




Low-lying Roads: Yarmouth

An Economic Development
Administration Disaster Grant
Project

Cape Cod Commission: Heather McElroy, Martha Hevenor, Michele White and Liz Kellam
Woods Hole Group: Joe Famely

Purpose and Objectives of Workshop

- 
- **Review flood projections and impacts on roadways for the town under future scenarios**
 - **Discuss vulnerable low-lying roads or other transportation infrastructure**
 - **Prepare the town to address priority road segments for design and permitting**

Agenda

- Project Overview
- Vulnerability and Risk Assessment
- Results of Low-Lying Roads Screening
- Breakout Groups/Discussion
- Next Steps



Low Lying Roads Project

10

TOWNS

EDA and MVP
funding thru 2023

Vulnerability assessment of low-lying roads and transportation infrastructure

Municipal prioritization

Potential design solutions

NEXT STEPS: PUBLIC MEETINGS

Prioritize most critical road segments for development of alternative solutions for sea level rise and storm surge adaptation

FALL - DECEMBER

6 public workshops

LATE WINTER - SPRING

4 public workshops

FALL

Yarmouth, Orleans,
Eastham, Wellfleet,
Sandwich, Dennis

WINTER

Barnstable, Bourne,
Brewster, Truro

SPRING

HAZARD
Storms, SLR
& Flooding

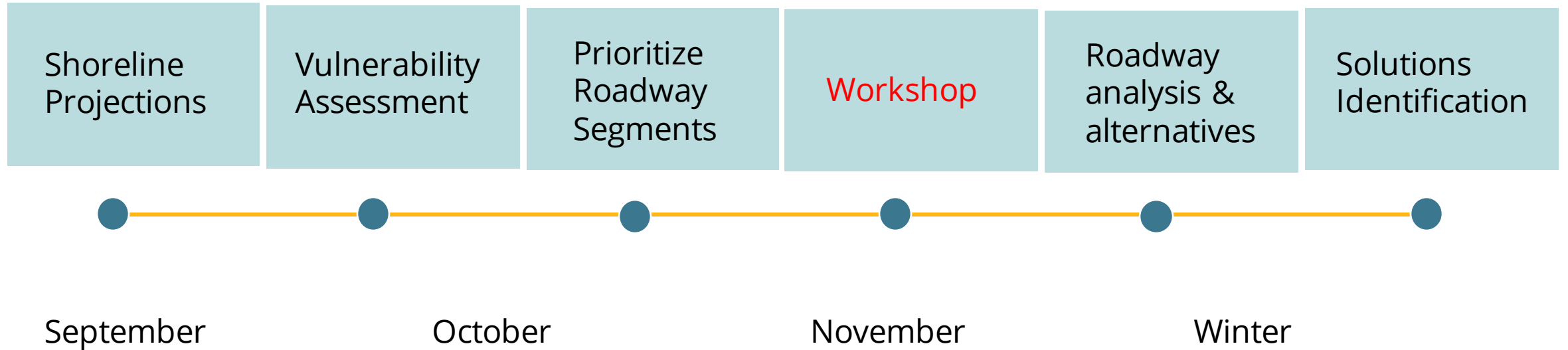


Adaptation Strategies



- | Green Infrastructure, or Nature-based Solutions
- | Gray Infrastructure, or Traditional Engineering Structures
- | Other approaches – Managed Retreat, Abandonment

PROJECT TIMELINE



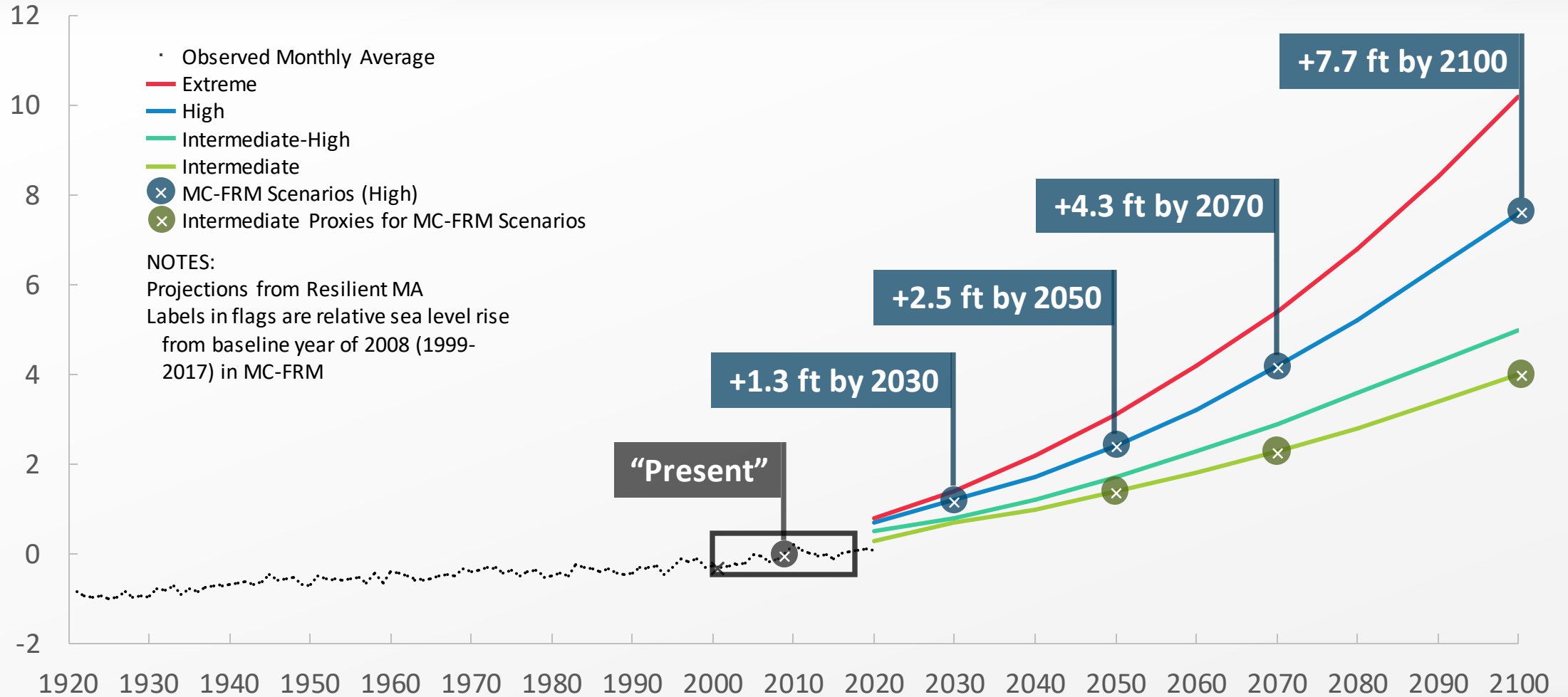
Questions?

- Workshop Purpose or Objectives
- Low Lying Roads project
 - Key components
 - Vulnerability Assessment - Identify Potential Sites
 - Public Outreach and Engagement
 - Roadway Feasibility and Alternative Solutions
 - Solutions Identification
 - Timeline

MA EOEEA Probabilistic Sea Level Rise Projections

MC-FRM NORTH (DeConto & Kopp, 2017)

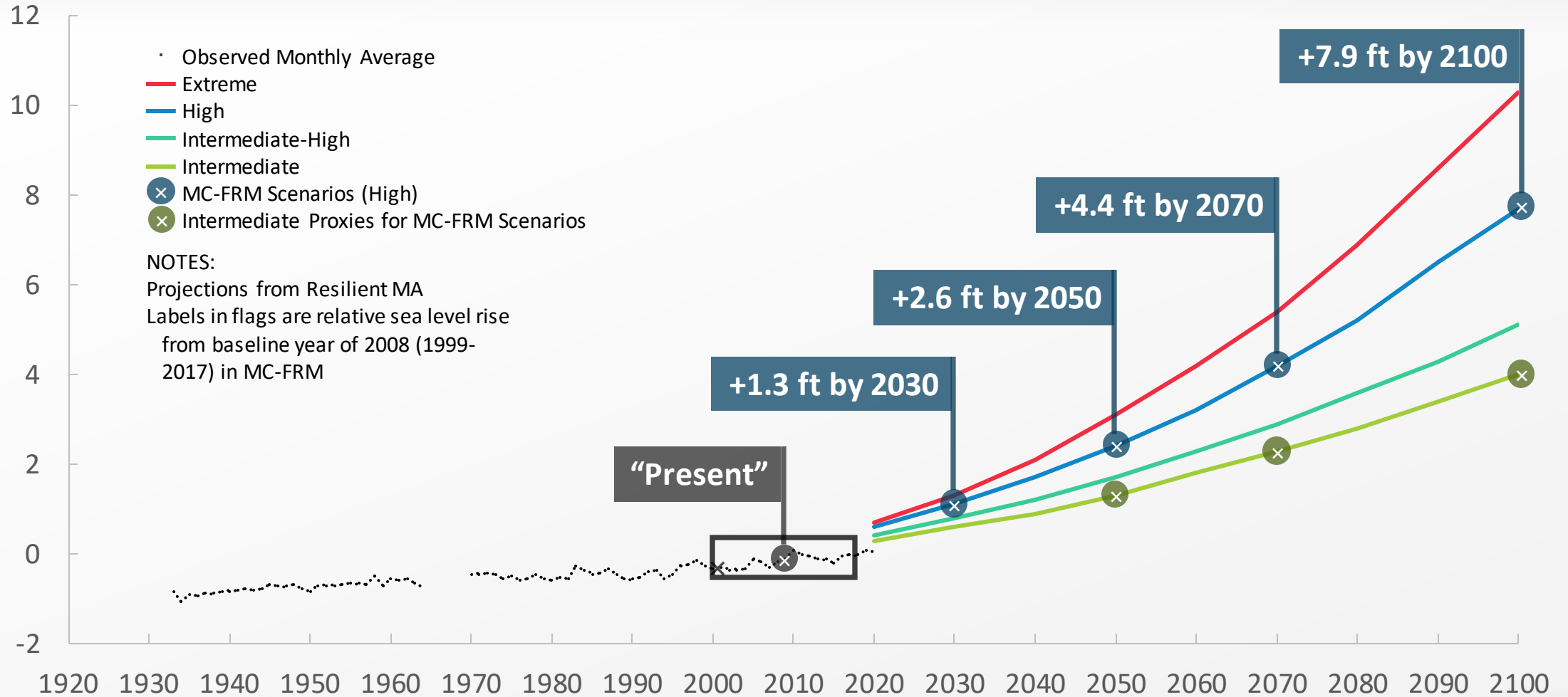
Relative Mean Sea Level (feet NAVD88)



