Coastal Resilience Hydraulic Modeling Guidance

2026 ACEC-NH & NHDOT
Technical Transfer Conference

April 16, 2026

Coastal Hydraulic and Hydrodynamic Supplement

NHDOT Comment Review Draft

Prepared for:

New Hampshire DOT Department of Transportation

Route 1A in Rye, NH (Photo Credit: GZA)

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Coastal H&H Supplement

What is the NHDOT "Coastal Supplement?"

A technical manual for the transportation planning, engineering, and design in NH's coastal environment:

- ✓ coastal hydrologic and hydraulic guidance for NHDOT personnel and Consultants
- ✓ supplements existing NHDOT design manuals
- ✓ simple approach and workflow for NHDOT design and evaluation of coastal roads, bridges, and other tidal crossings
- ✓ workflow applies to most NHDOT projects in the coastal area
- ✓ supports implementation of NHDOT coastal resilience improvement projects

Introduction & Background

Why is it needed?

Current and Future Vulnerability of New Hampshire Roads and Bridges:

Potential impacts from coastal flooding and wave effects:

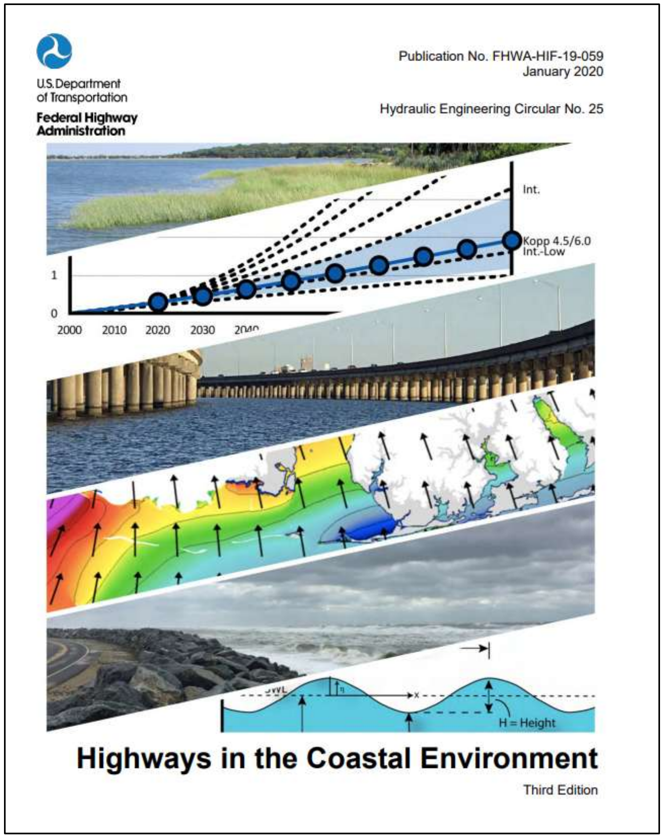
- use disruption
- impacts to evacuation routes
- excessive damage
- repair and maintenance costs
- public safety hazards
- property damage

Introduction & Background

Why is it needed?

NHDOT consistency with FHWA and AASHTO technical and design guidance for Coastal Roads and Bridges:

- ✓ FHWA Highways in the Coastal Environment, 3rd Edition, Publication No. FHWA-HIF-19-059, Hydraulic Engineering Circular No. 25, dated January 2020
- ✓ AASHTO "Guide Specifications for Bridges Vulnerable to Coastal Storms", dated 2008 and with 2023 Interim Revisions

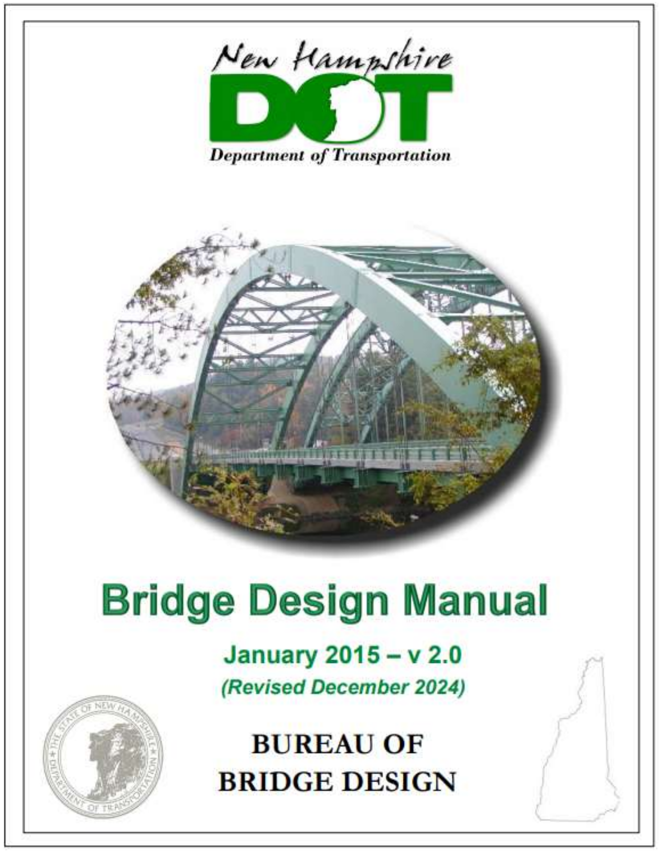


Introduction & Background

Why is it needed?

Supplement existing design guidance and manuals to include coastal engineering:

- ✓ Characterization of coastal environmental conditions, including non-stationary environmental design parameters
- ✓ Design frequencies: road and bridge flooding, wave run-up and overtopping, overwash, erosion, and scour
- ✓ Roadway and pavement design
- ✓ Development and application of associated environmental loads and stresses
- ✓ Compound flooding (e.g., combined riverine and tidal flooding)
- ✓ Design of erosion and scour countermeasures.



Introduction & Background

Why is it needed?

