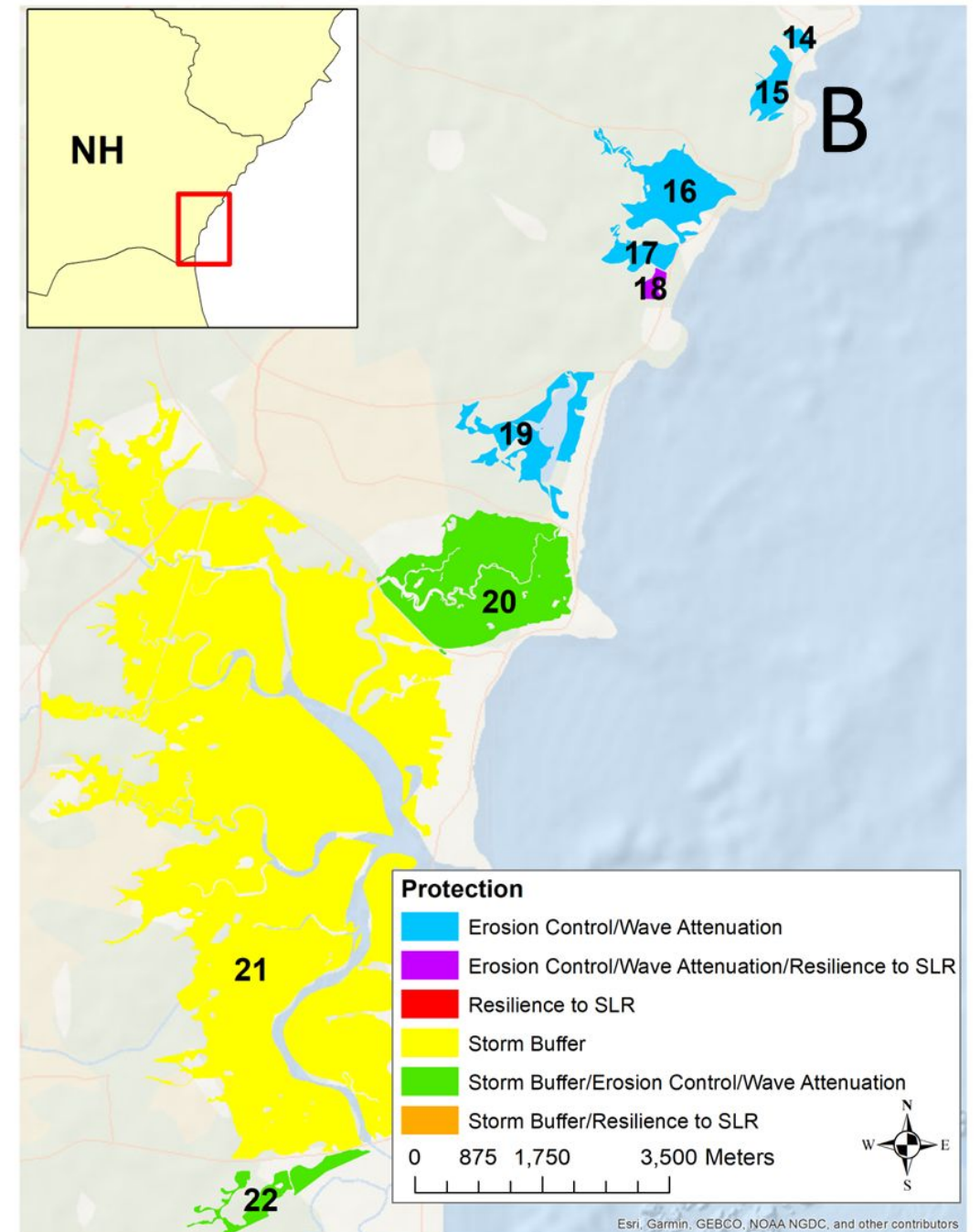
- *Low Unvegetated to Vegetated Ratio*: Erosion Reduction and Wave Attenuation
- *High Index of Ecological Integrity*: Strong Buffer to Storms
- *Low % MHHW Covers Salt Marsh Area*: Resilient to SLR

## Beaches:

- *Long Profile Length*: Buffer Zone to Storms
- *High Elevation*: Wave Attenuation & Resilient to SLR
- *Large Volume*: Erosion Control