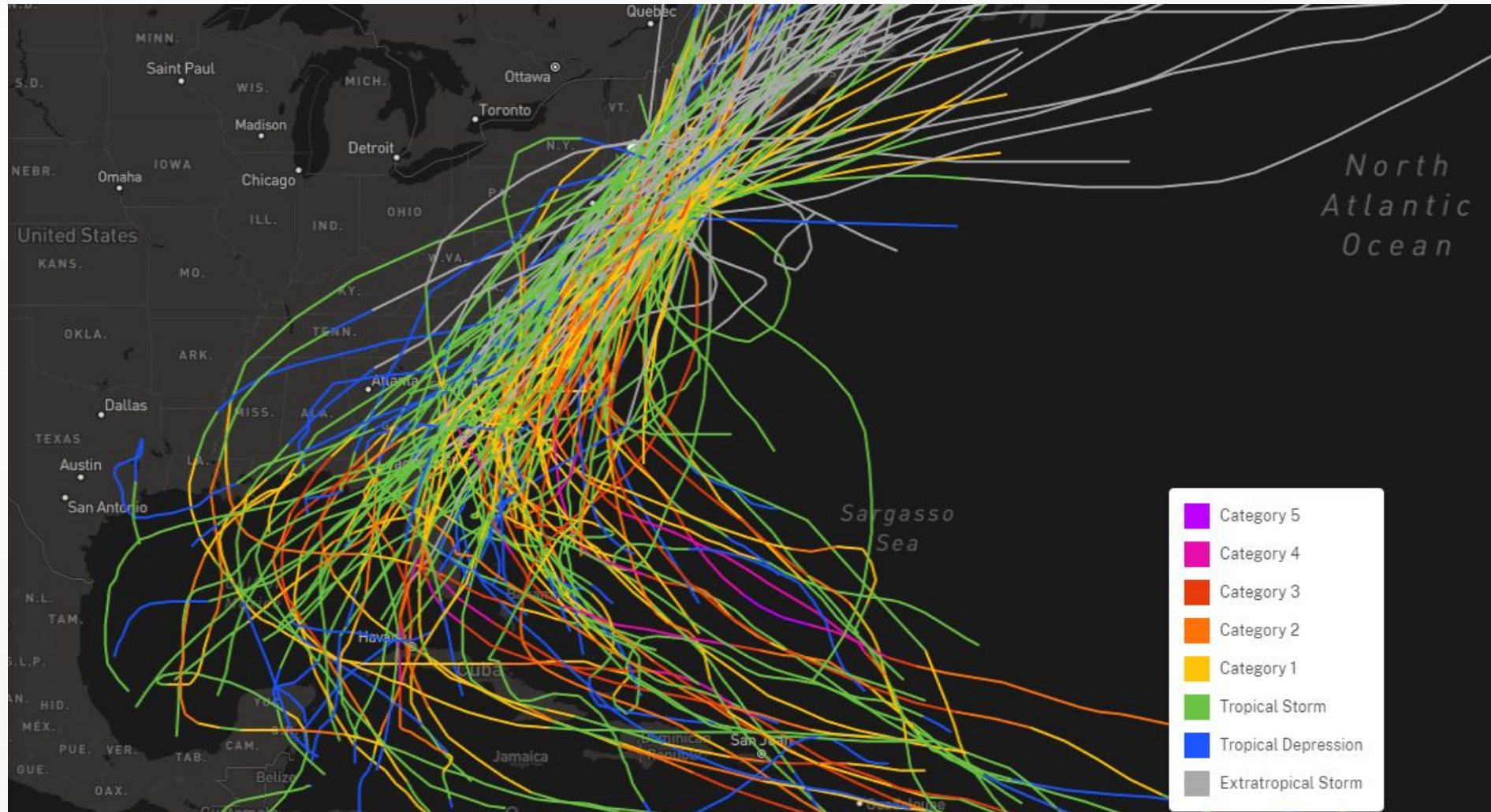
MA EOEEA Probabilistic Sea Level Rise Projections

MC-FRM SOUTH (DeConto & Kopp, 2017)

Relative Mean Sea Level (feet NAVD88)

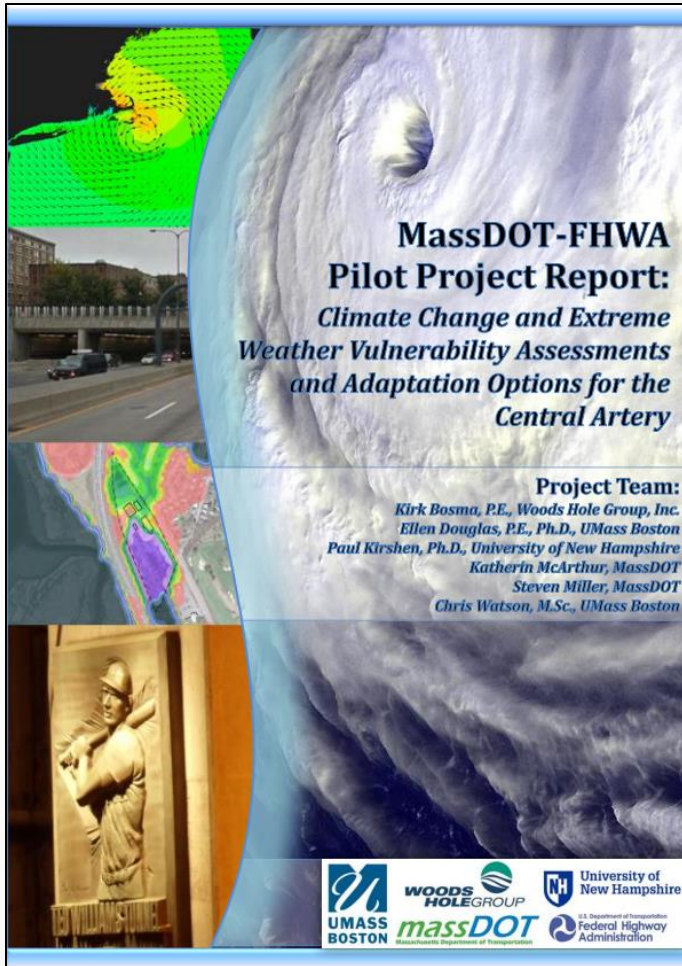


Tropical / Extra-tropical Storms



NOAA National Ocean Service

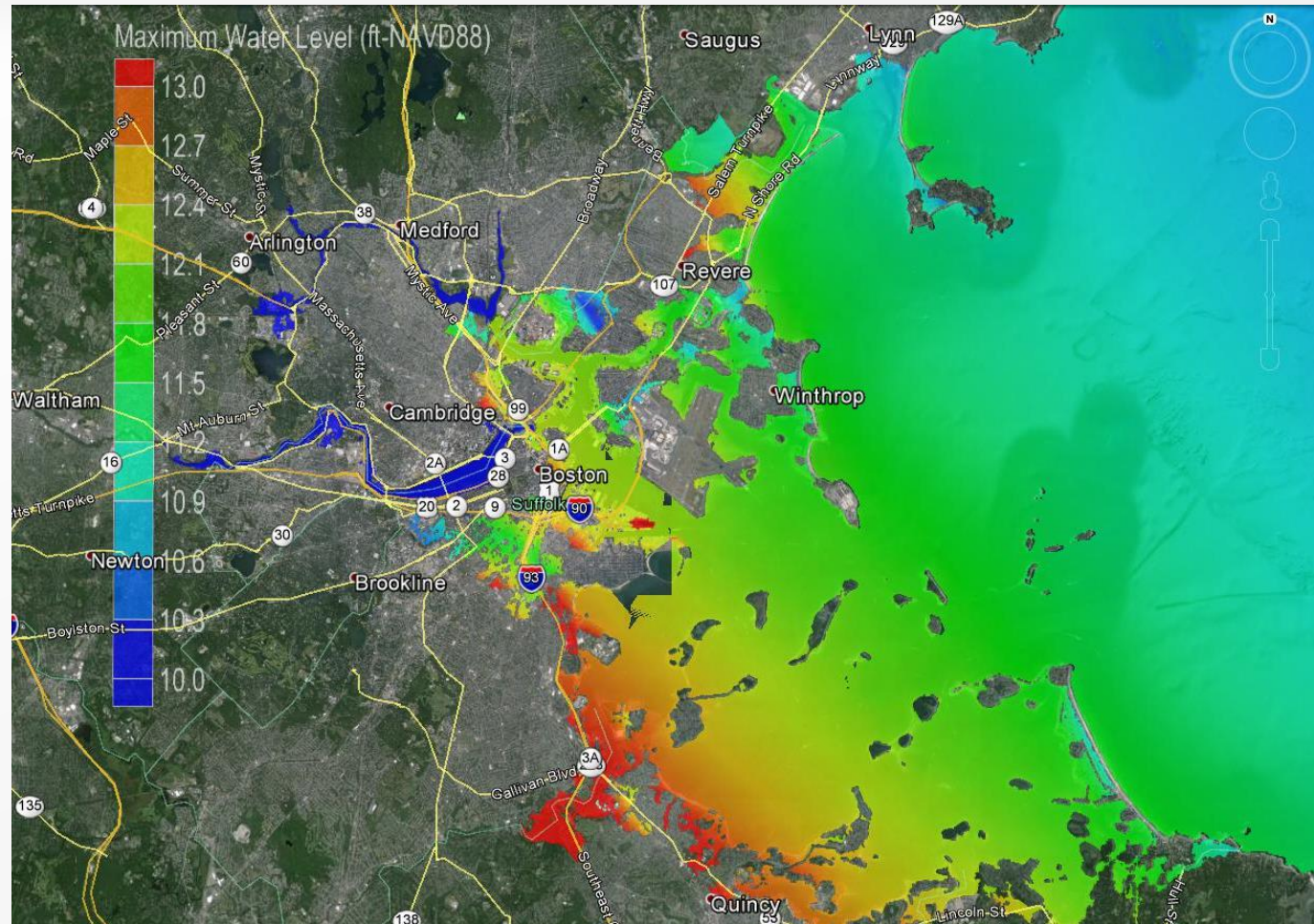
Why Hydrodynamic Modeling? Why Probabilistic?



