VULNERABILITY ASSESSMENT

2017 UPDATE

Each of the hazards was reviewed and updated to reflect both the revised information obtained for the updated *Hazard Identification and Analysis* section and the most recent modeling and data collection, primarily for flood. Discussion of vulnerability to Sea Level Rise and Land Subsidence has been updated using the region's most well-regarded sources. All hazard names were edited to provide consistency with the *Hazard Identification and Analysis*. **Table 5.1** was updated with new Hazards U.S. Multi-Hazard (HAZUS-MH) exposure data. **Tables 5.2, 5.3 and 5.4** were updated with more recent NFIP data, **Table 5.5** was created based on newly designated repetitive flood loss areas, and **Table 5.6** contains updated vulnerability data from new HAZUS modeling runs. A revised system of ranking the hazards was added as well. The tables at the end of the section regarding Conclusions on Hazard Risk were all updated. All figures were updated to reflect current conditions.

INTRODUCTION

The *Vulnerability Assessment* section builds on the information provided in the *Hazard Identification and Analysis* section by identifying community assets and development trends in the region, then assessing the potential impact and amount of damage (loss of life and/or property) that could be caused by each hazard event addressed in this risk assessment. The primary objective of this level of vulnerability assessment is to prioritize hazards of concern to the region, adding to the foundation for mitigation strategy and policy development. Consistent with the preceding sections, the following hazards are addressed in this assessment:

- FLOODING
- SEA LEVEL RISE AND LAND SUBSIDENCE
- TROPICAL/COASTAL STORM
- SHORELINE EROSION
- TORNADO
- WINTER STORM
- EARTHQUAKE
- WILDFIRE
- DROUGHT
- EXTREME HEAT
- HAZARDOUS MATERIALS INCIDENT

To complete the vulnerability assessment, best available data were collected from a variety of sources, including local, state and federal agencies, and multiple analyses were applied through qualitative and quantitative means (further described below). Additional work will be done on an ongoing basis to enhance, expand, and further improve the accuracy of the baseline results, and it is expected that this vulnerability assessment will continue to be refined through future plan updates as new data and loss estimation methods become available.

The findings presented in this section with regard to vulnerability were developed using best available data, and the methods applied have resulted in an approximation of risk. These estimates should be used to understand relative hazard risk and the potential losses that may be incurred; however, uncertainties are inherent in any loss estimation methodology, arising from incomplete knowledge concerning specific hazards and their effect on the built environment, as well as incomplete data sets and from approximations and simplifications that are necessary in order to provide a meaningful analysis. Further, most data sets contain relatively short periods of record which increases the uncertainty of any statistically-based analysis.

METHODOLOGIES USED

Two distinct risk assessment methodologies were used in the formation of this vulnerability assessment. The first consists of a ***quantitative*** analysis that relies upon best available data and technology, while the second approach consists of a somewhat ***qualitative*** analysis that relies on local knowledge and rational decision making. Upon completion, the methods are combined to create a "hybrid" approach for assessing hazard vulnerability for the region that allows for some degree of quality control and assurance. The methodologies are briefly described and introduced here and are further illustrated throughout this section.

QUANTITATIVE METHODOLOGY

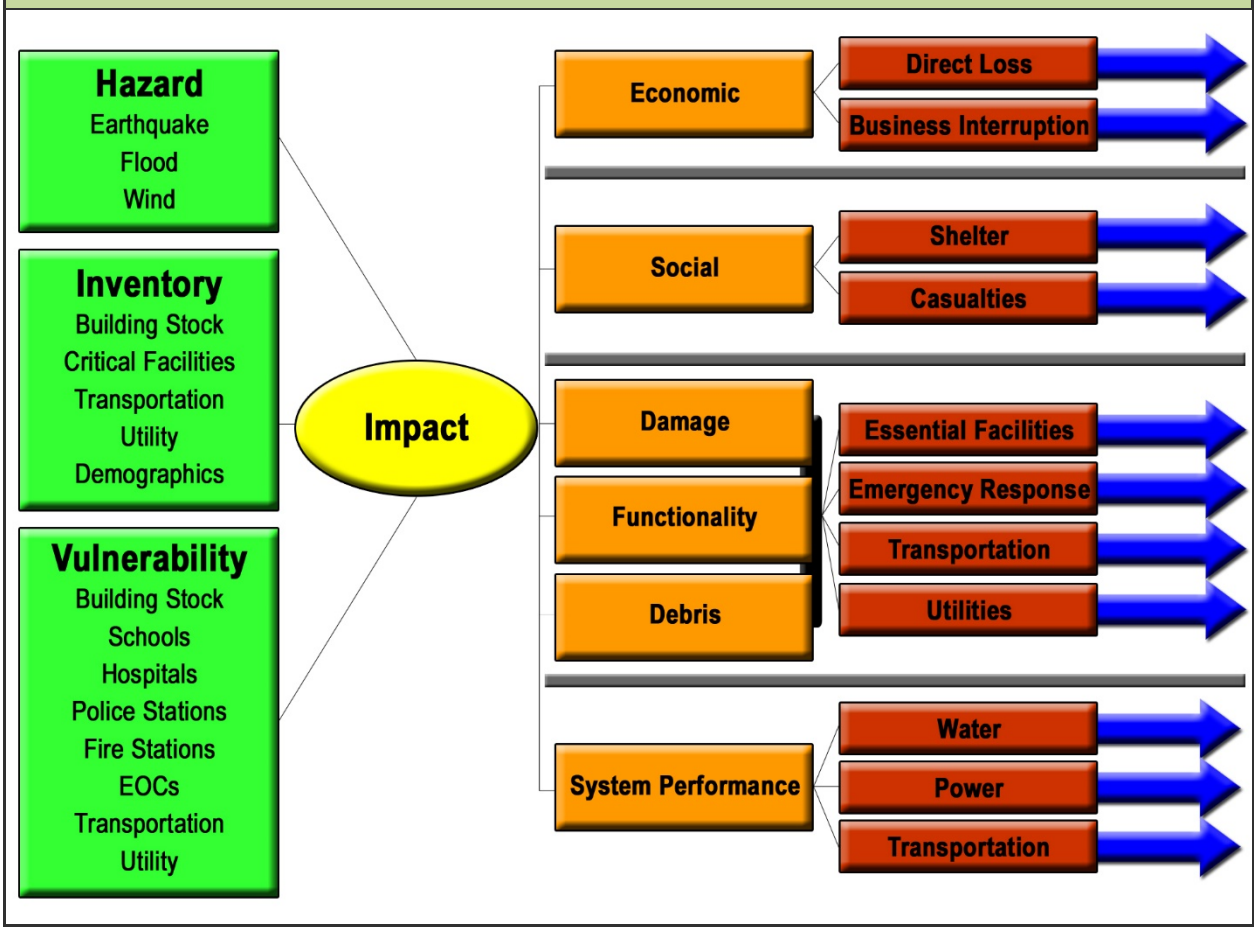
The quantitative assessment involved the use of the most recent version of Hazards U.S. Multi-Hazard software, a geographic information system (GIS)-based loss estimation tool available from FEMA, along with a statistical risk assessment methodology for hazards outside the scope of HAZUS-MH. For the flood hazard, the quantitative assessment incorporates a detailed GIS-based approach. When combined, the results of these vulnerability studies are used to form an assessment of potential hazard losses (in dollars) along with the identification of specific community assets that are deemed at-risk.

Explanation of HAZUS-MH and Statistical Risk Assessment Methodology

HAZUS-MH is FEMA's standardized loss estimation software package, built on an integrated GIS platform using a national inventory of baseline geographic data (including information on the region's general building stock and dollar exposure). Originally designed for the analysis of earthquake risks, FEMA expanded the program in 2003 to allow for the analysis of multiple hazards: namely the flood and wind (hurricane wind) hazards. By providing estimates on potential losses, HAZUS-MH facilitates quantitative comparisons between hazards and assists in the prioritization of hazard mitigation activities.

HAZUS-MH uses a statistical approach and mathematical modeling of risk to predict a hazard's frequency of occurrence and estimated impacts based on recorded or historic damage information. The HAZUS-MH risk assessment methodology is parametric, in that distinct hazard and inventory parameters—such as wind speed and building type—were modeled using the HAZUS-MH software to determine the impact on the built environment. **Figure 5.1** shows a conceptual model of HAZUS-MH methodology. More information on HAZUS-MH loss estimation methodology is available through FEMA at www.fema.gov/hazus.

FIGURE 5.1: CONCEPTUAL MODEL OF HAZUS^{MH} METHODOLOGY



Sources: FEMA

This risk assessment used HAZUS-MH to produce regional profiles and estimated losses for three of the hazards addressed in this section: flooding, tropical/coastal storm winds, and earthquake. For each of these hazards, HAZUS-MH was used to generate probabilistic "worst case scenario" events to show the extent of potential damages. Both earthquake and wind were modeled using HAZUS Level 1 and flood was modeled using HAZUS Level 2.

Explanation of GIS-based (Non-HAZUS^{MH}) Risk Assessment Methodology

For hazards outside the scope of HAZUS-MH, a statistical risk assessment methodology was designed and in previous plans, this method was applied to generate potential loss estimates. The approach was based on the same principles as HAZUS-MH, but did not rely on readily available automated software. Historical data were compiled for each hazard to relate occurrence patterns with existing hazard models. Statistical evaluations were then applied in combination with engineering modeling to develop damage functions that generate annualized losses.

The use of the statistical risk assessment methodology was used in previous plans to provide a determination of estimated annualized loss[1] for several hazards. However, in recent years, the historical data from which these conclusions were made have become less reliable. For example, damages for wildfire were not reported for the two most recent reporting periods, and the communities reviewing the

[1] By annualizing estimated losses, the historic patterns of frequent smaller events are coupled with infrequent but larger events to provide a balanced presentation of the long-term risk.

historical damage data from the NCDC expressed concern that the damages were severely underestimated. Until more reliable historical damage data can be provided, a more qualitative methodology for examining historical losses and making conclusions about future risk was needed as shown below.

Despite the shortcomings of certain historical data, this analysis included collection of and updates to relevant GIS data from local, state and national sources. These sources include each community's GIS Department, FEMA, Virginia Department of Forestry (VDOF), and NOAA. Once all data were acquired, GIS was used to demonstrate and spatially analyze risks to people, public buildings and infrastructure. Primary data layers included Census 2010 data, along with geo-referenced point locations for public buildings, critical facilities, and infrastructure elements. Using these data layers, risk was assessed and described by determining the parcels and/or point locations that intersected with the delineated hazard areas.

QUALITATIVE METHODOLOGY

The qualitative assessment relies less on technology and more on historical and anecdotal data, community input, and professional judgment regarding expected hazard impacts. The qualitative assessment completed for Hampton Roads is based on committee member dot voting to indicate their priorities for mitigation spending. The members present at the first planning meetings on October 21, 22 and 23, 2015, were divided into groups of four people and provided "dot mitigation grants" in the following amounts: 1 - $1,000,000 grant (yellow dot); 2 - $250,000 grants (blue dots); and 4 - $25,000 grants (red dots).

Each group was then tasked with determining how they would spend their mitigation dollars. The groups were reminded that projects must be cost-beneficial and that FEMA urges communities to "Prioritize mitigation actions based on level of risk a hazard poses to lives and property." Each group then discussed amongst themselves, and placed their dot grants next to the hazards they considered a priority for spending. Results are shown in **Table 5.15** at the end of this section. Communities were reminded of a full range of hazards based on the hazards included in the previous mitigation actions for the region, including: flood, sea level rise, tropical storm, severe thunderstorm, tsunami, urban fire, winter storm/nor'easter, drought, dam failure, tornado, extreme heat, earthquake, wildfire, erosion, sinkhole, mosquito diseases, hazardous materials incidents, terrorism, biological threats, radiological threats, and pandemic flu. Although this list is not a comprehensive list of all hazards that may ever impact the region, the resultant hazards summarized in this section were determined by committee members to be the necessary hazards for the purposes of determining mitigation actions.

While the quantitative assessment focuses on using best available data, computer models and GIS technology, this qualitative ranking system relies more on historical data, local knowledge, and the general consensus of the planning committee. The results allow identified hazards to be ranked against one another.

SUMMARY

Using both the qualitative and quantitative analyses to evaluate the hazards that impact the region provided planning committee members with a dual-faceted review of the hazards. This allowed officials to recognize those hazards that may potentially be costly, but also to plan and prepare for hazards that may not cause much monetary damage, but could put a strain on the local resources needed to recover.

All conclusions of the vulnerability assessment completed for the region are presented in "Conclusions on Hazard Risk" at the end of this section. Qualitative findings for each hazard are detailed in the hazard-by-hazard vulnerability assessment that follows, beginning with an overview of general asset inventory and exposure data for each jurisdiction.

OVERVIEW OF VULNERABILITY

GENERAL ASSET INVENTORY

The total dollar exposure of buildings within the study area is estimated to be almost $197 billion. This figure is based on an estimated 560,000 buildings located throughout the region based on the HAZUS default inventory (**Table 5.1**). The data provide an estimate of the aggregated replacement value for the region's assets and indicate that at least 60 percent of the structures are of wood construction.