NHDOT compliance with State of New Hampshire Climate Policies as established by RSA 483-B:

*"New Hampshire **state agencies** involved in planning, siting, and design of state-funded structures and facilities, public works projects, and **transportation projects**, as well as land acquisition and management, and other environmental activities in the coastal and Great Bay regions of New Hampshire, **shall reference the Coastal Risks and Hazards Commission report, "Sea Level Rise, Storm Surges, and Extreme Precipitation in Coastal New Hampshire: Analysis of Past and Projected Trends," for guidance on all potentially affected activities. Agencies shall develop, as possible and appropriate, uniform standards of guidance**, in conformity with the report. Efforts designed with a previous report identified in paragraph I (UNH-2019-2020 New Hampshire Coastal Flood Risk Summary) shall not be required by the department to adapt their designs to accommodate the findings of an updated report but may do so as practicable."*

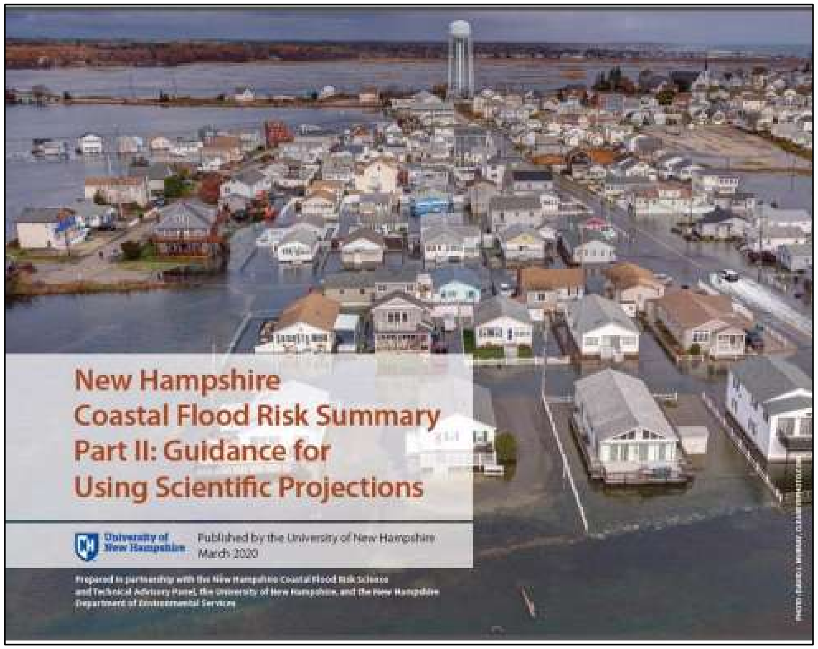
Note: **bold** added here for emphasis

Introduction & Background

Why is it needed?

NHDOT compliance with State of New Hampshire Coastal Resilience and Climate Adaptation Data and Recommendations Guidance

- ✓ New Hampshire Coastal Flood Risk Summary Part 1: Science, 2019 (**2025 update released 1/2026**)
- ✓ New Hampshire New Hampshire Coastal Flood Risk Summary Part II: Guidance for Using Scientific Projections, 2020 (**2026 update in progress**)



Introduction & Background

Why is it needed?

NHDOT compliance approach uses the *NHDOT Coastal Flood Risk Tolerance Framework*

- ✓ Climate Data
- ✓ Asset Data
- ✓ Criticality Assessment
- ✓ Vulnerability and Risk Assessment
- ✓ Implementation

technical manual

New Hampshire Coastal Flood Risk Tolerance

Task 5: Implementation Guide

prepared for

New Hampshire Department of Transportation

prepared by

Cambridge Systematics, Inc.
101 Station Landing, Suite 410
Medford, MA 02155

Introduction & Background

Why is it needed?

Consistency with Regulatory Requirements for Tidal Crossings

Design guidance and performance requirements and regulations for design of Tier 4 Tidal Crossings:

- ✓ Chapter Env-Wt 900 Stream Crossings
- ✓ Chapter Env-Wt 600 Coastal Lands and Tidal Waters/Wetlands

NEW HAMPSHIRE RESILIENT TIDAL CROSSINGS PROJECT

Advancing high priority tidal culvert replacements through Tier 4 Tidal Stream Crossing Rules

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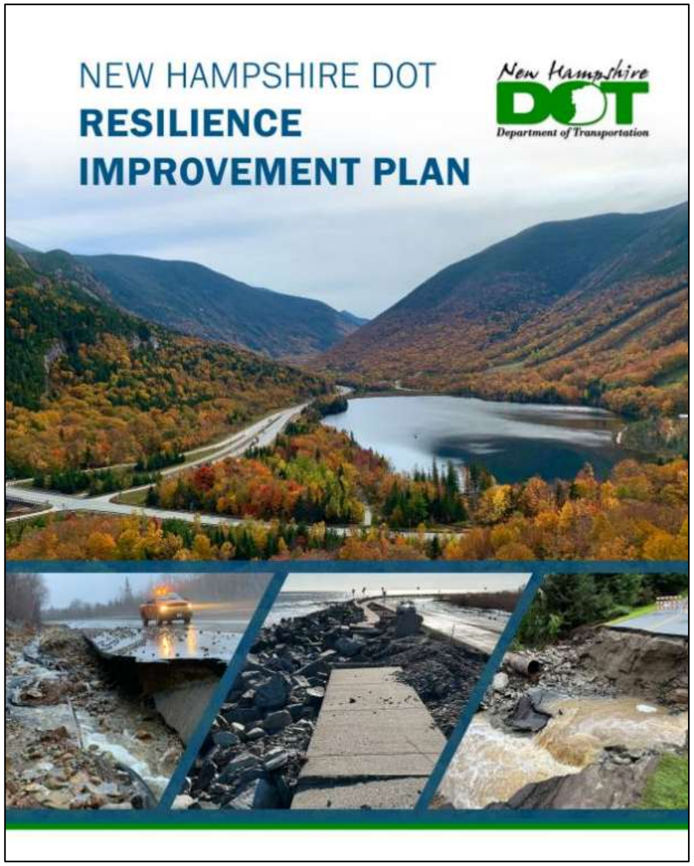
Introduction & Background

Why is it needed?

NHDOT Resilience Improvement Plan

- ✓ Supports implementation of New Hampshire's **Resilience Improvement Plan** with technical data and coastal engineering guidance



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Introduction & Background

Coastal Supplement Development Timeline

- ✓ Draft Coastal Supplement completed December 2025
- ✓ Coordination with NHDES for consistency with updates to the NH Coastal Flood Risk Part I: Science and Part II: Guidance for Using Scientific Projections – *in progress*
- ✓ Refinement and addressing NHDOT review comments – *in progress*
- ✓ Final for publication – *late spring/early summer (est.)*

Early Preview and Introduction - today

Coastal Supplement – Table of Contents

Subject to Change.