**MassDOT-FHWA
Pilot Project Report:
Climate Change and Extreme
Weather Vulnerability Assessments
and Adaptation Options for the
Central Artery**

Project Team:
Kirk Bosma, P.E., Woods Hole Group, Inc.
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Katherin McArthur, MassDOT
Steven Miller, MassDOT
Chris Watson, M.Sc., UMass Boston

Logos:
UMASS BOSTON, WOODS HOLE GROUP, University of New Hampshire, U.S. Department of Transportation Federal Highway Administration



Massachusetts Coast Flood Risk Model (MC-FRM)

INPUTS



SEA LEVEL
RISE



TROPICAL / EXTRA-
TROPICAL STORMS



LANDSCAPE



ELEVATION



CHANGING
CLIMATE

PROBABILISTIC /
HYDRODYNAMIC
MODEL



Includes relevant physical processes:
sea level rise, tides, storm surge, wind, wave setup
/ run-up / overtopping, future climate scenarios

Future version to incorporate coastal erosion



FLOOD
PROBABILITY



FLOOD
DEPTH



FLOOD
DURATION



FLOOD
VOLUMES



FLOOD
PATHWAYS



WINDS



WAVES



CURRENTS

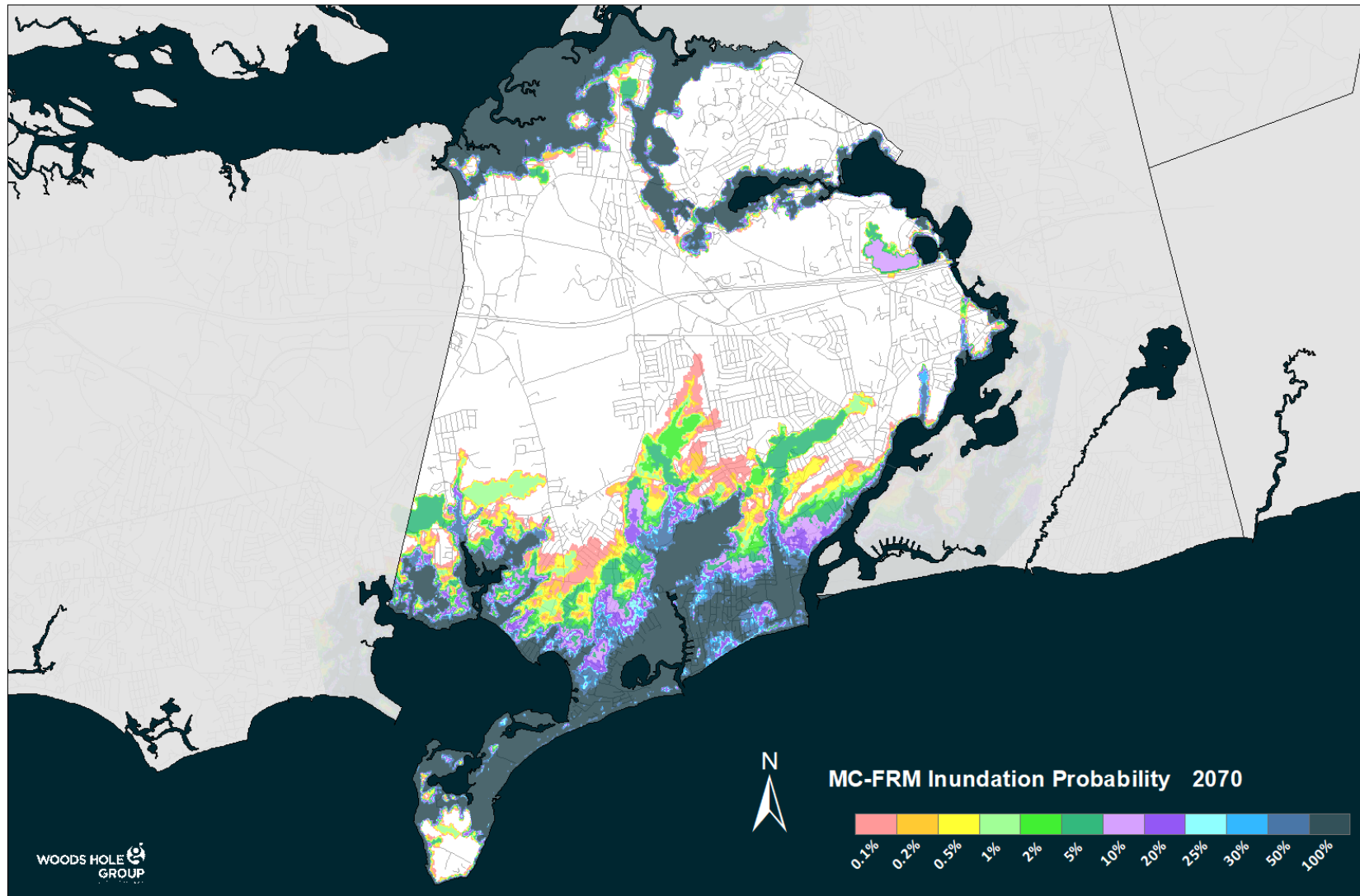


OUTPUTS

MC-FRM Resolution - Yarmouth



MC-FRM Coastal Flood Exceedance Probability – Yarmouth



Massachusetts Coast Flood Risk Model

SUMMARY

Hydrodynamically modeled projections

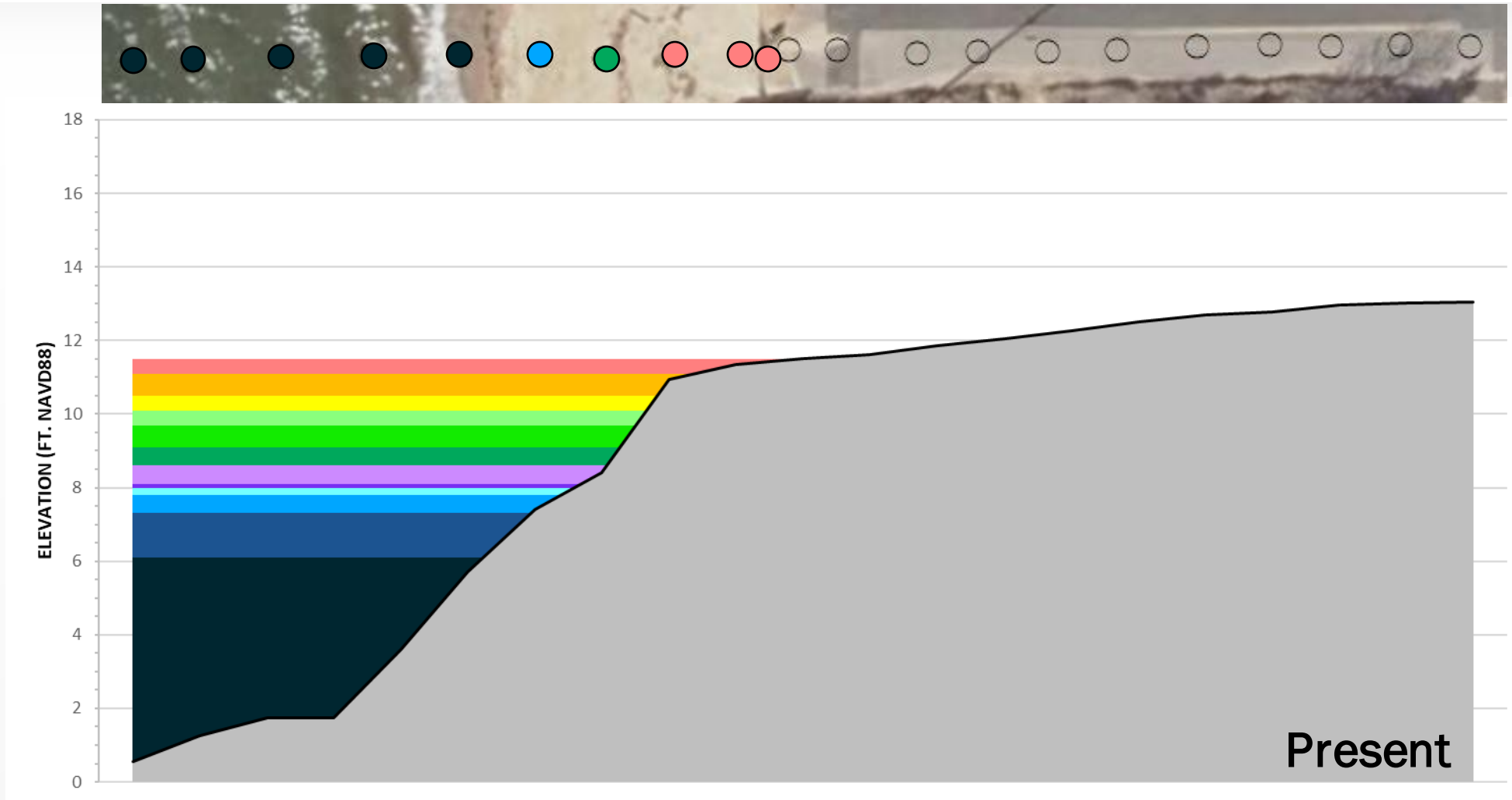
Sea level rise and storm surge – combined

Annual chance of flooding under 2030/2050/2070 climate conditions

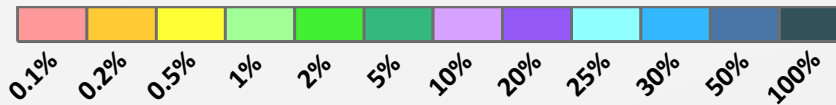
QUESTIONS?