TABLE 5.1: EXPOSURE OF THE BUILT ENVIRONMENT

SUBREGION	COMMUNITY	BUILDING INVENTORY BY TYPE OF CONSTRUCTION			
		WOOD	MANUFACTURED HOMES	MASONRY, CONCRETE, STEEL	TOTAL
Peninsula	Hampton	$9,417,390,000	$35,354,000	$5,869,377,000	$15,322,121,000
	Newport News	$12,025,853,000	$95,133,000	$8,591,073,000	$20,712,059,000
	Poquoson	$1,170,328,000	$7,518,000	$505,595,000	$1,683,441,000
	Williamsburg	$897,152,000	$0	$1,031,132,000	$1,928,284,000
	James City County	$6,443,669,000	$62,242,000	$3,528,137,000	$10,034,048,000
	York County	$6,115,462,000	$16,293,000	$3,085,417,000	$9,217,172,000
Southside	Norfolk	$14,220,270,000	$28,826,000	$14,923,791,000	$29,172,887,000
	Portsmouth	$6,249,290,000	$14,733,000	$4,002,116,000	$10,266,139,000
	Suffolk	$6,245,529,000	$48,297,000	$3,368,659,000	$9,662,485,000
	Virginia Beach	$35,038,833,000	$77,650,000	$19,926,533,000	$55,043,016,000
	Chesapeake	$17,095,310,000	$93,252,000	$9,501,654,000	$26,690,216,000
Western Tidewater	Isle of Wight County	$2,730,967,000	$83,702,000	$1,565,721,000	$4,380,390,000
	Franklin	$504,056,000	$0	$407,347,000	$911,403,000
	Southampton County	$1,088,809,000	$50,583,000	$656,343,000	$1,795,735,000
TOTAL		**$119,242,918,000**	**$613,583,000**	**$76,962,895,000**	**$196,819,396,000**

Source: HAZUS-MH

ESSENTIAL FACILITIES

There is no universally accepted definition of what constitutes essential facilities and infrastructure, nor is one associated with FEMA and DMA 2000 planning requirements. However, for purposes of this Plan, essential facilities and infrastructure are identified as "*those facilities or systems whose incapacity or destruction would present an immediate threat to life, public health, and safety or have a debilitating effect on the economic security of the region*." This typically includes the following facilities and systems based on their high relative importance for the delivery of vital services, the protection of special populations, and other important functions in the region; however, for the HAZUS modeling performed for this risk analysis, each community provided their own list of what they consider essential facilities:

- Emergency Operations Center (EOC)
- Hospital and medical care facilities

- Police stations
- Fire stations
- Public schools designated as shelters
- Hazardous materials facilities
- Water (and wastewater) facilities
- Energy facilities (electric, oil and natural gas)
- Communication facilities

Table 5.2 shows the results of a simple overlay analysis of the essential facilities that are located in the 100-year floodplain, 500-year floodplain, and the Storm Surge Zone for a Category 3 hurricane.

TABLE 5.2: CRITICAL FACILITIES LOCATED IN HAZARD AREAS

SUBREGION	COMMUNITY	100-YEAR FLOODPLAIN	500-YEAR FLOODPLAIN	STORM SURGE ZONE (CATEGORY 3 STORM)
Peninsula	Hampton	3	7	24
	Newport News	2	0	4
	Poquoson	3	3	0
	Williamsburg	0	0	0
	James City County	7	0	0
	York County	7	10	2
Southside	Norfolk	9	5	47
	Portsmouth	2	3	8
	Suffolk	2	0	4
	Virginia Beach	26 (2 V Zone)	14	65
	Chesapeake	4	3	20
Western Tidewater	Isle of Wight County	0	0	0
	Franklin	1	0	0
	Southampton County	4	8	0
REGION TOTAL		**70**	**53**	**174**

FLOODING

The vulnerability assessment for the flood hazard includes the findings of the qualitative assessment conducted, an overview of NFIP statistics, repetitive loss properties (as defined and identified by the NFIP), estimates of potential losses, and future vulnerability.

As described in detail in the *Hazard Identification and Analysis* section, the NCDC has records for 87 significant flood events in the past 20 years (1995 to 2015) for the region, amounting to approximately $130 million in reported property damage. Also discussed in the *Hazard Identification and Analysis* are historic storms such as Hurricanes Isabel, Floyd and the 1933 hurricane that each caused notable flooding in the region. Historically, Hampton Roads is vulnerable to the flood hazard and flood events, which occur on a frequent basis.

NFIP STATISTICS AND REPETITIVE LOSS PROPERTIES

Table 5.3 provides basic background information regarding the number of flood insurance policies and the value of those policies for NFIP-participating communities in the study area. As shown in Table 5.3, the communities in the Hampton Roads region joined the NFIP throughout the 1970s, 1980s and into the 1990s. In order to join the NFIP, each participating jurisdiction is required to adopt and enforce its own floodplain management ordinance. As a result, structures built after joining the NFIP are assumed to be less vulnerable to flood hazards than those built prior to joining, assuming other environmental conditions remain constant.

TABLE 5.3: NFIP DATA FOR PARTICIPATING COMMUNITIES					
SUBREGION	COMMUNITY	NFIP ENTRY DATE	CURRENT EFFECTIVE FIRM DATE	CURRENT NUMBER OF NFIP POLICIES	INSURANCE IN-FORCE
Peninsula	Hampton	1/15/1971	8/16/2011	11,076	$2,752,401,900
	Newport News	5/2/1977	12/9/2014	2,515	$627,732,100
	Poquoson	5/16/1977	12/16/2014	3,310	$877,069,600
	Williamsburg	11/20/1981	9/28/2007	47	$11,971,100
	James City County	2/6/1991	12/16/2015	1,006	$275,598,300
	York County	12/16/1988	1/16/2015	3,394	$980,284,400
Southside	Norfolk	8/1/1979	12/16/2014	12,324	$3,203,123,000
	Portsmouth	7/2/1971	8/3/2015	3,618	$884,828,100
	Suffolk	11/16/1990	8/3/2015	943	$280,794,800
	Virginia Beach	4/23/1971	1/16/2015	24,200	$6,453,533,800
	Chesapeake	2/2/1977	12/16/2014	8,841	$2,383,084,100
Western Tidewater	Isle of Wight County	8/19/1991	9/4/2002	397	$116,904,100
	Smithfield	12/5/1990	9/4/2002	108	$32,979,900
	Windsor	8/1/1990	9/4/2002	6	$1,204,000
	Franklin	8/15/1980	9/4/2002	148	$39,465,400
	Southampton County	12/15/1982	9/4/2002	127	$26,582,600
	Boykins	4/1/1982	9/4/2002	7	$1,901,500
	Branchville	3/30/1979	9/4/2002	0	$0
	Courtland	7/5/1982	9/4/2002	20	$5,822,600
	Ivor	11/4/2002	No Special Flood Hazard Area	1	$350,000
Totals				**72,088**	**$18,955,631,300**

Source: NFIP Policy Statistics as of April 30, 2015 (not cumulative)

Reducing the number of repetitive loss (RL) properties insured by the NFIP is a nationwide emphasis of FEMA. An RL is defined as any insurable building for which two or more claims of more than $1,000 were paid by the NFIP within any rolling 10-year period, since 1978. A repetitive loss property may or may not be currently insured by the NFIP. An RL property may or may not be currently insured by the NFIP. Per data provided by the Virginia Department of Conservation and Recreation in June 2015, a total of 4,514 RL properties as defined by the NFIP have been identified within the study area communities. These 4,514 properties have experienced a total of $239 million individual insured losses for the structure and contents combined. The average payment for each qualifying claim was $19,190. There are 4,408 residential properties (98 percent) and 106 non-residential properties on the list.

The NFIP also designates severe repetitive losses (SRL) in a community. As defined by the Flood Insurance Reform Act of 2004, SRLs are 1- to 4-family residences that have had four or more claims of more than $5,000 or at least two claims that cumulatively exceed the building's value. The Act created new funding mechanisms to help mitigate flood damage for these properties. The study area communities have 319 SRL properties identified by the NFIP, with a total of 1,713 losses. Total

payments for these 319 properties were over $42 million. **Table 5.4** provides summary details for the communities with regard to each community's repetitive losses.

TABLE 5.4: NFIP REPETITIVE LOSS PROPERTIES

REGION	COMMUNITY	REPETITIVE FLOOD LOSSES			
		NUMBER OF PROPERTIES	VALUE OF LOSSES	NUMBER OF LOSSES	AVERAGE PAYMENT PER CLAIM
Peninsula	Hampton	936	$48,166,174	2541	$18,956
		SEVERE REPETITIVE FLOOD LOSSES			
		70	$10,407,881	365	$28,515
	Newport News	121	$13,037,268	294	$44,344
		SEVERE REPETITIVE FLOOD LOSSES			
		3	$189,943	11	$17,268
	Poquoson	971	$42,927,508	2375	$18,075
		SEVERE REPETITIVE FLOOD LOSSES			
		25	$3,033,475	117	$25,927
	Williamsburg	4*	$104,271	9	$11,586
	James City County	35	$2,345,563	95	$24,690
		SEVERE REPETITIVE FLOOD LOSSES			
		2	$146,768	8	$18,346
	York County	236	$15,330,549	560	$27,376
		SEVERE REPETITIVE FLOOD LOSSES			
		11	$1,772,861	50	$35,457
Southside	Norfolk	958	$48,354,230	2837	$17,044
		SEVERE REPETITIVE FLOOD LOSSES			
		93	$12,251,484	516	$23,743
	Portsmouth	229	$10,009,951	631	$15,864
		SEVERE REPETITIVE FLOOD LOSSES			
		16	$2,070,120	86	$24,071
	Suffolk	17	$2,285,818	50	$45,716
	Virginia Beach	574	$34,205,856	1768	$19,347
		SEVERE REPETITIVE FLOOD LOSSES			
		62	$8,673,919	361	$24,027
	Chesapeake	395	$19,611,525	1214	$16,154
		SEVERE REPETITIVE FLOOD LOSSES			
		37	$3,523,288	199	$17,705
Western Tidewater	Isle of Wight County	23	$1,584,416	60	$26,407
	Smithfield	3	$71,418	7	$10,203
	Franklin	6	$686,165	12	$57,180
	Southampton County	9	$557,595	19	$29,347
Totals		4,514	$239,206,889	12,465	19190
		SEVERE REPETITIVE FLOOD LOSSES			
		319	$42,069,739	1,713	24559

** Williamsburg officials have conducted additional research into these data and contend the data do not represent a pattern of repetitive flooding.*
Sources: FEMA and NFIP (as of July 2015)

Figures 5.2 through 5.9 contain maps of the region's repetitive loss areas. Each designated area was identified by referencing maps of all historical NFIP flood claims, NFIP RL lists, the SRL list, a Digital

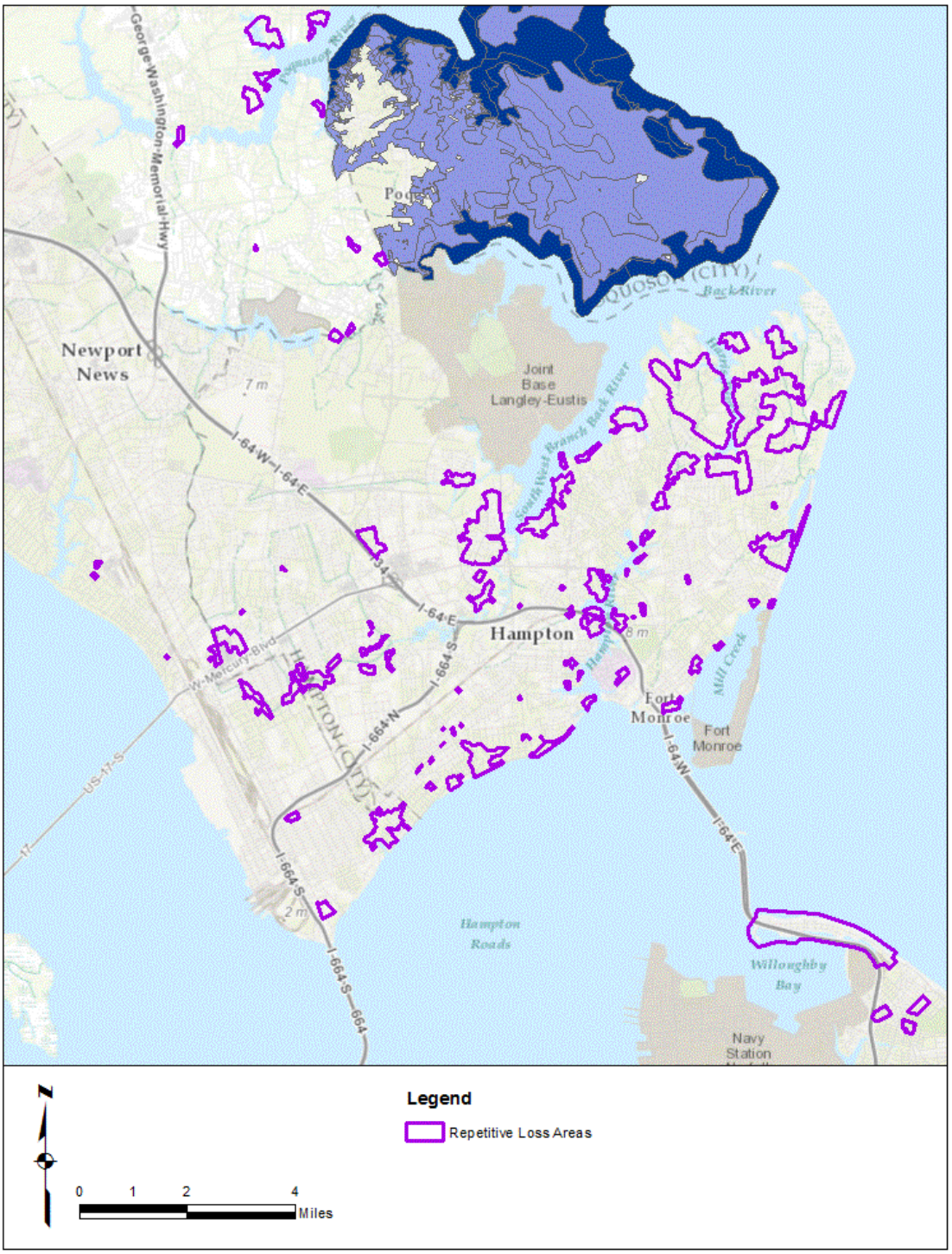
Elevation Model (DEM)-based depth grid of the 100-year floodplain, and the HAZUS results regarding predicted flood damages from a 100-year flood for individual structures. As shown in **Table 5.5**, There are 4,514 properties on FEMA's repetitive loss list and an additional 55,179 parcels identified as being within those repetitive loss areas. Other structures near the ones listed by the NFIP may have been uninsured during the floods, may have had single flood insurance claims, or may have had multiple claims under different policies that the claims system did not recognize as being the same repetitively flooded address.

