SHA Climate Change Adaptation Plan with Detailed Vulnerability Assessment

MOITS

December 9, 2014

Discussion

- Objectives
- Framework
- Data, Tools
- Methodology
- Results
- Next Steps

Pilot Study Objectives

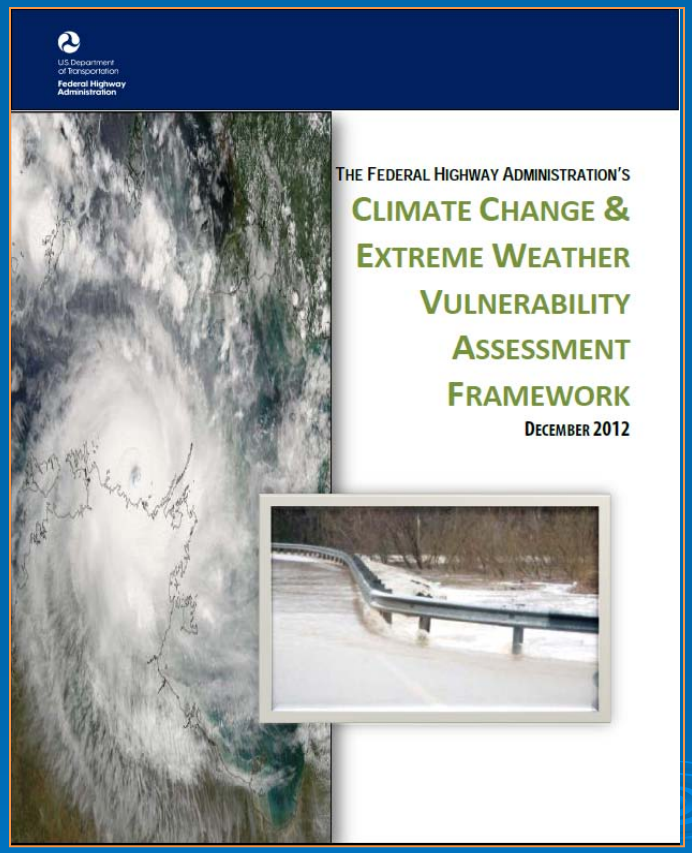
- Assess Vulnerability to SHA's Assets
- Develop Approaches to Address Current and Future Risk
- Provide Recommendations for Policy or Process Changes

Floating Debris Lodged in a Bridge during Flood Event at Seneca Creek in Germantown, MD
Photo Source: (FEMA/Skolnik 2006)

"Improve Resiliency of Maryland's Transportation System"

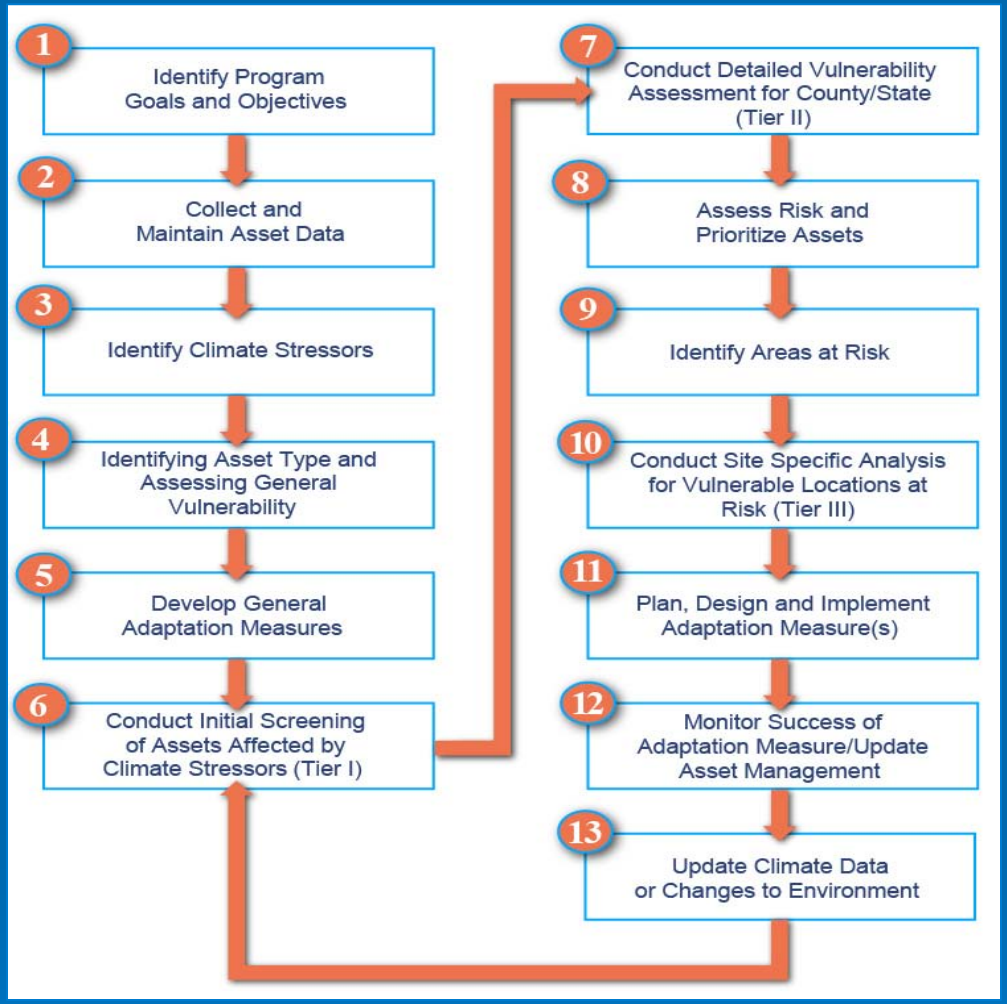
Develop Framework

- Modified Framework
  - Conducted General Assessment of Asset Vulnerabilities and Adaptation Measures
- Incorporated Different Screening Approaches
  - Climate Change Impact Zone
- Process Repeatable



"Draft" Framework

Process repeatable when new climate data is available or changes to the environment occur



Identify Climate Stressors

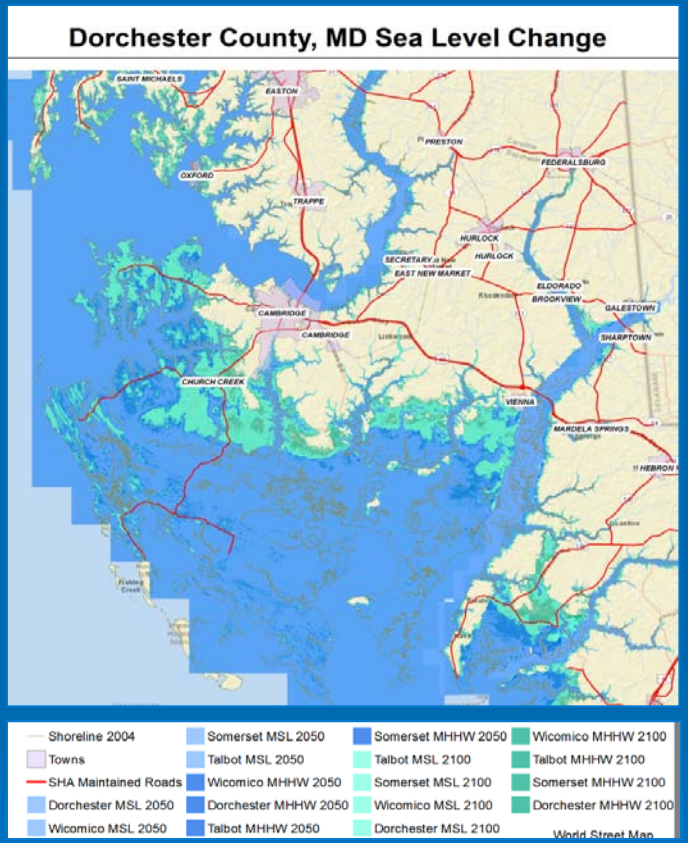
Studied in Detail for Maryland

Sea Level Change	• USACE Procedures Established in Circular No. 1165-2-212 (2013) • Newer LiDAR and Assign Nearest Tidal Station
Storm Surge	• HAZUS-MH 2.1 (Category 3 Storm Used) • Stillwater Depth Grids Developed
Precipitation	• Micro-scale Data Obtained from C-MIP • Riverine Modeling in HAZUS-MH2.1 (future)

2050 & 2100 Sea Level Change

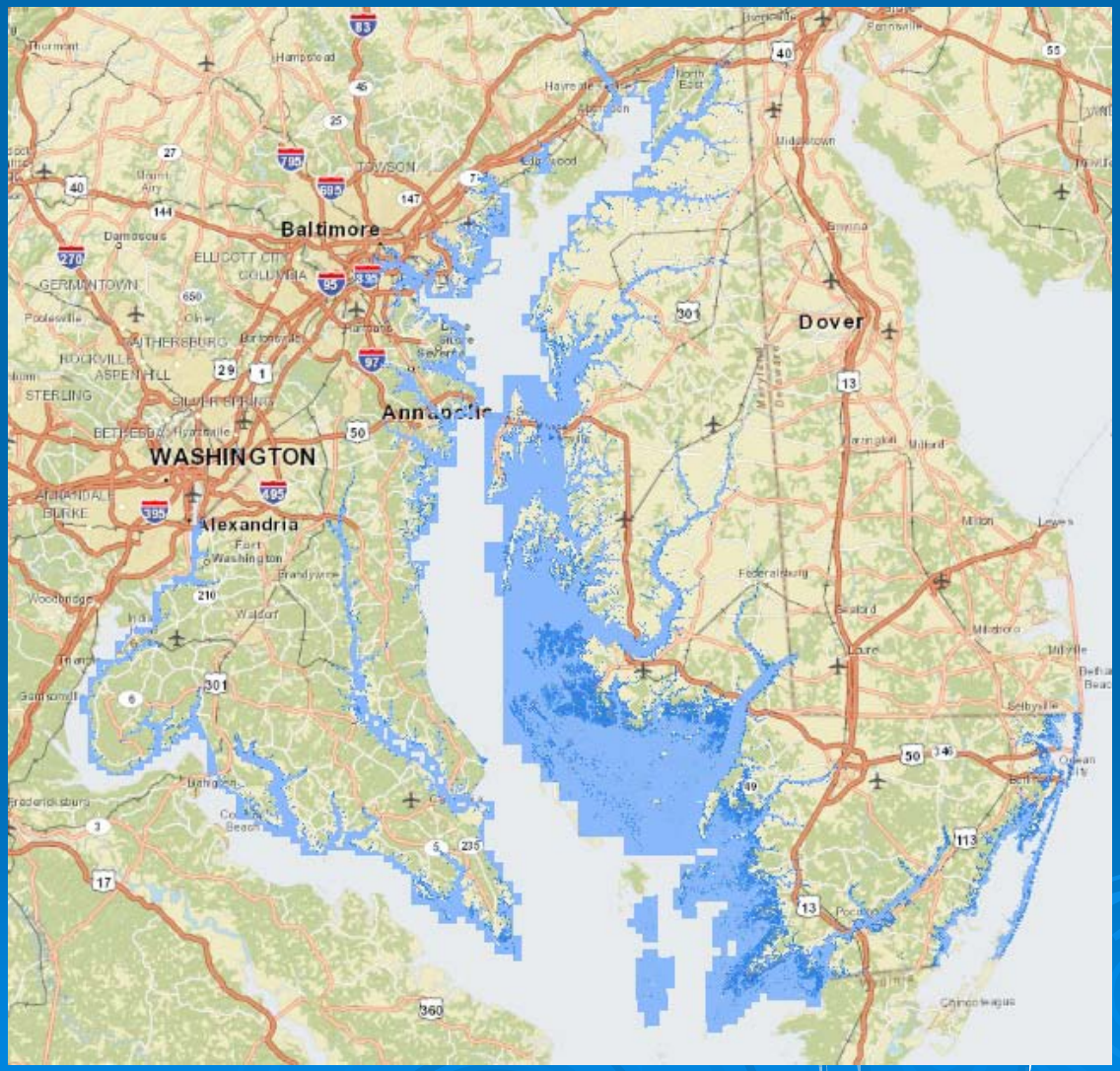
Eastern Shore Regional GIS Cooperative – Salisbury University

		2050		2100	
County	Tidal Station	MSL	MHHW	MSL	MHHW
Allegany	None	-	-	-	-
Anne Arundel	Annapolis	2.08	2.79	5.7	6.41
Baltimore	Baltimore	2.01	2.87	5.59	6.45
Baltimore City	Baltimore	2.01	2.87	5.59	6.45
Calvert	Solomons Island	2.1	2.82	5.76	6.48
Caroline	Cambridge	2.11	3.13	5.78	6.8
Carroll	None	-	-	-	-
Cecil	Chesapeake City	1.98	3.63	5.56	7.21
Charles	Washington DC	2.21	3.83	5.78	7.4
Dorchester	Cambridge	2.11	3.13	5.78	6.8
Frederick	None	-	-	-	-
Garrett	None	-	-	-	-
Harford	Baltimore	2.01	2.87	5.59	6.45
Howard	None	-	-	-	-
Kent	Annapolis	2.08	2.79	5.7	6.41
Montgomery	None	-	-	-	-
Prince Georges	Washington DC	2.21	3.83	5.78	7.4
Queen Annes	Annapolis	2.08	2.79	5.7	6.41
Somerset	Cambridge	2.11	3.13	5.78	6.8
St. Mary's	Solomons Island	2.1	2.82	5.76	6.48
Talbot	Cambridge	2.11	3.13	5.78	6.8
Washington	None	-	-	-	-
Wicomico	Cambridge	2.11	3.13	5.78	6.8
Worcester	Ocean City	2.06	3.25	5.86	7.05



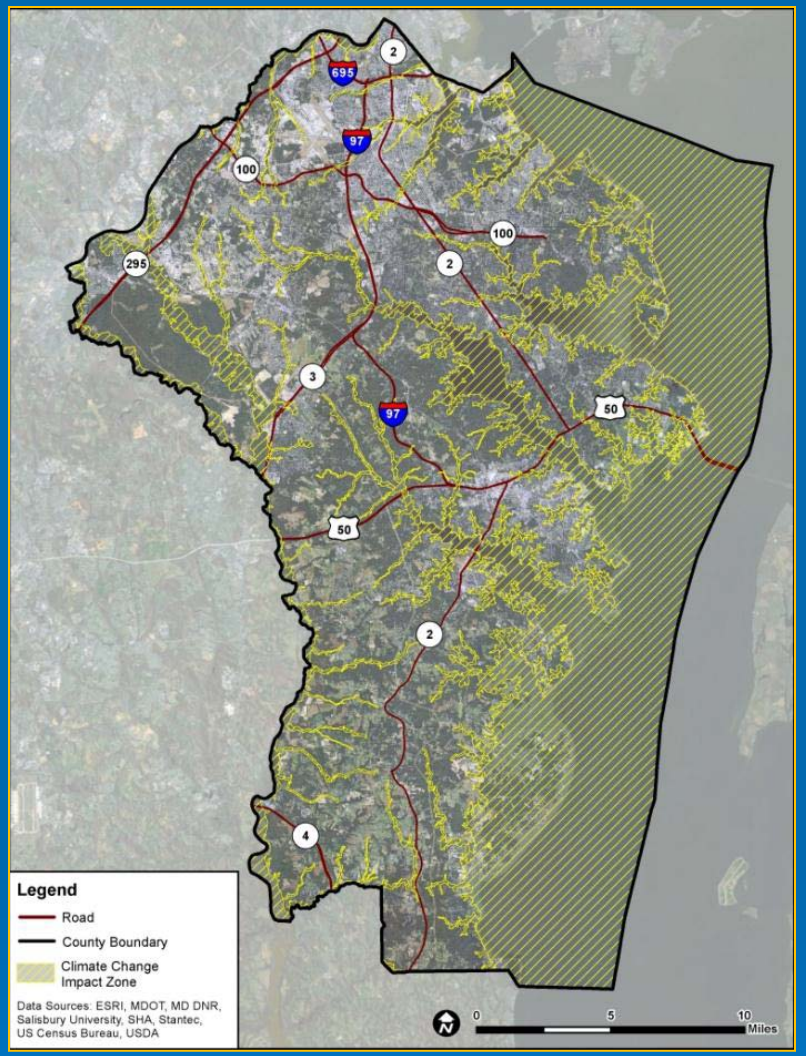
Methodology – USACE: Sea-Level Change Considerations for Civil Works Programs, October 2013