Cape Cod Low Lying Roads Vulnerability Assessment Methods



COASTAL FLOOD EXCEEDANCE PROBABILITY

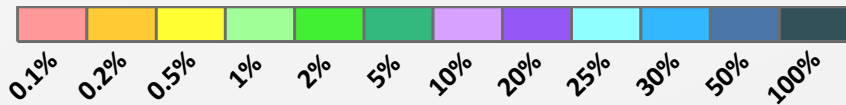


Cape Cod Low Lying Roads Vulnerability Assessment Methods



2030

COASTAL FLOOD EXCEEDANCE PROBABILITY

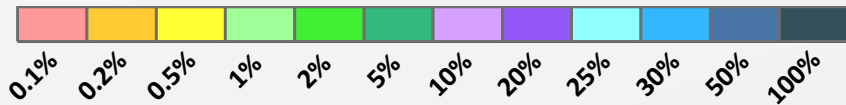


Cape Cod Low Lying Roads Vulnerability Assessment Methods



2050

COASTAL FLOOD EXCEEDANCE PROBABILITY

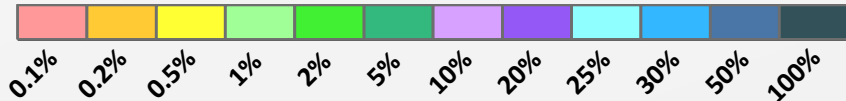


Cape Cod Low Lying Roads Vulnerability Assessment Methods

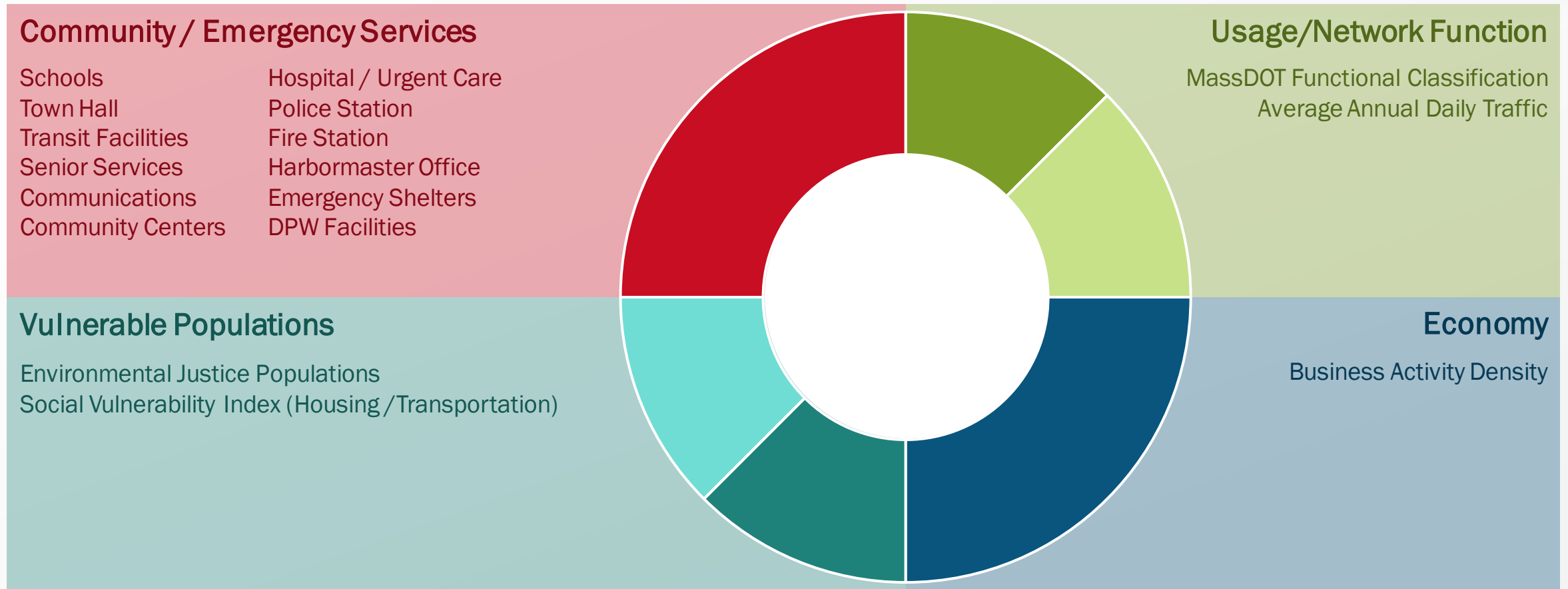


2070

COASTAL FLOOD EXCEEDANCE PROBABILITY

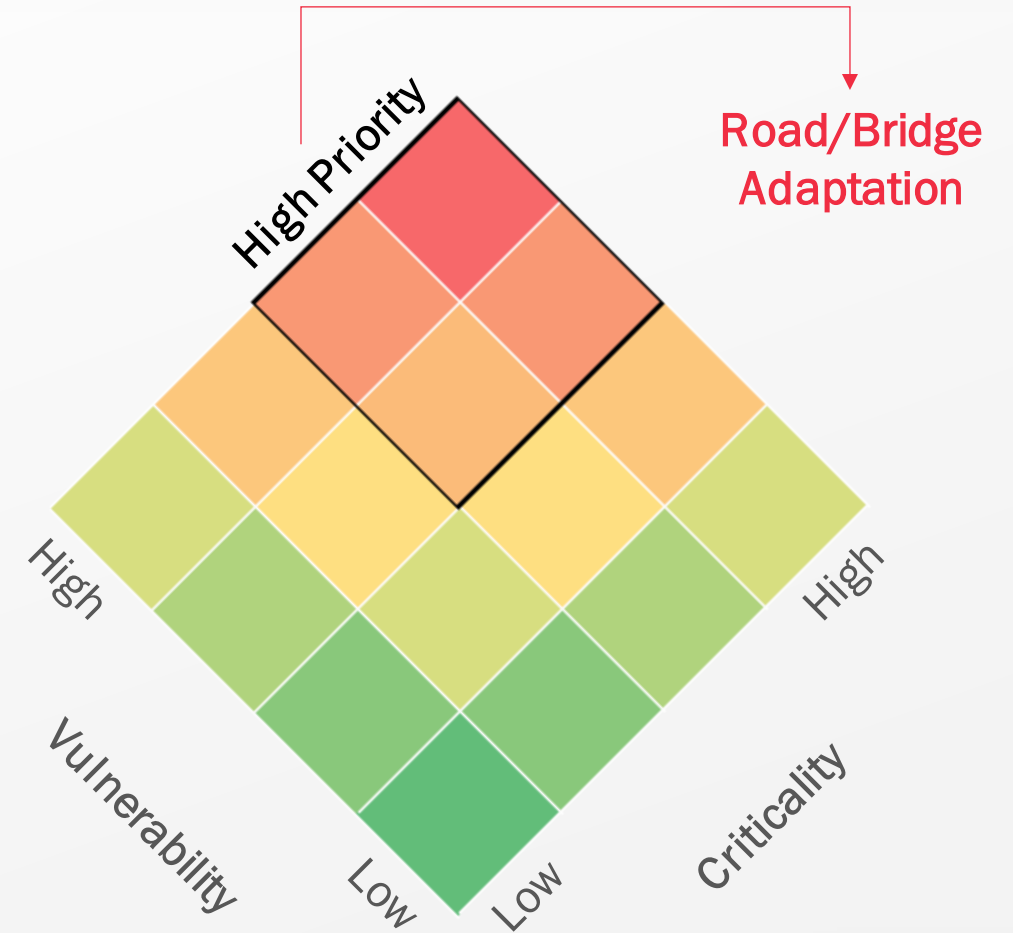


Cape Cod Low Lying Roads Criticality Scoring Framework

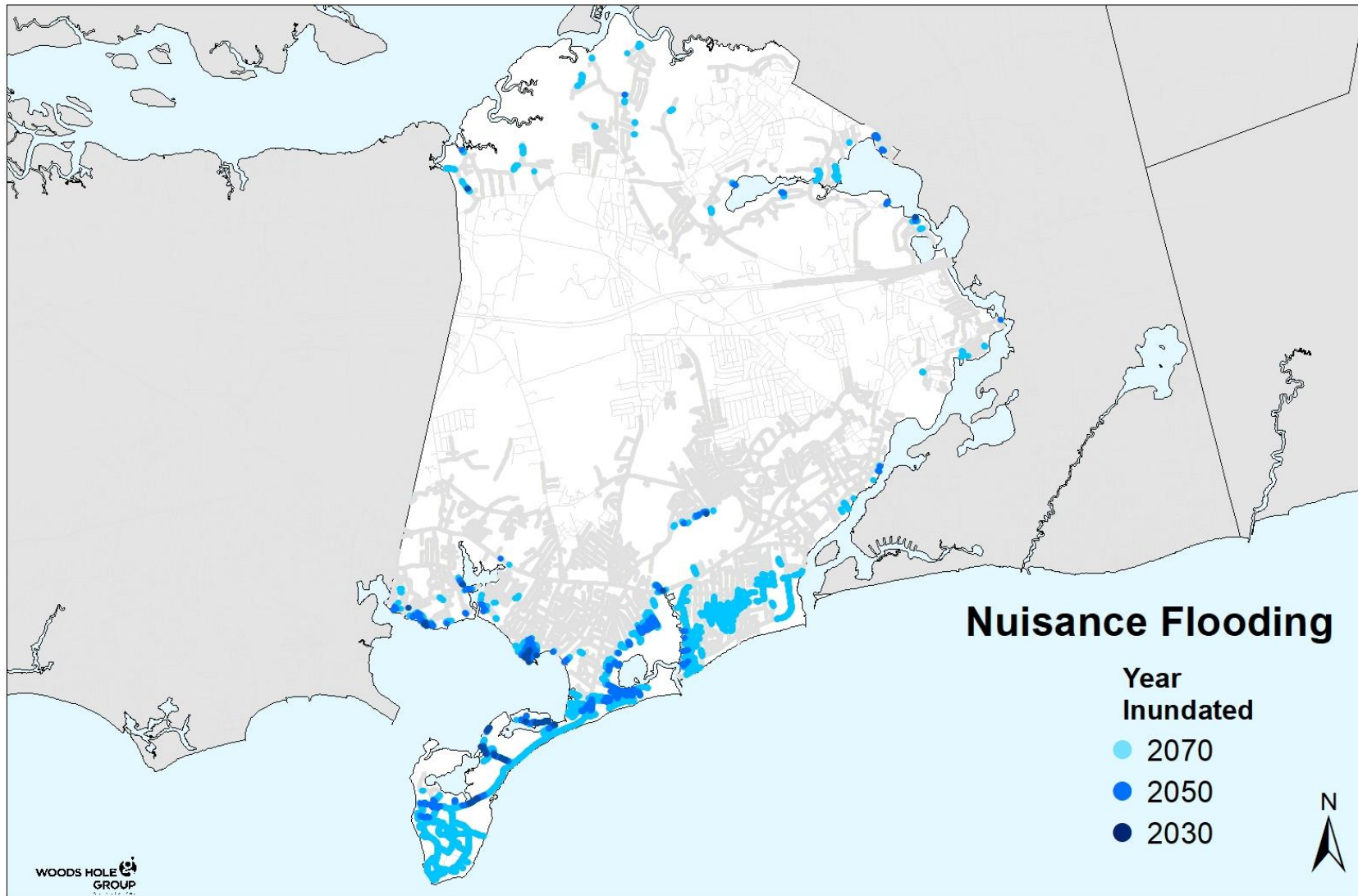


Cape Cod Low Lying Roads Risk Assessment Approach

1. Extract roadway/bridge critical elevations (CEs)