TABLE 5.5: REPETITIVE FLOOD LOSS AREA DETAILS

REGION	COMMUNITY	REPETITIVE FLOOD LOSS AREAS		
		NUMBER OF RL AREAS	NUMBER OF PROPERTIES OR BUILDINGS	SOURCES OF FLOODING
Peninsula	Hampton	71	8,940	Low-lying land along the banks of tidal rivers and creeks are regularly inundated by nor'easters and tropical storms. Newmarket Creek overflows banks during coastal storms and heavy rains. Wind driven storm tides drive water into smaller tributaries and flood low-lying areas. Along Chesapeake Bay, wind and wave velocity, coastal flooding and overwash during coastal storms causes damage.
	Newport News	24	1,113	Low-lying land along the banks of tidal rivers and creeks are regularly inundated by nor'easters and tropical storms. Newmarket Creek overflows banks during coastal storms and heavy rains. Wind driven storm tides drive water into smaller tributaries and flood low-lying areas. Along James River, wind and wave velocity, coastal flooding and overwash during coastal storms causes damage.
	Poquoson	1	4,810	Low-lying land along the banks of tidal rivers and creeks are regularly inundated by nor'easters and tropical storms.
	James City County	10	643	Low-lying land along the banks of tidal rivers and creeks are regularly inundated by nor'easters and tropical storms. Stormwater drainage from heavy rains cause flooding in some riverine watersheds.
	York County	15	3,323	Low-lying land along the banks of tidal rivers and creeks are regularly inundated by nor'easters and tropical storms.
Southside	Norfolk	89	11,933	Low-lying land along the banks of tidal rivers and creeks are regularly inundated by nor'easters and tropical storms. Stormwater drainage from heavy rains cause flooding in some riverine watersheds. Tidal inundation of stormwater system increases flooding in some neighborhoods.
	Portsmouth	25 maps	1,974	Low-lying land along the banks of tidal rivers and creeks are regularly inundated by nor'easters and tropical storms. Stormwater drainage from heavy rains cause flooding in some riverine watersheds. Tidal inundation of stormwater system increases flooding in some neighborhoods. Seawall damaged.
	Suffolk	12	81	Low-lying land along the banks of tidal rivers and creeks are regularly inundated by nor'easters and tropical storms.
	Virginia Beach	6	18,939	Low-lying land along the banks of tidal rivers and creeks are regularly inundated by nor'easters and tropical storms. Stormwater drainage from heavy rains cause flooding in some riverine watersheds. Tidal inundation of stormwater system increases flooding in some neighborhoods.

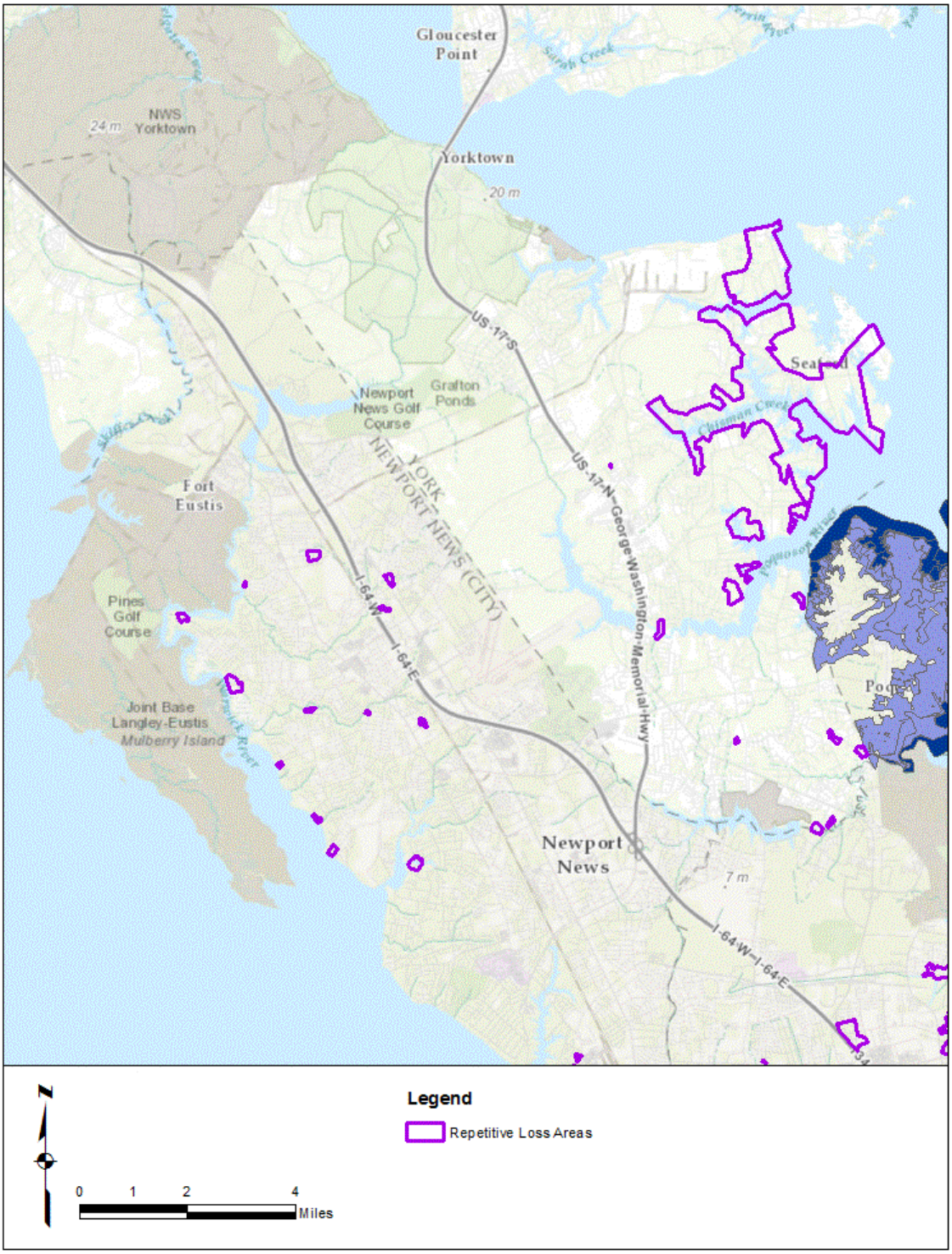
TABLE 5.5: REPETITIVE FLOOD LOSS AREA DETAILS				
REGION	COMMUNITY	REPETITIVE FLOOD LOSS AREAS		
		NUMBER OF RL AREAS	NUMBER OF PROPERTIES OR BUILDINGS	SOURCES OF FLOODING
	Chesapeake	47	3,011	Low-lying land along the banks of tidal rivers and creeks are regularly inundated by nor'easters and tropical storms. Flat terrain hinders stormwater
Western Tidewater	Isle of Wight County	13	151	Low-lying land along the banks of tidal rivers and creeks are regularly inundated by nor'easters and tropical storms.
	Smithfield	1	45	Low-lying land along the banks of tidal rivers and creeks are regularly inundated by nor'easters and tropical storms.
	Franklin	2	462	Blackwater River overflows its banks and tributary banks as a result of heavy rain in the upper parts of the watershed causing severe flooding in the downtown area.
	Southampton County	4	74	The Blackwater and Nottoway River systems overflow their banks as a result of heavy rain in the watershed, causing pockets of flooding especially where tributaries flow into main rivers.
Totals		320	55,499	

FIGURE 5.2: NFIP REPETITIVE FLOOD LOSS AREAS, LOWER PENINSULA



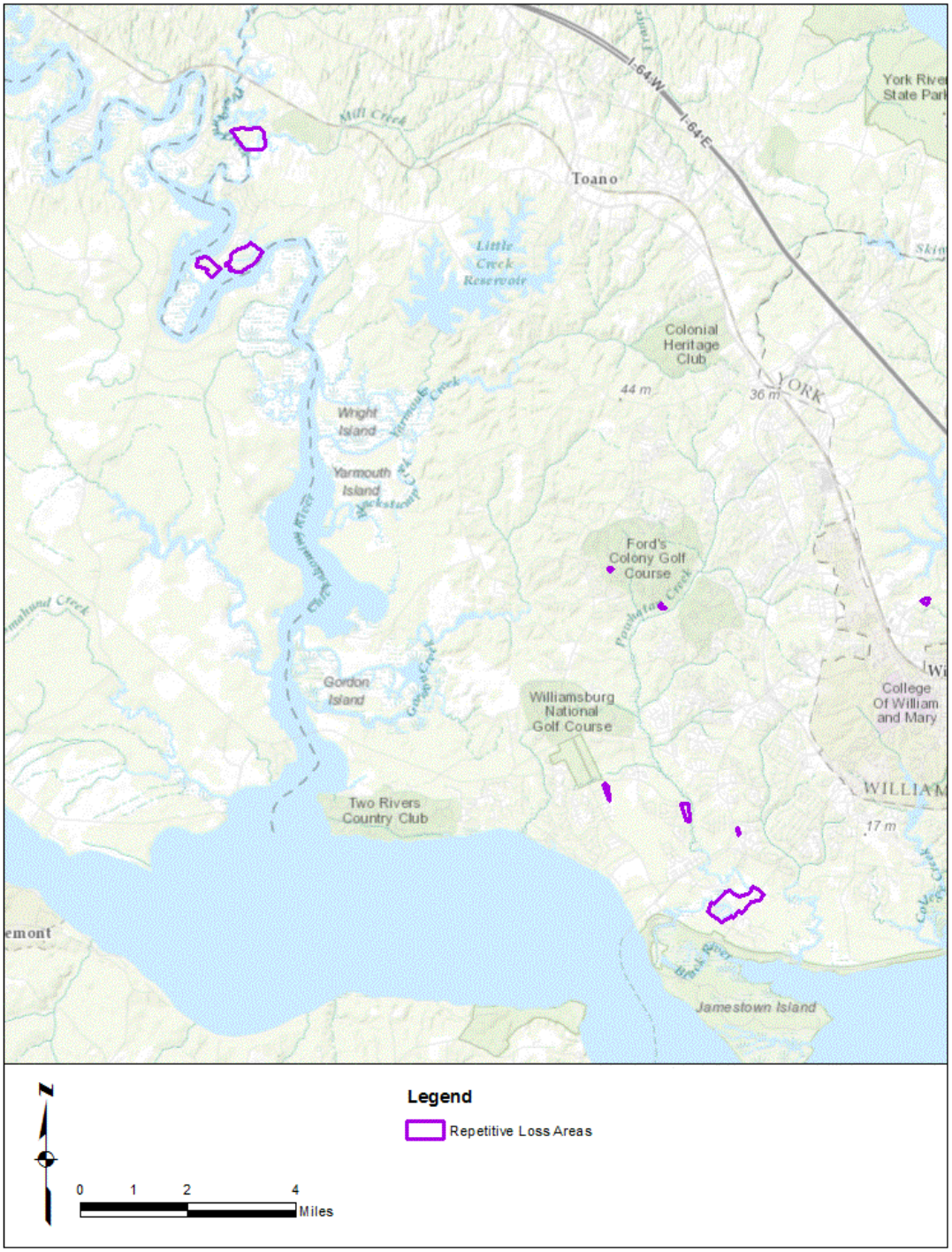
*Poquoson designated entire SFHA as repetitive loss area
Source: VDEM, 2015 data