2050 & 2100 Sea Level Change



Initial Screening

- Climate Change Impact Zone Map Created Using GIS
- Eliminate assets at low to no risk prior to use of VAST
- Used SLOSH (Cat 3), 2100 MHHW, FEMA 100 year Floodplain, plus 50 ft. buffer



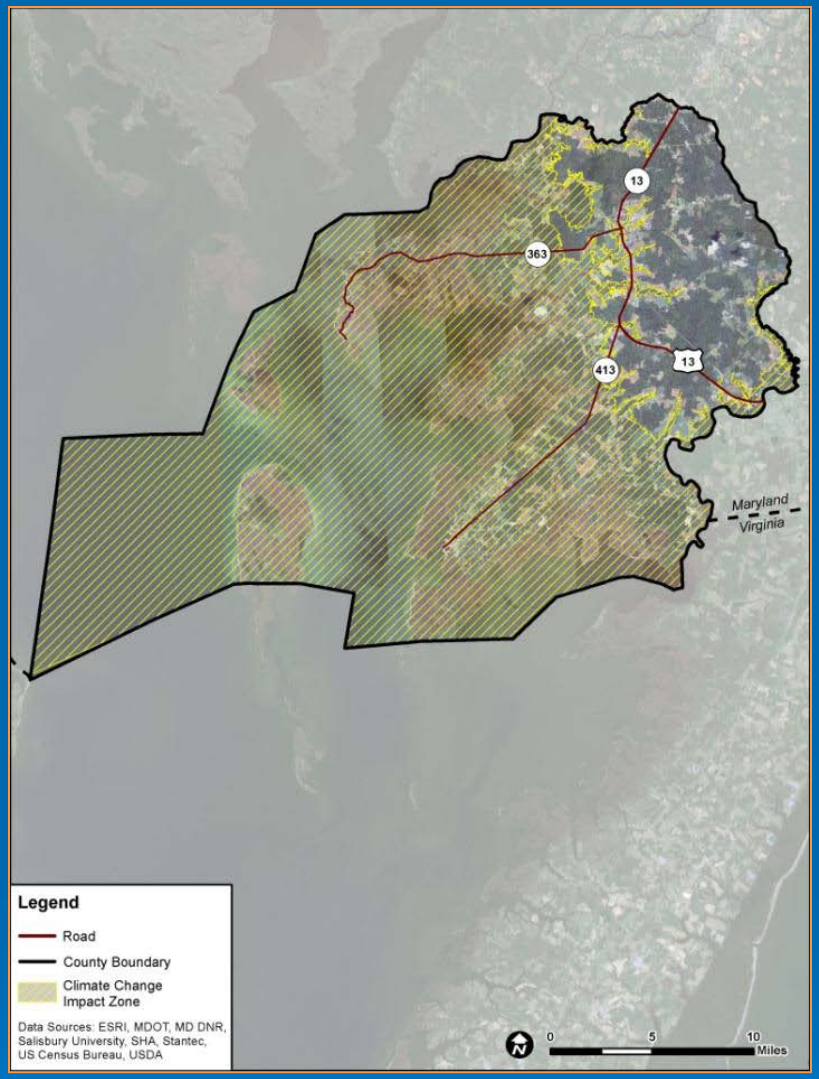
Climate Change Impact Zone
Anne Arundel, MD

Results of Screening

Assets	Anne Arundel County		Somerset County	
	Number of Assets	Evaluated in More Detail	Number of Assets	Evaluated in More Detail
Bridges including large culverts	517	150	86	72
Small culverts and conveyances	Culverts- 12,024 Conveyances- 8,601	Culverts- 1,174 Conveyances- 843	Culverts- 1153 Conveyances 1135	Culverts- 739 Conveyances 847
Miles of roadway	2,554.28 miles	114.99 miles	503.92 miles	285.2 miles

Assess Vulnerability

- Two Pilot Counties
- Initial Screening of Assets
- SLC – Permanent Inundation
- Tools Used
  - Hazard Vulnerability Index
  - VAST

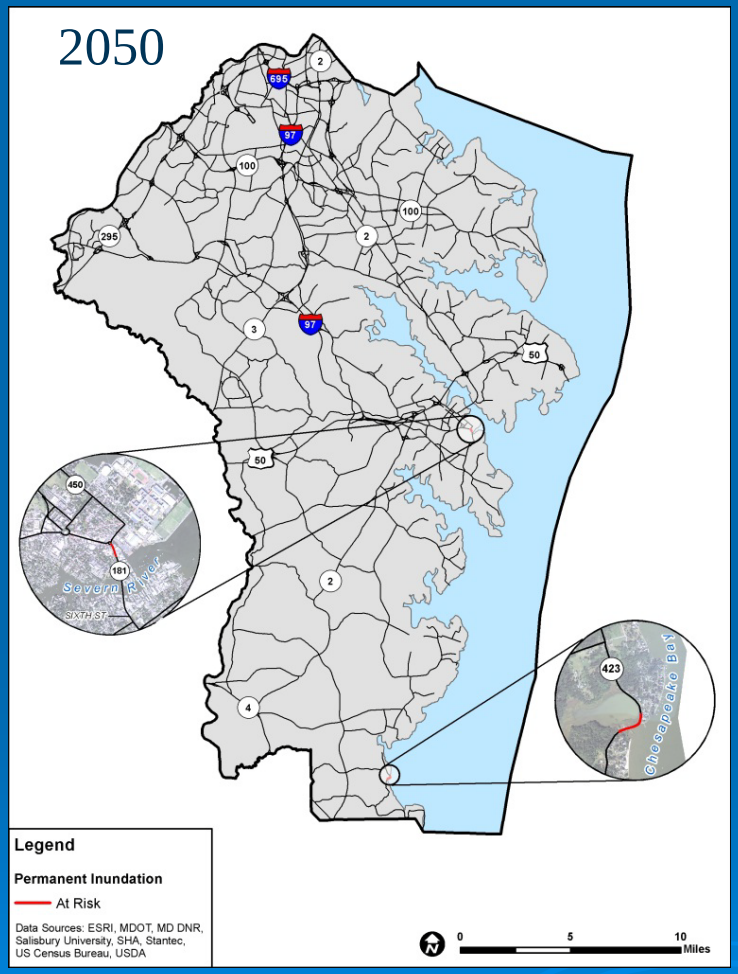


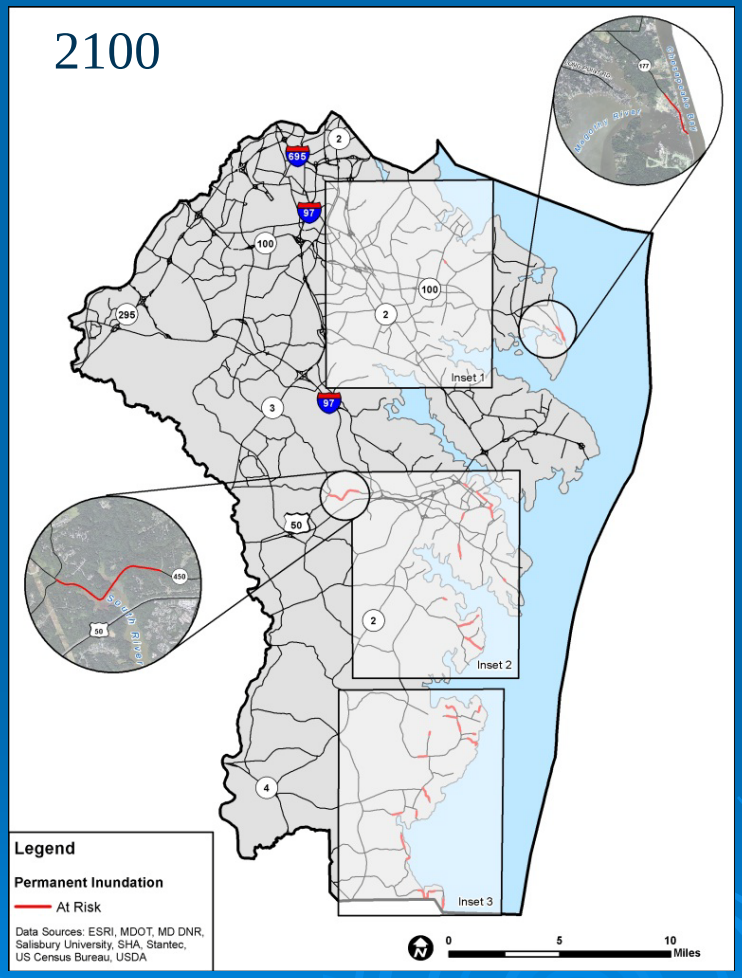
Change Impact Zone
Somerset County, MD

Results - Roadways

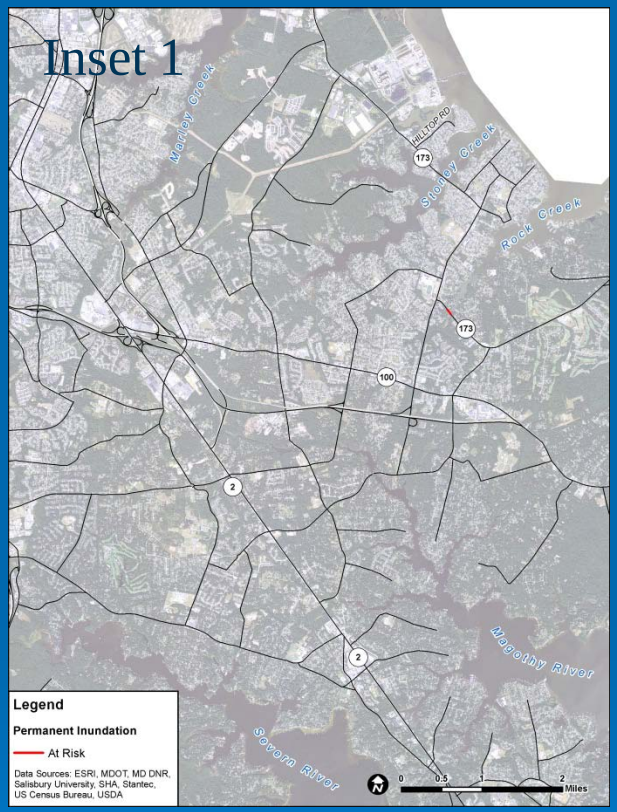
- Permanent Inundation
  - Anne Arundel County 2050 & 2100 Sea Level Change (USACE)
  - Somerset County 2050 & 2100 Sea Level Change (USACE)
- Hazard Vulnerability Index (HVI)
  - Anne Arundel County 2050 & 2100 Sea Level Change with 100 Year Storm Event (HAZUS-MH)
    - Storm Surge Considerations (Still Water)
  - Somerset County 2050 & 2100 Sea Level Change with 100 Year Storm Event (HAZUS-MH)
    - Storm Surge Considerations (Still Water)