Coastal Supplement – Part 1

Limits of NHDOT Coastal Area

- ✓ New Hampshire **Coastal Program** Coastal Zone
- ✓ Areas included in the **NHDOT *Coastal Flood Risk Tolerance* Framework**

NHDOT Coastal Area includes:

- ✓ 17 coastal municipalities, Maine border to the Massachusetts border, and extending inland
- ✓ Representing about 10% population
- ✓ 18 miles of Atlantic Ocean coastline
- ✓ About 326 miles of tidal shoreline, including tidal wetlands/salt marshes*
- ✓ Includes the tidal stretch of the Piscataqua River
- ✓ Great Bay Estuary and Hampton-Seabrook Estuary
- ✓ Harbors (Portsmouth, Hampton and Rye)
- ✓ Beaches (e.g., Seabrook, Hampton, Rye)
- ✓ Includes ocean islands (Isle of Shoals)

*Ref. New Hampshire Inventory of Tidal Shoreline Protection Structures

New Hampshire Coastal Program Limits

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Coastal Supplement – Part 1

NH Roadways are Identified by:

- ✓ Highway Tier - Tier 1 through Tier 3 roads, bridges
  - 1,905 segments of roadway; +/- 287 centerline miles
  - 154 bridges
- ✓ Functional Class
  - Principal Arterial – Interstate (49 miles)
  - Principal Arterial – Freeway (57 miles)
  - Principal Arterial – Other (40 miles)
  - Minor Arterial (77 miles)
  - Major Collector (118 miles)
  - Minor Collector (13 miles)
- ✓ Roadway Criticality
  - High
  - Medium
  - Low
- ✓ Roadway Vulnerability
  - High
  - Medium
  - Low
  - None

Coastal Supplement – Part 1

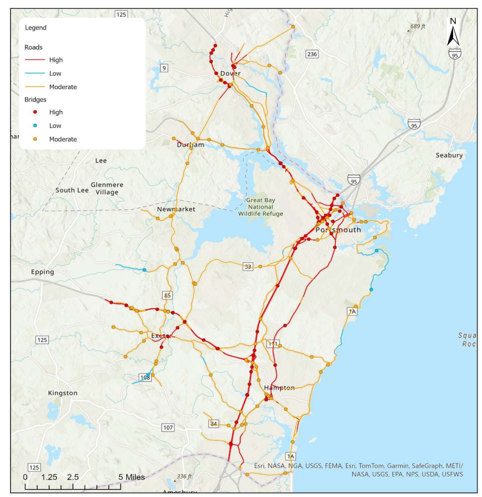
Roadway Criticality Classification

- ✓ Roads and bridges are assigned levels of "infrastructure criticality" ranked from **High** to **Moderate** to **Low**
- ✓ Based on:
  - ✓ **Usage and Operational Importance**
  - ✓ **Socioeconomic Importance**
  - ✓ **Health and Safety Importance**

* Reference: Technical Memorandum "New Hampshire Coastal Flood Risk Tolerance, *Task 5: Implementation Guide*"; *Subtask 3 Report - Developing the Framework: Criticality Determination*, Cambridge Systematics LLC

Criticality	Number of Roadway Segments	Road Miles	Number of Bridges*
High	696 (37%)	132 (40%)	71 (46%)
Moderate	1,158 (61%)	187.6 (57%)	80 (52%)
Low	51 (3%)	11.6 (4%)	4 (3%)
Total	1,905	331.2	155

Reference: Technical Memorandum "New Hampshire Coastal Flood Risk Tolerance, *Subtask 3 Report - Developing the Framework: Criticality Determination*", Cambridge Systematics LLC



NHDOT RIP Assessment Results: Criticality and Vulnerability

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Coastal Supplement – Part 1

Roadway Vulnerability Assessment:

- ✓ **Exposure:** whether an asset or system is located in an area experiencing direct effects of coastal flooding;
- ✓ **Sensitivity:** how the asset or system fares when exposed to coastal flooding; and
- ✓ **Adaptive capacity:** the system's ability to cope with potential coastal flooding impacts.

Note: The Vulnerability Assessment Scoring Tool (VAST) is a spreadsheet tool that guides transportation personnel in conducting a quantitative, indicator-based vulnerability screen of their transportation assets.

Ref. FHWA

Table 3.1 Vulnerability Construct for Sea Level Rise

Asset Type	Exposure (33%)	Sensitivity (33%)	Adaptive Capacity (33%)
Roads	• Flood inundation depth by scenario (100%): – 2050: MHHW + 2 ft sea level rise (SLR) – 2100: MHHW + 6 ft SLR – Subtract elevation data from Digital Surface Model (DSM)	• Built Condition (50%) • Pavement Condition (25%) • HTF (using 2 feet SLR as proxy) (25%) – Not used for 2100	• Functional Class (50%) • AADT (25%) • Network Density (25%)
Bridges	• Flood inundation depth by scenario (100%): – 2050: MHHW + 2 ft SLR – 2100: MHHW + 6 ft SLR – Subtract maximum approach roadways elevation from DSM	• Substructure condition (50%) • Scour Condition (25%) • HTF (using 2 feet SLR as proxy) (25%) – Not used for 2100.	• Functional Class (67%) • AADT (33%)

Note: Indicator weights are indicated in parentheses.