 - › From LiDAR at 20m interval along surface
2. Compile 2030/2050/2070 MC-FRM water surface elevations (WSEs)
 - › 0.1%, 0.2%, 0.5%, 1%, 2%, 5%, 10%, 20%, 100%
3. Compare CEs to WSEs to determine vulnerability
 - › Highest probability WSE exceeding CE
4. Score road segment criticality
 - › Usage/Network Function
 - › Economy
 - › Vulnerable Populations
 - › Community and Emergency Services
5. $\text{Probability} * \text{Criticality} = \text{Risk}$
6. Prioritize high-risk road segments for community consideration



Low Lying Roads Nuisance (MHW) Flooding (Yarmouth)



Road Miles 2030

0.6/330.2

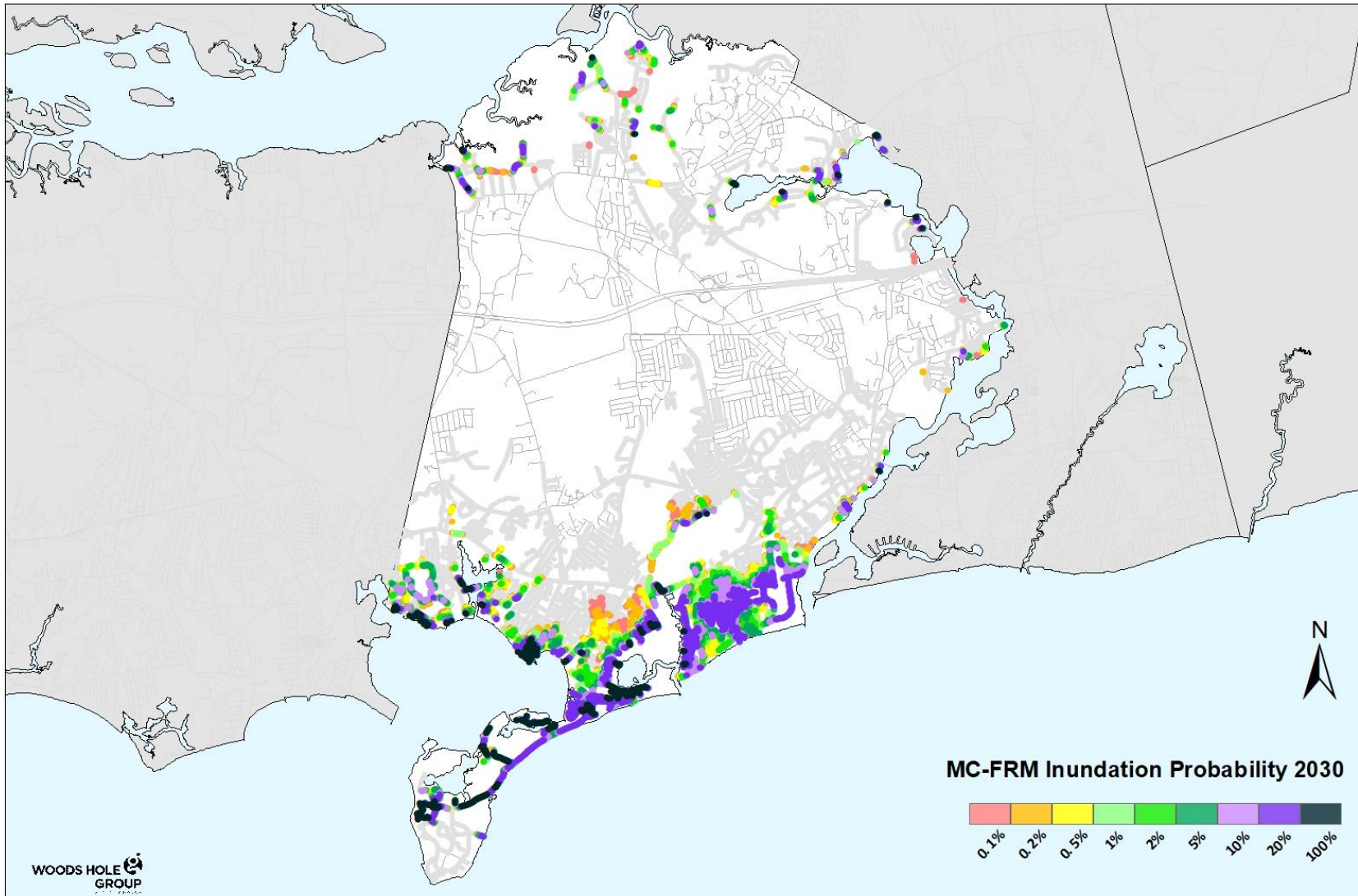
Road Miles 2050

4.3/330.2

Road Miles 2070

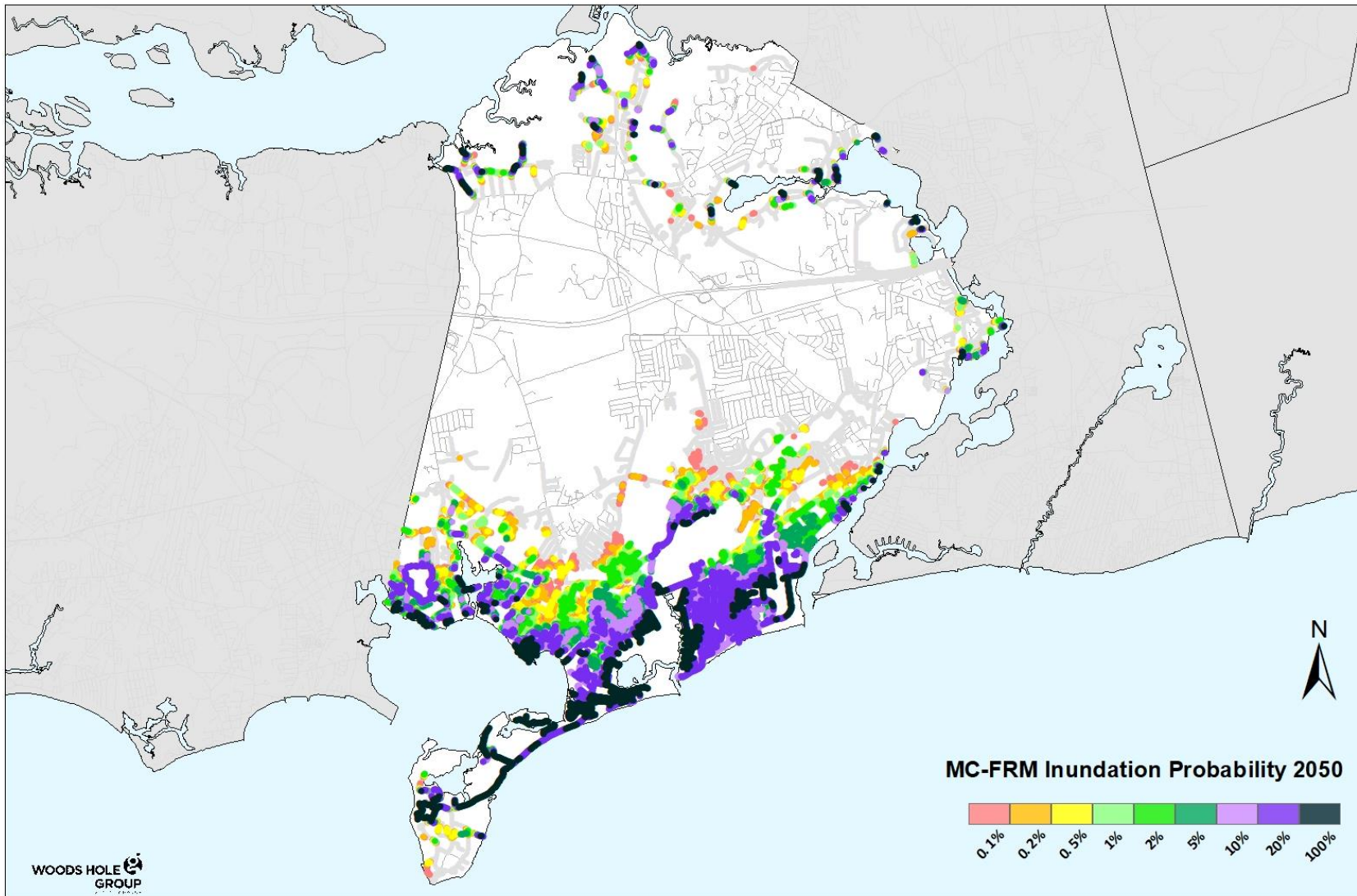
23.2/330.2

Low Lying Roads 2030 Inundation Probability (Yarmouth)