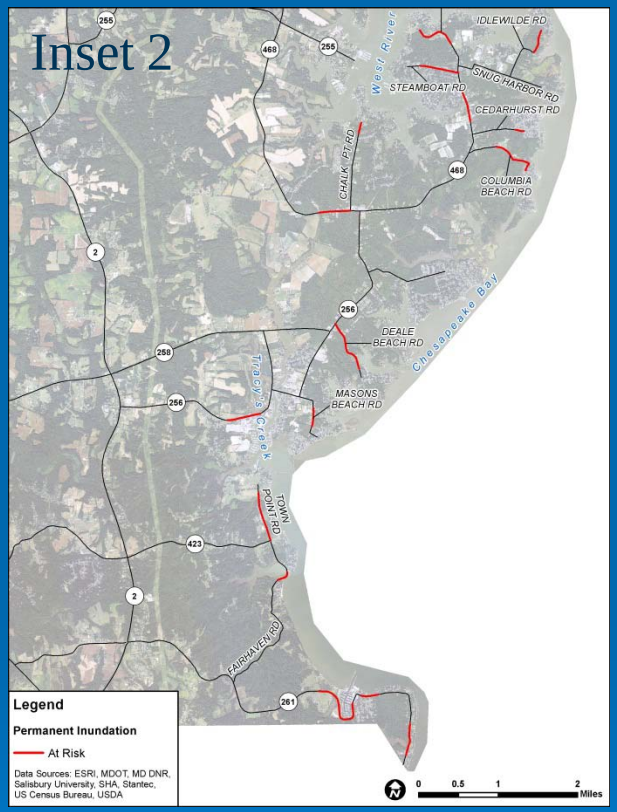
Permanent Inundation for Anne Arundel

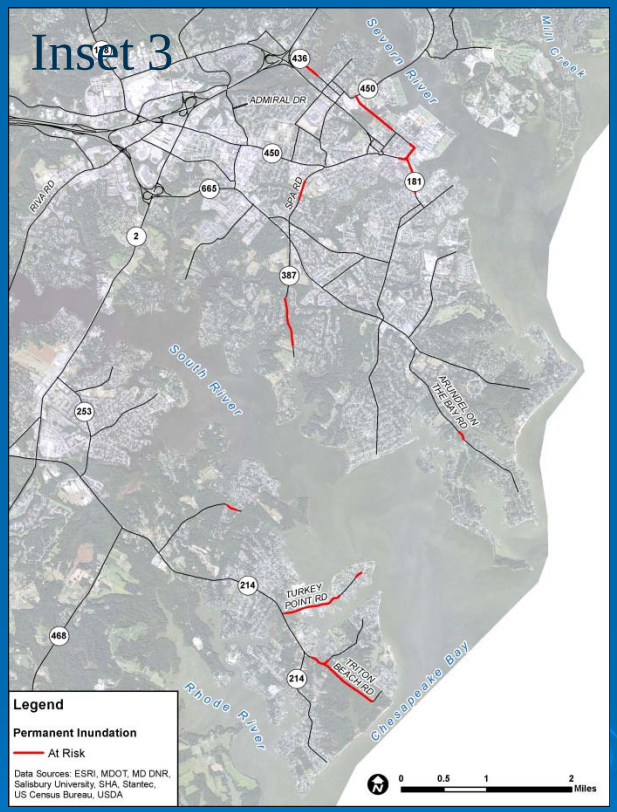




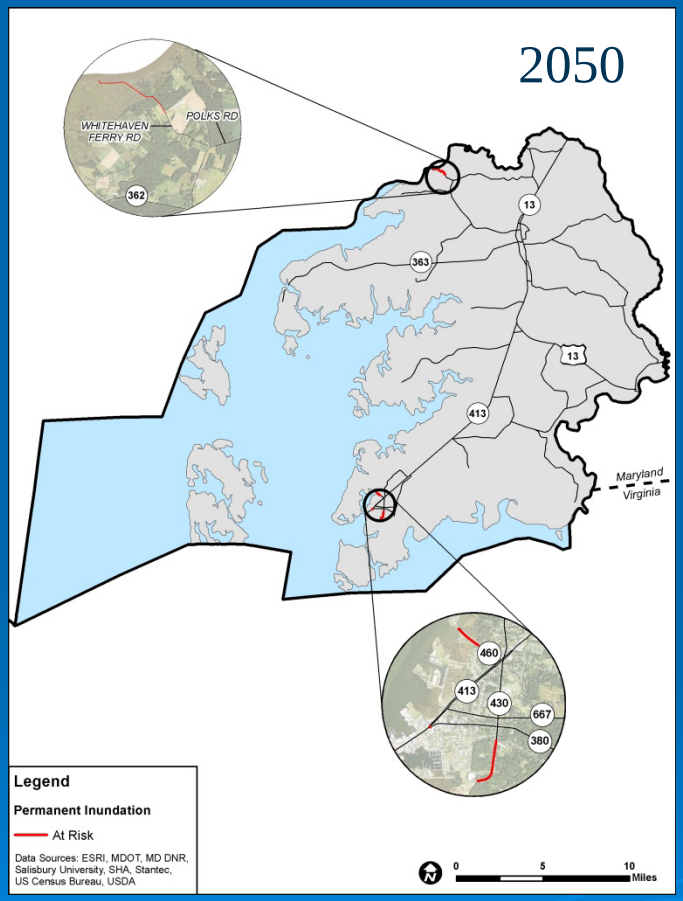
Permanent Inundation Anne Arundel 2100

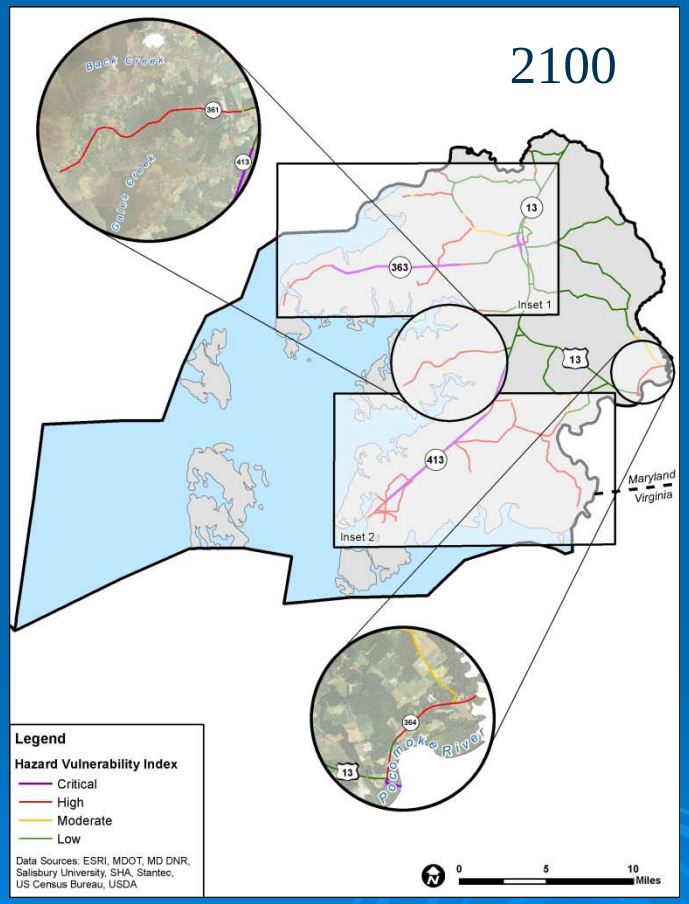




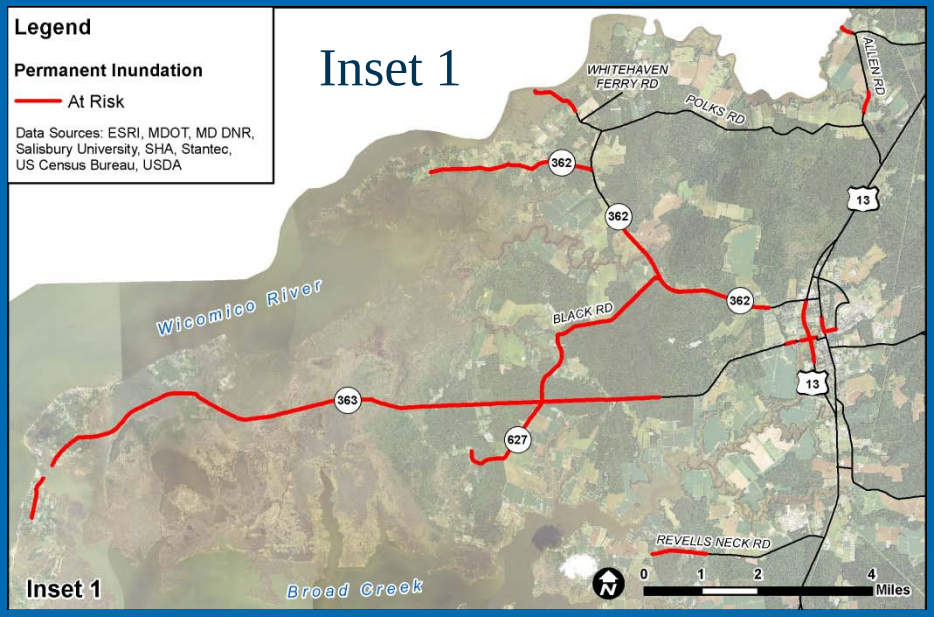


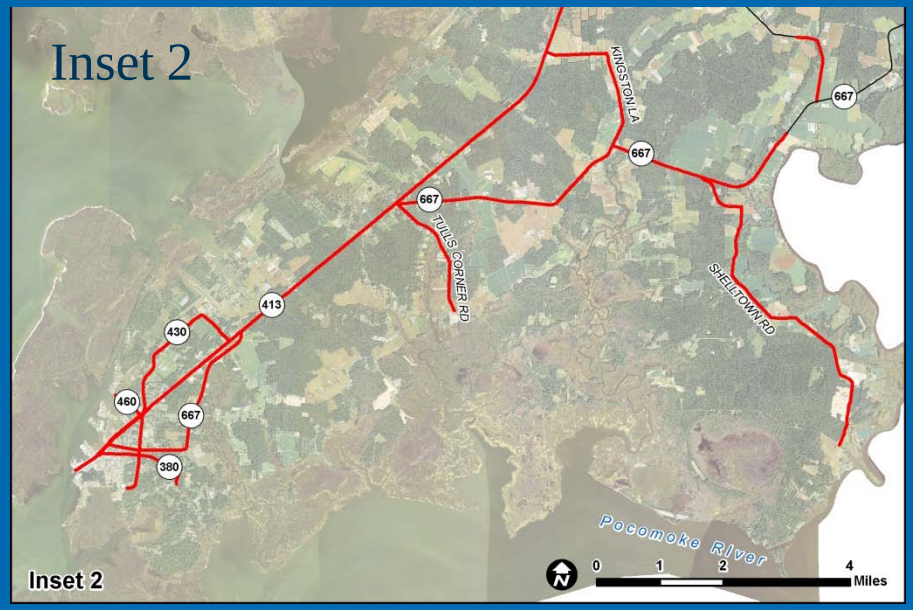
Permanent Inundation Somerset County





Permanent Inundation Somerset County - 2100





Hazard Vulnerability Index (HVI)

$$Risk = (Evacuation\ Code * 0.5 + 1) * \left(\frac{(Flood\ Depth\ Code + 0.01)}{4}\right) * \left(\frac{0.7}{Functional\ Classification}\right)$$

Evacuation	Code
No	0
Yes	1

Flood Depth (Feet)	Code
No Flood	0
0 – 0.5	1
0.5 - 1	2
1 - 2	3
>2	4

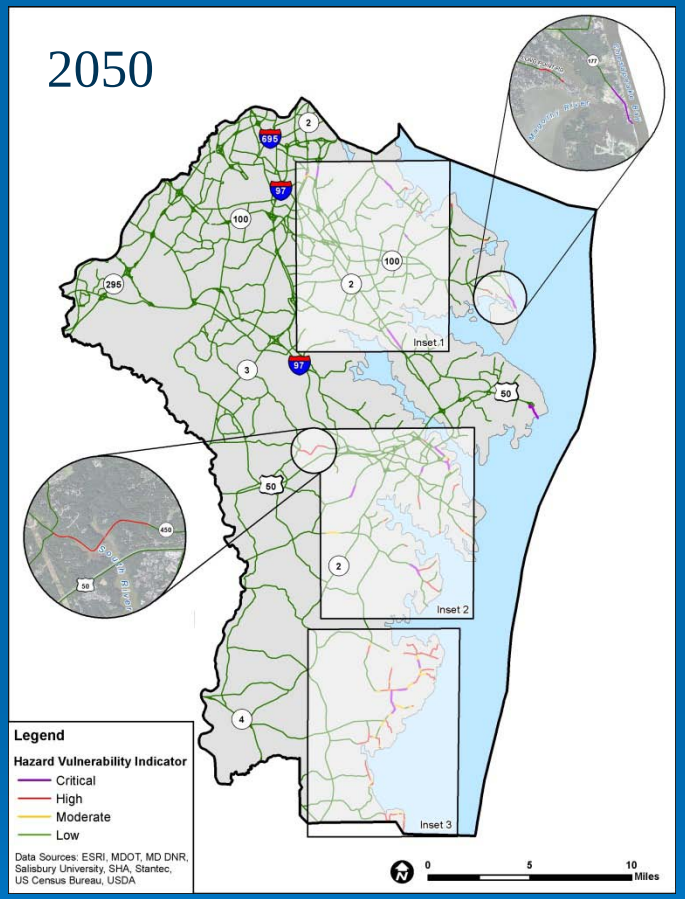
Value	SHA Functional Class
1	Interstate
2	Principal Arterial – Other Freeways and Expressways
3	Principal Arterial – Other
4	Minor Arterial
5	Major Collector
6	Minor Collector
7	Local

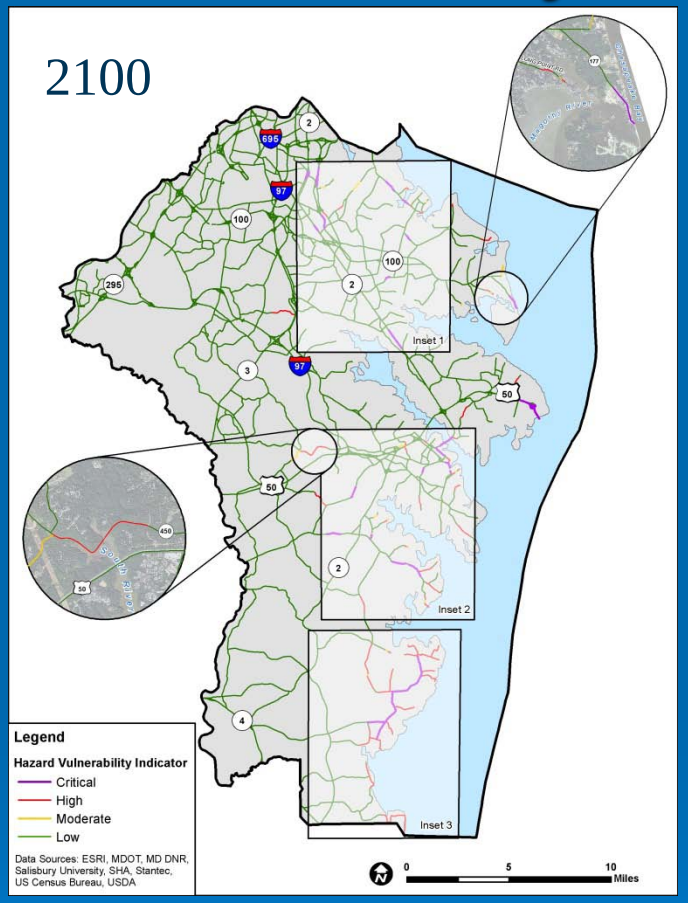
Hazard Vulnerability Index (HVI)

Risk	
Value	Category
> 0.15	Critical
0.1 – 0.15	High
0.01 – 0.1	Moderate
< 0.01	Low

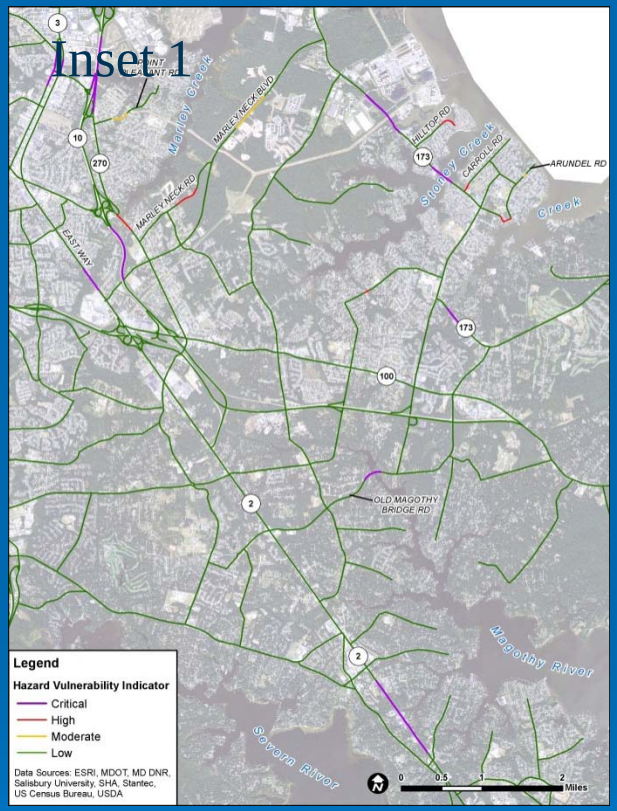
- Critical:
  - Lower Bound of Flood Depth Code of 4 and Evacuation Route for Any Roadway
  - Lower Bound of Any Flooding to Functional Classification 1 Roadways (Interstates)
- High:
  - Lower Bound is Flood Depth Code of 4 for Any Roadway
- Moderate:
  - Flood Depth Code 1-3 for Functional Classifications 2-7
- Low:
  - No Flooding