Table 3.2 Vulnerability Construct for Sea Level Rise Plus 1% Storm Surge

Asset Type	Exposure (33%)	Sensitivity (33%)	Adaptive Capacity (33%)
Roads	• Flood inundation depth by scenario (100%): – 2050: MHHW + 2 ft SLR + 1% storm surge – 2100: MHHW + 6 ft SLR+ 1% storm surge – Subtract elevation data from DSM	• Built Condition (50%) • Pavement Condition (25%) • Flood Protection Infrastructure (25%)	• Functional Class (50%) • AADT (25%) • Network Density (25%)
Bridges	• Flood inundation depth by scenario (100%): – 2050: MHHW + 2 ft SLR+ 1% storm surge – 2100: MHHW + 6 ft SLR + 1% storm surge – Subtract maximum approach roadways elevation from DSM	• Substructure condition (50%) • Scour Condition (25%) • Flood Protection Infrastructure (25%)	• Functional Class (67%) • AADT (33%)

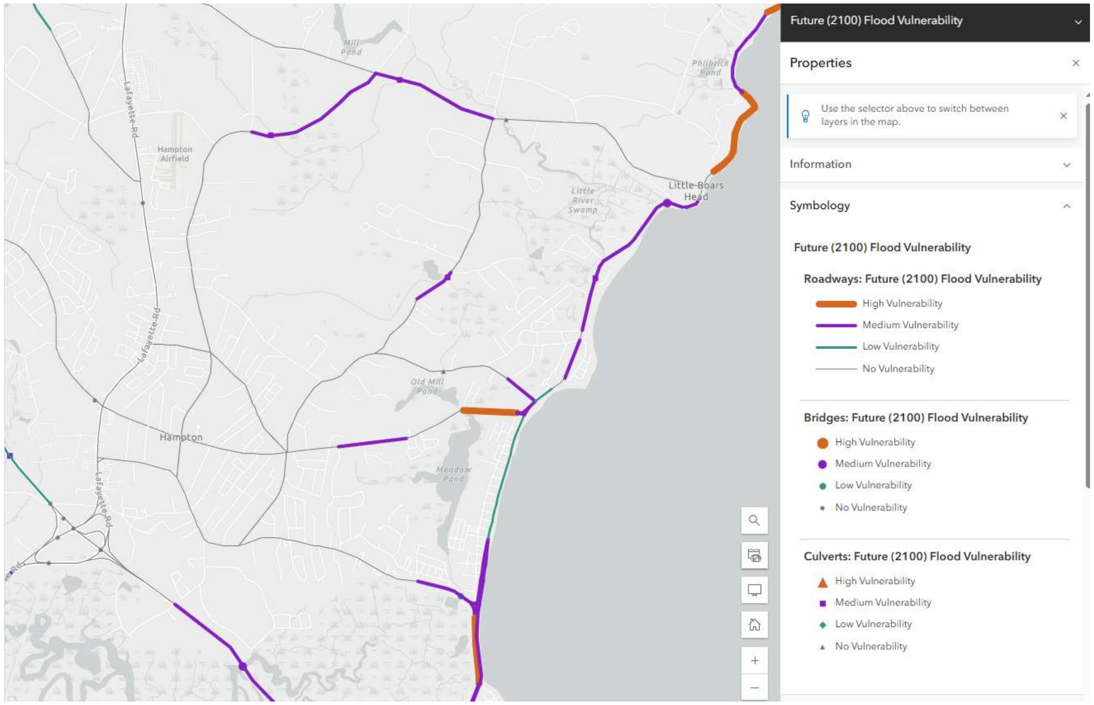
Note: Indicator weights are indicated in parentheses. As discussed in Section 2.1, this vulnerability assessment for this hazard was conducted only for assets within FEMA VE, AE, and AO zones, as identified in FEMA 100-Year Coastal Flood Maps.

Reference: "New Hampshire Coastal Flood Risk Tolerance, *Subtask 2: Climate and Asset Data Scoping and Review; Subtask 4: Vulnerability and Risk Assessment"* Cambridge Systematics LLC

Coastal Supplement – Part 1

Roadway Vulnerability Assessment:

- ✓ Tidal flooding:
  - Current: about **8 miles** of roadway and **28 bridges**
  - Year 2100: increase to about **16 miles** and **33 bridges**
- ✓ Extreme Flood (100-year MRI):
  - Current: about **21 miles** of roadway and **30 bridges**
  - Year 2100: increases to about **22 miles** of roadway, remains at about **30 vulnerable bridges**



Reference: "New Hampshire Coastal Flood Risk Tolerance, *Subtask 2: Climate and Asset Data Scoping and Review; Subtask 4: Vulnerability and Risk Assessment"* Cambridge Systematics LLC

Risk-Based Analysis and Design Workflow

The purposes of this workflow are to:

- Incorporate a **simple risk-based design approach** based on roadway function criticality
- Identify design frequencies
- Incorporate non-stationary climate parameters such as sea level rise consistent with federal and State resilience and climate policies
- Identify appropriate design/service lives for application of climate (and other) non-stationary parameters
- Identify requirements and Levels of Study for coastal hydrologic and hydraulic analyses and reports
- Require sensitivity analyses in order to identify critical outcomes at MRIs other than design benchmarks

Coastal Supplement – Part 1

Coastal Highway Workflow

Step 1:
Select Roadway Category (Functional System Code)

Step 2:
Select AEP/MRI for Serviceability and Check for Failure

Step 3:
Select appropriate Design Life based on Roadway Category

Step 4:
Select appropriate Roadway or Bridge "Criticality" based on Roadway

Step 5:
Select appropriate Vulnerability and Risk Tolerance Category

Step 6:
Select appropriate Sea Level Rise Scenario based on Vulnerability and/or Risk Tolerance Category