FIGURE 5.3: NFIP REPETITIVE FLOOD LOSS AREAS, MIDDLE PENINSULA



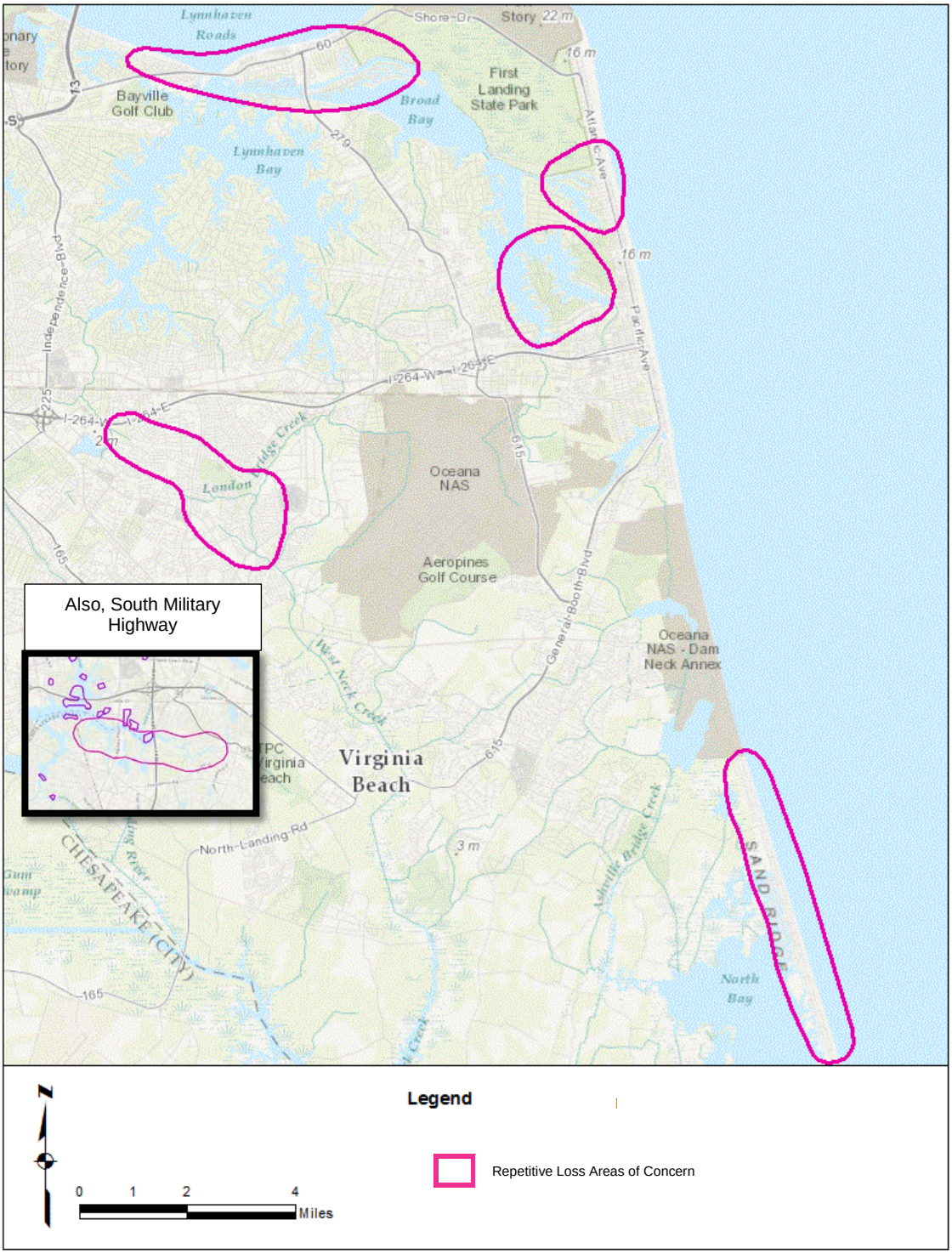
Source: VDEM, 2015 data

FIGURE 5.4: NFIP REPETITIVE FLOOD LOSS AREAS, UPPER PENINSULA



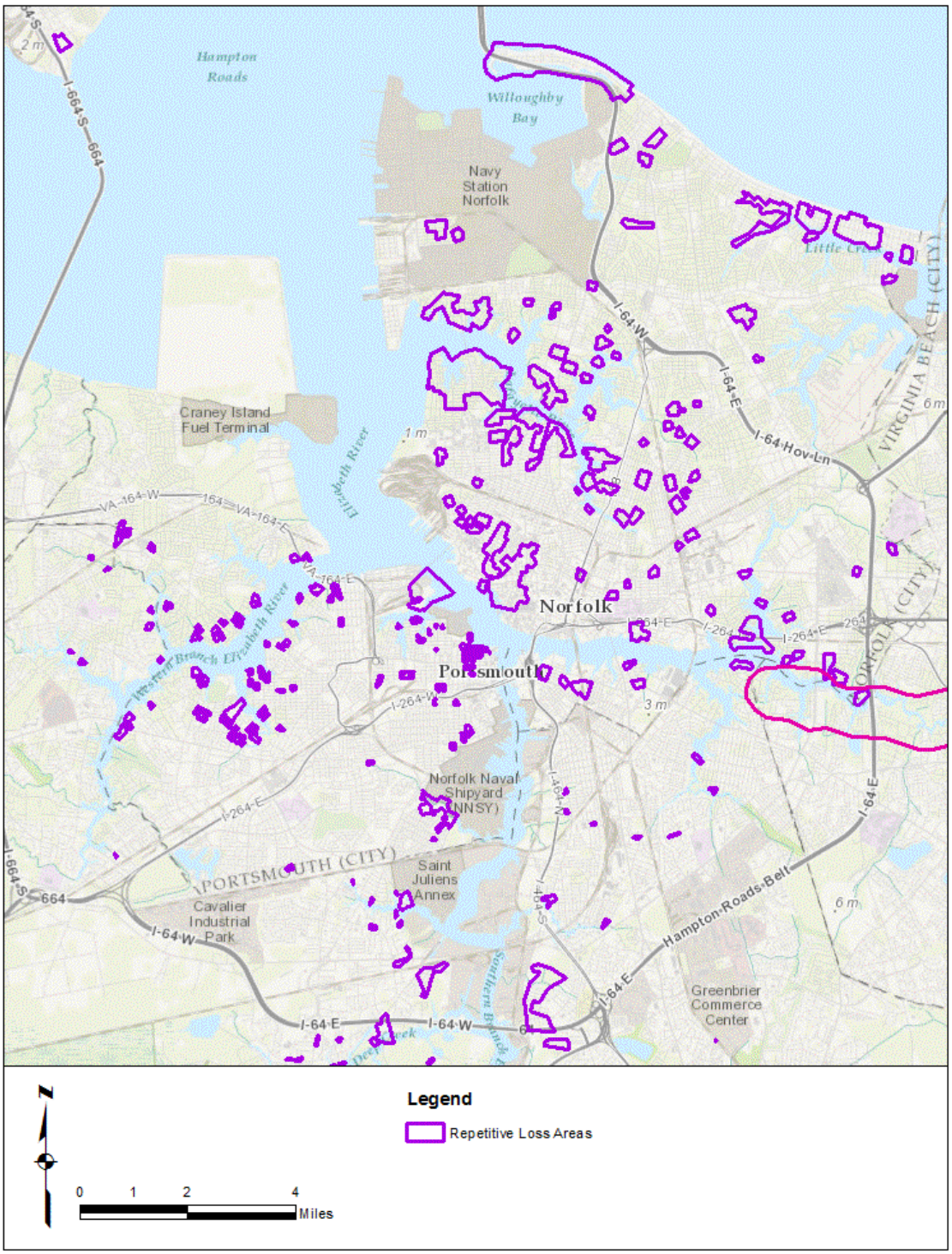
Source: VDEM, 2015 data

FIGURE 5.5: NFIP REPETITIVE FLOOD LOSS AREAS OF CONCERN, VIRGINIA BEACH



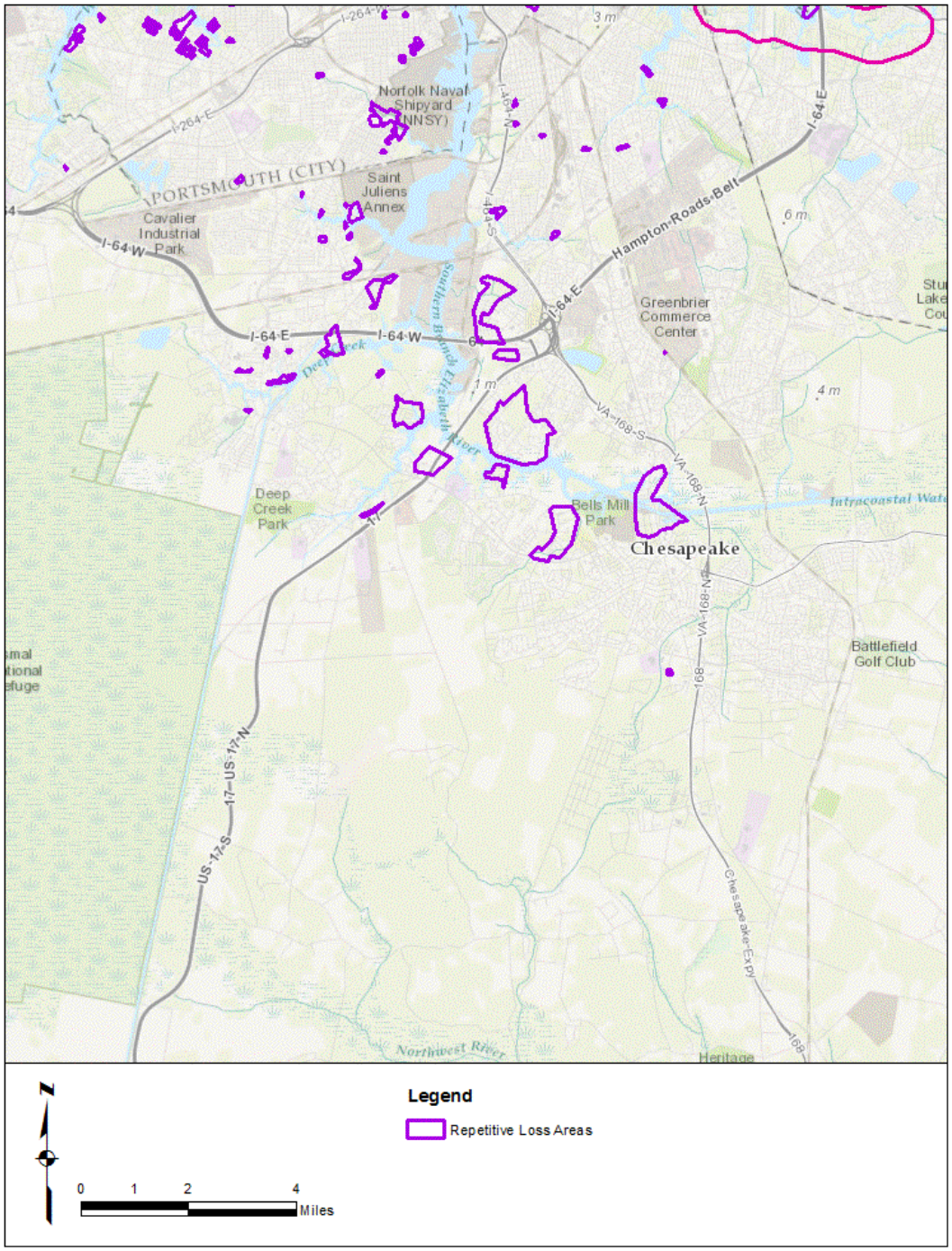
Source: VDEM, 2015 data

FIGURE 5.6: NFIP REPETITIVE FLOOD LOSS AREAS, NORFOLK, PORTSMOUTH



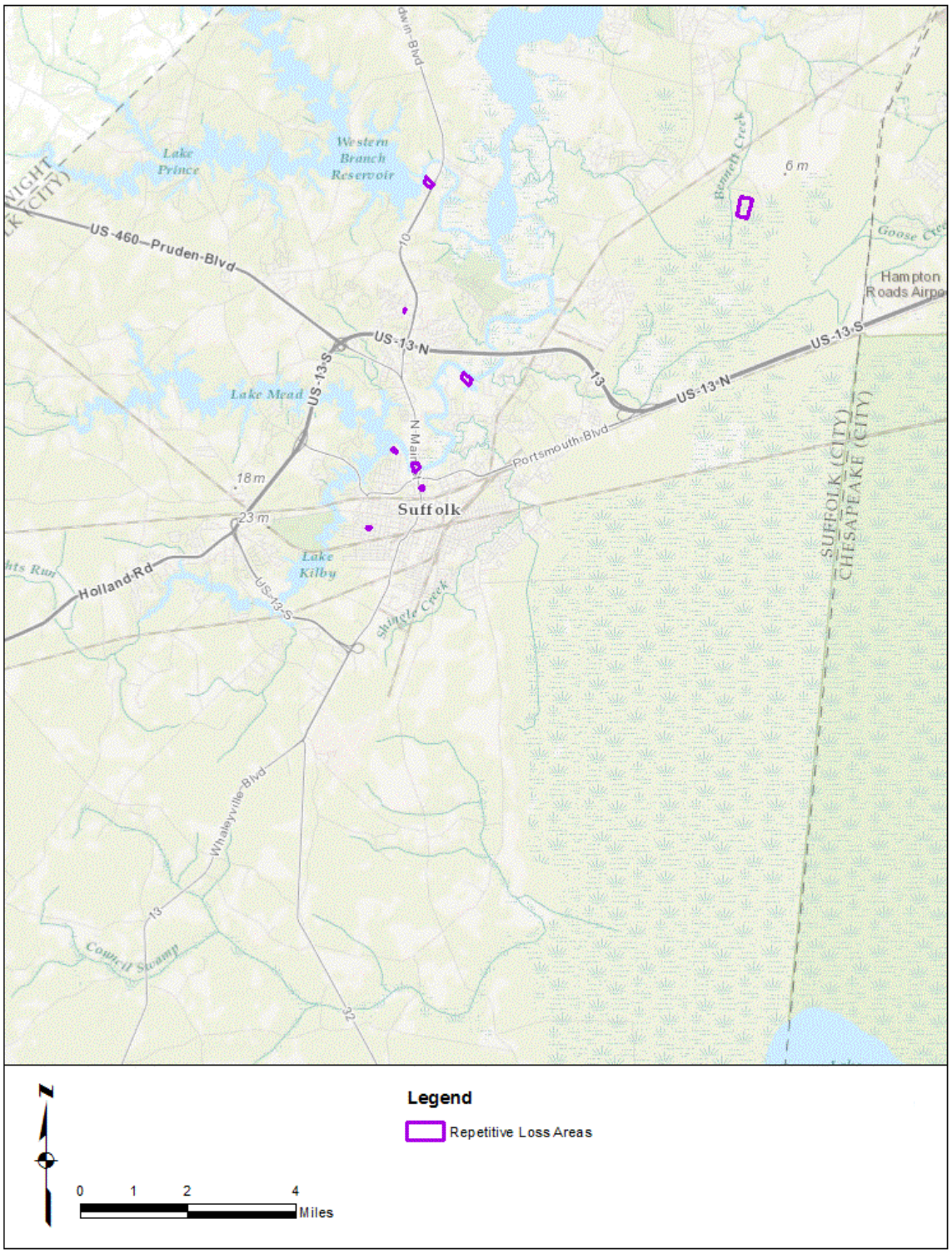
Source: VDEM, 2015 data

FIGURE 5.7: NFIP REPETITIVE FLOOD LOSS AREAS, CHESAPEAKE



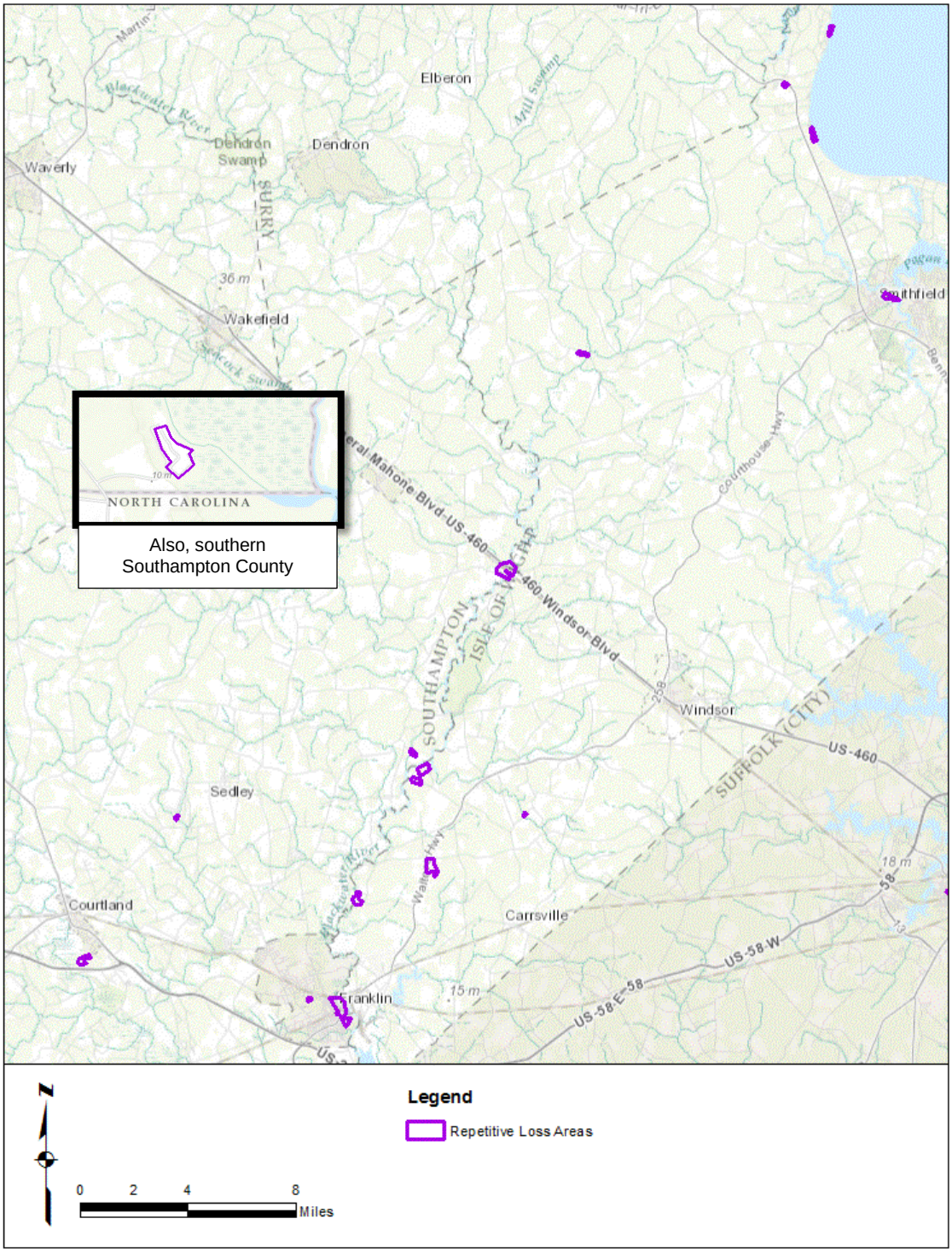
Source: VDEM, 2015 data

FIGURE 5.8: NFIP REPETITIVE FLOOD LOSS AREAS, SUFFOLK



Source: VDEM, 2015 data

FIGURE 5.9: NFIP REPETITIVE FLOOD LOSS AREAS, ISLE OF WIGHT, SMITHFIELD, SOUTHAMPTON COUNTY, FRANKLIN



Source: VDEM, 2015 data

ESTIMATES OF POTENTIAL LOSSES

For the updated flood vulnerability analysis, participating communities were asked to share as much information as possible about individual structures in their communities, including:

- Elevation Certificate data or lowest floor elevation;
- address;
- year built;
- number of stories;
- building cost;
- content cost;
- building type;
- square footage;
- construction class;
- foundation type; and/or
- occupancy/use code.

As part of the flood hazard vulnerability assessments, analysts used the datasets provided by each community to construct the necessary base datasets required by HAZUS to conduct a detailed, Level 2 hazard assessment. The following highlights the data source and processing methodology for each of the input datasets required by HAZUS:

Digital Elevation Model (DEM)
The DEM used for the HAZUS analysis was developed by the Hampton Roads Planning District Commission by combining three separate LiDAR-derived DEMs. The three datasets were acquired between 2010 and 2014. Together, the datasets provide coverage for all of the Hampton Roads Planning District:

1) Isle of Wight County, James City County, Suffolk, and Williamsburg (2010)
2) Franklin and Southampton County (2012)
3) Chesapeake, Hampton, Newport News, Norfolk, Poquoson, Portsmouth, Virginia Beach, and York County (2014)

The individual datasets were mosaicked together in ArcGIS, with priority given to the most recent and most accurate datasets. The original DEMs did not have the same horizontal resolution, so as part of the merging process they were each resampled to a resolution of five feet. The coordinate system for the DEM is NAD 1983 HARN State Plane Virginia South, and the vertical datum is the North American Vertical Datum of 1988.

Flood Hazard Data and Depth Rasters
Geospatial analysts obtained the most recent effective Digital Flood Insurance Rate Map databases from the FEMA Map Service Center for the region. The 100-year floodplain boundary and associated Base Flood Elevations (BFE) were used as the flooding source input to HAZUS for calculating the loss estimations.

User Defined Facilities (Building Data)
Each community provided building data in the form of either parcels, building footprints or address points. The datasets were inconsistent across the communities, but from each dataset, analysts were able to determine the basic structural attributes (i.e. value, foundation type, occupancy class, etc.) required by HAZUS to perform a loss estimation.

First Floor Elevations (FFE)
Each structure was assigned a relative FFE according to the guidelines listed in the HAZUS Flood Model Technical Manual. These values were neither surveyed nor field verified, but were instead algorithmic estimates provided by HAZUS. For example, a structure with a slab-on-grade foundation would have a FFE of 1 foot above Highest Adjacent Grade (HAG) and a crawl space foundation would have a FFE of 3 feet over HAG. This data input is identified as a potential area for increasing the accuracy of the model output in future updates to the plan. By collecting and using real-world data on FFEs, the model will provide more accurate results for individual structures.

Using the DEM, depth rasters and building data listed above, a building level 100-year flood vulnerability analysis was conducted for each flood-prone community. HAZUS uses the associated 100-year depth at each structure and compares that to the assigned FFE to determine the predicted depth of flooding at each

structure. Then, using depth damage curves, HAZUS determines the building and content damage percentage for each structure, which corresponds to a dollar figure based on the assessed value of each structure.