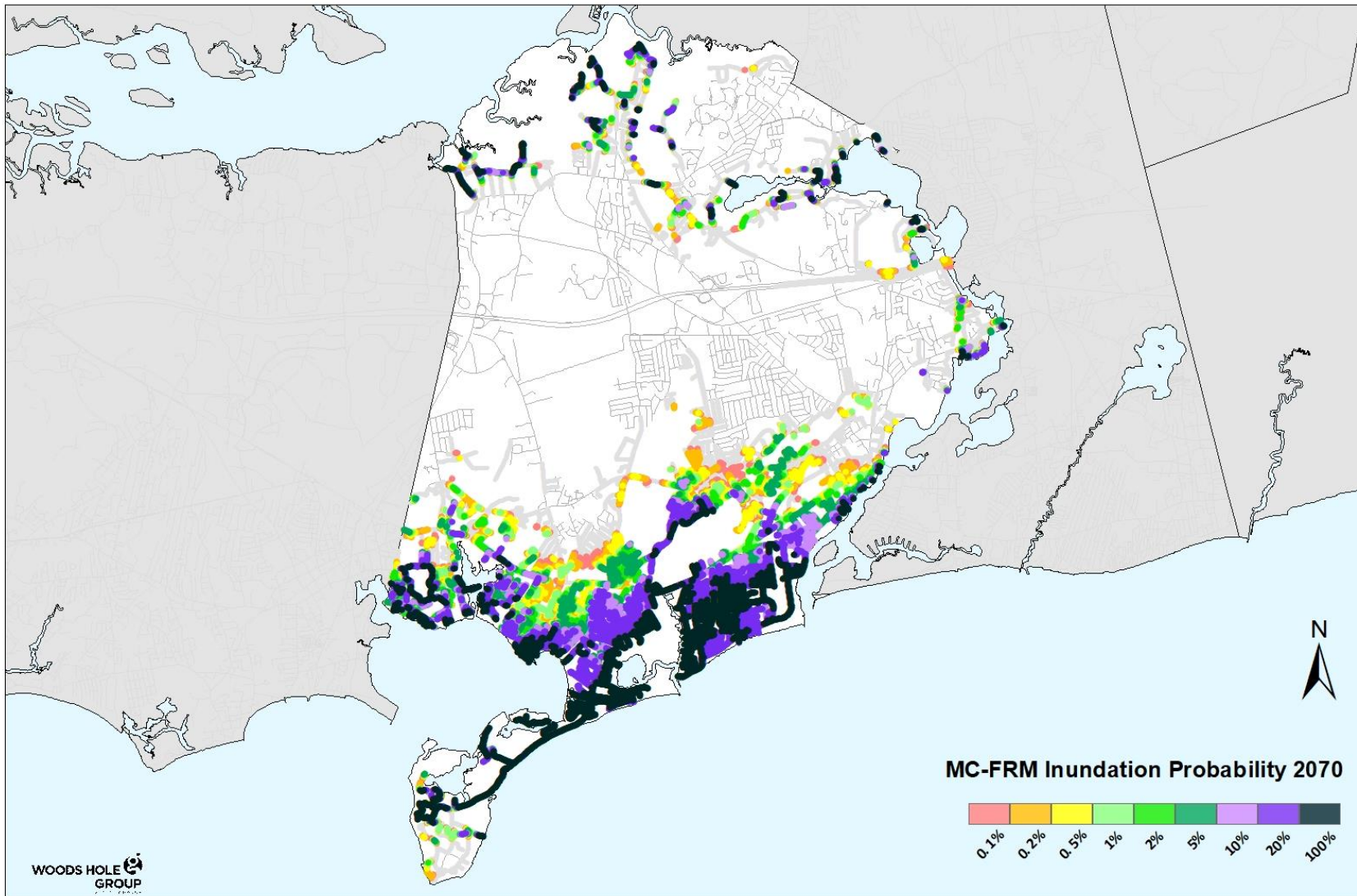
%	Road miles
0.1	52.2
0.2	49.2
0.5	44.7
1	39.8
2	34.7
5	27.8
10	22.3
20	16.1
100	3.7

Low Lying Roads 2050 Inundation Probability (Yarmouth)



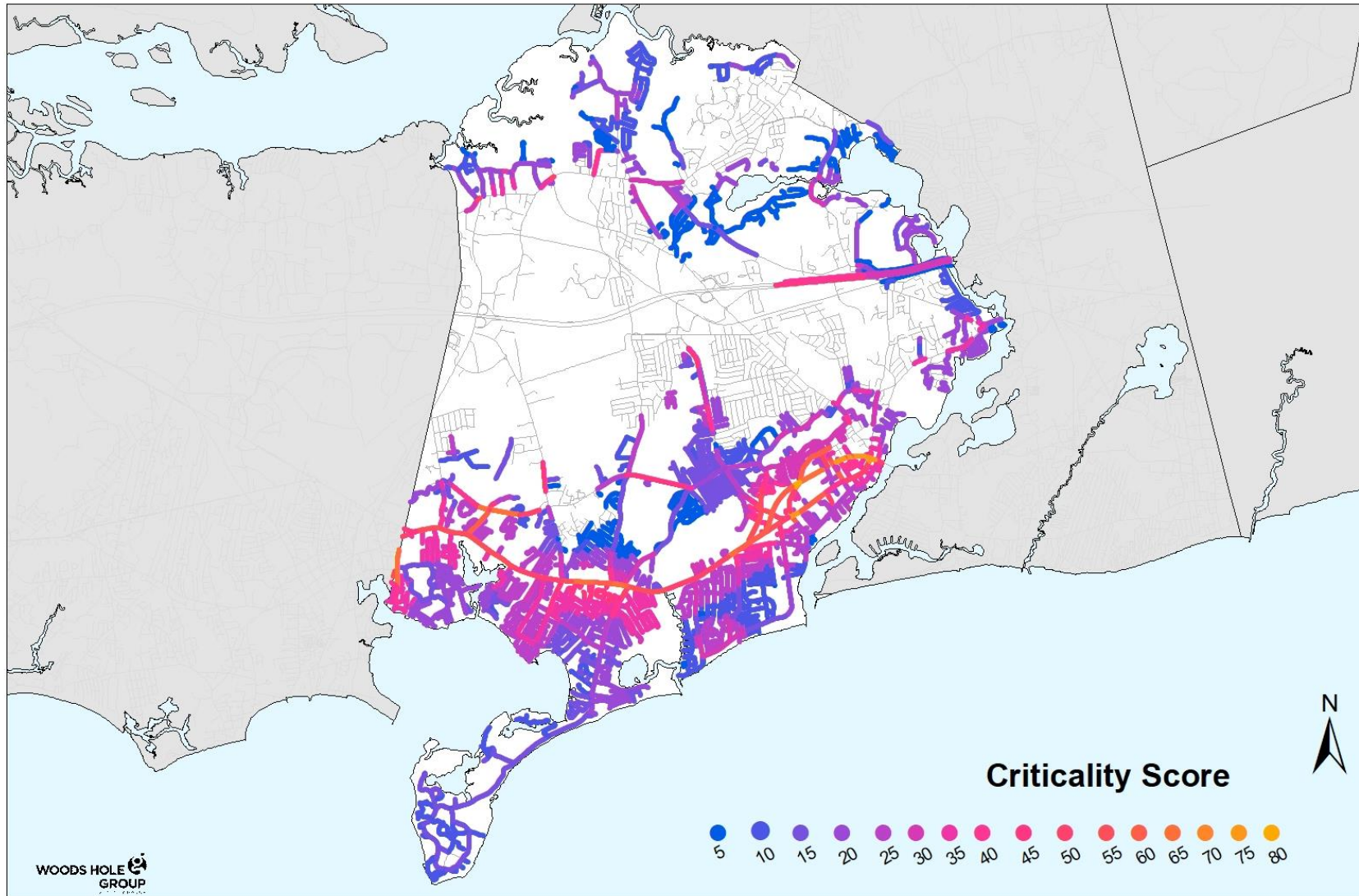
%	Road miles
0.1	104.1
0.2	98.1
0.5	87.8
1	78.9
2	71.0
5	58.9
10	49.2
20	38.6
100	13.8

Low Lying Roads 2070 Inundation Probability (Yarmouth)