Step 7:
Complete Hydrologic and Hydraulic Analyses

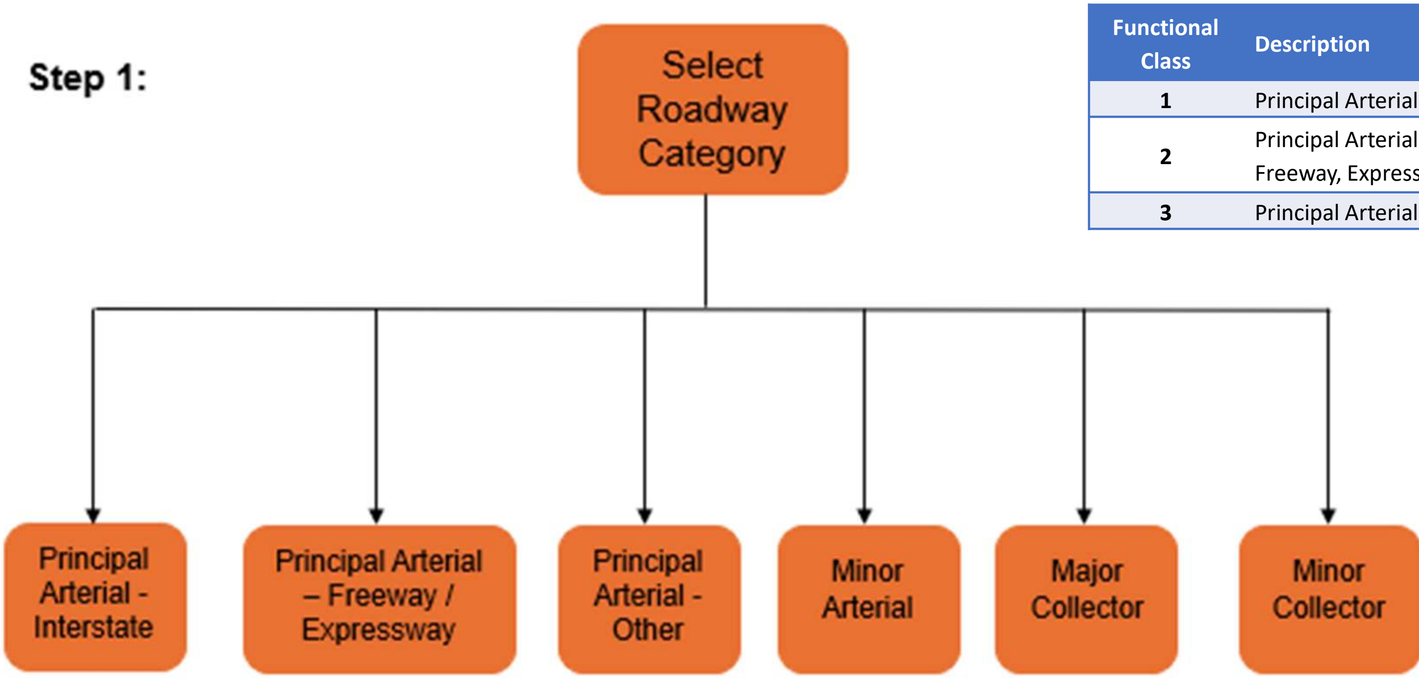
Step 8:
Analyze and Design the Structure using LRFD or ASD

Step 9:
Perform Sensitivity Analysis over full range of probabilities

Coastal Highway Workflow

Step 1: Select Roadway Category by Functional Class

Functional Class	Description	Functional Class	Description
1	Principal Arterial – Interstate	4	Minor Arterial
2	Principal Arterial – Other Freeway, Expressway	5	Major Collector
3	Principal Arterial – Other	6	Minor Collector



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Coastal Supplement – Part 1

Coastal Highway Workflow

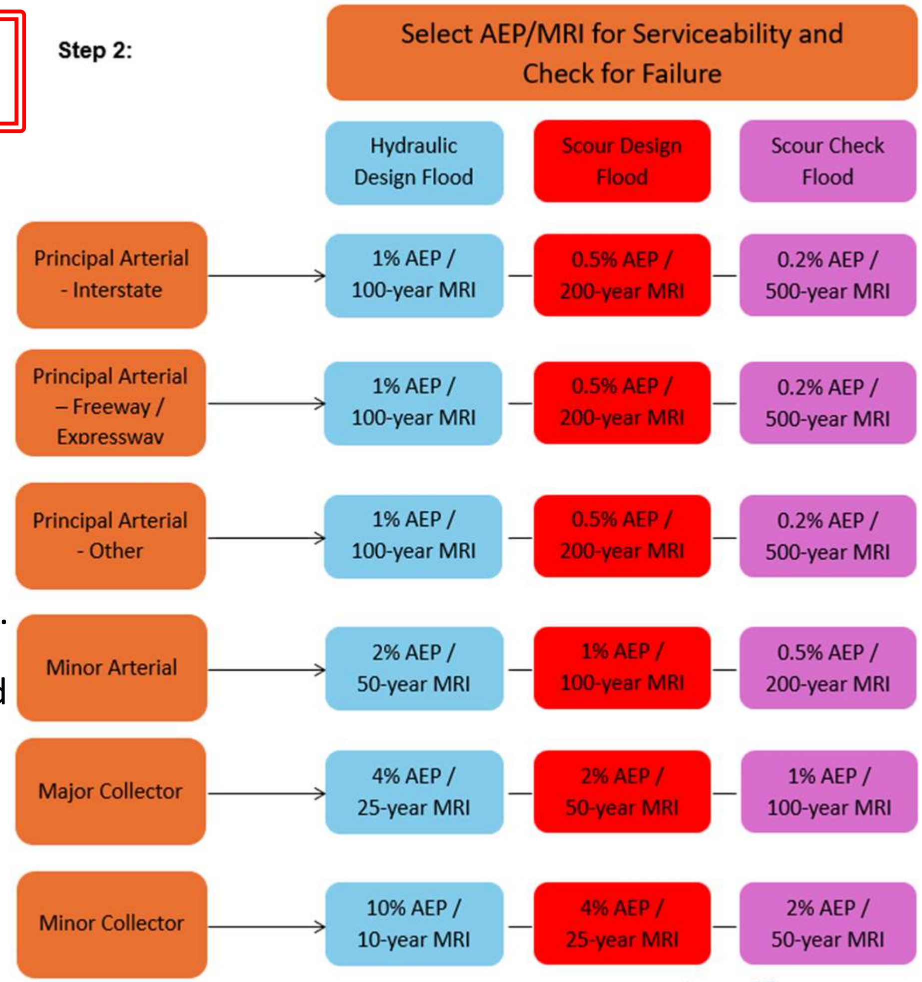
Subject to Change.

Step 2: Select Design Frequencies (AEP/MRI) by Functional Class and Application

Design frequencies (AEP/MRI) are selected by Roadway Functional Class and by application (hydraulic design, scour design and scour check) based on:

1) serviceability design considerations; and
2) failure design conditions (e.g., Check Flood conditions).

These values may be a minimum but may be adjusted upward (i.e., lower probability event) on a project basis.