## Dunes:

- *High Dune Crest Elevation*: Block Storm Surge
- *Large Dune Area*: Resilient to Storms and Wave Attenuation





# Natural Feature Metrics and Properties that Protect Roads

## Salt Marshes:

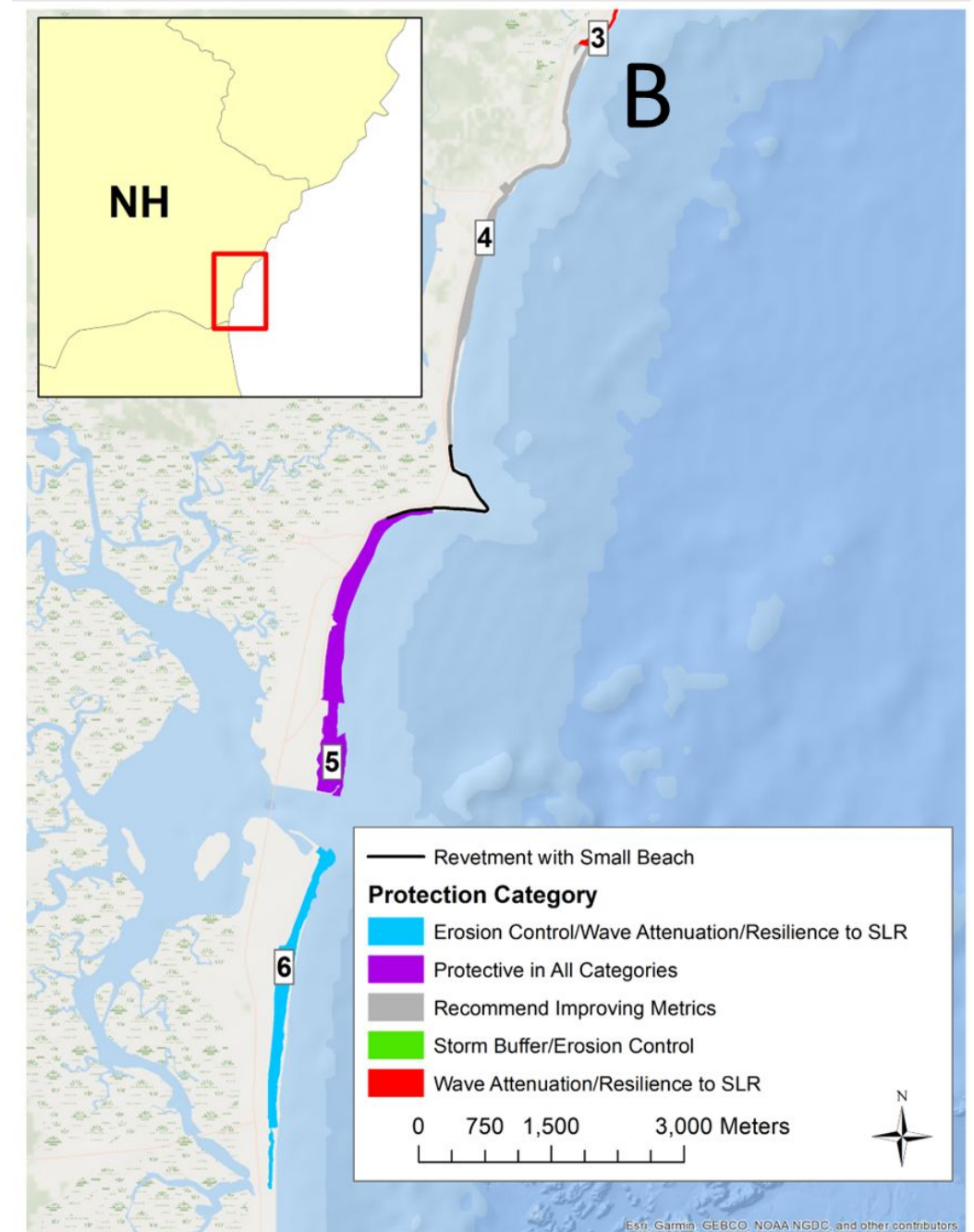
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## Beaches:

- *Long Profile Length*: Buffer Zone to Storms
- *High Elevation*: Wave Attenuation & Resilient to SLR
- *Large Volume*: Erosion Control