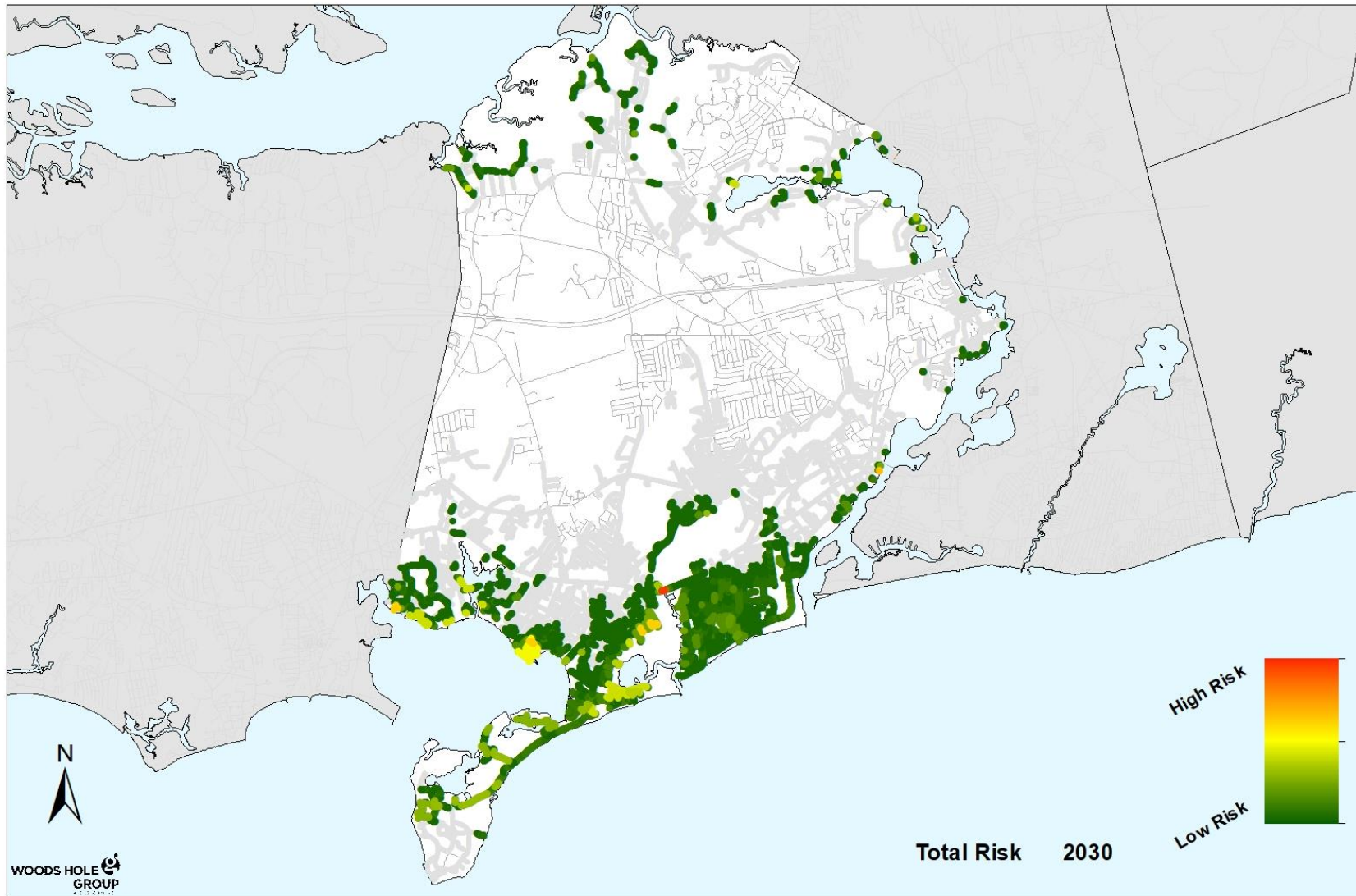


%	Road miles
0.1	116.4
0.2	110.9
0.5	100.5
1	90.4
2	82.5
5	73.2
10	62.1
20	53.4
100	29.3

Low Lying Roads Criticality Scoring (Yarmouth)



Low Lying Roads 2030 Risk Results (Yarmouth)



High Risk Road Segments

Route 28*

Bayview Street

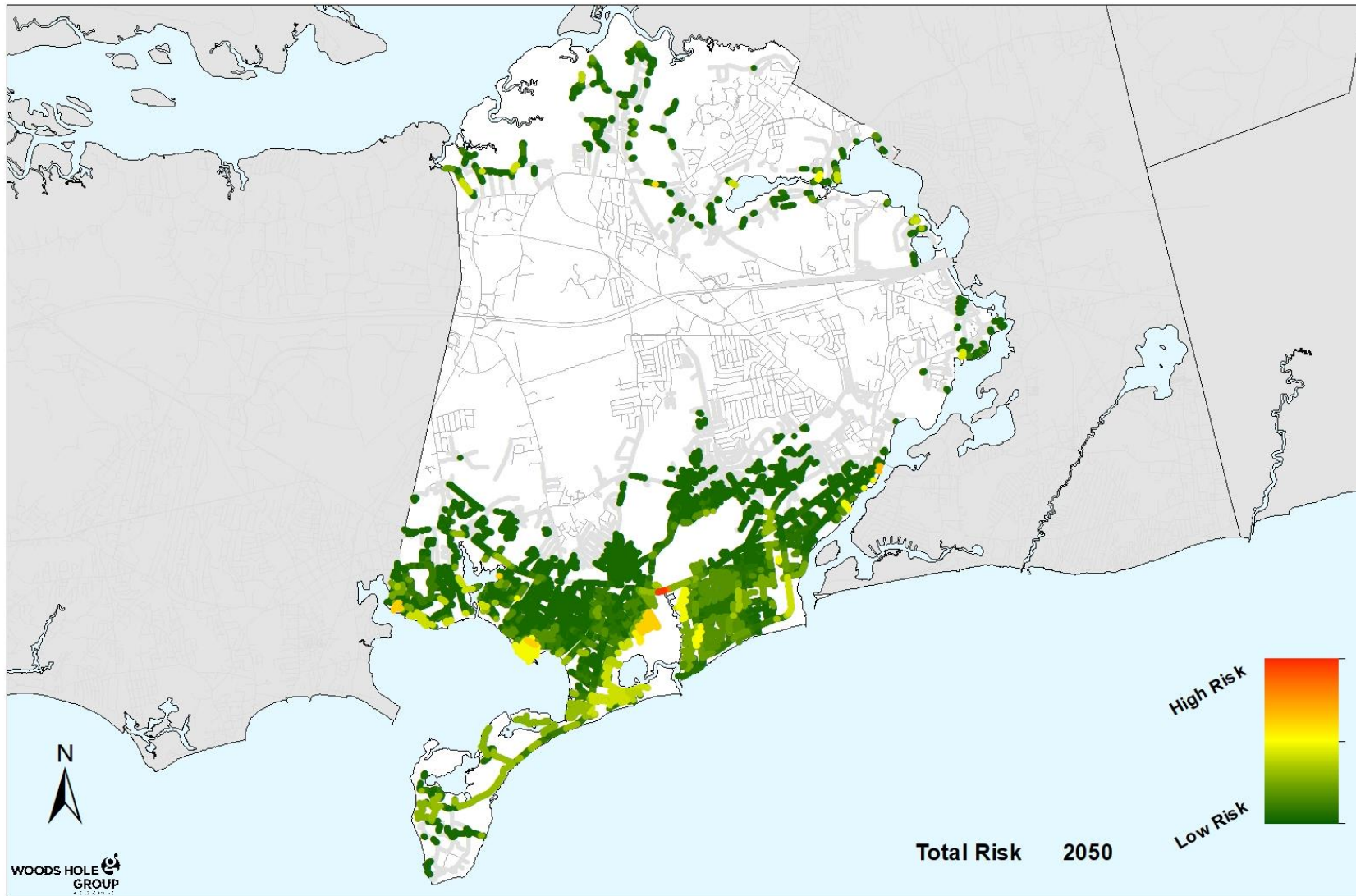
Iroquois Blvd, Nauset Lane, Niagara Lane, Pawnee Road and Sioux Rd

Rhode Island Ave and Broadway Street

Berry & New Hampshire Ave, Shore Rd, Vermont Ave

Prince Rd

Low Lying Roads 2050 Risk Results (Yarmouth)



High Risk Road Segments

Route 28*

Bayview Street

Iroquois Blvd, Nauset Lane, Niagara Lane, Pawnee Road and Sioux Rd

Rhode Island Ave and Broadway Street

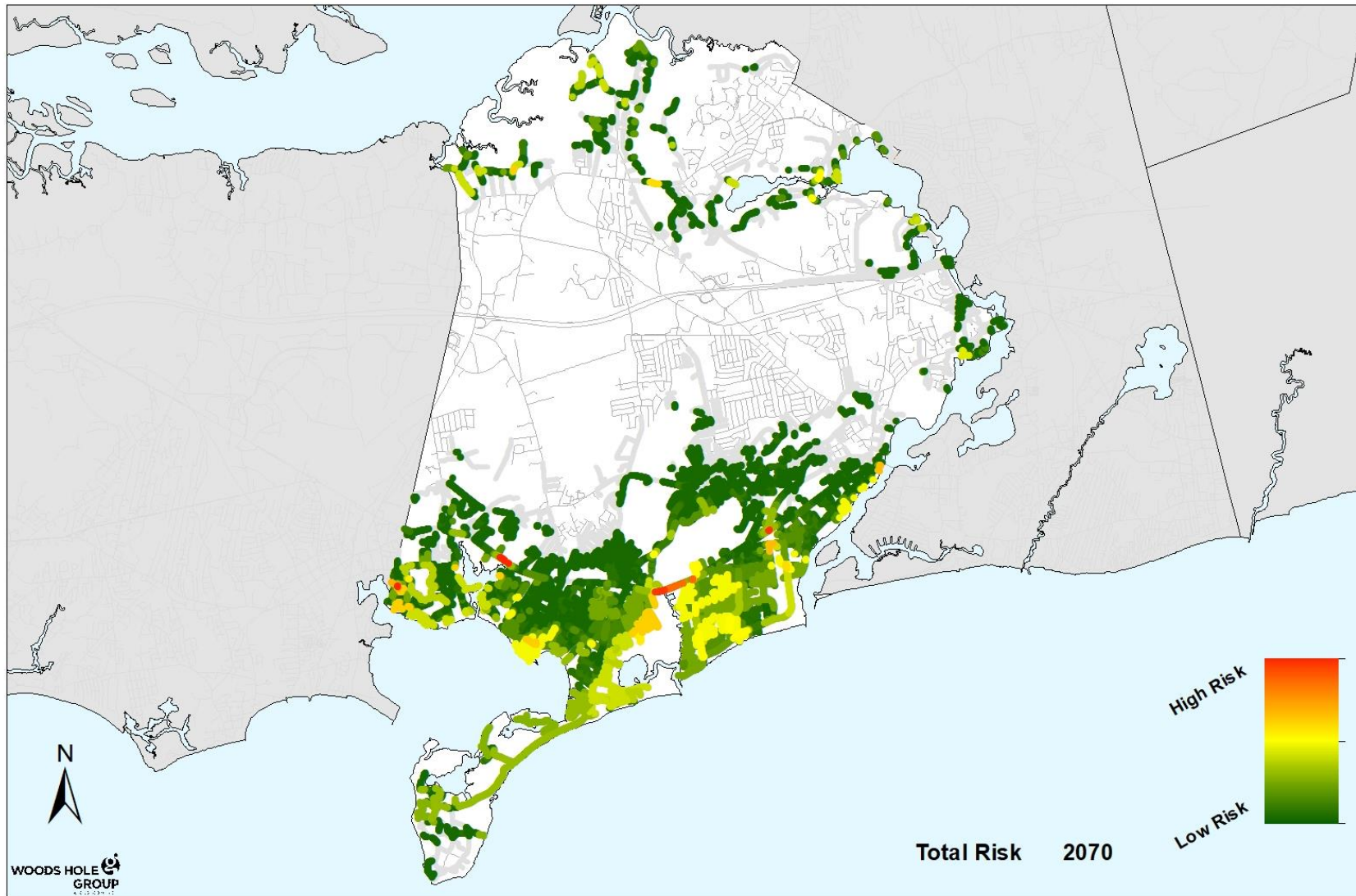
Berry & New Hampshire Ave, Shore Rd, Vermont Ave

