Methods and Issues with Predicting the Impact of Periodic Flooding using a Range of Sea-Level Change Scenarios on Transportation Infrastructure

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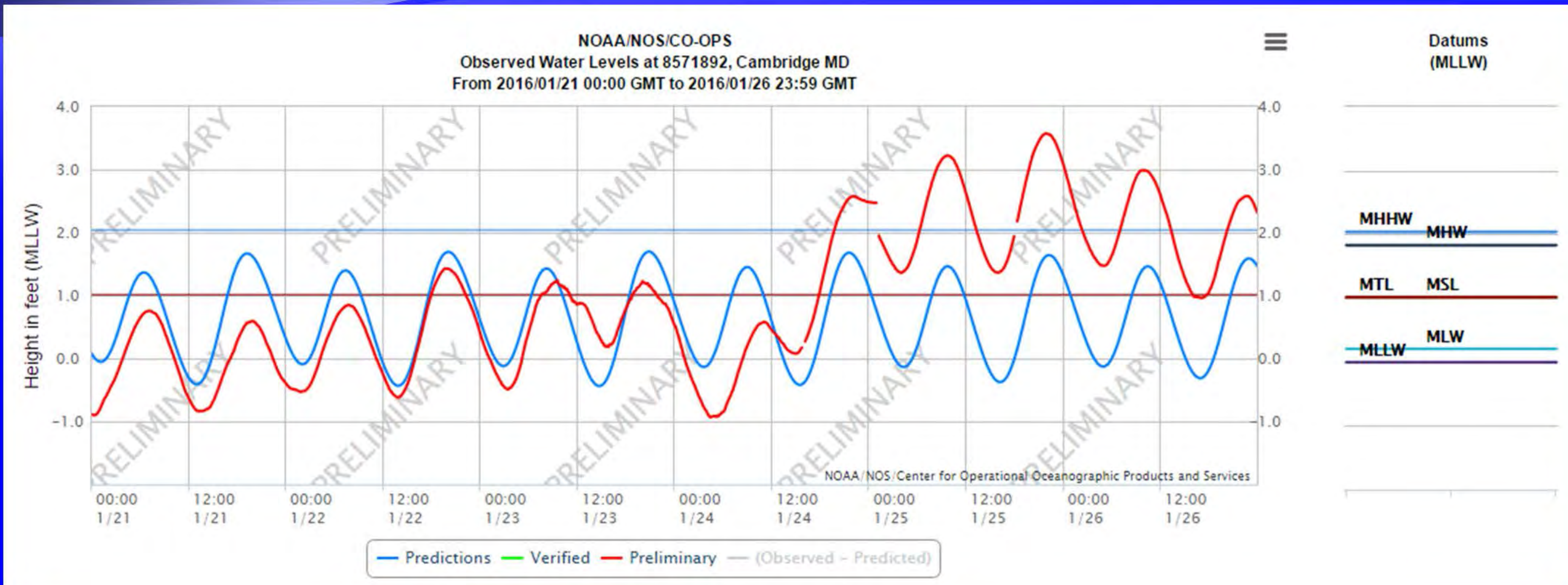
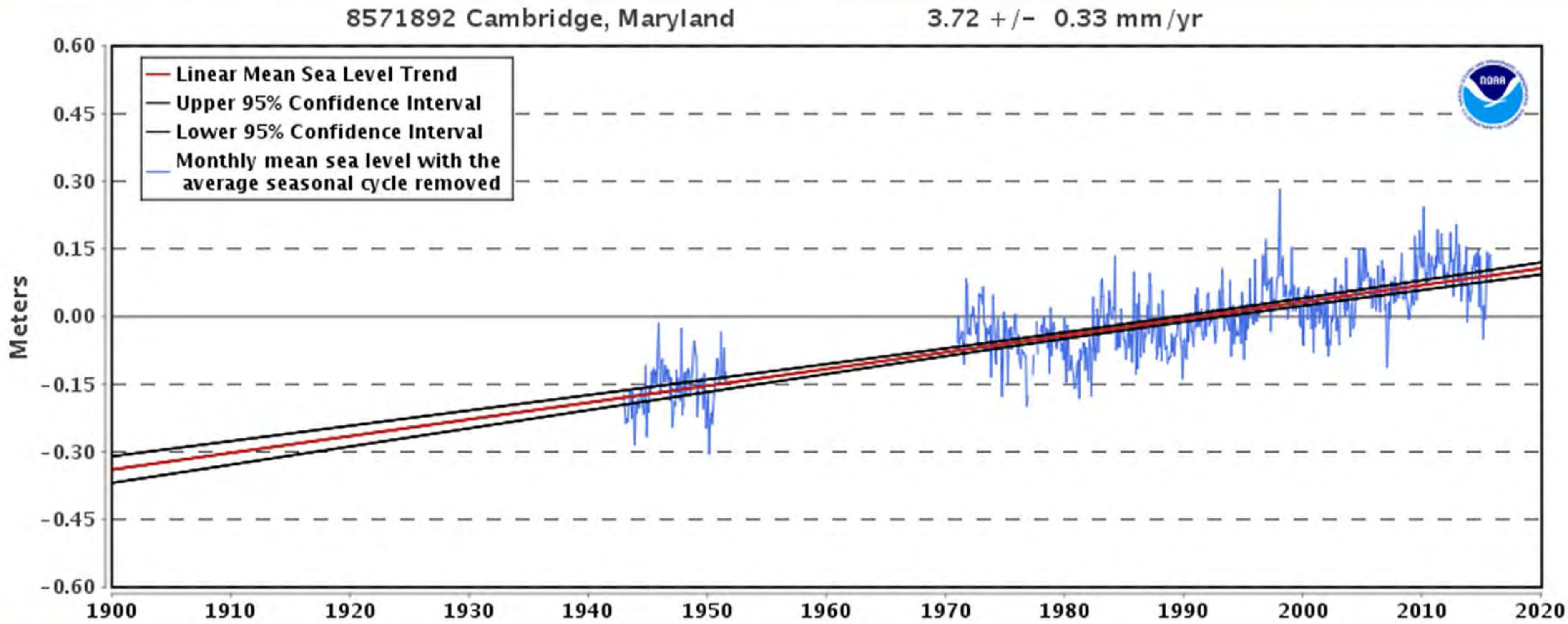
Spring High Tide, Wingate, MD 2007