Table 5.6 provides a detailed listing of the number of structures expected to be damaged, and the dollar losses predicted. In previous HAZUS runs for these regional hazard mitigation plans, the flood vulnerability results were run using HAZUS Level 1 which combines or estimates damages at the Census tract level – there is no building level analysis so the results are predictably greater than with HAZUS Level 2. As expected, the vulnerability analysis summarized in Table 5.6 shows a reduction over previous Level 1 analyses, but many committee members expressed concern that the results are perhaps too low and do not accurately reflect the conditions experienced after Hurricane Isabel, which resembled a 100-year frequency flood event in many parts of Hampton Roads. The key data missing are the exact FFE for flood-prone structures, which would greatly improve the accuracy of the estimated vulnerability.

TABLE 5.6: HAZUS FLOOD DAMAGE VULNERABILITY RESULTS

SUBREGION	COMMUNITY	NUMBER OF BUILDINGS MODERATELY DAMAGED (15-49% OF VALUE)	NUMBER OF BUILDINGS SUB-STANTIALLY DAMAGED	BUILDING LOSSES	CONTENT LOSSES	INVENTORY LOSSES
Peninsula	Hampton	1,696	0	$66,454,685	$36,858,927	$5,537,339
	Newport News	463	8	$49,965,691	$102,837,473	$48,883,533
	Poquoson	1,088	12	$39,310,852	$19,174,311	$539,678
	Williamsburg	2 structures in Special Flood Hazard Area (SFHA); no damage predicted.				
	James City County	20	0	$1,453,197	$473,439	$0
	York County	146	0	$109,911,650	$204,923,596	$211,317,219
Southside	Norfolk	1,154	0	$81,875,507	$99,171,200	$28,227,113
	Portsmouth	94	5	$14,015,336	$20,583,938	$30,098,433
	Suffolk	5	0	$190,938	$447,274	$503,228
	Virginia Beach	356	0	$19,861,960	$20,552,564	$3,542,009
	Chesapeake	1,260	0	$73,665,489	$50,414,821	$14,776,711
Western Tidewater	Isle of Wight County	17	0	$4,068,078	$8,694,919	$7,975,198
	Smithfield	9	0	$4,424,147	$14,472,143	$15,873,322
	Windsor	0	0	$0	$0	$0
	Franklin	75	0	$7,174,366	$21,436,438	$19,024,847
	Southampton County	88	3	$4,253,048	$3,928,022	$2,017,067
	Boykins	2	0	$12,283	$6,432	$0
	Branchville	0	0	$0	$0	$0
	Capron	0	0	$0	$0	$0
	Courtland	0	0	$66,830	$24,427	$0
	Ivor	0	0	$0	$0	$0
	Newsoms	0	0	$0	$0	$0
Totals		6,473	28	**$476,704,057**	**$603,999,924**	**$388,315,697**

Sources: HAZUS-MH

Clearly, much of the Hampton Roads region is susceptible to costly damage resulting from flood events and Figures 4.1 through 4.10 indicate where the flood risk is highest. The lower Peninsula (Hampton and Poquoson) and developed areas of Southside (Norfolk, Virginia Beach, Chesapeake and Portsmouth) have the highest numbers of repetitive losses and highest predicted number of structures expected to be damaged in a 100-year flood event based on the HAZUS data. Hampton, Poquoson, Norfolk and Chesapeake all have more than 1,000 structures that are highly vulnerable to the 100-year flood event, and these areas are likely the most vulnerable in the region. York County has fewer structures susceptible, but the value of those structures is higher, so the vulnerability is consequently higher. The repetitive flood loss areas shown in Figures 5.2 through 5.9 indicate where within each community the flood damage has historically been highest and can be expected to continue into the future without large-scale mitigation measures to reduce flood vulnerability.

FUTURE VULNERABILITY AND LAND USE

Future vulnerability will be determined, in part, by local officials. Flood hazard and SLOSH maps are available to indicate what areas of the region are most vulnerable to these hazards. These planning tools are used to help guide development away from hazardous areas. Local officials are responsible for enforcing local floodplain management regulations, flood damage prevention ordinances, and other forms of development policies that restrict new development in flood hazard areas. Additional discussion of actions these communities have taken to reduce future flood vulnerability is provided in Section 6, the Capability Assessment.

SEA LEVEL RISE AND LAND SUBSIDENCE

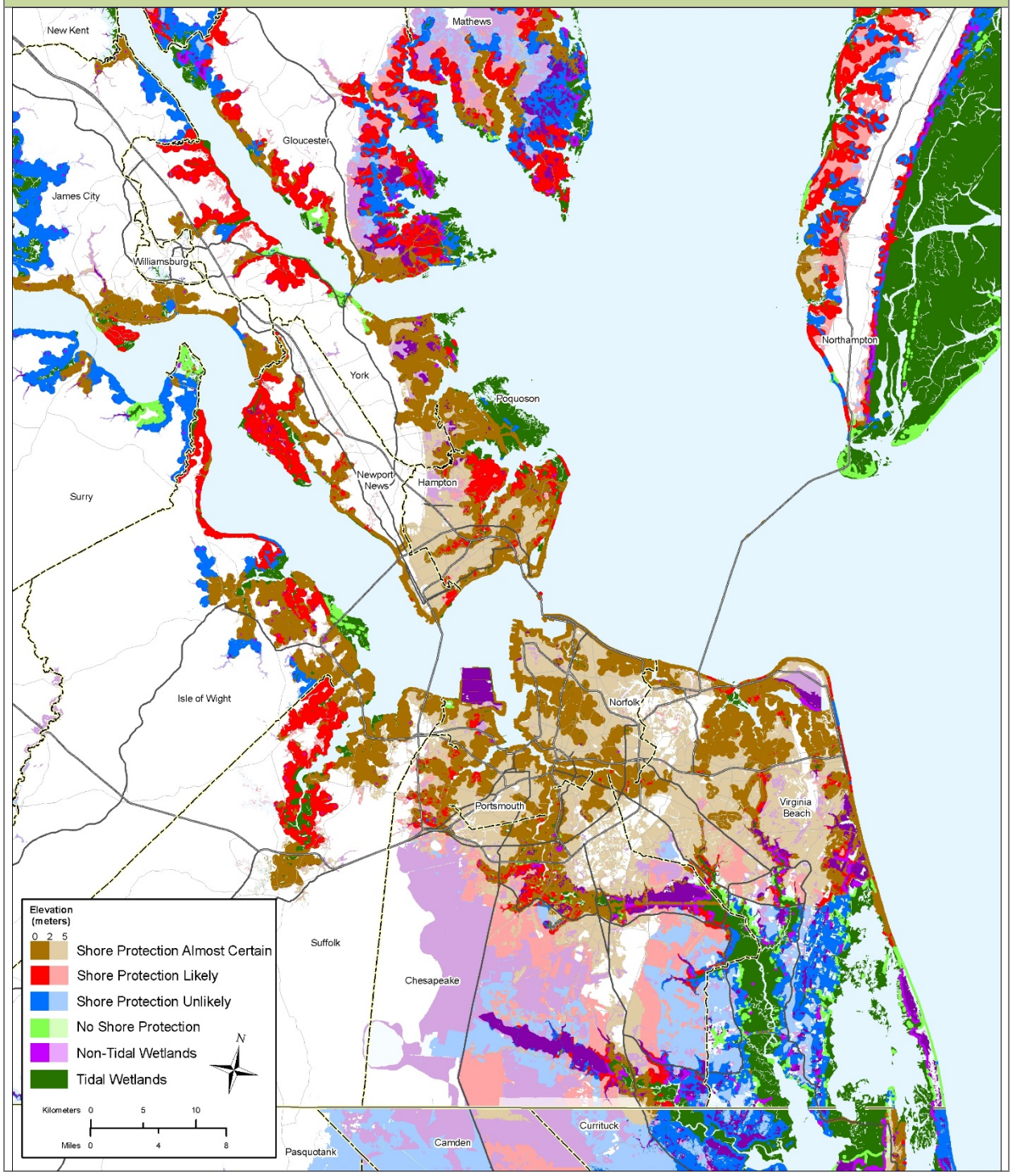
Historical evidence shows that much of the Hampton Roads region is already experiencing some degree of sea level rise. As discussed in the *Hazard Identification and Analysis* section, data from Sewells Point at the Norfolk Naval Base indicate that sea level in the past 70 years has risen at a rate of approximately 4.44 millimeters per year and sea level rise at that rate is expected to continue and possibly accelerate. Vulnerability to sea level rise can be looked at in terms of economic losses resulting from future flood event damages, and by examining expectations for future land use and development patterns and highlighting what infrastructure and real estate will potentially be affected by rising tides. In both cases, this analysis assumes somewhat static conditions with regard to flood mitigation capabilities. A changing regulatory climate, development pressure, or economic conditions could dramatically affect the impact of sea level rise.