## Dunes:

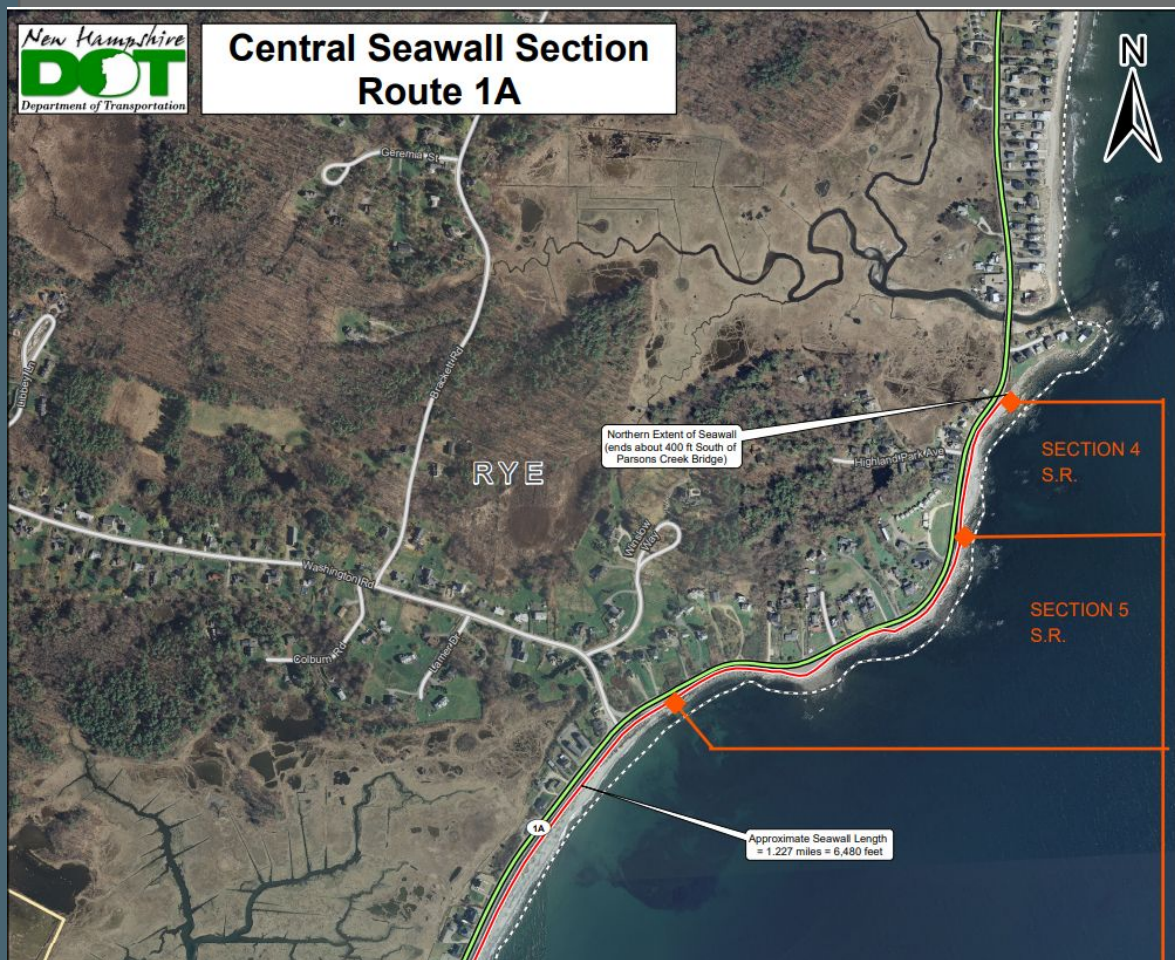
- *High Dune Crest Elevation*: Block Storm Surge
- *Large Dune Area*: Resilient to Storms and Wave Attenuation





# How are we becoming more Resilient?

## 1 of 3: Focus Areas



- Transportation Infrastructure
  - Pavement resilience
  - Nature Based Solutions
  - Fortify/Relocate
- Housing
  - Home elevation/Buyout
  - Managed retreat
  - Climate Migration
- Power Grid
- Business and Economic Impacts