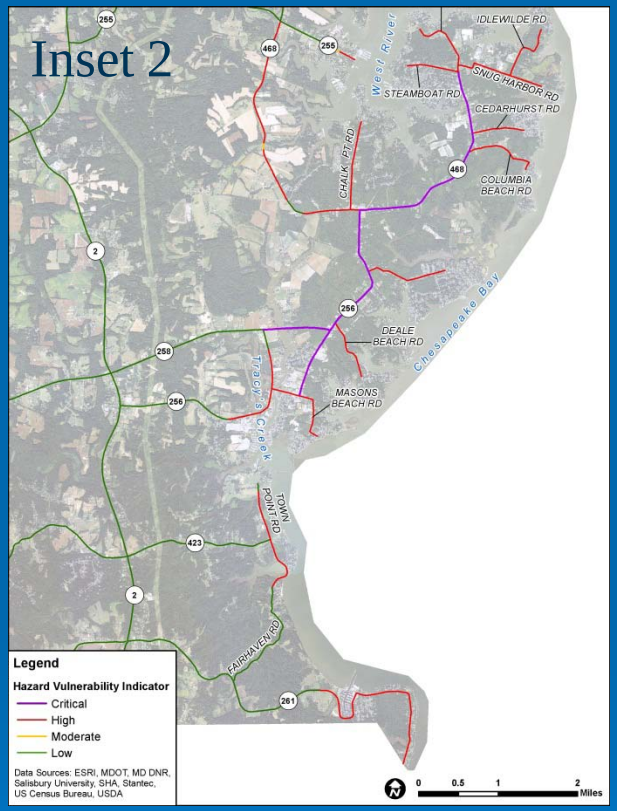
HVI for Anne Arundel County

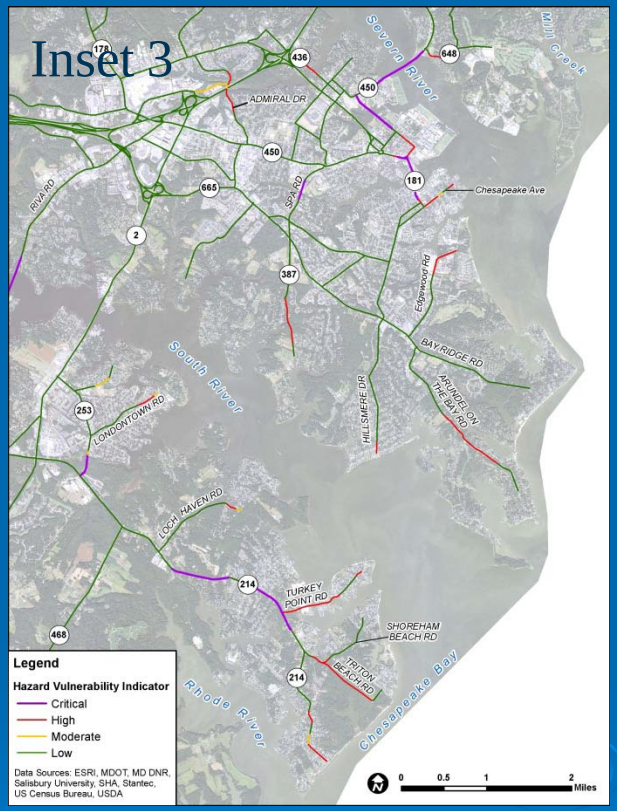




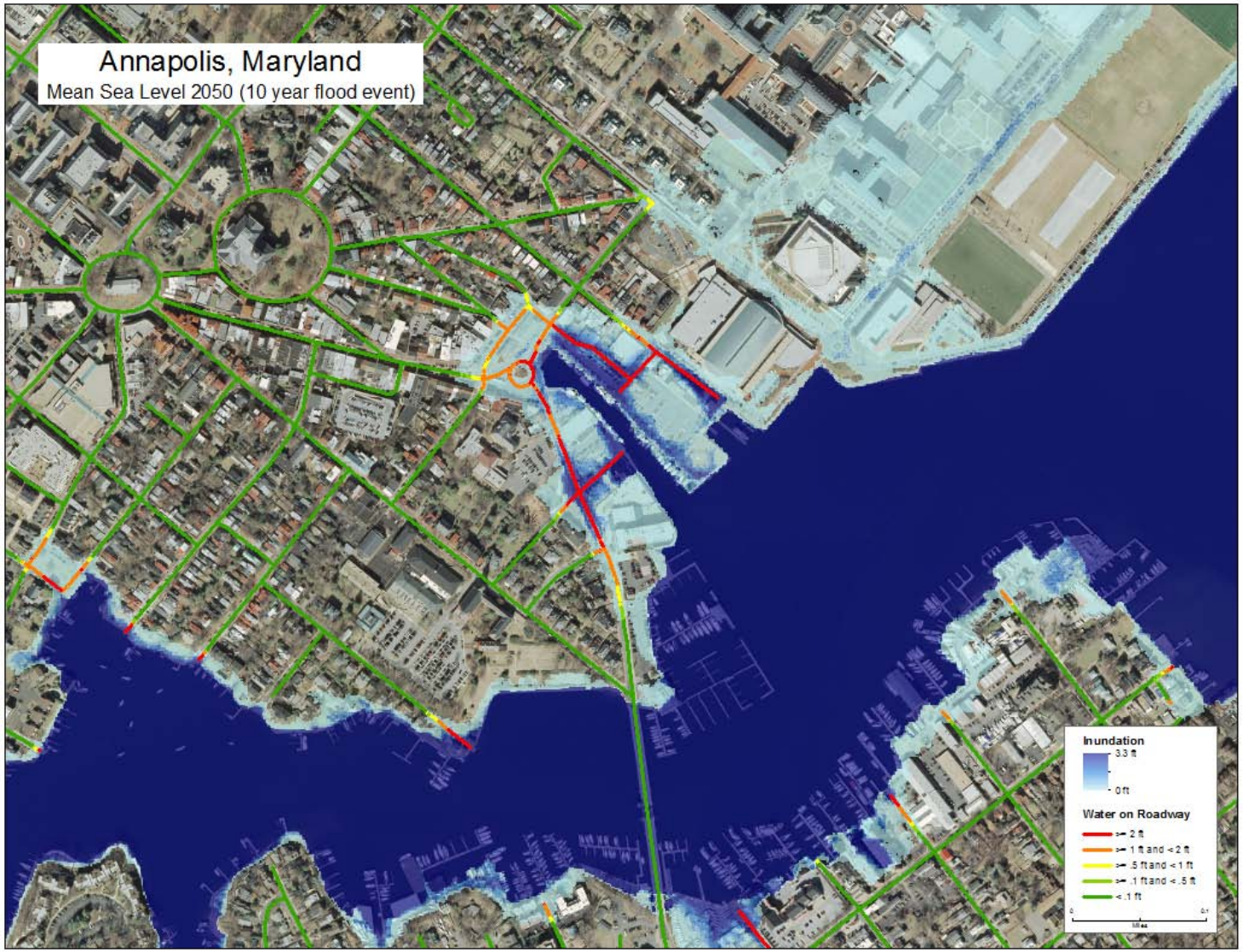
HVI for Anne Arundel County 2100



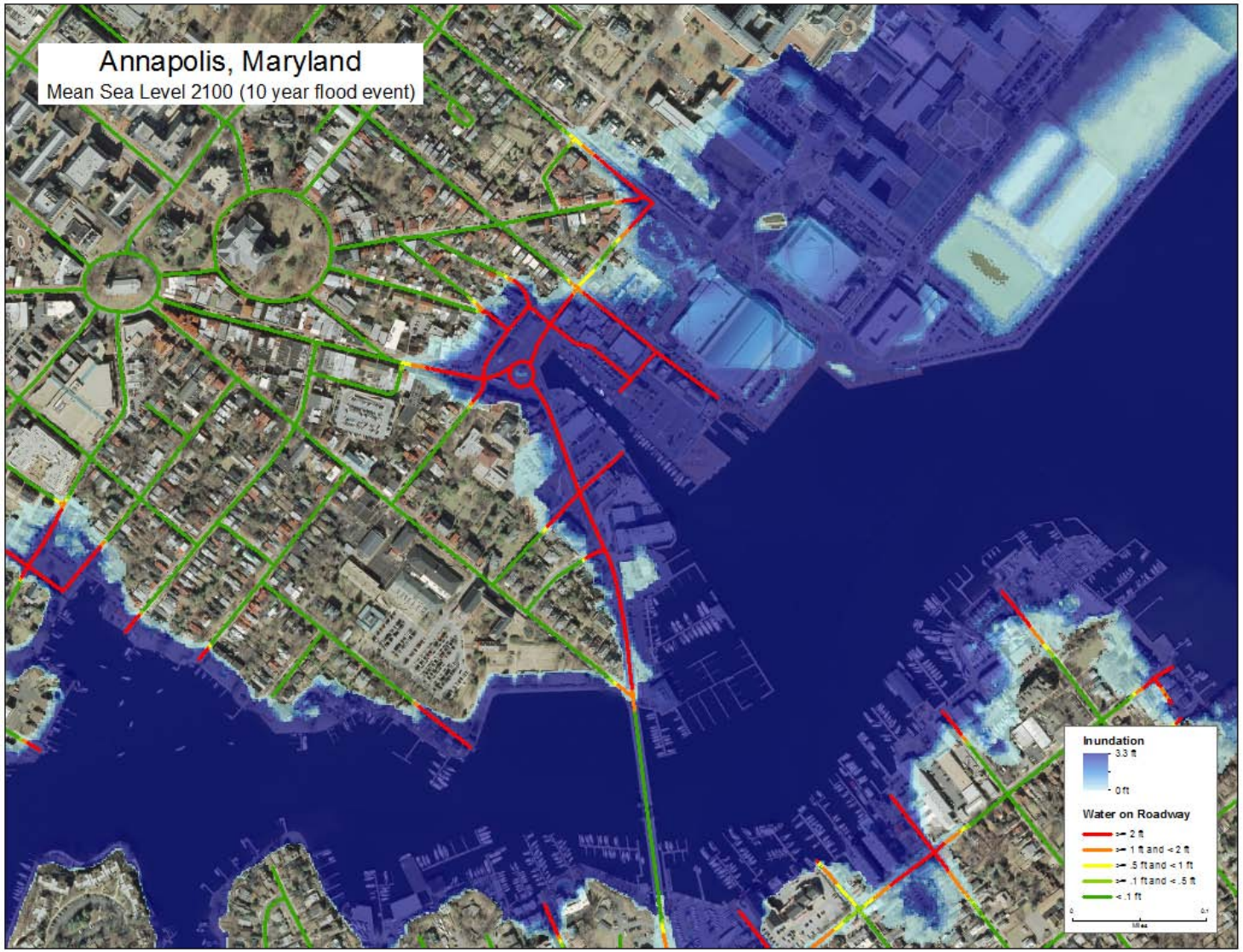




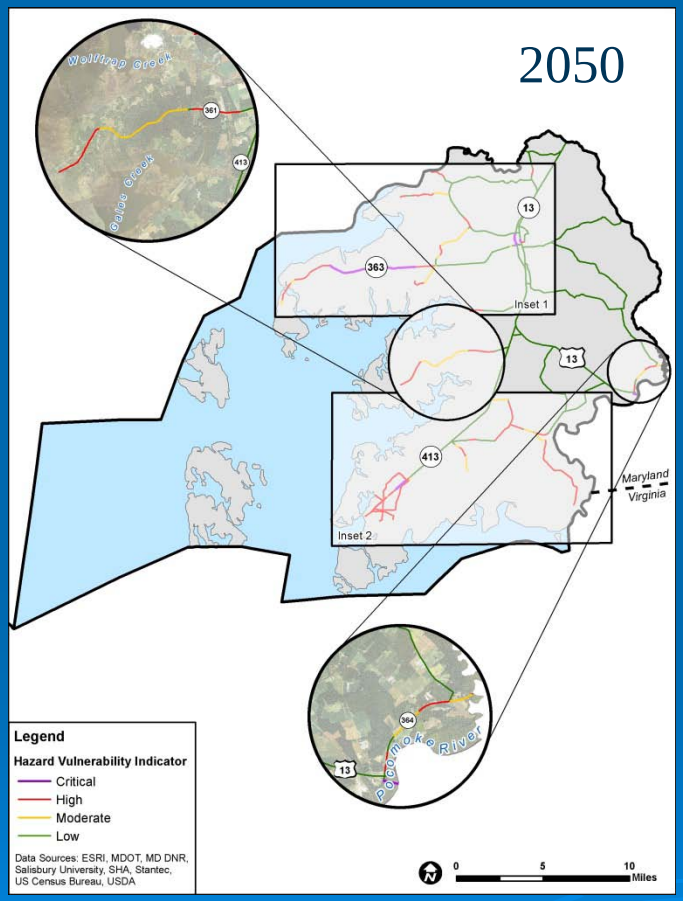
HVI for Annapolis 2050

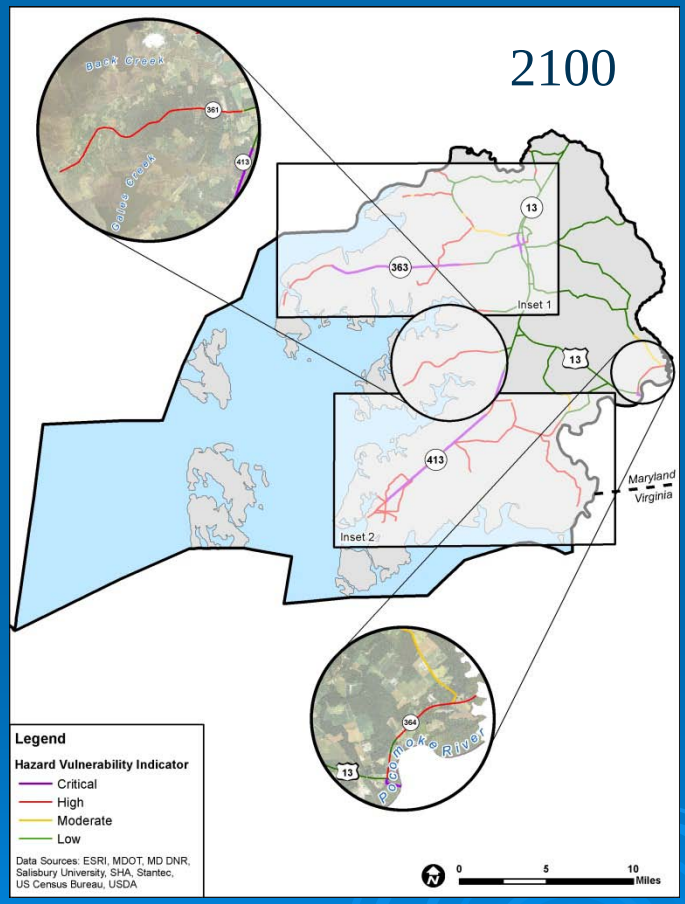


HVI for Annapolis 2100

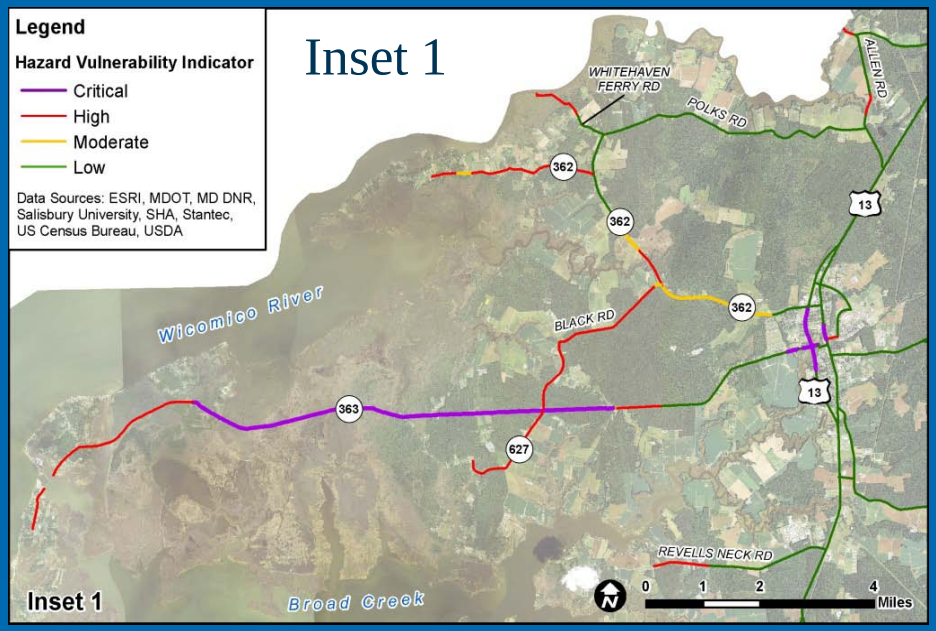