Wanda Diane Cole, RC&D Inc. in Sea Level Rise: Technical Guidance for Dorchester County, 2008

Rising Tides will Impact Flooding

- Maryland has 3,190 miles of coast (longest relative to its area in the US!)
- The Mid-Atlantic region is predicted to have some of the worst impacts of SLC because of the combination of rise, subsidence, and relative position to the North Atlantic Gyre
- Maryland SHA needs a measured way to prioritize and mitigate the potential impact of baseline SLC on SHA assets, as well as the increased impact of coastal flooding that will result


NOAA/NOS/CO-OPS
Observed Water Levels at 8571892, Cambridge MD
From 2016/01/21 00:00 GMT to 2016/01/26 23:59 GMT
Height in feet (MLLW)
4.0
3.0
2.0
1.0
0.0
-1.0
00:00 1/21
12:00 1/21
00:00 1/22
12:00 1/22
00:00 1/23
12:00 1/23
00:00 1/24
12:00 1/24
00:00 1/25
12:00 1/25
00:00 1/26
12:00 1/26
PRELIMINARY
NOAA/NOS/Center for Operational Oceanographic Products and Services
Predictions
Verified
Preliminary
(Observed - Predicted)
Datums (MLLW)
MHHW
MHW
MTL
MSL
MLW
MLLW


8571892 Cambridge, Maryland
3.72 +/- 0.33 mm/yr
Linear Mean Sea Level Trend
Upper 95% Confidence Interval
Lower 95% Confidence Interval
Monthly mean sea level with the average seasonal cycle removed
Meters
0.60
0.45
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020

Overall Process of SLC Vulnerability Assessment

- High-resolution LiDAR data
- USACE estimates of SLC (SLR + subsidence), both MSL and MHHW in both 2050 and 2100
- Tidal flow network to remove unconnected inundated areas
- HAZUS-MH flood depth grids for 10%, 4%, 2%, 1%, and 0.2%-chance floods
- Hazard Vulnerability Index (HVI)
- Network trace analysis to calculate SLC impact

Create Inundation Areas

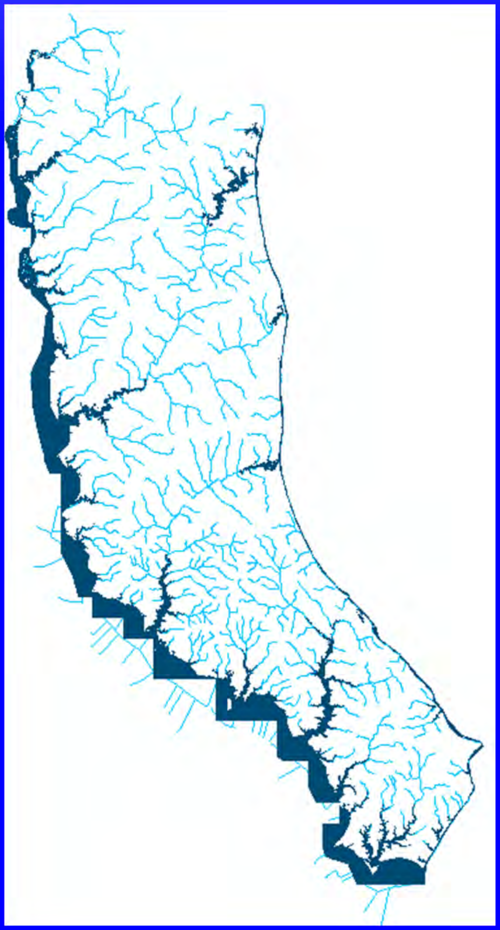
- Identified vulnerable elevations; elevations below anticipated sea-level rise
- 4 SLC scenarios
  - 2050 MSL
  - 2050 MHHW
  - 2100 MSL
  - 2100 MHHW
- Adjust current DEM to be future coastline
- "Bathtub" Model