ESTIMATES OF POTENTIAL LOSSES

Detailed economic loss estimates for sea level rise and land subsidence are extremely difficult to develop because the response of individual property owners to sea level rise is inherently unpredictable and variable over both time and space. Regional experience over the past 50 years indicates that shoreline protection measures will be reinforced to protect threatened structures, hindering the ability of wetlands and shorelines to adjust naturally as the water level rises. So models based on permanent inundation can dramatically overstate losses.

A recent project conducted by VIMS created maps depicting the likelihood of shore protection along the Virginia coast as part of a nationwide study reporting on the development of coastal land most vulnerable to rising sea level (*Environmental Research Letters*, 2009). The purpose of the project was to motivate dialogues about the appropriate measures to address rising sea level by creating maps that depict the likely response given current practices and policies. The maps divide coastal low lands in the coastal communities into four categories: developed (shore protection almost certain), intermediate (shore protection likely), undeveloped (shore protection unlikely), and conservation (no shore protection) (**Figure 5.10**). More detailed maps for each community along the vulnerable coast are available through the VIMS Center for Coastal Resources management web site at:
http://ccrm.vims.edu/climate_change/slr_maps/index.html.

FIGURE 5.10: SEA LEVEL RISE PLANNING MAPS



Source: Environmental Research Letters, 2009

One methodology for estimating average annual losses expected from sea level rise is supported by FEMA. The agency issued a report to Congress documenting the estimated impact of relative sea level rise on the Flood Insurance Rate Maps, *Projected Impact of Relative Sea Level Rise on the National Flood Insurance Program*, FEMA, October 1991, http://papers.risingsea.net/Flood-Insurance.html. The agency estimates

that existing development in the coastal zone would experience a 36% to 58% increase in annual damages for a 1-foot rise in sea level by 2100, and a 102% to 200% increase resulting from a 3-foot rise by 2100.

The lack of detailed elevation information for the existing pre-FIRM and post-FIRM building inventory in much of Hampton Roads further hinders efforts to calculate detailed future average annual flood damages using increasing 100-year flood elevations. For example, calculations of sea level rise losses may be supported by the argument that areas below a certain elevation will be permanently inundated and evacuated. The FEMA study assumes that the current elevation distribution of post-FIRM construction relative to the 100-year flood elevation holds steady for future construction, when in fact many communities in the region are currently implementing and enforcing freeboard requirements, and many base flood elevations recently changed as a result of a restudy of coastal areas. The obsolescence of buildings is not accounted for in the FEMA predictions; presumably, the number of pre-FIRM and post-FIRM buildings built to outmoded floodplain management standards should decline with time. Replacement structures must be in compliance with NFIP regulations in effect at the time of their construction.

If communities are in need of more detailed annualized estimates for the economic impacts of sea level rise in the future, to include impacts to infrastructure and individual structures, two primary data needs must be addressed:

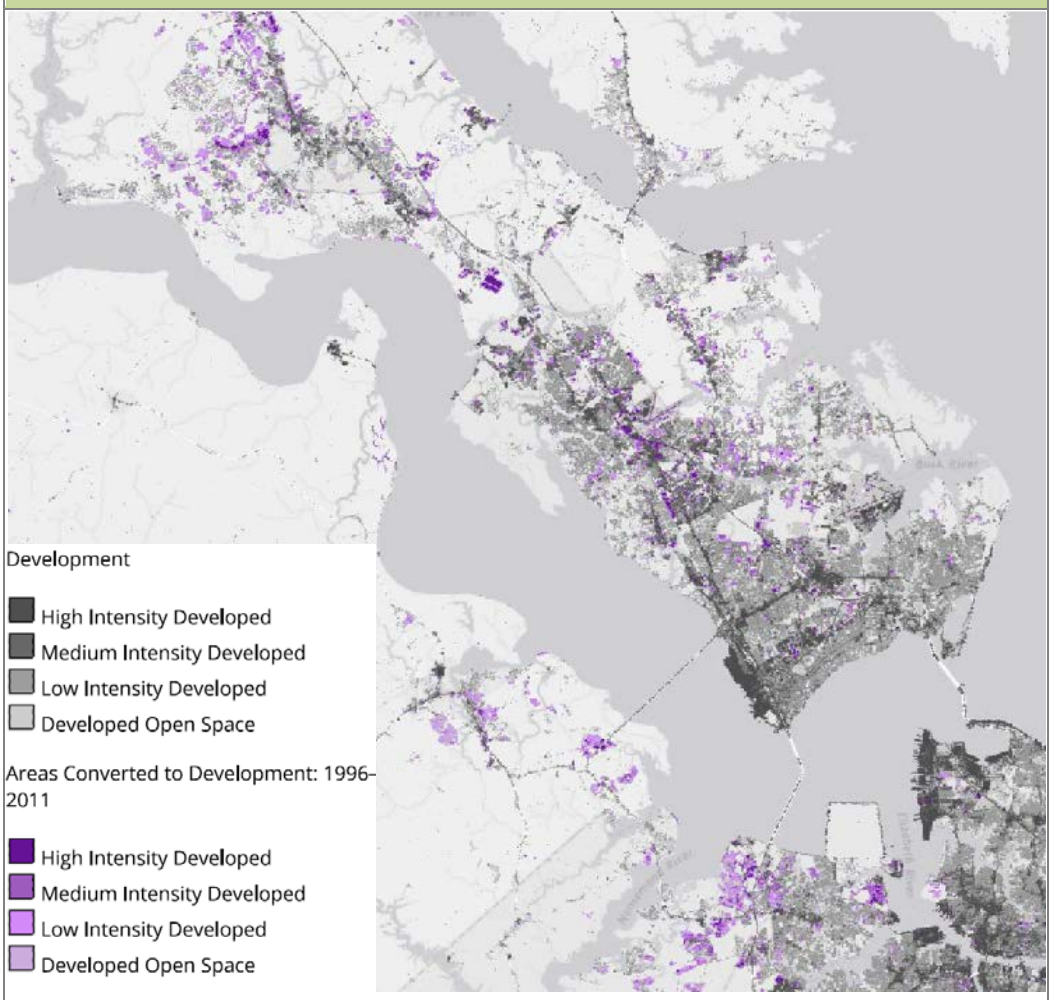
1. Lowest floor elevations for structures in and near the existing SFHA. Side-scan LIDAR methods have been developed that can quickly collect the data needed.
2. HAZUS Level 2 or Level 3 analysis for multi- frequency flood events and flood depths to provide sufficient results for annualization.

The costs associated with these data needs are significant and communities should individually weigh whether the detailed estimates would then significantly alter their selection of mitigation measures to address sea level rise. The use of limited funds to implement mitigation measures to prevent damage must be contrasted with whether additional study of the impacts is necessary to acquire new funds or convince the public or elected officials of the need for action.

FUTURE VULNERABILITY AND LAND USE

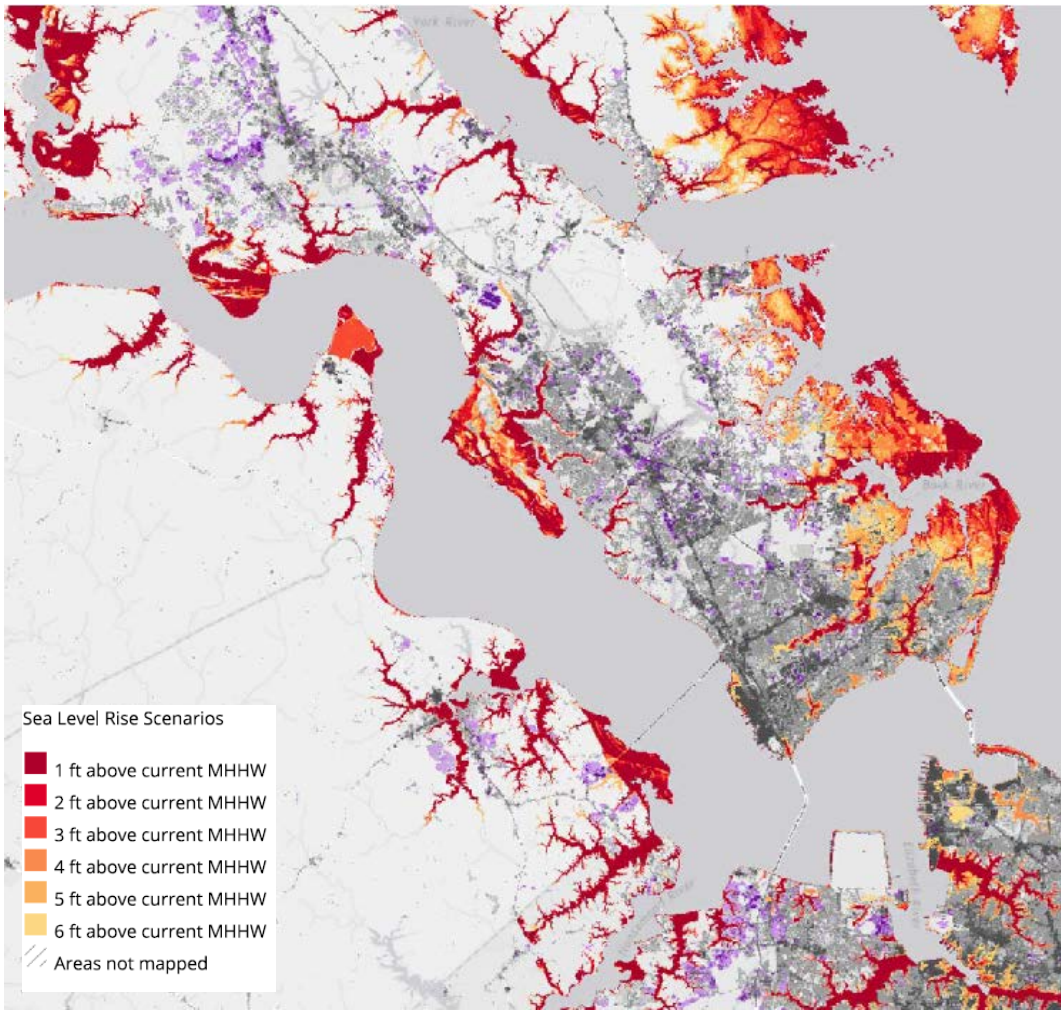
The NOAA Coastal Flood Exposure Mapper tool (http://www.coast.noaa.gov/floodexposure/#/map) uses recent land cover data to show where areas being developed may be impacted by varying levels of sea level rise. This tool can help provide planners with information needed to focus sea level rise mitigation efforts geographically. Summary maps are shown for each Hampton Roads subregion in **Figures 5.11 through 5.16**.