# How are we becoming more Resilient?

## 2 of 3: Project Additions to the Ten-Year Plan

Sea Wall Revetment in North Hampton and Rye (42312A-D)



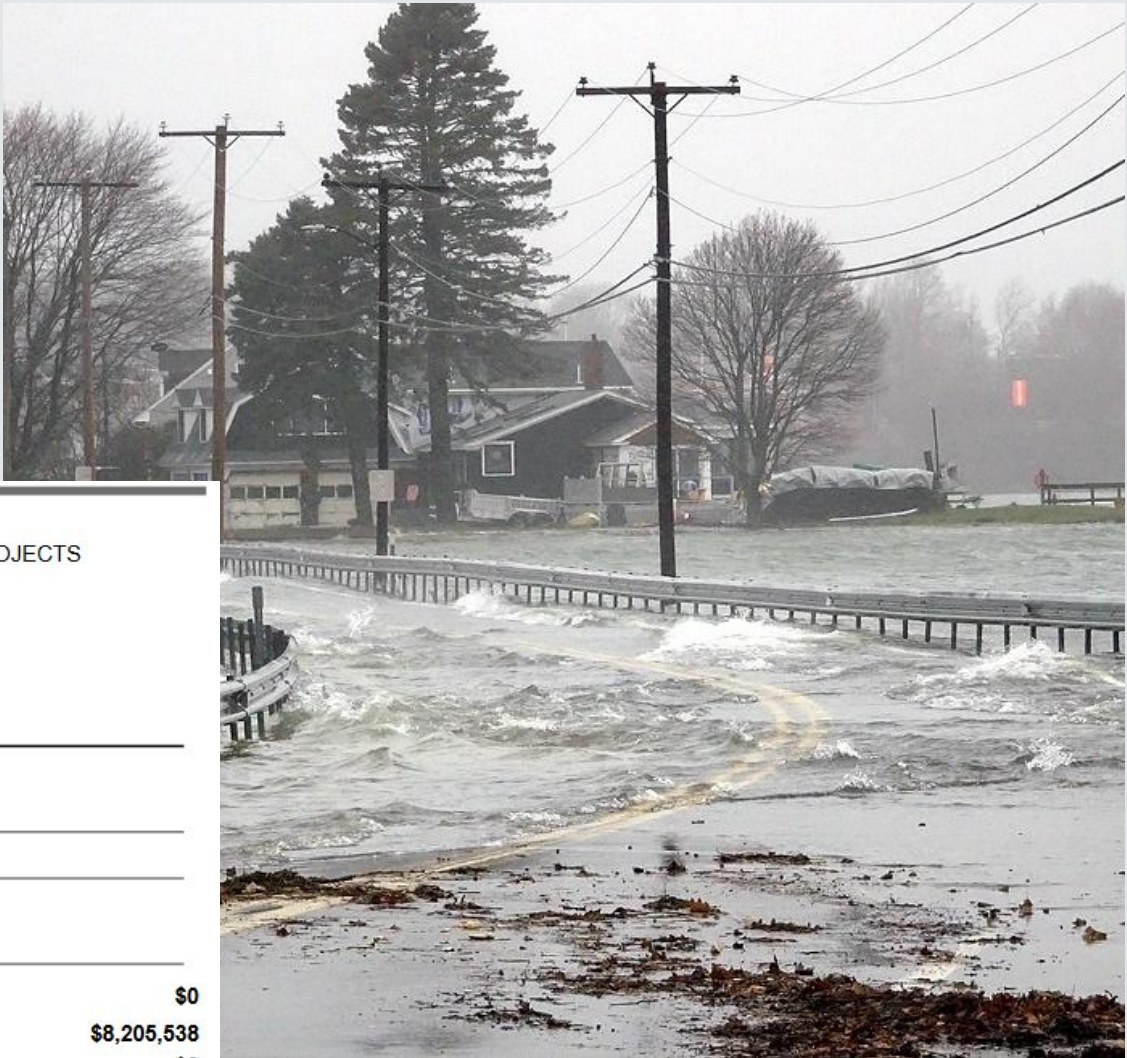
NORTH HAMPTON-RYE (42312A)			
Route/Road NH 1A		Category INDIVIDUAL PROJECTS	
Scope RECONSTRUCTION OF REVETMENT SEA WALLS		Strategy TIER 5	
Phase	Year	Funding	Program
Preliminary Engineering	2025	399,245	Federal-Aid Highway
Right of Way	2025	28,518	Federal-Aid Highway
Construction	2026	13,603,418	FEMA
Total		\$14,031,180	Previous Funding \$0 Current TYP Funding \$14,031,180 Future Funding Required \$0 Total Project Cost \$14,031,180