Trouble with the "Bathtub" Model

- A selection of all areas less than the value of SLC will include local minima
- The local minima are not connected to the tidal waterway and therefore, are unlikely to be impacted by SLC

To Solve the Local Minima Problem

- Take NHD high-resolution flowlines
- Create a network dataset
- Use the Bay and other polygonal tidal water bodies as network destinations
- Find all flowlines that connect to tidal waters
- Delete any SLC area that does not intersect a tidal flowline



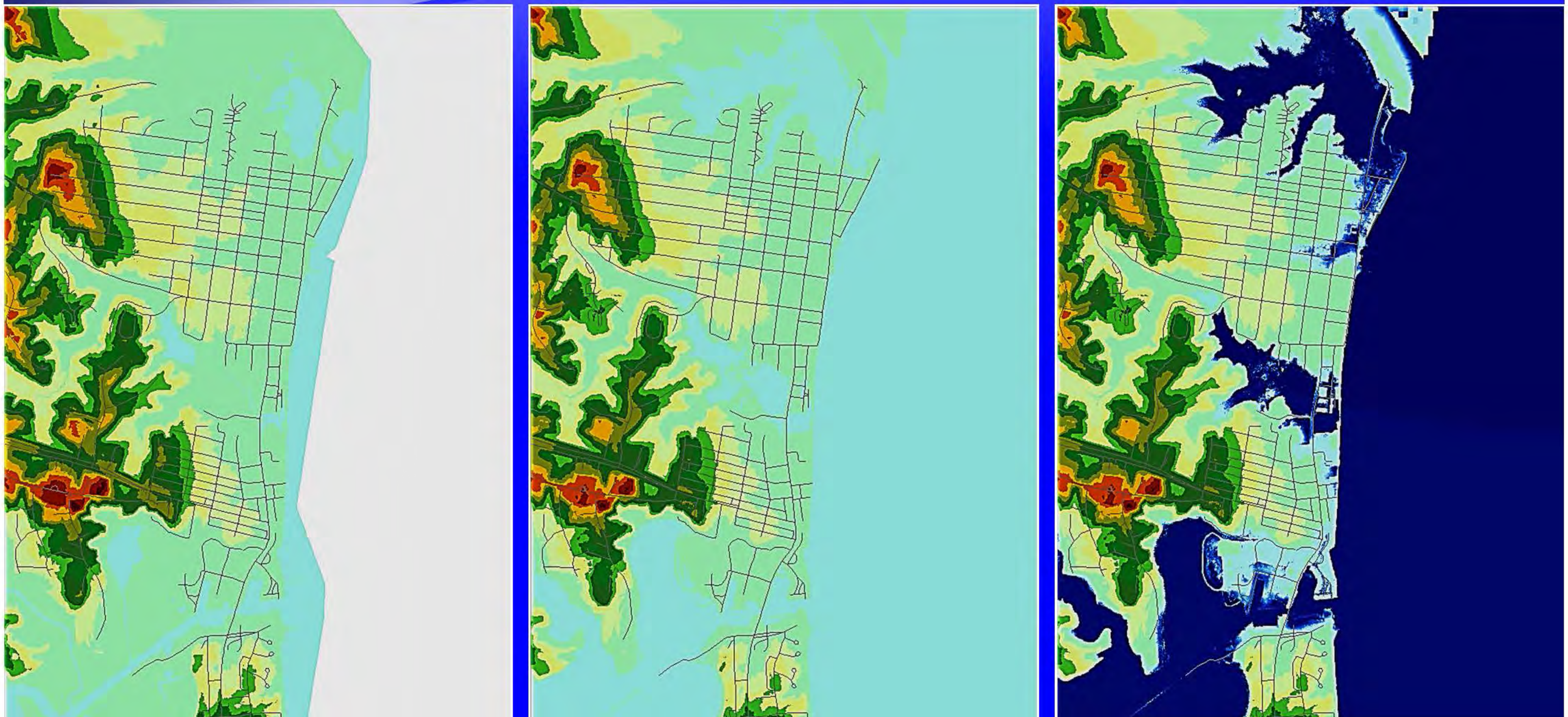
Create Flood Depth Grids

- Modeled expected depth of flood water; each grid cell contains water depth calculation
- Recurrence intervals of 10%-, 4%-, 2%-, 1%-, and 0.2%-chance floods
- 4 SLC scenarios – 2050 & 2100, MSL & MHHW
- Thus, 20 depth grids per county
- Manipulate the current DEM to simulate each SLC scenario
- Calculate the depth of flooding using HAZUS