FIGURE 5.11: DEVELOPMENT PATTERNS, PENINSULA



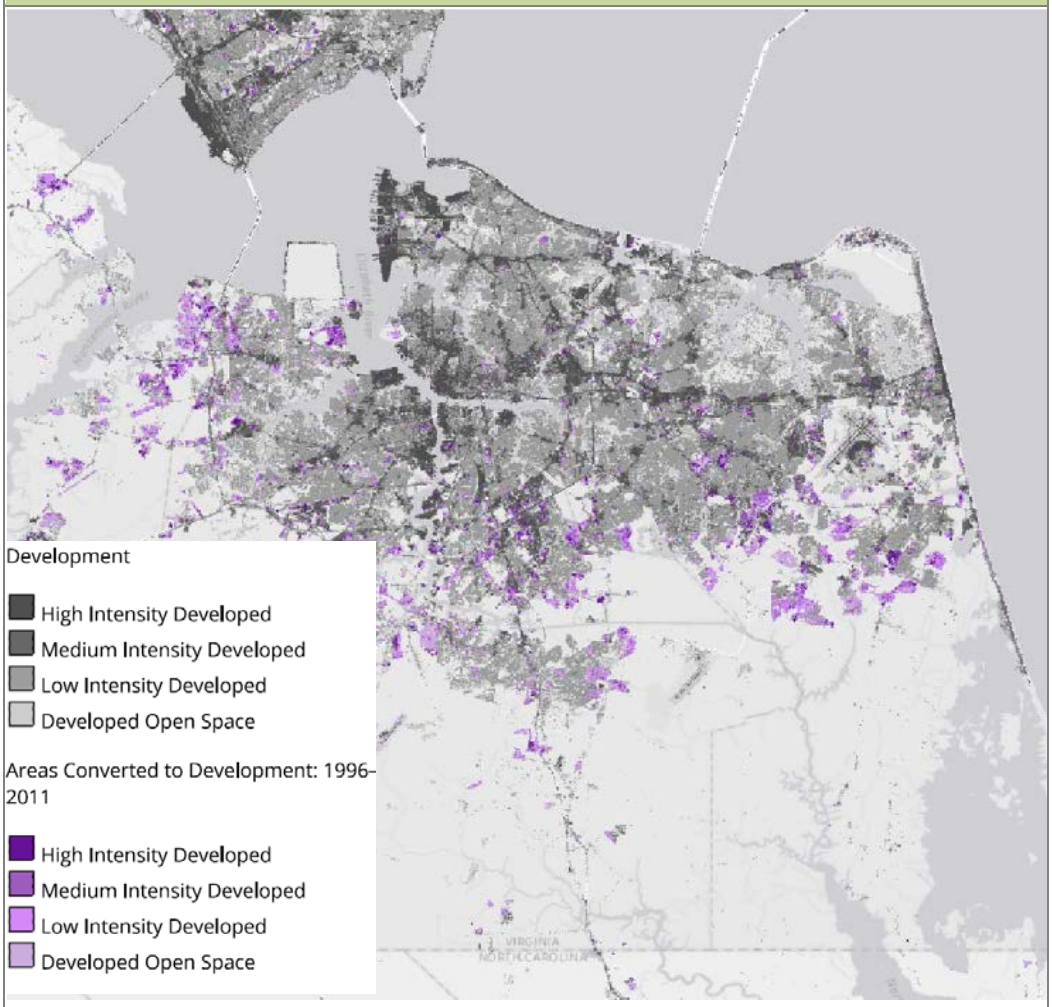
Source: NOAA Coastal Flood Exposure Mapper

FIGURE 5.12: SEA LEVEL RISE SCENARIOS, PENINSULA



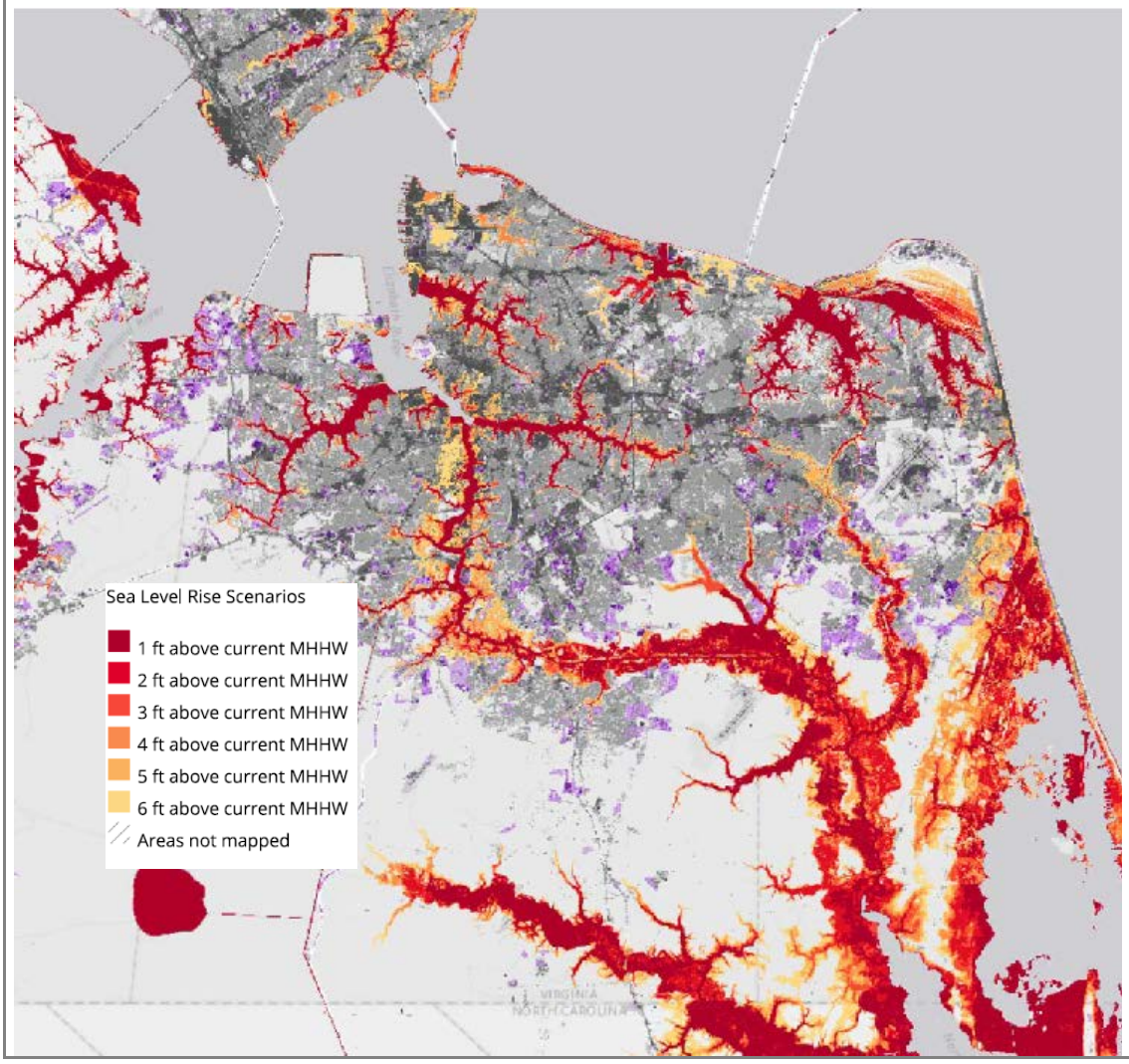
Source: NOAA Coastal Flood Exposure Mapper

FIGURE 5.13: DEVELOPMENT PATTERNS, SOUTHSIDE



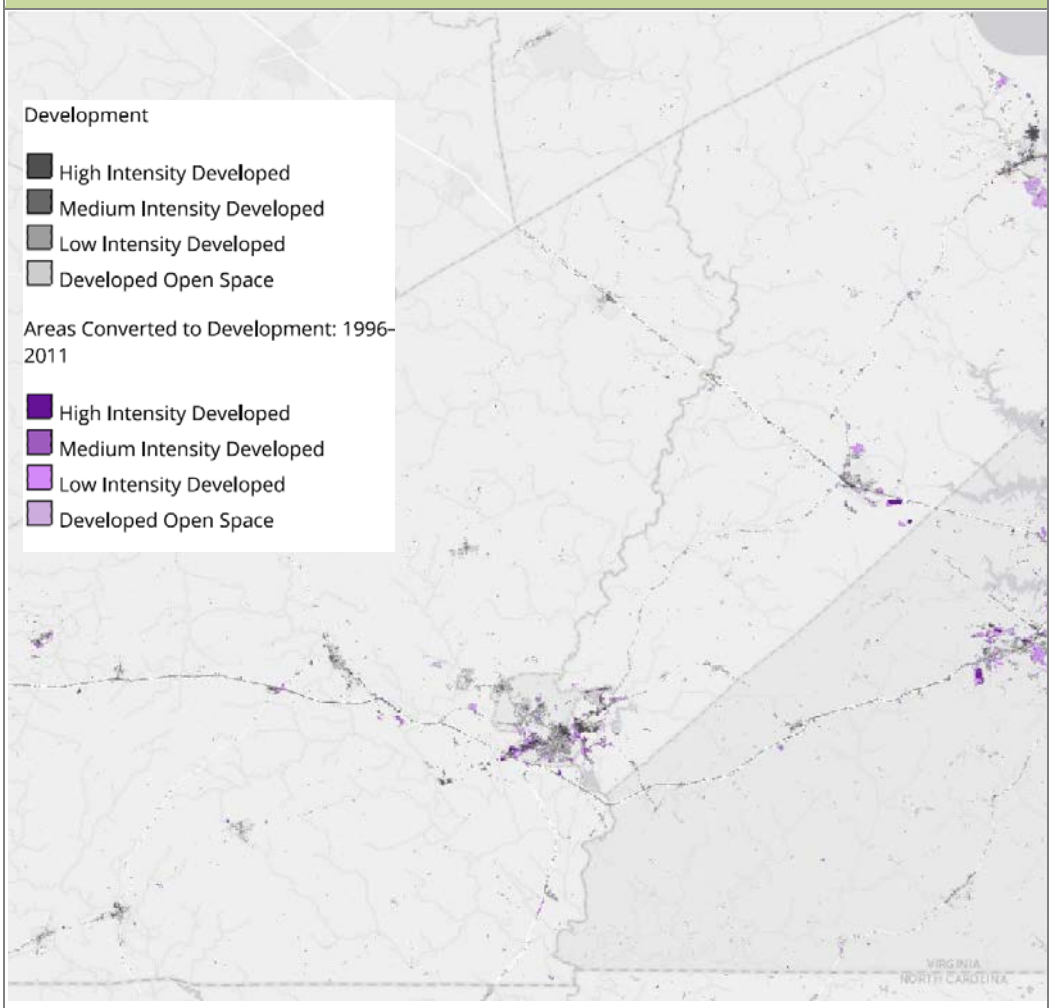
Source: NOAA Coastal Flood Exposure Mapper

FIGURE 5.14: SEA LEVEL RISE SCENARIOS, SOUTHSIDE



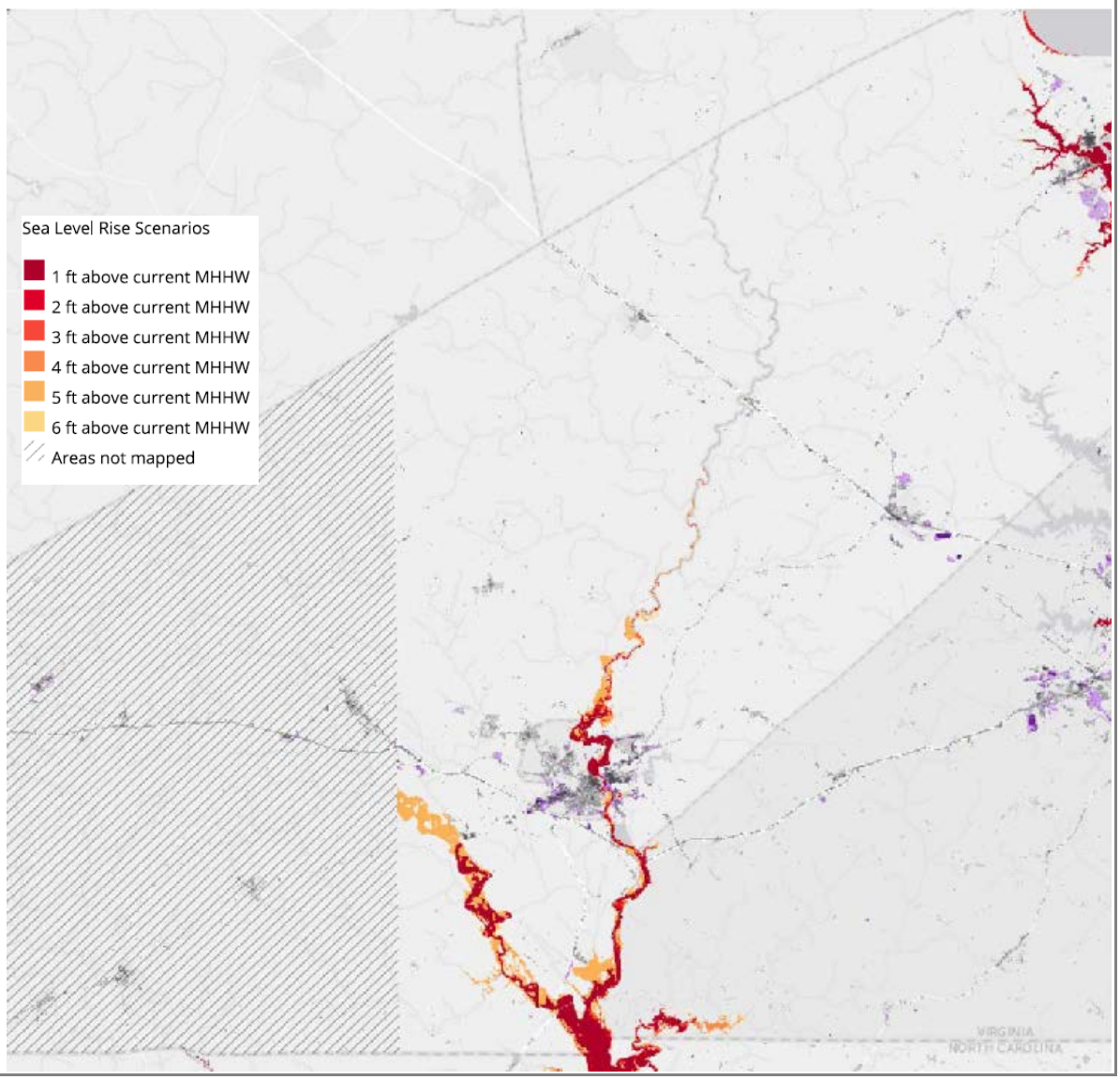
Source: NOAA Coastal Flood Exposure Mapper

FIGURE 5.15: DEVELOPMENT PATTERNS, WESTERN TIDEWATER



Source: NOAA Coastal Flood Exposure Mapper

FIGURE 5.16: SEA LEVEL RISE SCENARIOS, WESTERN TIDEWATER



Source: NOAA Coastal Flood Exposure Mapper

In a 2012 report entitled *Climate Change in Hampton Roads, Phase III: Sea Level Rise in Hampton Roads, Virginia,* HRPDC compiled maps and data to document those areas of the region that are exposed to one meter of sea level rise above spring high tide **(Figure 5.17)**. **Table 5.7** summarizes the report's findings, which highlight over $8.3 billion of vulnerability or exposure in the built environment. Norfolk, Virginia Beach and Chesapeake are the Hampton Roads communities with the highest population exposed to sea level rise. Hampton is fourth on the list and even has a larger number of housing units exposed than Chesapeake. Poquoson is a smaller community, but with a very high percentage of its land area and population exposed, the City must deal with the increasing vulnerability on a very frequent basis. The exposure to sea level rise is lowest in the western part of the study area, including Southampton County and Franklin, where sea level rise may cause some moderate changes in river levels, but is not expected to have the dramatic impacts on homes, roads and businesses that it will in the eastern portion of the study area.