Prince Rd

Allen Street

Pamet Road

Low Lying Roads 2070 Risk Results (Yarmouth)



High Risk Road Segments

Route 28*

Bayview Street

Iroquois Blvd, Nauset Lane, Niagara Lane, Pawnee Road and Sioux Rd

Rhode Island Ave and Broadway Street

Berry & New Hampshire Ave, Shore Rd, Vermont Ave

Prince Rd

Allen Street

Pamet Road

Bayview Street

Route 28*

Old Main Street

Breezy Point Road and Willow Street

Mattakese Road

Courtland Way

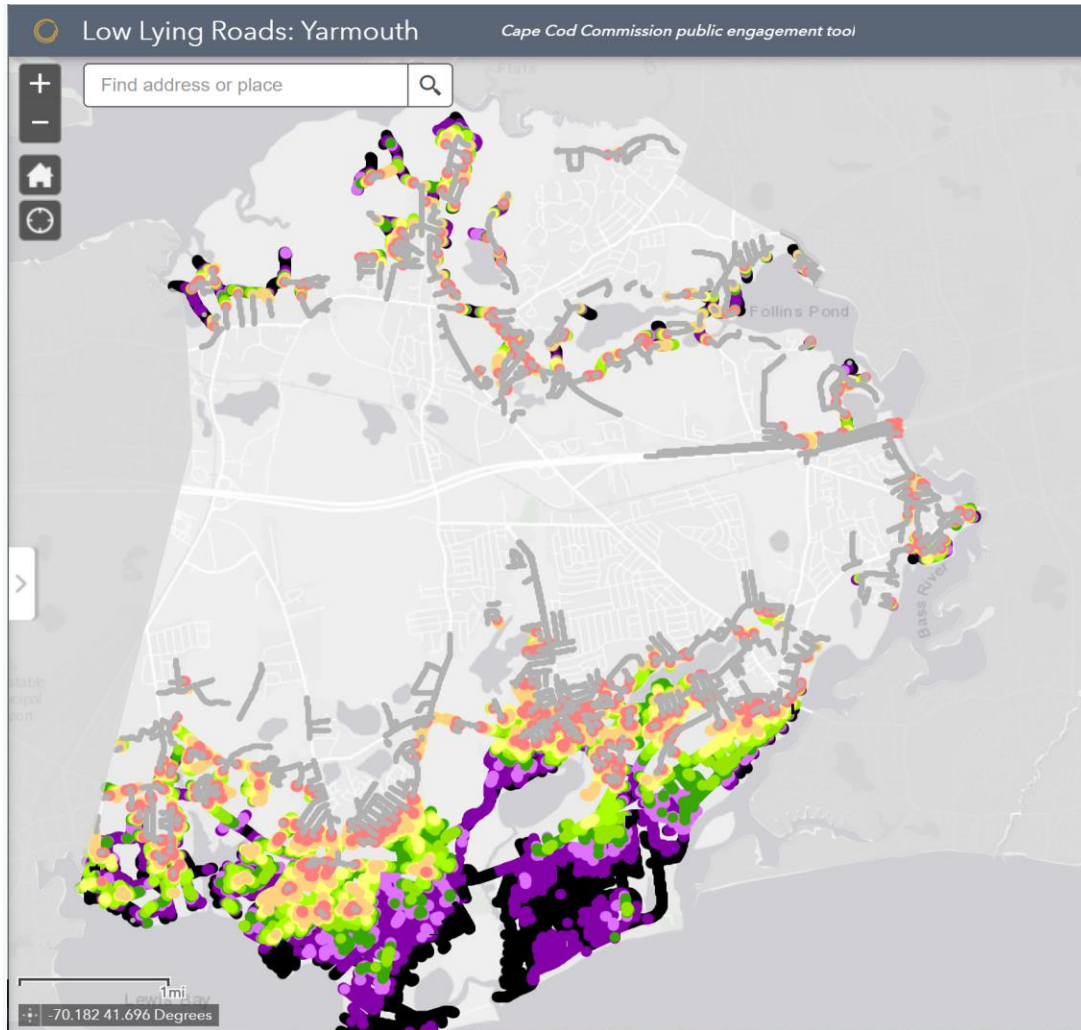
Summary of High Priority Road Segments (Yarmouth)

	Name	Length (ft)	Description	Segment Storm Probability (%)			Nuisance Length (ft)		
				2030	2050	2070	2030	2050	2070
A	*Route 28	1200	Roadway & bridge btw Neptune Ln and Courtland Way	0.5-100	20-100	100	40	40	480
B	Bayview Street	300	Roadway leading to Bayview Street Beach	100	100	100		240	320
C	Iroquois Blvd, Nauset Lane, Niagara Lane, Pawnee Road and Sioux Rd	2940	Low lying neighborhood w/ multiple vulnerable roadways	0.5-100	20-100	100		1700	2820
D	Rhode Island Ave and Broadway Street	740	Intersection of RI Ave and Broadway St	20-100	100	100		380	720
E	Berry & New Hampshire Ave, Shore Rd, Vermont Ave	2240	Low lying neighborhood w/ multiple vulnerable roadways	100	100	100	300	1580	2240
F	Prince Rd	260	Isolated neighborhood east of Baxter Ave	100	100	100		260	260
G	Allen Street	100	Entrance to Packet Landing Boat and Marina	5-20	20-100	100		20	80
H	Pamet Road	420	Roadway segments at southern end of road south of Sioux Rd	10-100	100	100		240	420
I	Bayview Street	200	Intersection Bayview St and Willow Ave	2-10	20	100		20	20
J	*Route 28	300	Route 28 btw Cosyhome Terrace and Standish Way	2-5	20	100			
K	Old Main Street	120	Roadway btw Route 28 and South St	2-5	20	100			
L	Breezy Point Road and Willow Street	640	Intersection of Breezy Point Rd and Willow St	2-10	20	100			
M	Mattakese Road	80	Roadway branching off of Nearmeadows Rd	1-5	20	100			
N	Courtland Way	520	Roadway running south from Route 28	2-10	20	100			280

* = MassDOT roadway

LOW LYING ROADS

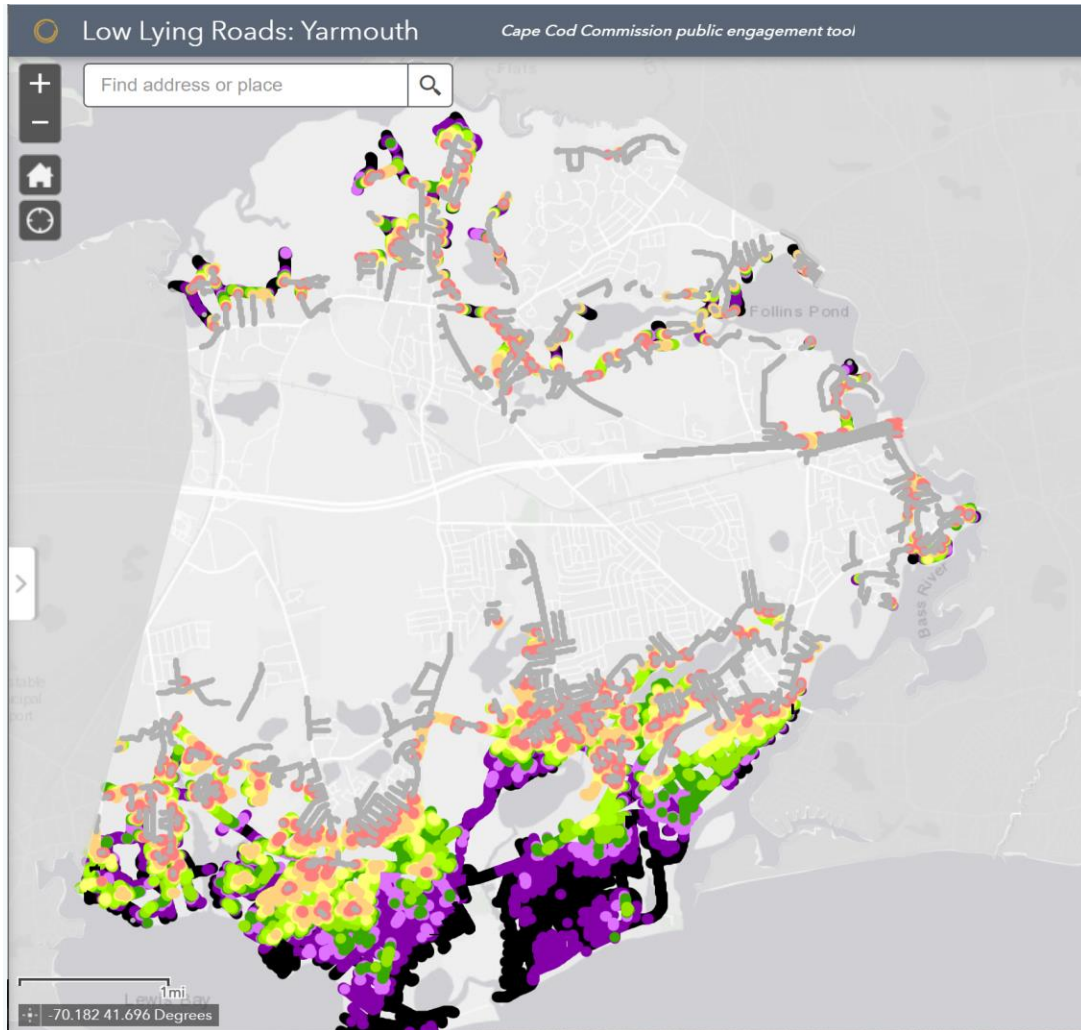
Group Discussion



**DISCUSSION
ORIENTATION**

LOW LYING ROADS

Group Discussion



DISCUSSION QUESTIONS

1. Are there roads that we missed?
2. How would you prioritize these roads – what local knowledge or concerns can you bring to the discussion?
3. What are the high-priority road segments?

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NEXT STEPS

- Town staff to select 2 road segments
- Feasibility analysis
- 3 solutions + costs per segment
- Solutions available to view on Low Lying Road webpage late spring 2022:
<https://www.capecodcommission.org/our-work/low-lying-roads-project/>

THANK YOU!