HAZUS MH 2.1

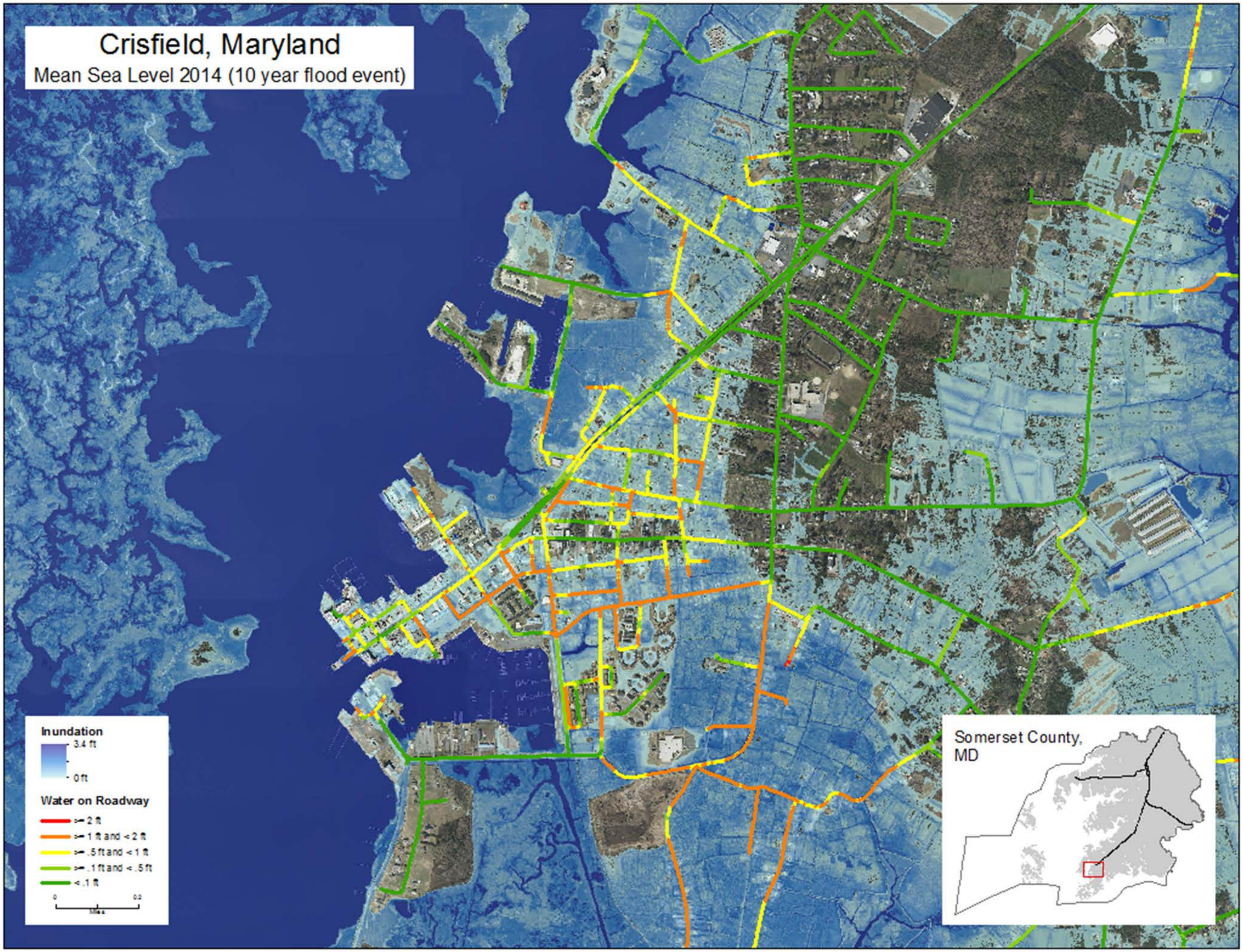
- Developed for FEMA to model potential losses from earthquakes, floods, and hurricane wind
- Flood model calculates depth grids per recurrence interval using simplified versions of best available hydrology and hydraulic models
- Simplified versions match the data we have available and the scale of our analysis
- Significant amount of pre- and post-event accuracy testing with good results