# How are we becoming more Resilient?

## 2 of 3: Project Additions to the Ten-Year Plan

Causeway  
Improvements to 1B  
from Goat Island to  
New Castle



**NEW CASTLE NH ROUTE 1B CAUSEWAY (44493)**

Route/Road NH ROUTE 1B

Category INDIVIDUAL PROJECTS

Scope MODIFICATIONS TO THE PORTION OF ROUTE 1B  
THAT RUNS FROM GOAT ISLAND TO NEW CASTLE  
ISLAND

Strategy TIER 2

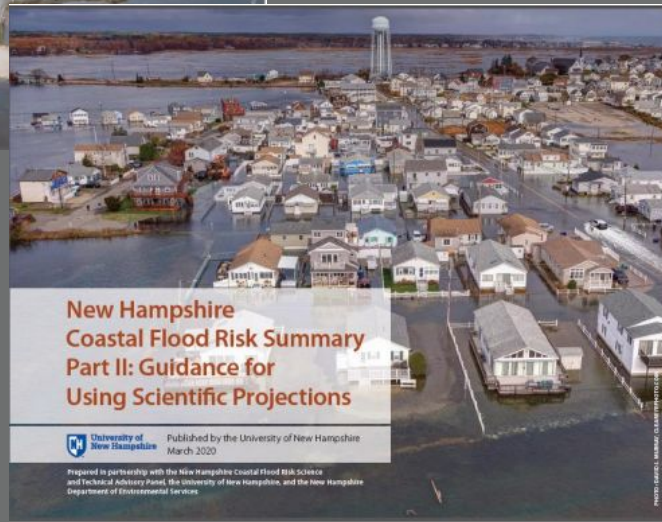
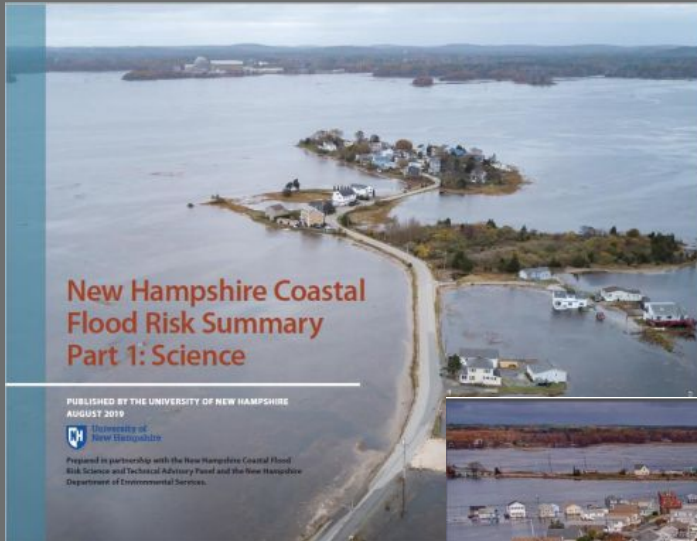
Phase	Year	Funding	Program
Preliminary Engineering	2028	270,758	Federal-Aid Highway
Preliminary Engineering	2030	591,153	Federal-Aid Highway
Right of Way	2030	6,840	Federal-Aid Highway
Construction	2033	3,935,693	Federal-Aid Highway
Construction	2034	3,401,095	Federal-Aid Highway

Total	\$8,205,538	Previous Funding	\$0
		Current TYP Funding	\$8,205,538
		Future Funding Required	\$0
		Total Project Cost	\$8,205,538