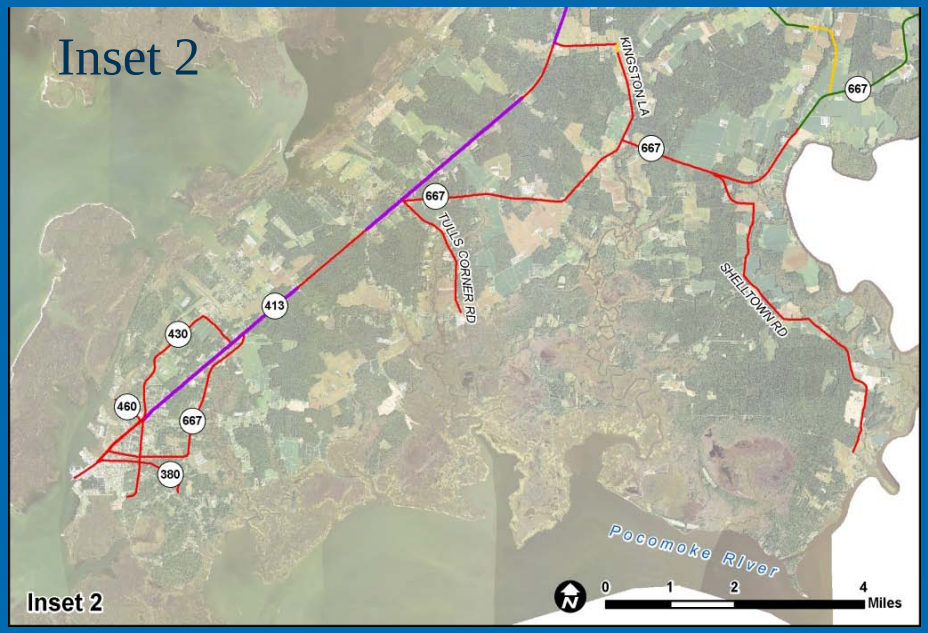
HVI for Somerset County



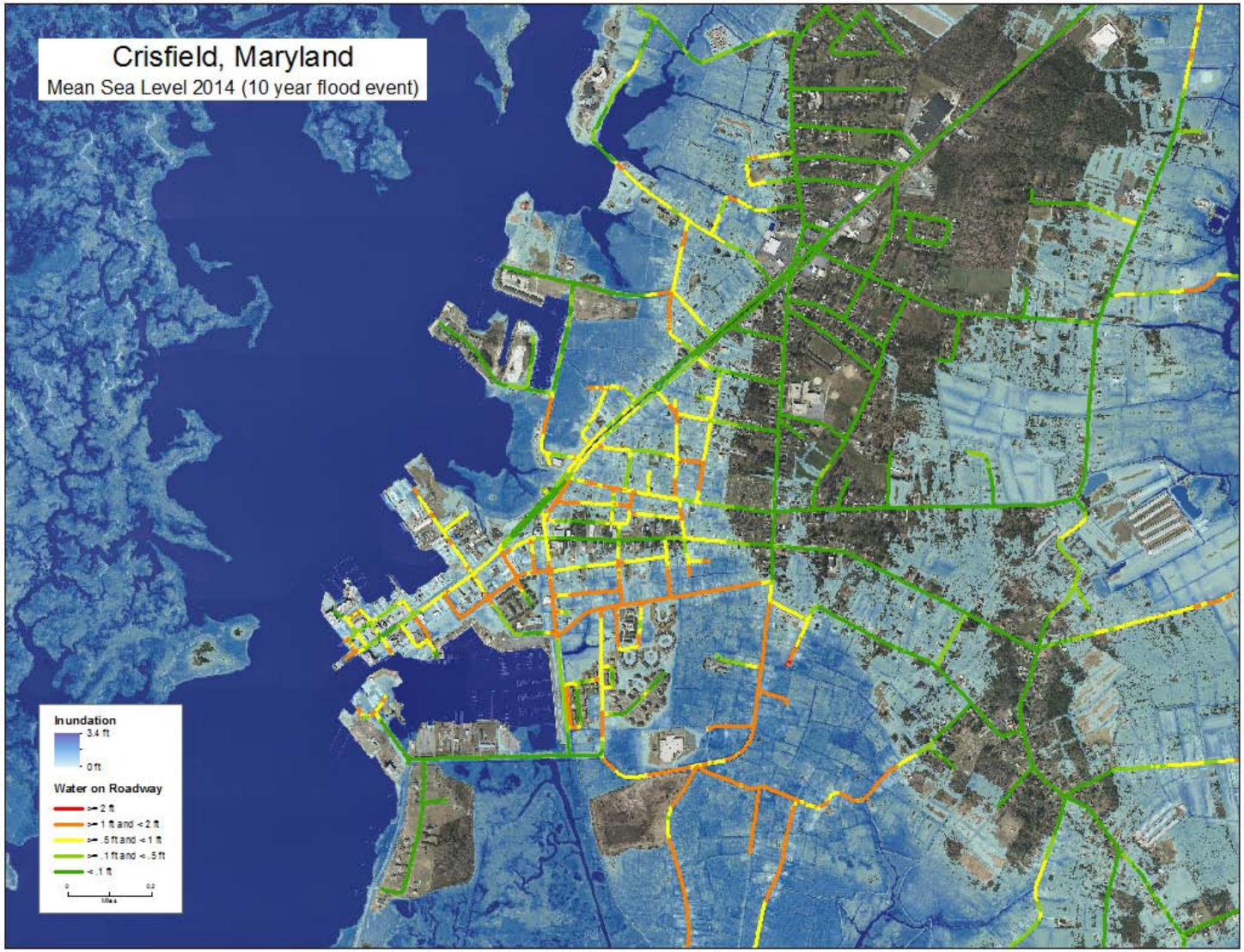


HVI for Somerset County 2100

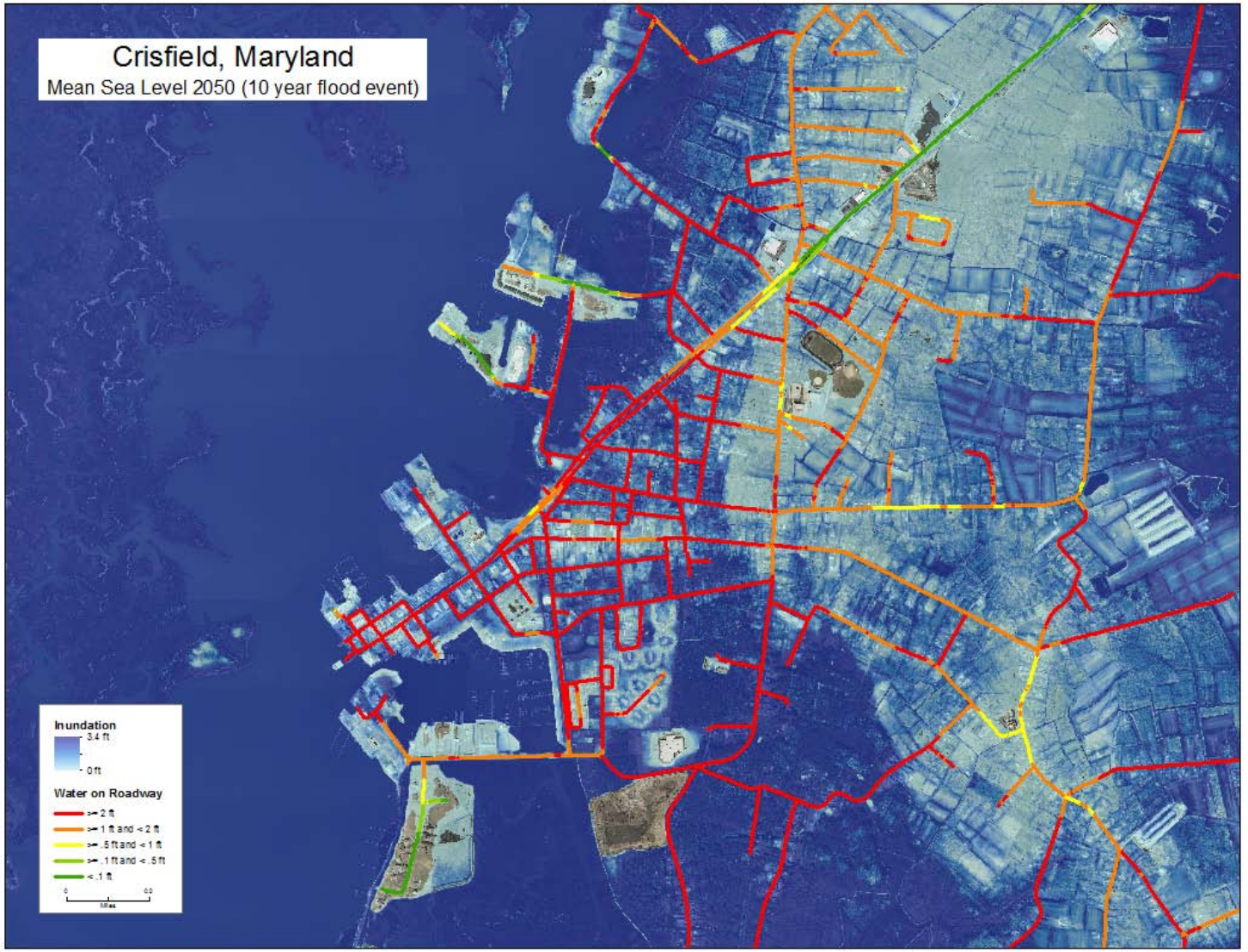




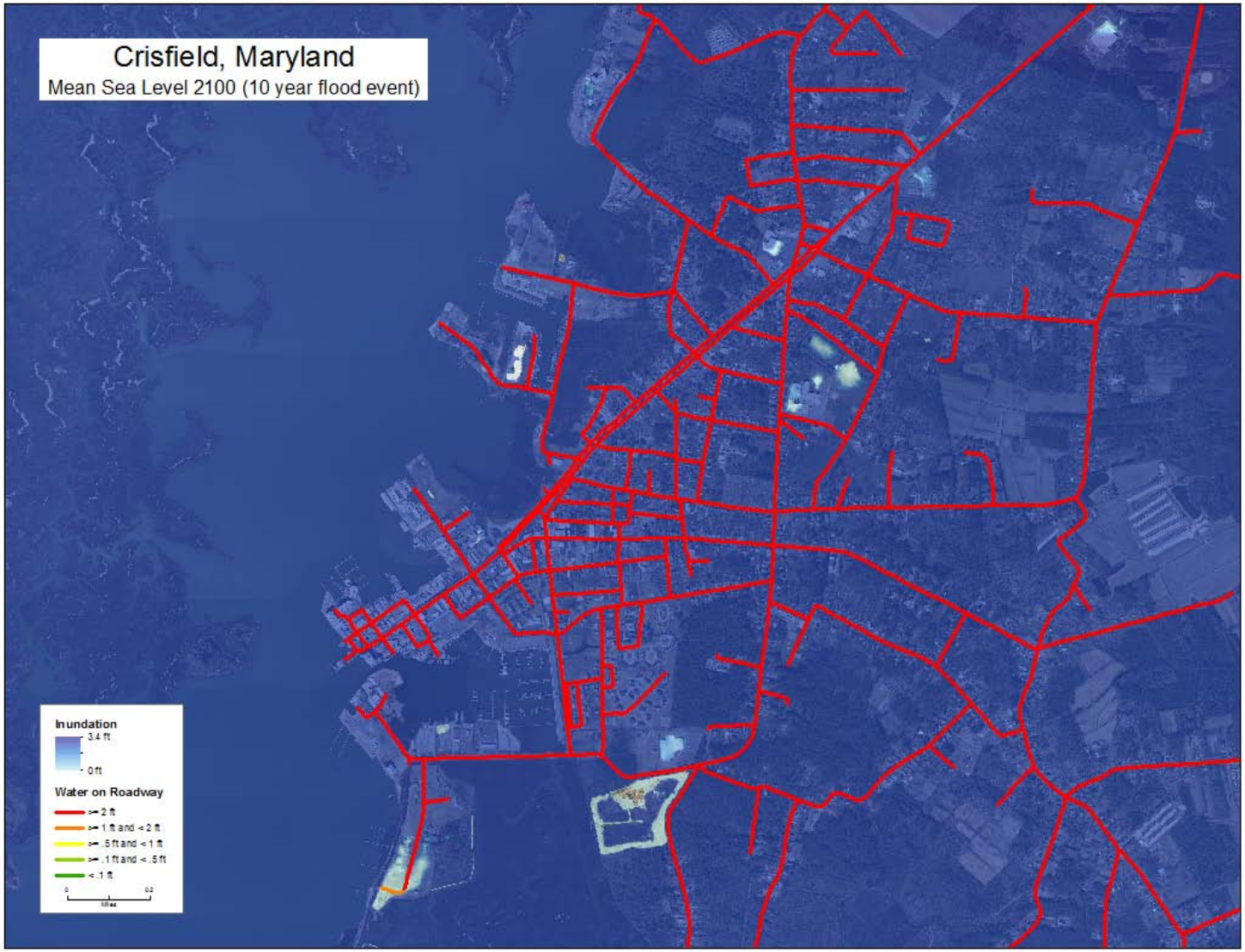
HVI for Crisfield 2014



HVI for Crisfield 2050



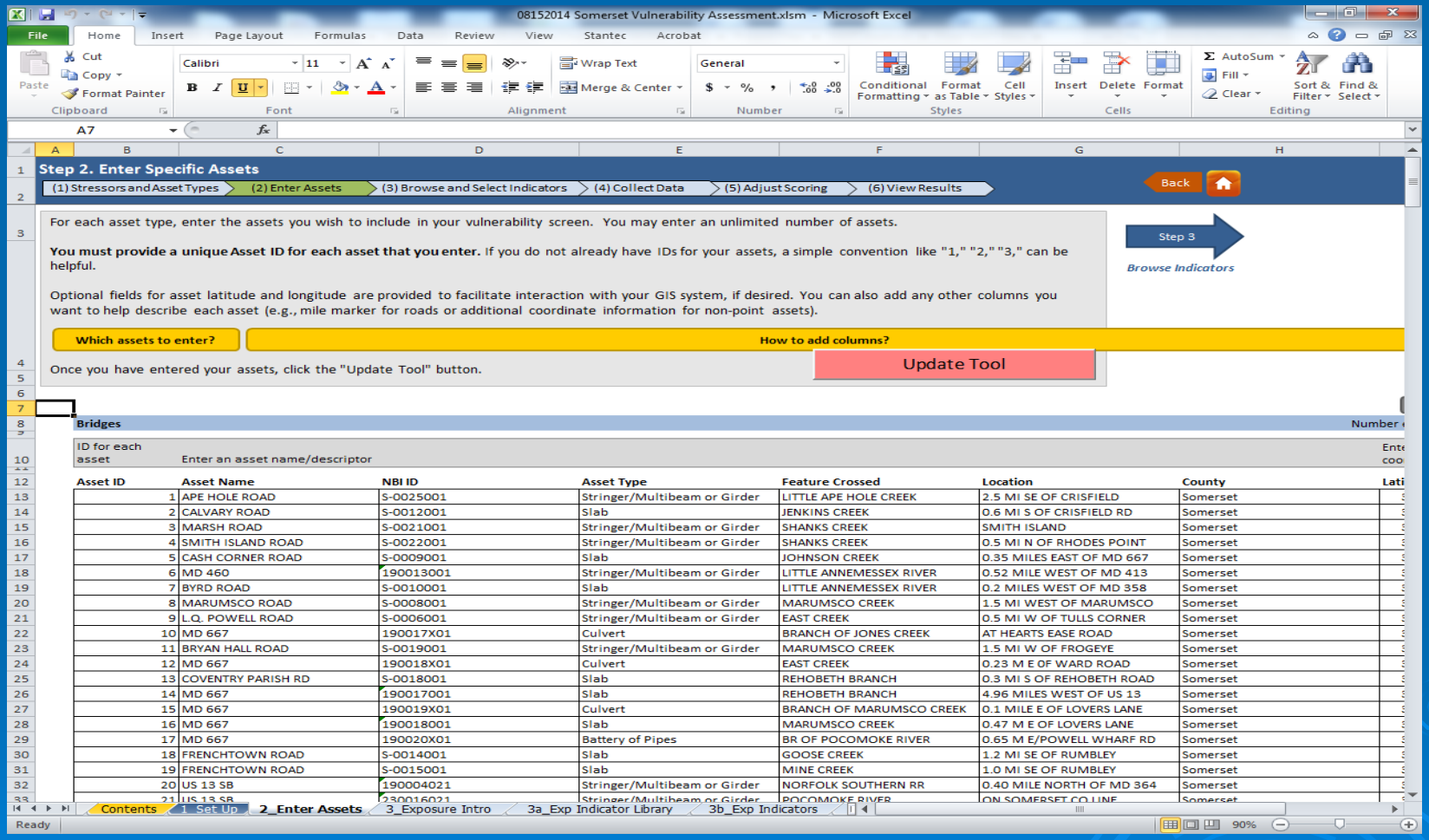
HVI for Crisfield 2100



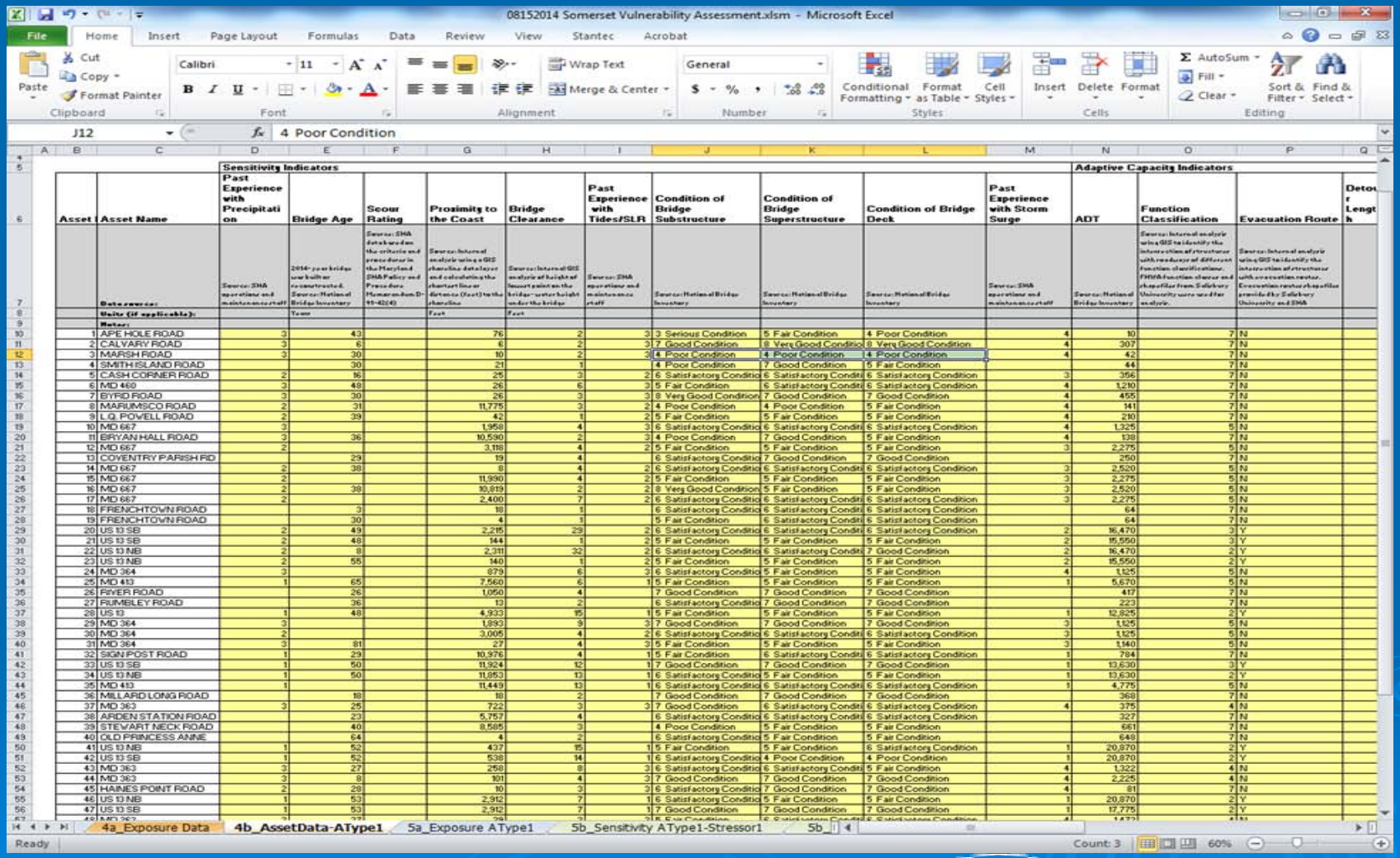
VAST - Input and Results

- 150 assets in Anne Arundel County (bridges and culverts)
- 72 assets in Somerset County (bridges and culverts)
- Input Information
  - Asset data
  - Exposure data
  - Sensitivity data
  - Adaptive Capacity data
- Output
  - Vulnerability Score for all structures
  - 10 most vulnerable assets to each climate stressor
  - Maps and tables showing most vulnerable structures