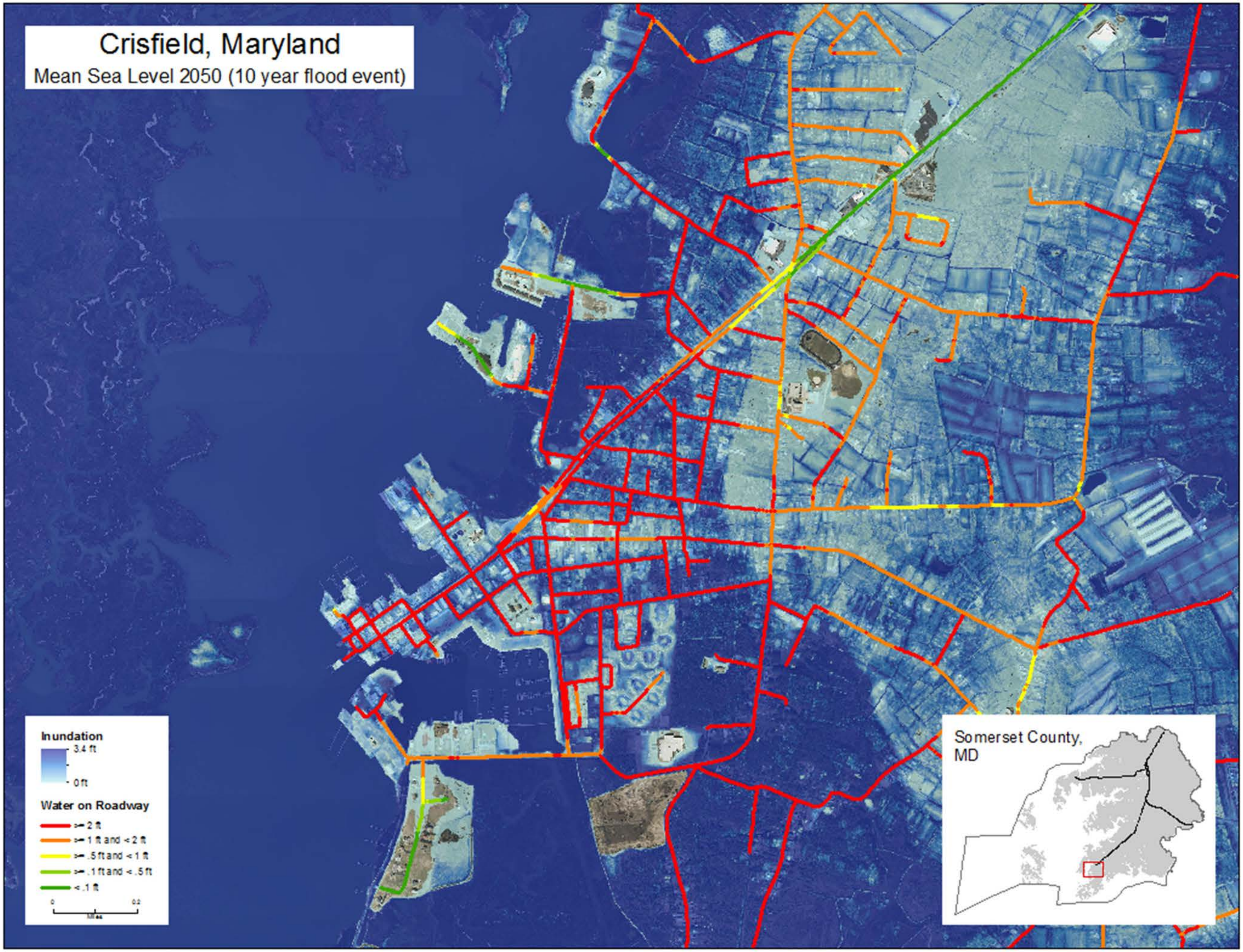
Today, MSL 2050, 1% Flood Depth



Development of Hazard Vulnerability Index (HVI)

- Once the modeled depth of water, both with and without coastal flooding, was calculated, we need a way to assess the vulnerability of each road segment
- Priority is given to pre-defined evacuation routes, higher route functional classes, and deeper water
- HVI = ([Evacuation Route]*.5+1) * ([Flood Depth]+.01)/4) * (1.0/[Functional Class])*.7


Crisfield, Maryland
Mean Sea Level 2014 (10 year flood event)
Inundation
3.4 ft
0 ft
Water on Roadway
>= 2 ft
>= 1 ft and < 2 ft
>= .5 ft and < 1 ft
>= .1 ft and < .5 ft
< .1 ft
0
0.2
Somerset County,
MD


Crisfield, Maryland
Mean Sea Level 2050 (10 year flood event)
Inundation
3.4 ft
0 ft
Water on Roadway
>= 2 ft
>= 1 ft and < 2 ft
>= .5 ft and < 1 ft
>= .1 ft and < .5 ft
< .1 ft
0
0.2
Miles
Somerset County, MD