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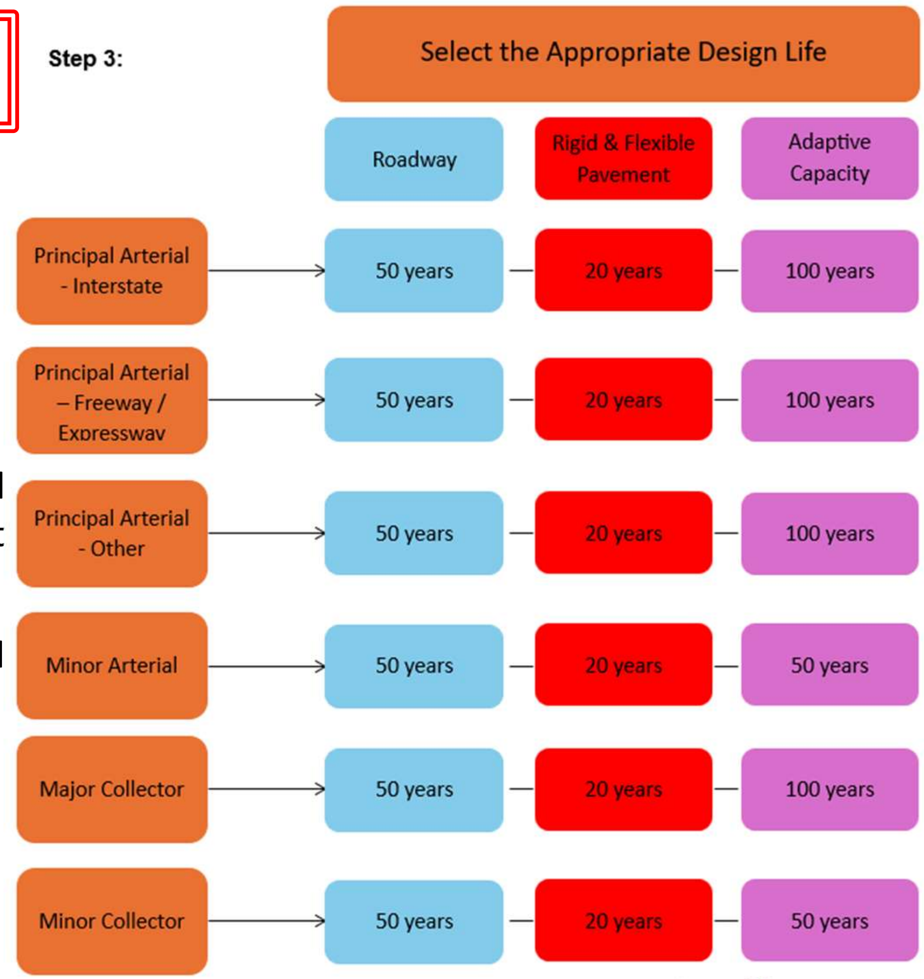
Coastal Supplement – Part 1

Coastal Highway Workflow

Subject to Change.

Step 3: Select Design Life by Function

- ✓ Design Life values are based on past practice and FHWA guidance.
- ✓ These values are a minimum but may be adjusted upward (e.g., to reflect an expected Service Life) on a project basis.
- ✓ Adaptive Capacity values may also be adjusted upward based on Roadway Criticality.



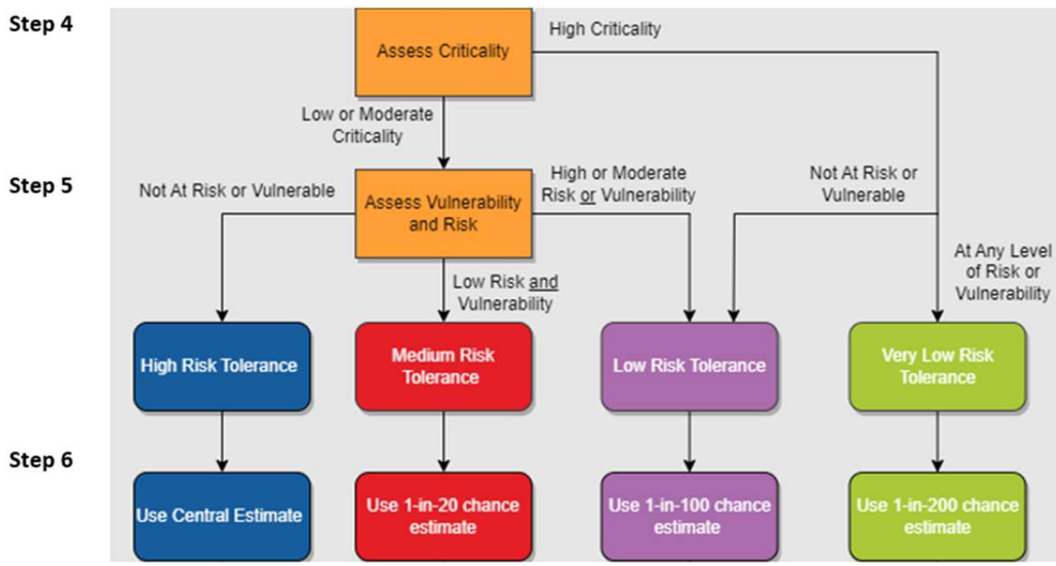
Coastal Supplement – Part 1

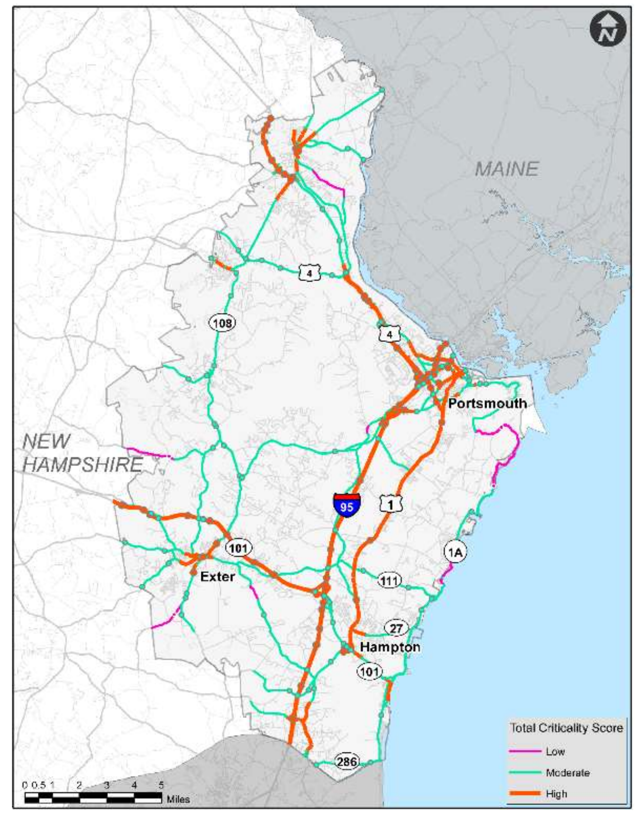
Subject to Change.