VAST Input – Asset Information



Asset Data



08152014 Somerset Vulnerability Assessment.xlsm - Microsoft Excel

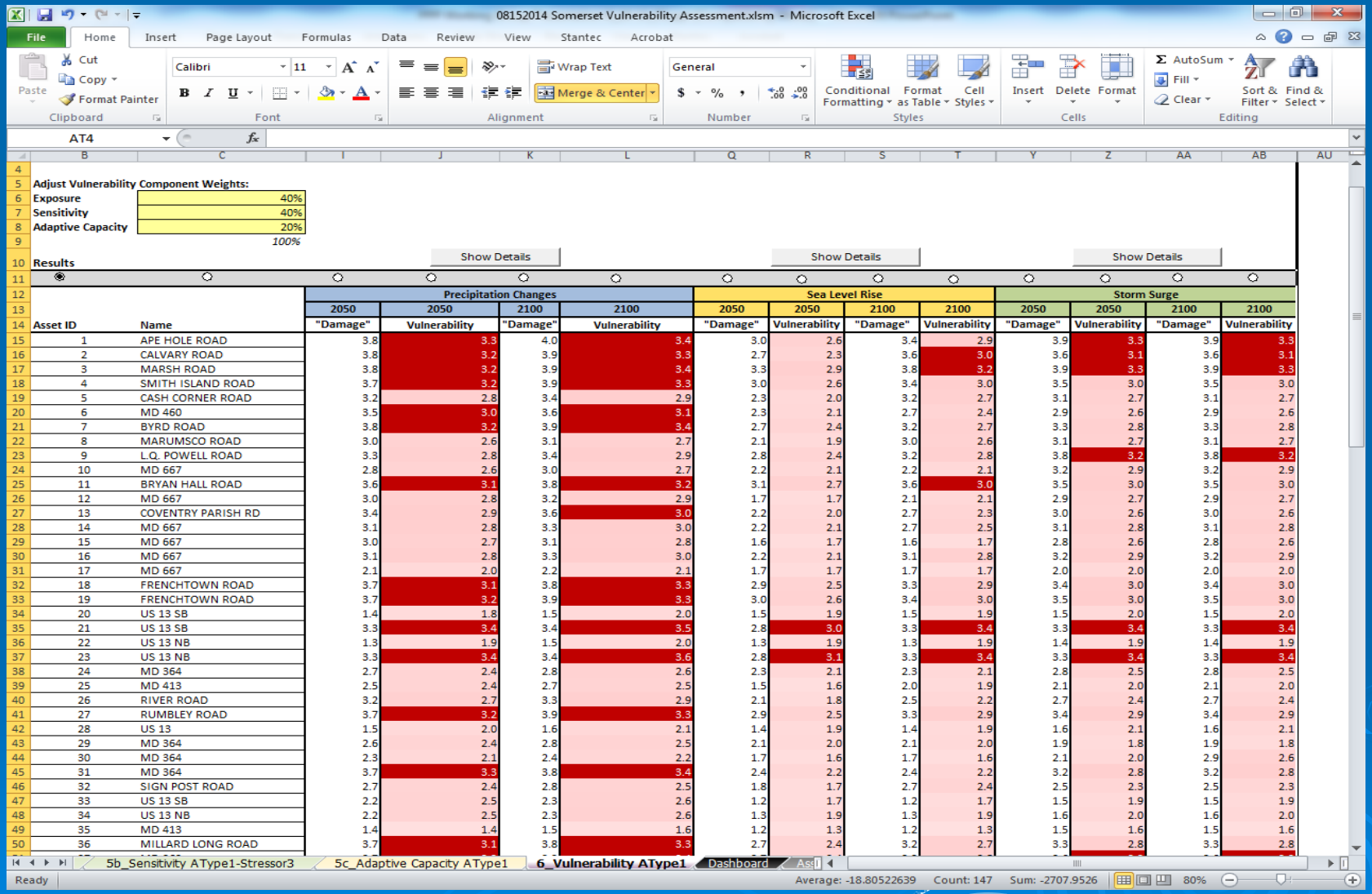
J12: 4 Poor Condition

			Sensitivity Indicators										Adaptive Capacity Indicators			
Asset	Asset Name	Past Experience with Precipitation	Bridge Age	Scour Rating	Proximity to the Coast	Bridge Clearance	Past Experience with Tides/SLR	Condition of Bridge Substructure	Condition of Bridge Superstructure	Condition of Bridge Deck	Past Experience with Storm Surge	ADT	Function Classification	Evacuation Route	Detour Length
	Data source:	Source: SHA operations and maintenance staff	2014 - year bridge was built or reconstructed. Source: National Bridge Inventory	Source: SHA data based on the criteria and procedure in the Maryland SHA Policy and Procedure Memorandum D-11-4(24)	Source: Internal analysis using a GIS shoreline data layer and calculating the shortest line distance (feet) to the shoreline	Source: Internal GIS analysis of height of lowest point on the bridge - water height under the bridge	Source: SHA operations and maintenance staff	Source: National Bridge Inventory	Source: National Bridge Inventory	Source: National Bridge Inventory	Source: SHA operations and maintenance staff	Source: National Bridge Inventory	Source: Internal analysis using GIS to identify the intersection of structure with roadways of different function classifications. FHWA function classes and shapefiles from Salisbury University were used for analysis.	Source: Internal analysis using GIS to identify the intersection of structure with evacuation routes. Evacuation routes shapefiles provided by Salisbury University and SHA	
	Units (if applicable):		Years		Feet	Feet									
	Notes:														
1	APE HOLE ROAD	3	43		76	2	3	3 Serious Condition	5 Fair Condition	4 Poor Condition	4	10	7	N	
2	CALVARY ROAD	3	6		6	2	3	7 Good Condition	8 Very Good Condition	8 Very Good Condition	4	307	7	N	
3	MARSH ROAD	3	30		10	2	3	4 Poor Condition	4 Poor Condition	4 Poor Condition	4	42	7	N	
4	SMITH ISLAND ROAD		30		21	1		4 Poor Condition	7 Good Condition	5 Fair Condition		44	7	N	
5	CASH CORNER ROAD	2	16		25	3	2	6 Satisfactory Condition	6 Satisfactory Condition	6 Satisfactory Condition	3	356	7	N	
6	MD 460	2	49		26	6	3	5 Fair Condition	6 Satisfactory Condition	6 Satisfactory Condition	4	1,210	7	N	
7	BYRD ROAD	3	30		26	3	3	8 Very Good Condition	7 Good Condition	7 Good Condition	4	455	7	N	
8	MARUMSCO ROAD	2	31		11,775	3	2	4 Poor Condition	4 Poor Condition	5 Fair Condition	4	141	7	N	
9	L.Q. POWELL ROAD	2	39		42	1	2	5 Fair Condition	5 Fair Condition	5 Fair Condition	4	210	7	N	
10	MD 667	3			1,958	4	3	6 Satisfactory Condition	6 Satisfactory Condition	6 Satisfactory Condition	4	1,325	5	N	
11	BRYAN HALL ROAD	3	36		10,590	2	3	4 Poor Condition	7 Good Condition	5 Fair Condition	4	138	7	N	
12	MD 667	2			3,118	4	2	5 Fair Condition	5 Fair Condition	5 Fair Condition	3	2,275	5	N	
13	COVENTRY PARISH RD		29		19	4		6 Satisfactory Condition	7 Good Condition	7 Good Condition		250	7	N	
14	MD 667	2	38		8	4	2	6 Satisfactory Condition	6 Satisfactory Condition	6 Satisfactory Condition	3	2,520	5	N	
15	MD 667	2			11,990	4	2	5 Fair Condition	5 Fair Condition	5 Fair Condition	3	2,275	5	N	
16	MD 667	2	38		10,819	2	2	8 Very Good Condition	5 Fair Condition	5 Fair Condition	3	2,520	5	N	
17	MD 667	2			2,400	7	2	6 Satisfactory Condition	6 Satisfactory Condition	6 Satisfactory Condition	3	2,275	5	N	
18	FRENCHTOWN ROAD		3		18	1		6 Satisfactory Condition	6 Satisfactory Condition	6 Satisfactory Condition		64	7	N	
19	FRENCHTOWN ROAD		30		4	1		5 Fair Condition	6 Satisfactory Condition	6 Satisfactory Condition		64	7	N	
20	US 13 SB	2	49		2,215	29	2	6 Satisfactory Condition	6 Satisfactory Condition	6 Satisfactory Condition	2	16,470	3	Y	
21	US 13 SB	2	48		144	1	2	5 Fair Condition	5 Fair Condition	5 Fair Condition	2	15,550	3	Y	
22	US 13 NB	2	8		2,311	32	2	6 Satisfactory Condition	6 Satisfactory Condition	7 Good Condition	2	16,470	2	Y	
23	US 13 NB	2	55		140	1	2	5 Fair Condition	5 Fair Condition	5 Fair Condition	2	15,550	2	Y	
24	MD 364	3			879	6	3	6 Satisfactory Condition	5 Fair Condition	5 Fair Condition	4	1,125	5	N	
25	MD 413	1	65		7,560	6	1	5 Fair Condition	5 Fair Condition	5 Fair Condition	1	5,670	5	N	
26	RIVER ROAD		26		1,050	4		7 Good Condition	7 Good Condition	7 Good Condition		417	7	N	
27	RUMBLEY ROAD		36		13	2		6 Satisfactory Condition	7 Good Condition	7 Good Condition		223	7	N	
28	US 13	1	48		4,933	15	1	5 Fair Condition	5 Fair Condition	5 Fair Condition	1	12,825	2	Y	
29	MD 364	3			1,893	9	3	7 Good Condition	7 Good Condition	7 Good Condition	3	1,125	5	N	
30	MD 364	2			3,005	4	2	6 Satisfactory Condition	6 Satisfactory Condition	6 Satisfactory Condition	3	1,125	5	N	
31	MD 364	3	81		27	4	3	5 Fair Condition	5 Fair Condition	5 Fair Condition	3	1,140	5	N	
32	SIGN POST ROAD	1	29		10,976	4	1	5 Fair Condition	6 Satisfactory Condition	6 Satisfactory Condition	1	784	7	N	
33	US 13 SB	1	50		11,924	12	1	7 Good Condition	7 Good Condition	7 Good Condition	1	13,630	3	Y	
34	US 13 NB	1	50		11,853	13	1	6 Satisfactory Condition	5 Fair Condition	5 Fair Condition	1	13,630	2	Y	
35	MD 413	1			11,449	13	1	6 Satisfactory Condition	6 Satisfactory Condition	6 Satisfactory Condition	1	4,775	5	N	
36	MILLARD LONG ROAD		18		18	2		7 Good Condition	7 Good Condition	7 Good Condition		368	7	N	
37	MD 363	3	25		722	3	3	7 Good Condition	6 Satisfactory Condition	6 Satisfactory Condition	4	375	4	N	
38	ARDEN STATION ROAD		23		5,757	4		6 Satisfactory Condition	6 Satisfactory Condition	6 Satisfactory Condition		327	7	N	
39	STEWART NECK ROAD		40		8,585	3		4 Poor Condition	5 Fair Condition	5 Fair Condition		661	7	N	
40	OLD PRINCESS ANNE		64		4	2		6 Satisfactory Condition	5 Fair Condition	5 Fair Condition		648	7	N	
41	US 13 NB	1	52		437	15	1	5 Fair Condition	5 Fair Condition	6 Satisfactory Condition	1	20,870	2	Y	
42	US 13 SB	1	52		538	14	1	6 Satisfactory Condition	4 Poor Condition	4 Poor Condition	1	20,870	2	Y	
43	MD 363	3	27		258	8	3	6 Satisfactory Condition	6 Satisfactory Condition	5 Fair Condition	4	1,322	4	N	
44	MD 363	2	8		101	4	3	7 Good Condition	7 Good Condition	7 Good Condition	4	2,225	4	N	
45	HAINES POINT ROAD	2	28		10	3	3	6 Satisfactory Condition	7 Good Condition	7 Good Condition	4	81	7	N	
46	US 13 NB	1	53		2,912	7	1	6 Satisfactory Condition	5 Fair Condition	5 Fair Condition	1	20,870	2	Y	
47	US 13 SB	1	53		2,912	7	1	7 Good Condition	7 Good Condition	7 Good Condition	1	17,775	2	Y	

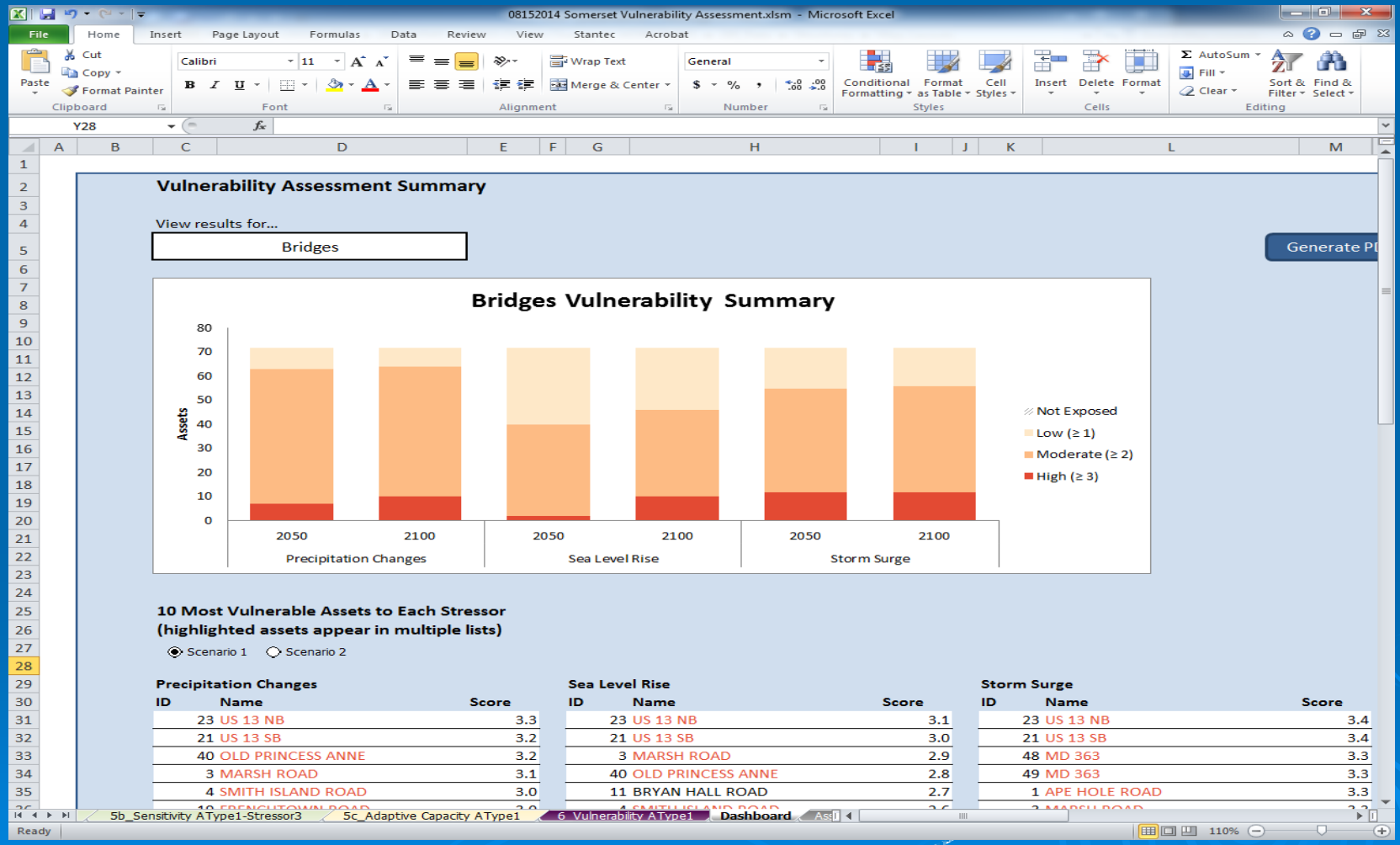
Sheet tabs: 4a_Exposure Data | 4b_AssetData-AType1 | 5a_Exposure AType1 | 5b_Sensitivity AType1-Stressor1 | 5b_