Percent of total road length by HVI and flood recurrence in 2015 MSL

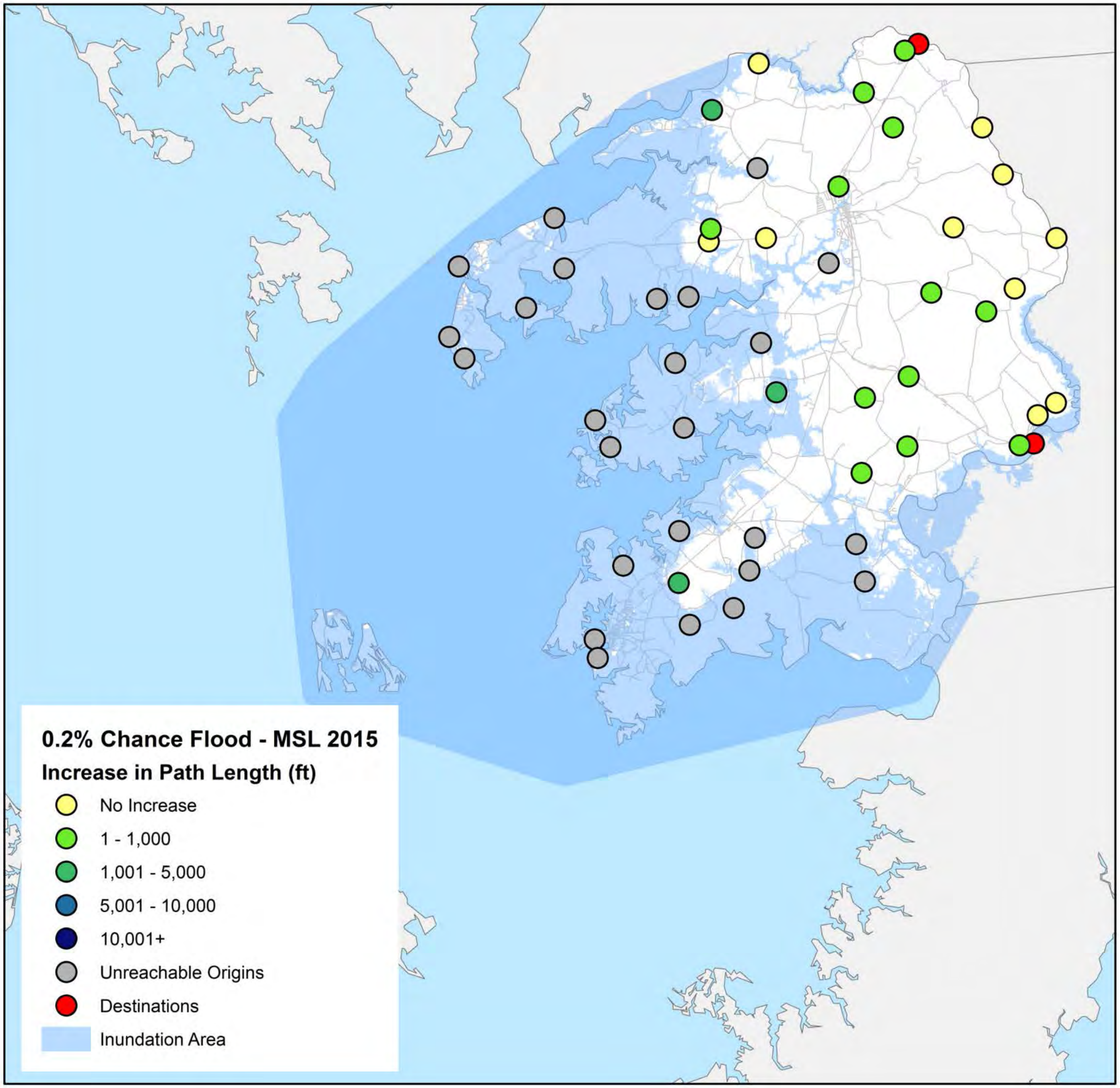
Level	No Flood	10% Chance	4% Chance	2% Chance	1% Chance	0.2% Chance
1	100.000%	82.745%	78.457%	73.509%	71.730%	66.110%
2	--	17.255%	21.536%	26.372%	28.035%	32.995%
3	--	--	0.007%	0.120%	0.235%	0.895%
4	--	--	--	--	--	--