Coastal Highway Workflow

Steps 4 through 6:

Select Design Sea Level Rise based on Roadway Criticality (CamSys), Vulnerability (CamSys) and Risk Tolerance





Step 6 SLR categories in development for consistency with NH Coastal Flood Risk Summary, Part 1: Science (2025) and Part II: Guidance for Using Scientific Projections (2026 est.) documents

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Coastal Supplement – Part 1

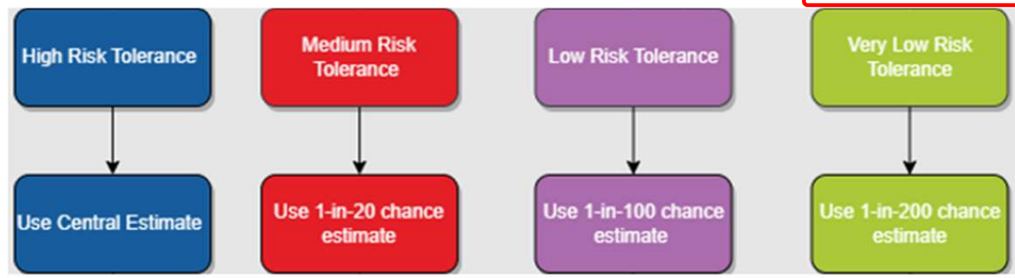
Subject to Change.

Coastal Highway Workflow

Step 6: Select Sea Level Rise projection for Design*

TIMEFRAME	HIGH TOLERANCE FOR FLOOD RISK	MEDIUM TOLERANCE FOR FLOOD RISK	LOW TOLERANCE FOR FLOOD RISK	VERY LOW TOLERANCE FOR FLOOD RISK
	Plan for the following RSLR estimate (ft)* *compared to sea level in the year 2000*			
	Lower magnitude, Higher probability	⟵	⟶	Higher magnitude, Lower probability
2030	0.7	0.9	1.0	1.1
2040	1.0	1.2	1.5	1.6
2050	1.3	1.6	2.0	2.3
2060	1.6	2.1	2.6	3.0
2070	2.0	2.5	3.3	3.7
2080	2.3	3.0	3.9	4.5
2090	2.6	3.4	4.6	5.3
2100	2.9	3.8	5.3	6.2
2110	3.3	4.4	6.1	7.3
2120	3.6	4.9	7.0	8.3
2130	3.9	5.4	7.9	9.3
2140	4.3	5.9	8.9	10.5
2150	4.6	6.4	9.9	11.7

NH Coastal Flood Risk Summary Part II: Guidance for Using Scientific Projections (**2020**)



Year	RCP	Central Estimate 50% probability SLR meets or exceeds:	Likely Range 67% probability SLR is between:	1-in-20 Chance 5% probability SLR meets or exceeds:	1-in-100 Chance 1% probability SLR meets or exceeds:	1-in-200 Chance 0.5% probability SLR meets or exceeds:	1-in-1000 Chance 0.1% probability SLR meets or exceeds:
2030	RCP 4.5*	0.5	0.3 - 0.7	0.9	1.0	1.1	1.3
2050	RCP 4.5*	0.9	0.5 - 1.3	1.6	2.0	2.3	2.9
2100	RCP 2.6	1.4	0.6 - 2.5	3.4	5.0	5.8	8.6
2100	RCP 4.5	1.9	1.0 - 2.9	3.8	5.3	6.2	8.7
2100	RCP 6.0	2.0	0.9 - 3.3	4.3	5.8	6.8	9.4
2100	RCP 8.5	2.6	1.5 - 3.8	4.9	6.5	7.5	10.0
2150	RCP 2.6	2.0	0.9 - 3.4	5.1	8.6	10.7	17.0
2150	RCP 4.5	2.7	1.2 - 4.6	6.4	9.9	11.7	18.1
2150	RCP 6.0**	N/A	N/A	N/A	N/A	N/A	N/A
2150	RCP 8.5	4.0	2.6 - 5.8	7.6	11.4	13.4	19.9

The color in the rows for RCP 4.5 corresponds to the colors shown in Figure 4.5
* The 2050 RSLR projections using the RCP 4.5 scenario are very similar to the projections using the RCP 2.6, RCP 6.0, and RCP 8.5 scenarios. See text and Figure 5 for additional explanation.
** Projections for RSL after 2100 are not available for RCP 6.0.

NH Coastal Flood Risk Summary Part I: Science (**2019**)

* In development for consistency with NH Coastal Flood Risk Summary, Part 1: Science (2025) and Part II: Guidance for Using Scientific Projections (2026 est.) documents

Coastal Highway Workflow

Step 7: Complete Hydrologic and Hydraulic Analyses and Report

Reference Part 2: Environmental Conditions for Assessment and Design of New Hampshire Coastal Roads, Bridges and Other Tidal Crossings

Chapter 6 – New Hampshire Coastal Setting

Chapter 7 – Coastal Storms

Chapter 8 – Tidal and Extreme Water Levels

Chapter 9 – Water Waves

Chapter 10 – Modeling of Coastal Processes

Chapter 11 – Levels of Study

Coastal Highway Workflow

Step 8: Analyze and Design Structure – Coastal Hydrologic and Hydraulic Engineering

For project design frequencies:

1. Roadway Flood Inundation:
- Tidal and extreme flood frequency
- Peak flood elevation and depth
- Flood duration (time series)
- Flood flow peak flow velocities
- Pavement and base, subbase, subgrade saturation (depth and duration)
- Over road wave heights and periods

2. Wave Effects (Bridges, Road Shoulder, Embankments):
- Wave height spectra distribution
- Wave set-up
- Wave crest elevation
- Wave run-up and overtopping
- Overtopping discharge rate

3. Compound Flooding:
- Joint probabilities
- Combined flow (discharge)
- Peak flood elevation; Peak flow velocity

4. Erosion and Sedimentation:
- Long term change (roads, bridges); sediment transport and deposition (coastal bridges)
- Bedform change (coastal bridges)