Ready | Count: 3 | 60%

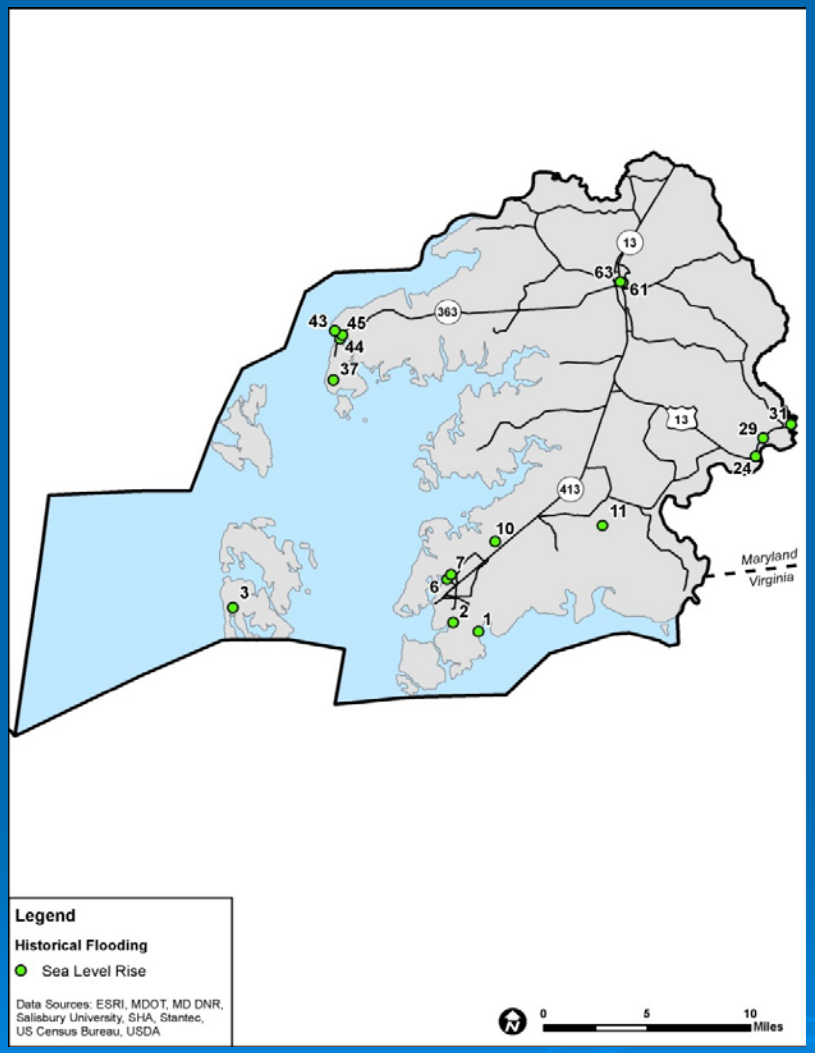
Results

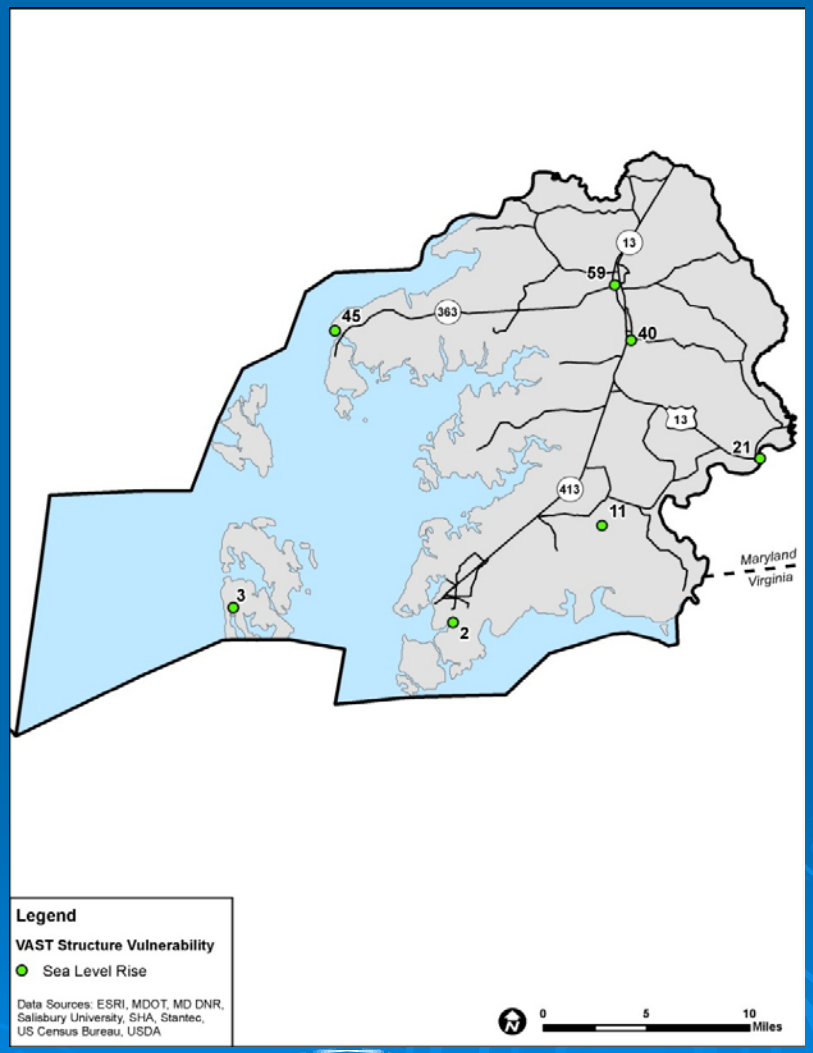

08152014 Somerset Vulnerability Assessment.xlsm - Microsoft Excel
Adjust Vulnerability Component Weights:
Exposure 40%
Sensitivity 40%
Adaptive Capacity 20%
100%
Results
Show Details
Show Details
Show Details
Precipitation Changes
Sea Level Rise
Storm Surge
Asset ID | Name | 2050 "Damage" | 2050 Vulnerability | 2100 "Damage" | 2100 Vulnerability | 2050 "Damage" | 2050 Vulnerability | 2100 "Damage" | 2100 Vulnerability | 2050 "Damage" | 2050 Vulnerability | 2100 "Damage" | 2100 Vulnerability
1 APE HOLE ROAD 3.8 3.3 4.0 3.4 3.0 2.6 3.4 2.9 3.9 3.3 3.9 3.3
2 CALVARY ROAD 3.8 3.2 3.9 3.3 2.7 2.3 3.6 3.0 3.6 3.1 3.6 3.1
3 MARSH ROAD 3.8 3.2 3.9 3.4 3.3 2.9 3.8 3.2 3.9 3.3 3.9 3.3
4 SMITH ISLAND ROAD 3.7 3.2 3.9 3.3 3.0 2.6 3.4 3.0 3.5 3.0 3.5 3.0
5 CASH CORNER ROAD 3.2 2.8 3.4 2.9 2.3 2.0 3.2 2.7 3.1 2.7 3.1 2.7
6 MD 460 3.5 3.0 3.6 3.1 2.3 2.1 2.7 2.4 2.9 2.6 2.9 2.6
7 BYRD ROAD 3.8 3.2 3.9 3.4 2.7 2.4 3.2 2.7 3.3 2.8 3.3 2.8
8 MARUMSCO ROAD 3.0 2.6 3.1 2.7 2.1 1.9 3.0 2.6 3.1 2.7 3.1 2.7
9 L.Q. POWELL ROAD 3.3 2.8 3.4 2.9 2.8 2.4 3.2 2.8 3.8 3.2 3.8 3.2
10 MD 667 2.8 2.6 3.0 2.7 2.2 2.1 2.2 2.1 3.2 2.9 3.2 2.9
11 BRYAN HALL ROAD 3.6 3.1 3.8 3.2 3.1 2.7 3.6 3.0 3.5 3.0 3.5 3.0
12 MD 667 3.0 2.8 3.2 2.9 1.7 1.7 2.1 2.1 2.9 2.7 2.9 2.7
13 COVENTRY PARISH RD 3.4 2.9 3.6 3.0 2.2 2.0 2.7 2.3 3.0 2.6 3.0 2.6
14 MD 667 3.1 2.8 3.3 3.0 2.2 2.1 2.7 2.5 3.1 2.8 3.1 2.8
15 MD 667 3.0 2.7 3.1 2.8 1.6 1.7 1.6 1.7 2.8 2.6 2.8 2.6
16 MD 667 3.1 2.8 3.3 3.0 2.2 2.1 3.1 2.8 3.2 2.9 3.2 2.9
17 MD 667 2.1 2.0 2.2 2.1 1.7 1.7 1.7 1.7 2.0 2.0 2.0 2.0
18 FRENCHTOWN ROAD 3.7 3.1 3.8 3.3 2.9 2.5 3.3 2.9 3.4 3.0 3.4 3.0
19 FRENCHTOWN ROAD 3.7 3.2 3.9 3.3 3.0 2.6 3.4 3.0 3.5 3.0 3.5 3.0
20 US 13 SB 1.4 1.8 1.5 2.0 1.5 1.9 1.5 1.9 1.5 2.0 1.5 2.0
21 US 13 SB 3.3 3.4 3.4 3.5 2.8 3.0 3.3 3.4 3.3 3.4 3.3 3.4
22 US 13 NB 1.3 1.9 1.5 2.0 1.3 1.9 1.3 1.9 1.4 1.9 1.4 1.9
23 US 13 NB 3.3 3.4 3.4 3.6 2.8 3.1 3.3 3.4 3.3 3.4 3.3 3.4
24 MD 364 2.7 2.4 2.8 2.6 2.3 2.1 2.3 2.1 2.8 2.5 2.8 2.5
25 MD 413 2.5 2.4 2.7 2.5 1.5 1.6 2.0 1.9 2.1 2.0 2.1 2.0
26 RIVER ROAD 3.2 2.7 3.3 2.9 2.1 1.8 2.5 2.2 2.7 2.4 2.7 2.4
27 RUMBLEY ROAD 3.7 3.2 3.9 3.3 2.9 2.5 3.3 2.9 3.4 2.9 3.4 2.9
28 US 13 1.5 2.0 1.6 2.1 1.4 1.9 1.4 1.9 1.6 2.1 1.6 2.1
29 MD 364 2.6 2.4 2.8 2.5 2.1 2.0 2.1 2.0 1.9 1.8 1.9 1.8
30 MD 364 2.3 2.1 2.4 2.2 1.7 1.6 1.7 1.6 2.1 2.0 2.9 2.6
31 MD 364 3.7 3.3 3.8 3.4 2.4 2.2 2.4 2.2 3.2 2.8 3.2 2.8
32 SIGN POST ROAD 2.7 2.4 2.8 2.5 1.8 1.7 2.7 2.4 2.5 2.3 2.5 2.3
33 US 13 SB 2.2 2.5 2.3 2.6 1.2 1.7 1.2 1.7 1.5 1.9 1.5 1.9
34 US 13 NB 2.2 2.5 2.3 2.6 1.3 1.9 1.3 1.9 1.6 2.0 1.6 2.0
35 MD 413 1.4 1.4 1.5 1.6 1.2 1.3 1.2 1.3 1.5 1.6 1.5 1.6
36 MILLARD LONG ROAD 3.7 3.1 3.8 3.3 2.7 2.4 3.2 2.7 3.3 2.8 3.3 2.8
5b_Sensitivity AType1-Stressor3
5c_Adaptive Capacity AType1
6_Vulnerability AType1
Dashboard
Ready
Average: -18.80522639 Count: 147 Sum: -2707.9526
80%

Vulnerability Assessment Summary

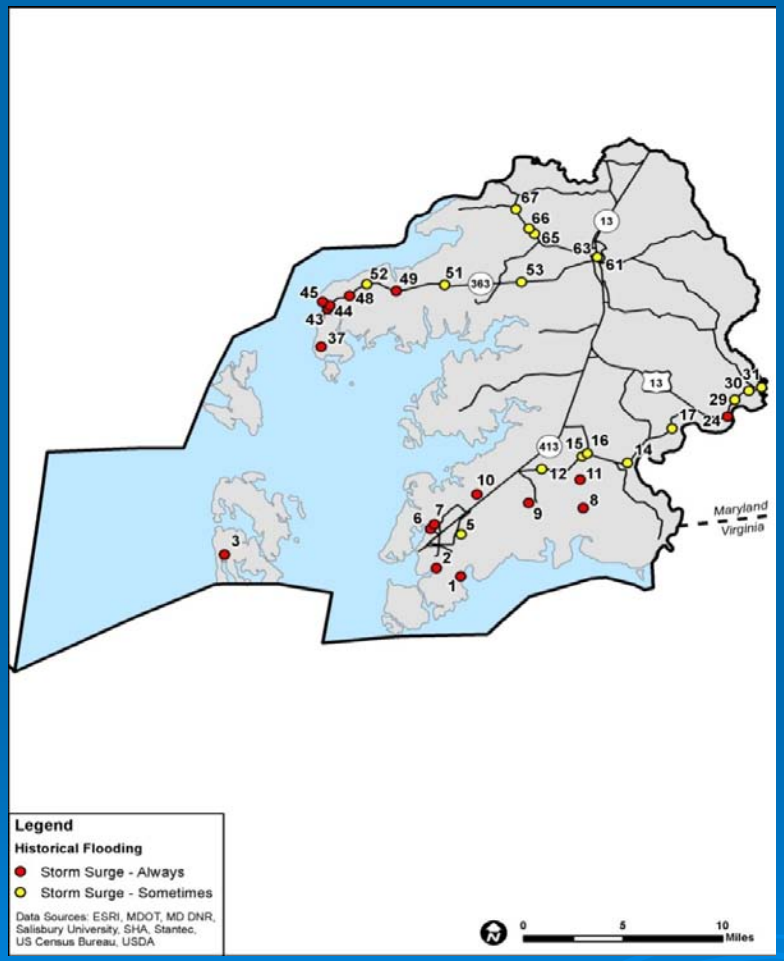


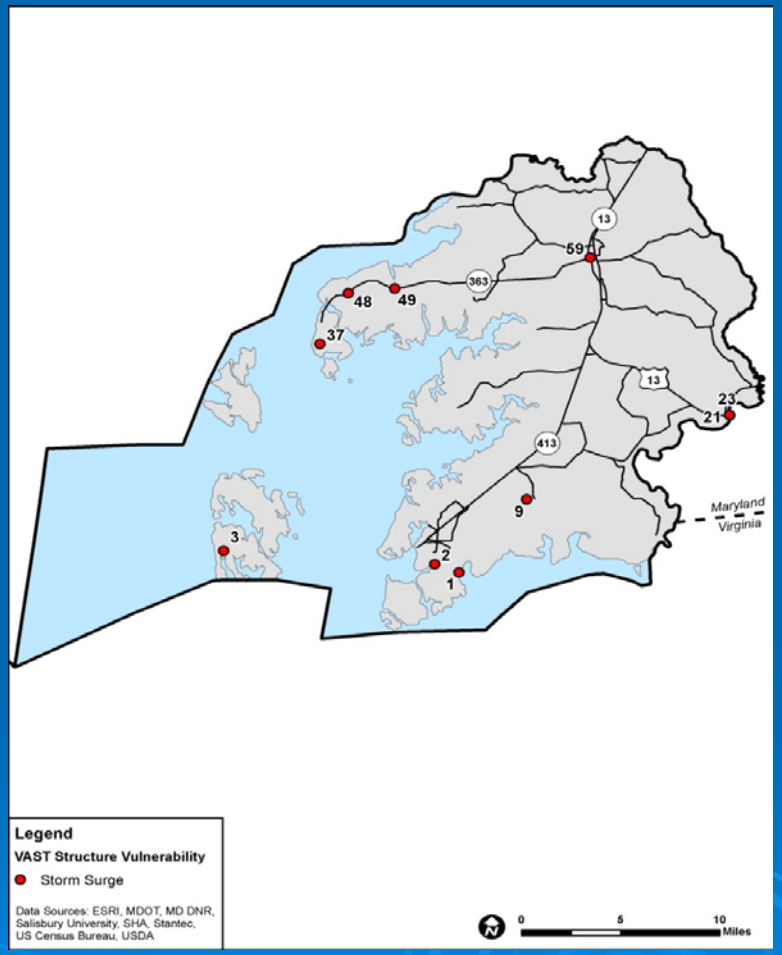
VAST vs. Historical Flooding - SLR



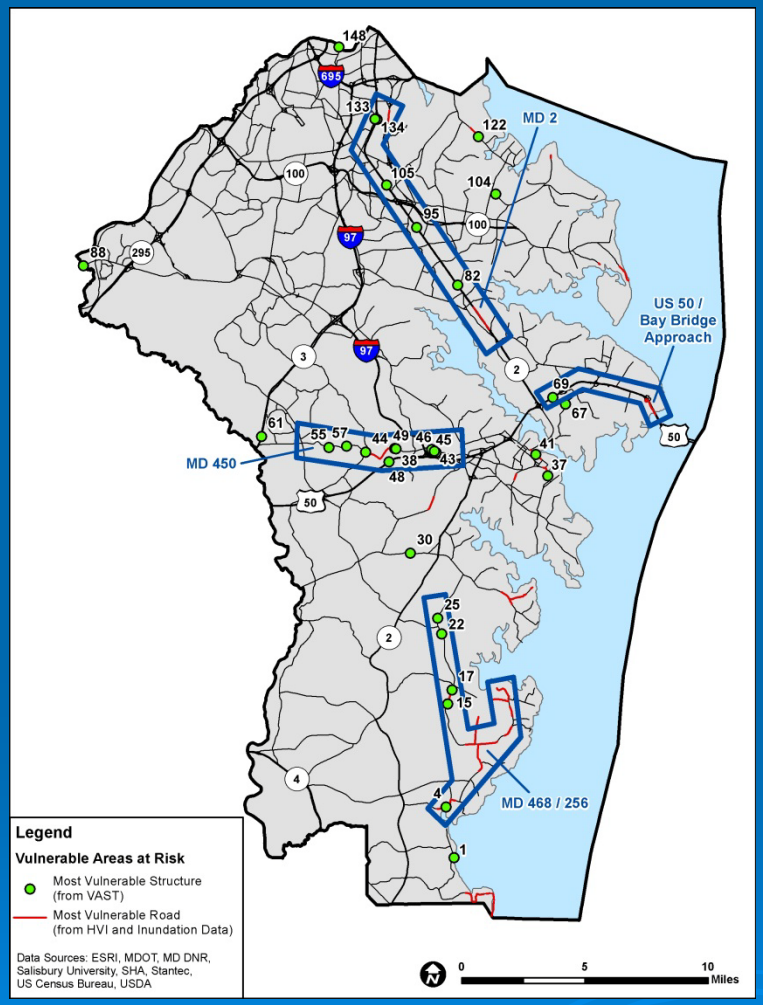


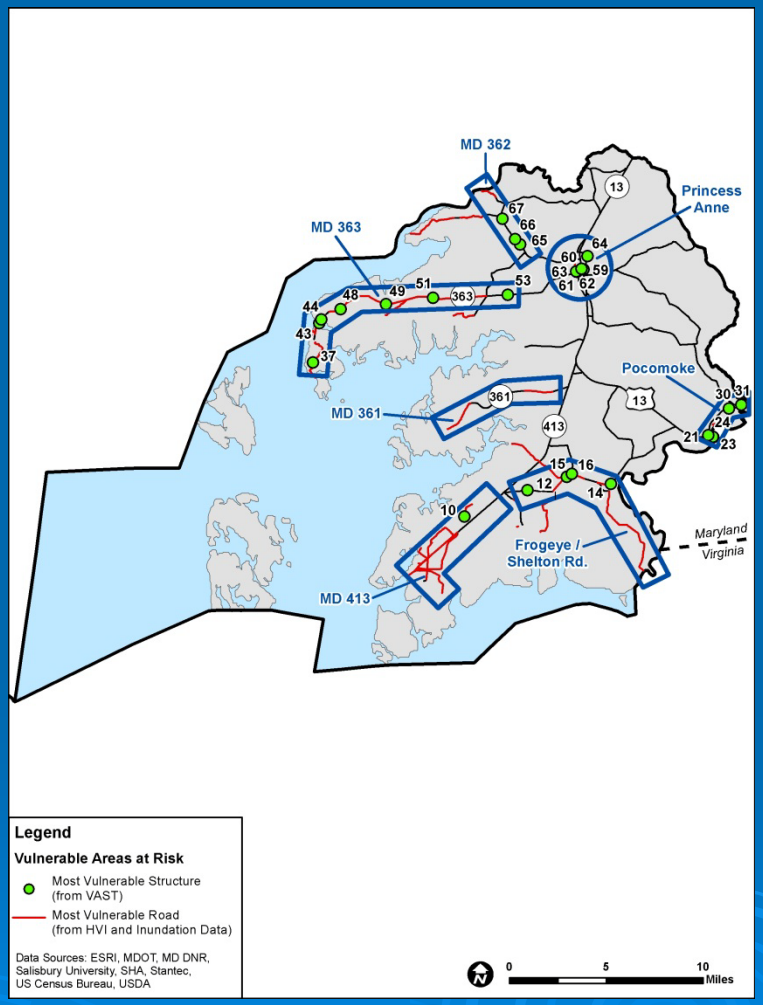
VAST vs. Historical Flooding – Storm Surge





Vulnerable Areas at Risk





Next Steps for SHA Climate Change Program

- Continue statewide county vulnerability assessments
- Brainstorm adaptation options for HVI categories
- Conduct Site Specific Analysis using a Holistic Approach in coordination with Local Stakeholders for “Vulnerable Locations at Risk” – Tier III Studies
- Conduct detailed Alternatives Evaluation with Cost-Benefit Analysis
- Coordination with Anne Arundel and Somerset Counties when origin to destination studies are complete