Percent of total road length by HVI and flood recurrence in 2050 MSL

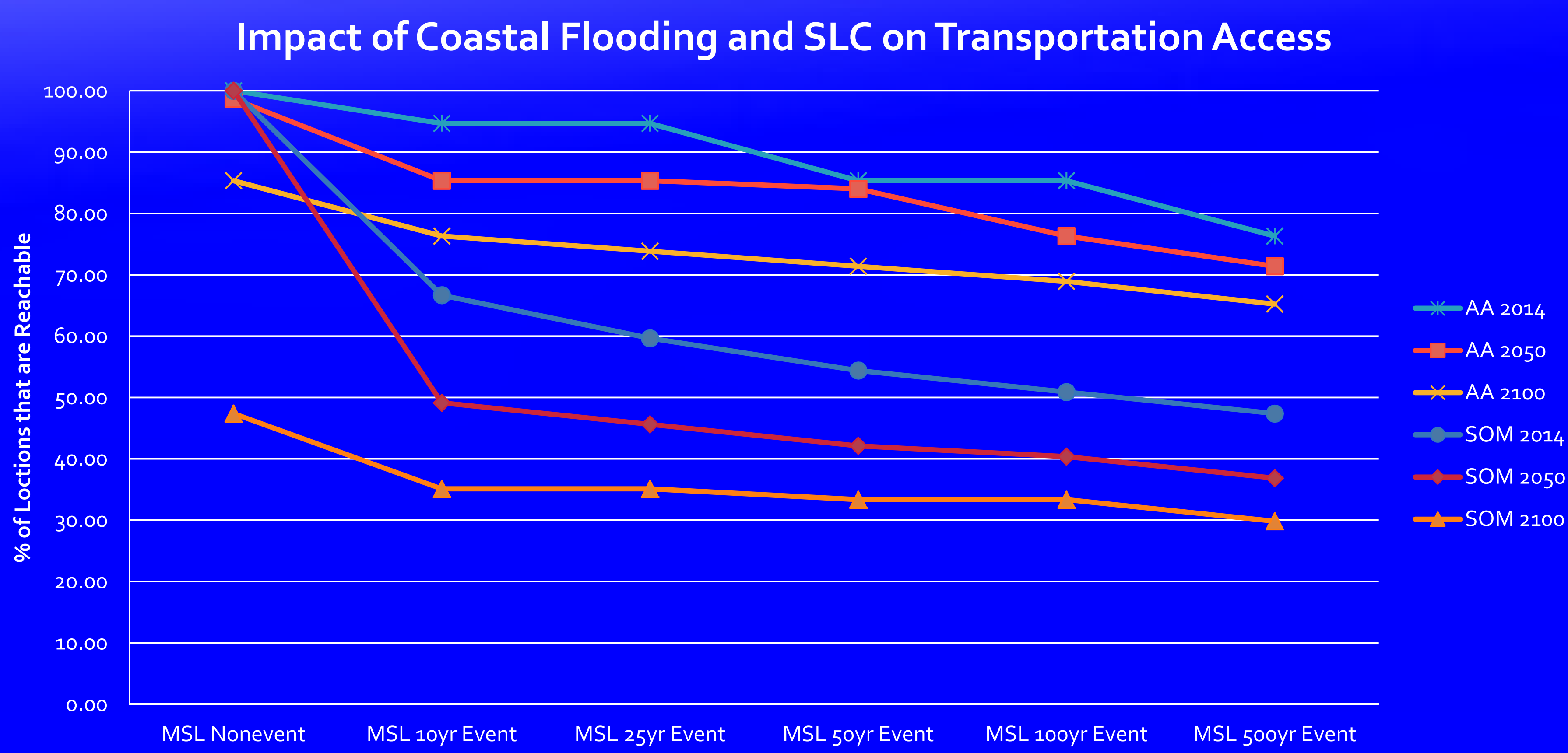
Level	No Flood	10% Chance	4% Chance	2% Chance	1% Chance	0.2% Chance
1	95.943%	67.751%	65.429%	60.833%	57.773%	52.160%
2	4.057%	31.823%	33.711%	38.170%	41.186%	46.538%
3	--	0.426%	0.860%	0.997%	1.040%	1.302%
4	--	--	--	--	--	--