5. Scour
- Contraction scour (horizontal; vertical)
- Local scour

6. Environmental Loads (Bridges, Other Structures)
- Hydrostatic
- Hydrodynamic
- Wave
- Debris

Coastal Highway Workflow

Step 8: Analyze and Design Structure – Coastal Design

For project design frequencies:

1. Coastal Bridge Design
- Deck elevation
- Load application
- Abutment design; revetments
- Scour countermeasures

2. Roadway Design
- Roadway elevation, geometry
- Roadway Drainage
- Pavement Structure:
  - Asphalt, concrete
  - Base, Subbase, Subgrade
  - Underdrains
  - Drainage swales, piping
  - Embankments, erosion and scour protection

3. Tidal Culverts and Crossing Structures
- Hydraulic capacity – design frequency flood; compound flooding
- Hydraulic capacity - passage of tidal flood flows
- Aquatic passage
- Erosion protection (washout countermeasures)

4. Shoreline Protection
- Revetments
- Seawalls
- Living Shorelines; NNBFs

Coastal Highway Workflow

Step 9: Sensitivity Analyses

- ✓ Evaluate complete range of MRI/AEP in addition to design frequency (1-year to 500-year MRI)
- ✓ Consideration of uncertainty around the mean value at the specified MRI (e.g., mean; 67% CI; 95%CI)
- ✓ Evaluate complete tidal range during design events in addition to peak water level (non-steady time series condition)
- ✓ Different source data and analysis methodologies (USACE NAACS; NOAA; FEMA; other)
- ✓ Compound flooding (joint probability)

Coastal Supplement – Part 2

Coastal Hydrologic Conditions

- ✓ **Elevated water levels** including stillwater elevation, wave crest elevation and water set-up (nuisance flooding; extreme flooding)
- ✓ **Wind** intensity in terms of 3-second gusts and sustained (e.g., 1-minute, 10-minute) for a specific exposure scenario, time averaging duration and elevation (usually the 10-meter elevation above ground surface), described on an all-direction basis and a directional basis
- ✓ **Wind-generated wave** heights and periods, including wave height spectral distribution
- ✓ **Currents:** Flood and wave-induced currents
- ✓ **Precipitation** intensity over different time averaging basis (e.g., 24-hour rain intensity)
- ✓ **Compound flooding** (combined riverine and tidal flooding, combined tidal flooding and stormwater)
- ✓ **Groundwater** elevation and depths
- ✓ **Temperature** (air and water)
- ✓ **Surface water and groundwater chemistry** (salinity, acidity, chloride, sulfates)

Coastal Supplement – Part 2

Coastal Hydrologic Conditions: Nonstationary

Non-stationarity can include an abrupt change, a periodic variability, or a gradual change. The coastal parameters that have exhibited, and are predicted to continue to exhibit, non-stationarity include:

- ✓ **Relative Sea Level Rise (RSLR)**: Increasing rate of sea level rise over time relative to today
- ✓ **Increasing Flood Elevations due to RSLR**: water levels (including stillwater elevation), total water level elevation, wave crest elevation, wave run-up
- ✓ **Increasing intensity** of tropical cyclones and possibly extratropical cyclones and rate of intensity increase over a storm track; increasing intensity of winds associated with a given event probability due to increasing storm intensity
- ✓ **Increasing wave heights** associated with a given event probability due to increasing wind intensity and water level
- ✓ **Increasing precipitation intensity** associated with a given event probability due to greater atmospheric moisture and stagnation (slowing) of storm track forward speed
- ✓ **Increasing average and peak temperature** (air and water) due to global warming
- ✓ **Changes to surface water chemistry** (salinity, acidity, chloride, sulfates) at a project location
- ✓ **Rise in coastal groundwater elevations** due to sea level along with changes in groundwater chemistry

Coastal Supplement – Part 2

Subject to Change.

Levels of Study

Level I

- ✓ Planning study and preliminary design, possibly for small/simple projects
- ✓ Publicly available data: wind, water levels, wave and precipitation
- ✓ Generally, assume peak value for each component for a given design frequency
- ✓ Generally, conservative

Level II

- ✓ Builds from Level I study
- ✓ Higher resolution topography & bathymetry for 3D Digital Elevation Model (site-specific surveys)
- ✓ Wind analysis of historic data (airports, buoys)
- ✓ 1D and 2D numerical modeling

Level III

- ✓ Builds from Level I and Level II studies
- ✓ 2D and 3D numerical circulation and wave modeling with non-steady conditions
    - Capture tidal changes, changes in storm wind fields and storm wave fields
    - Non-steady numerical modeling
- ✓ Event joint probabilities for compound flood conditions (riverine, participation, storm surge)
- ✓ Sensitivity analysis: simulations and load calculations of varying combinations of water level and wave heights
- ✓ Evaluation of effects of uncertainties

Coastal Supplement – Part 4

Subject to Change.

Application Examples: New Hampshire Road and Bridge Design

Coastal Revetment Reconstruction

Photo Credit: NHDOT

Road Damage Due to Wave Overtopping

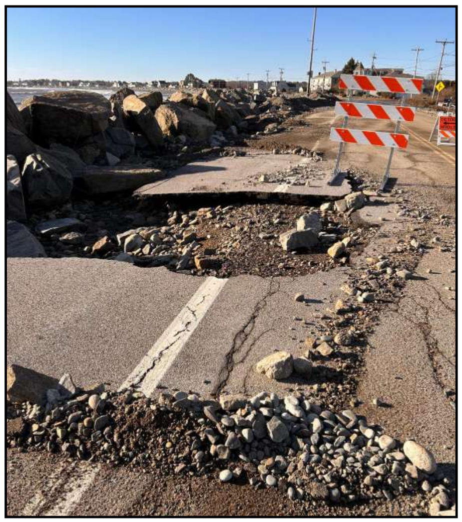


Photo Credit: NHDOT

Bridge Replacement and Approach Road

Photo Credit: NHDOT

Tidal Hydrologic and Hydraulic Analyses for Bridge Culvert Replacement

Photo Credit: NHDES

Questions? Comments?

Resilience Improvement Plan | Department of Transportation

New Hampshire Coastal Flood Risk Summary, Part I: Science, 2025 Update