# How are we becoming more Resilient?

## 3 of 3: Action Items

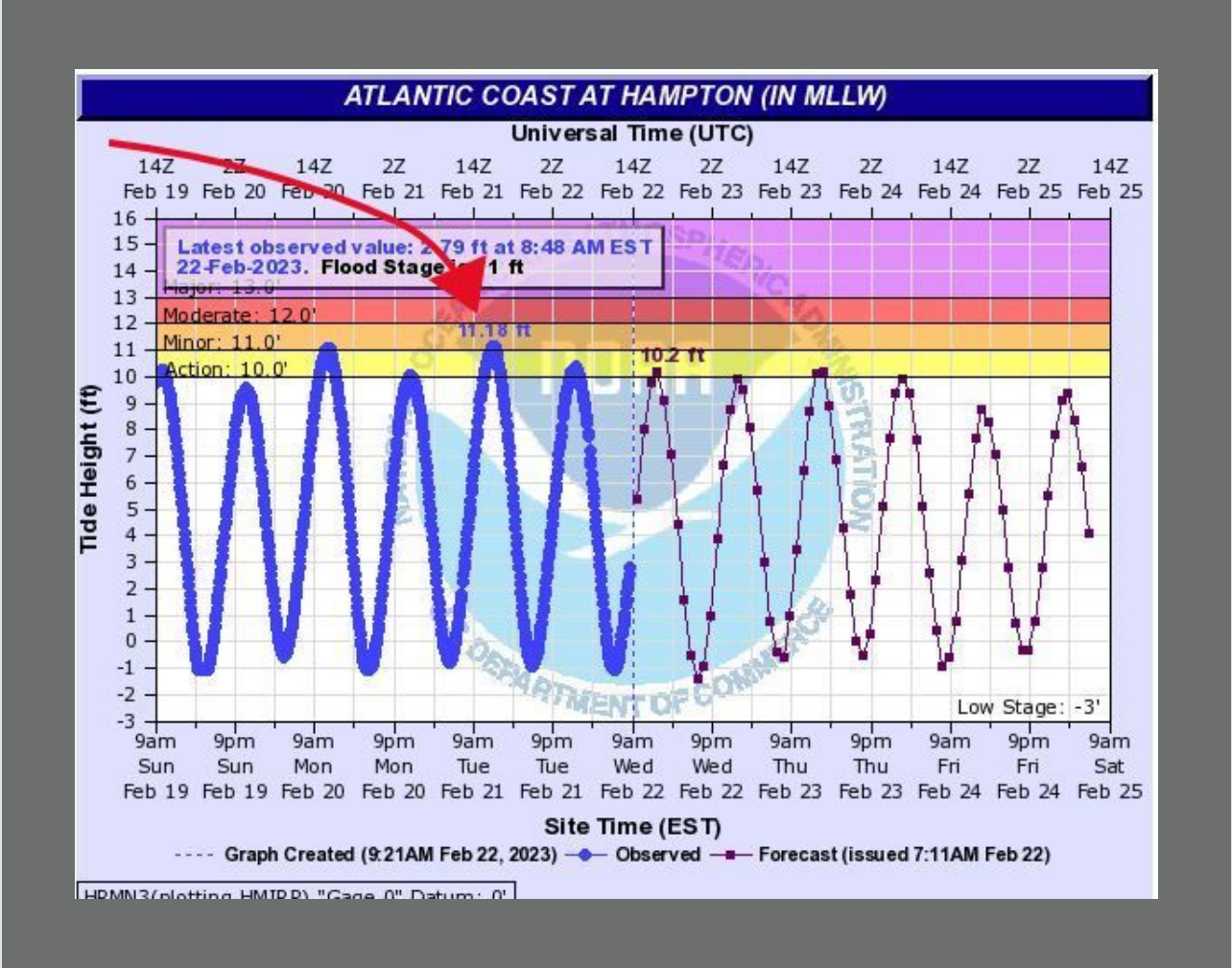


- Supporting greenhouse gas reduction policies
- Updated Science
- Coastal Resiliency Funds (RSA 36:53)
- Coastal Resiliency Cultural and Historic Resources District & Funds (RSA 12-A:68 & 69)
- Home Elevation/Buyout Program
- Hydrodynamic Coastal Flood Risk Model – Summer 2024
- Updating the Seacoast Transportation Corridor Vulnerability Assessment



## A photograph showing a residential street completely inundated with floodwater. In the foreground, a dark, cracked asphalt road leads into the water. On the left, a white house with a wooden deck is partially submerged. On the right, a yellow house and a white house are also partially submerged. Power lines and poles are visible on the left side. The background shows a distant shoreline under a cloudy sky.

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## View the Story Map