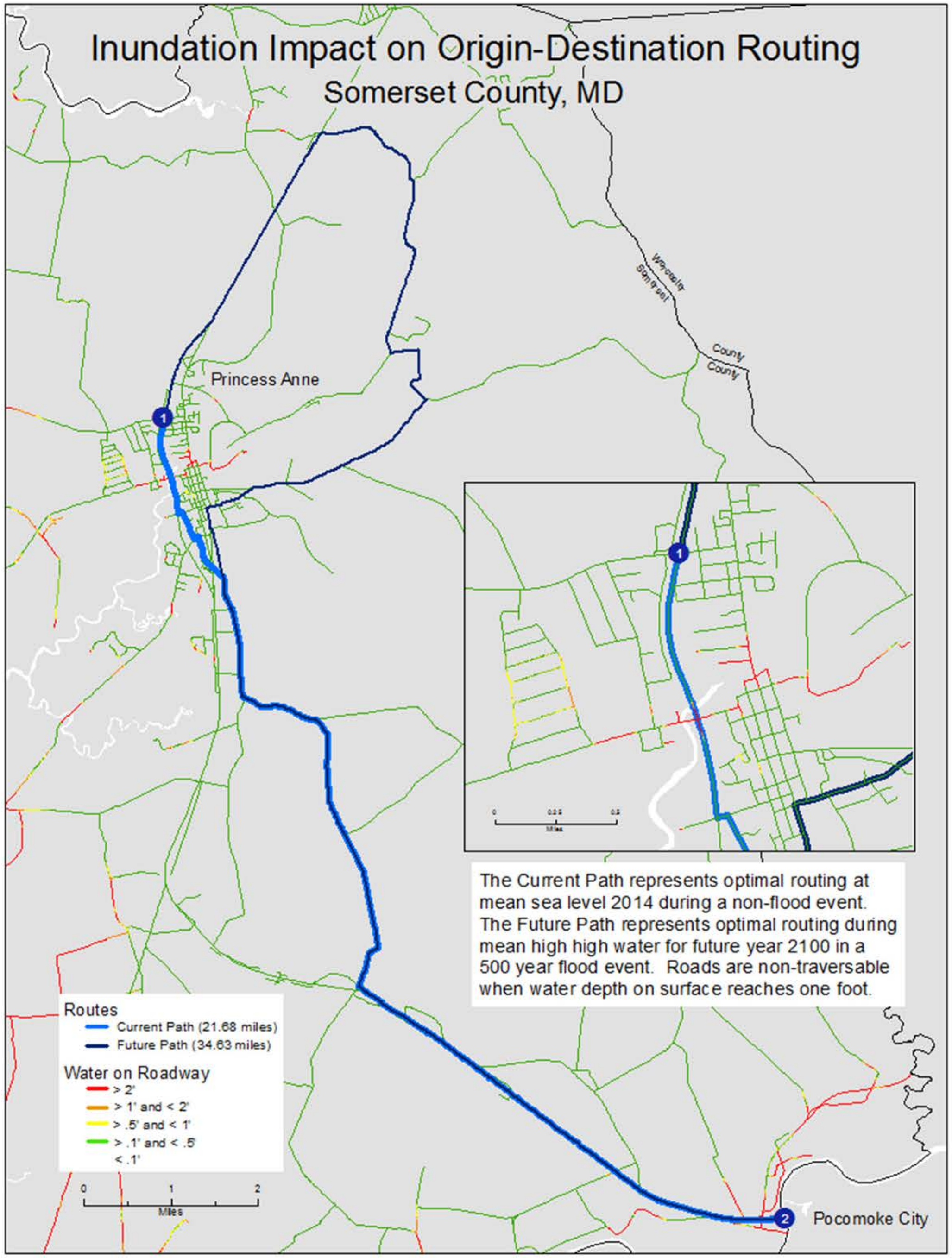
Network Trace Analysis

- Goal: Quantify SLC impact for prioritization
- Origin/Destination Routing
  - Random origins representing population distribution
  - Known destination representing egress points
- Find optimal path today between each O/D
- Find optimal path using HVI results
- Calculate anticipated changes to optimal path
  - Lengthening vs unreachable


0.2% Chance Flood - MSL 2015
Increase in Path Length (ft)
No Increase
1 - 1,000
1,001 - 5,000
5,001 - 10,000
10,001+
Unreachable Origins
Destinations
Inundation Area

Initial Observations: % Reachable Locations





Inundation Impact on Origin-Destination Routing
Somerset County, MD
Princess Anne
Pocomoke City
Wicomico County
Somerset County
The Current Path represents optimal routing at mean sea level 2014 during a non-flood event. The Future Path represents optimal routing during mean high high water for future year 2100 in a 500 year flood event. Roads are non-traversable when water depth on surface reaches one foot.
Routes
Current Path (21.68 miles)
Future Path (34.63 miles)
Water on Roadway
> 2'
> 1' and < 2'
> .5' and < 1'
> .1' and < .5'
< .1'
0
1
2
Miles

Important Caveats

- SLC estimates are a moving target and uncertainty expands significantly in 2100
- Elevation data is not as accurate in certain land cover
- SLC will not be as consistent across counties as we have modeled
- Flood scenarios do not include wave setup
- Coastline change due to SLC is not modeled
- Flood recurrence interval changes due to SLC are not modeled
- Damage estimates for roads are not well-defined
- Depth/damage curves likely locally specific
- Economic impact of a road closure?

Conclusions

- MDSHA has found the data useful for project prioritization
- We have been able to repurpose the depth grids for individual storm response
- Also being used for community vulnerability assessments
- Riverine modeling is currently underway
- But, significant uncertainty in changing recurrence intervals