TABLE 5.7: EXPOSURE TO ONE METER SEA LEVEL RISE ABOVE SPRING HIGH TIDE (MIDDLE ESTIMATE)

SUBREGION	COMMUNITY	LAND AREA (square miles)	POPULATION	HOUSING UNITS	ROADS (total miles)	BUSINESSES
Peninsula	Hampton	12.6	14,066	6,011	97.0	263
	Newport News	9.5	4,321	1,896	8.3	28
	Poquoson	11.8	6,770	2,597	38.7	115
	Williamsburg	0.2	275	137	0.1	0
	James City County	14.9	1,796	835	4.5	12
	York County	11.0	5,483	2,195	34.6	64
Southside	Norfolk	6.5	24,715	8,955	75.5	532
	Portsmouth	7.0	4,655	2,089	17.5	127
	Suffolk	14.4	4,691	1,715	4.7	21
	Virginia Beach	58.0	21,160	10,051	66.9	389
	Chesapeake	32.4	15,983	5,731	65.2	380
Western Tidewater	Isle of Wight County	13.4	3,046	1,263	2.0	16
	Franklin	0.6	74	33	0.1	0
	Southampton County	7.8	149	64	2.0	1
TOTALS		**200.1**	**107,184**	**43,572**	**417.1**	**1,948**

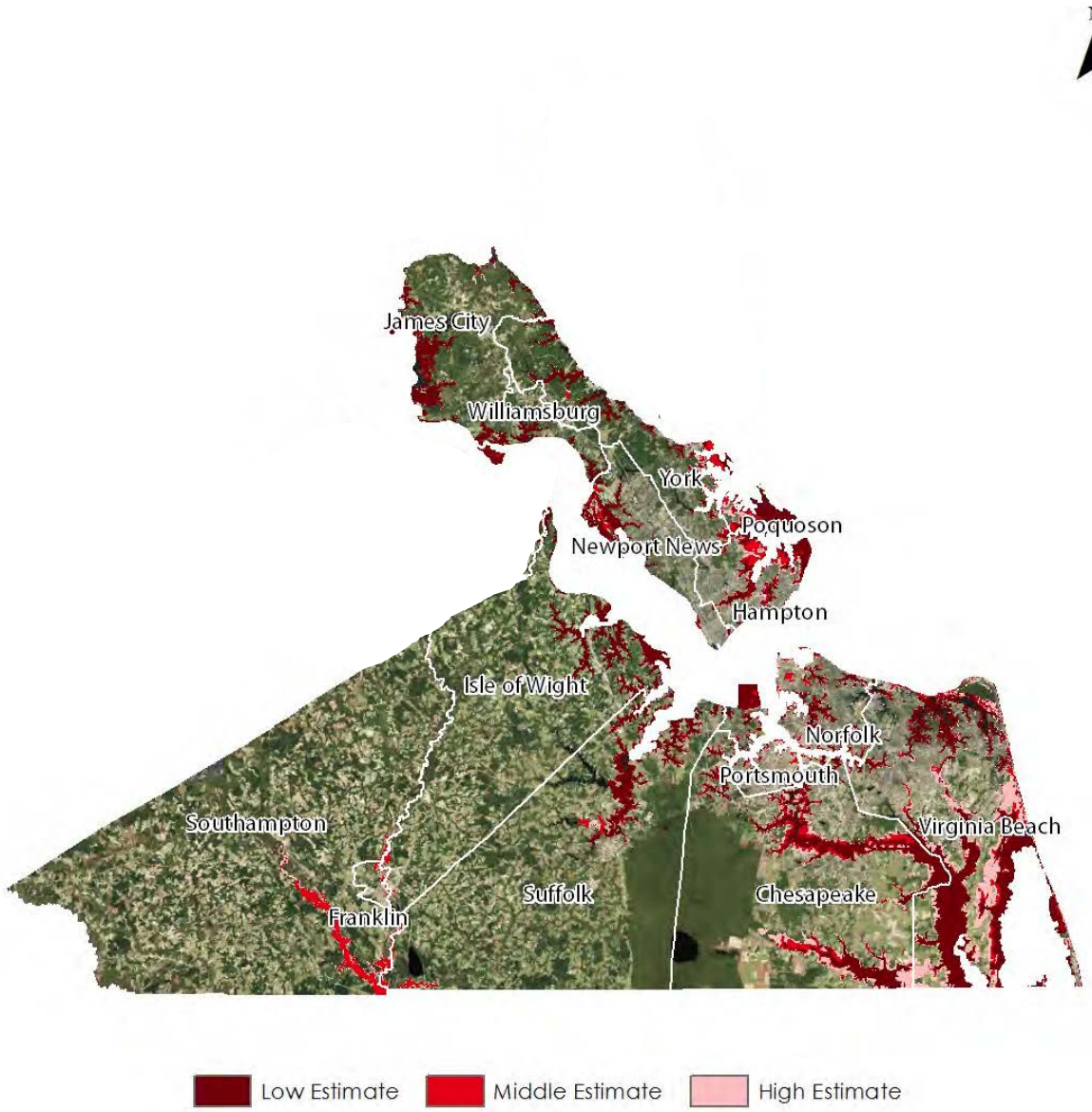
Source: *Climate Change in Hampton Roads, Phase III: Sea Level Rise in Hampton Roads, Virginia.* HRPDC, July 2012.

In addition to the 2012 HRPDC study cited above, the Old Dominion University Center for Sea Level Rise has spearheaded several significant research projects in the scientific community regarding sea level rise. With regard to vulnerability, the Center's web site provides the following compelling data points regarding the region's vulnerability to sea level rise:

- Military Impact: Norfolk Naval Base is home to 14 World War II era piers that are experiencing significant maintenance issues due to the rising sea levels that have occurred since they were built. These piers are being replaced over time, at a cost of $35-40 million per pier, according to the Department of Defense.
- Municipal Impacts: The Virginia Beach-Norfolk Metropolitan Statistical Area ranks 10th in the world in value of assets exposed to increased flooding from relative level rise, according to an analysis by RMS (a catastrophe modeling company). The City of Virginia Beach could lose about 45,000 acres from water inundation, assuming 4 foot of relative sea level rise without considering storm surge effects or sea level rise adaptation measures. Hampton Roads is rated second only to New Orleans as the most vulnerable area to relative sea level rise in the country. Ron Williams Jr., Assistant City Manager of Norfolk, has estimated that the city will need a total investment of $1 billion in the coming decades, including $600 million to overhaul and replace current city infrastructure.
- Economic Impacts: According to a recent study by the Hampton Roads Planning District Commission (HRPDC), costs from three feet of sea-level rise in the Hampton Roads region are

expected to range between $12 billion and $87 billion. According to the Virginia Governor's Commission on Climate Change in 2008, "The continued affordability and availability of insurance for Virginia's landowners is a concern as our climate changes. These effects are already being felt in Coastal Virginia. The frequency and severity of storms in the future are expected to exceed those of the past, and the insurance industry may not have the ability to handle several concurrent events."

FIGURE 5.17: AREAS EXPOSED TO ONE METER OF SEA LEVEL RISE ABOVE SPRING HIGH TIDE



Disclaimer: This map is for informational purposes only. Areas depicted as vulnerable are based on estimates only and should not be construed as being in imminent danger of inundation. The analysis depicted does not account for flood protection or control infrastructure. This map should not be used in place of official FEMA flood insurance rate maps. Users agree to hold harmless and blameless the Hampton Roads Planning District Commission and its representatives and its agents for any liability associated with the use of this map.

Source: *Climate Change in Hampton Roads, Phase III: Sea Level Rise in Hampton Roads, Virginia.* HRPDC, July 2012.

TROPICAL/COASTAL STORM

Historical evidence shows that Hampton Roads is vulnerable to damaging storm-force winds, whether associated with coastal storms like nor'easters, or tropical storms such as hurricanes. As discussed in detail in the *Hazard Identification and Analysis* section, 78 hurricanes and tropical storms have passed within 75 miles of the region since 1851. This equates to a 48 percent annual chance that a storm will similarly impact the region.

ESTIMATES OF POTENTIAL LOSSES

Detailed loss estimates for the wind damage associated with the tropical storm hazard were developed based on probabilistic scenarios using HAZUS-MH (Level 1 analysis). **Table 5.8** shows estimates of potential building damage for the 100-year return period, and annualized total losses. In summary, the region may be susceptible to an estimated total of approximately $1.19 billion in building damages from a 100-year wind event.

TABLE 5.8: ESTIMATES OF POTENTIAL BUILDING DAMAGE – WIND ONLY

SUBREGION	COMMUNITY	BUILDING DAMAGE	CONTENTS & INVENTORY DAMAGE	TOTAL*	ANNUALIZED TOTAL LOSSES
Peninsula	Hampton	$91,781,000	$42,021,000	$138,514,000	$7,265,000
	Newport News	$53,985,000	$10,663,000	$68,841,000	$5,035,000
	Poquoson	$9,575,000	$3,971,000	$13,874,000	$670,000
	Williamsburg	$1,366,000	$392,000	$1,766,000	$236,000
	James City County	$10,477,000	$3,944,000	$14,428,000	$1,841,000
	York County	$35,966,000	$18,024,000	$55,067,000	$2,997,000
Southside	Norfolk	$168,291,000	$28,515,000	$213,399,000	$10,494,000
	Portsmouth	$48,722,000	$8,960,000	$61,573,000	$3,824,000
	Suffolk	$23,969,000	$6,293,000	$31,191,000	$3,031,000
	Virginia Beach	$579,495,000	$190,242,000	$815,974,000	$37,078,000
	Chesapeake	$160,748,000	$55,549,000	$224,879,000	$12,459,000
Western Tidewater	Isle of Wight County	$8,008,000	$2,592,000	$10,789,000	$1,174,000
	Franklin	$381,000	$110,000	$491,000	$207,000
	Southampton County	$650,000	$268,000	$919,000	$437,000
Totals		**$1,193,414,000**	**$371,544,000**	**$1,651,705,000**	**$86,748,000**

* Also includes income losses from relocation, lost wages, and lost rental income.

Source: HAZUS-MH

Based on the data in Table 5.8, Virginia Beach, Chesapeake and Norfolk have the highest annualized total losses from wind associated with a 100-year wind event. These communities are also the most vulnerable for flood, so these 3 communities are considered the most vulnerable to the combined wind and flooding effects of Tropical Storms. Hampton and Newport News are also very vulnerable to wind

effects from the 100-year wind event. Franklin, Williamsburg and Southampton County are significantly further inland and are less likely to experience the devastating impacts of the remainder of Hampton Roads. Franklin has annualized wind-related damages of only $207,000; a small portion of the $37 million calculated for Virginia Beach.

HAZUS-MH was also used to produce building damage estimates based on percentage of damage (by damage state) for the 100-year return period (**Table 5.9**).

TABLE 5.9: NUMBER OF BUILDINGS DAMAGED, BY DAMAGE STATE[2] - 100-YEAR WIND EVENT

OCCUPANCY TYPE	MINOR	MODERATE	SEVERE	DESTRUCTION
Residential	29,180	3,407	70	68
Commercial	1,214	204	20	0
Industrial	307	45	8	0
Other	287	36	5	1
TOTAL	**30,988**	**3,692**	**103**	**69**

Source: HAZUS-MH

FUTURE VULNERABILITY AND LAND USE

All future structures built in Hampton Roads will likely be exposed to hurricane and tropical storm-force winds and may also experience damage not accounted for in the loss estimates presented in this section. The State's Uniform Statewide Building Code continues to reduce vulnerability of newly constructed buildings to the wind hazard.

[2] For detailed definitions of the four damage states, please refer to the HAZUS-MH User Manual for the Hurricane Model.

SHORELINE EROSION

As documented in the *Hazard Identification and Analysis* section, the Hampton Roads region is vulnerable to the long term effects of shoreline erosion. Coastal erosion remains a significant hazard of concern that must continue to be addressed through sustained shoreline management practices. To date, existing strategies for shoreline hardening and the implementation of numerous replenishment projects have been successful in minimizing major coastal erosion losses within parts of the planning region.

ESTIMATES OF POTENTIAL LOSSES

It is difficult to determine the amount of property or the number of structures that are vulnerable to the erosion hazard. The jurisdictions in the region have demonstrated, through past projects such as the Virginia Beach Erosion Control and Hurricane Protection Project that they are willing to take on projects to protect coastal residences and commercial buildings in the hazard zone.

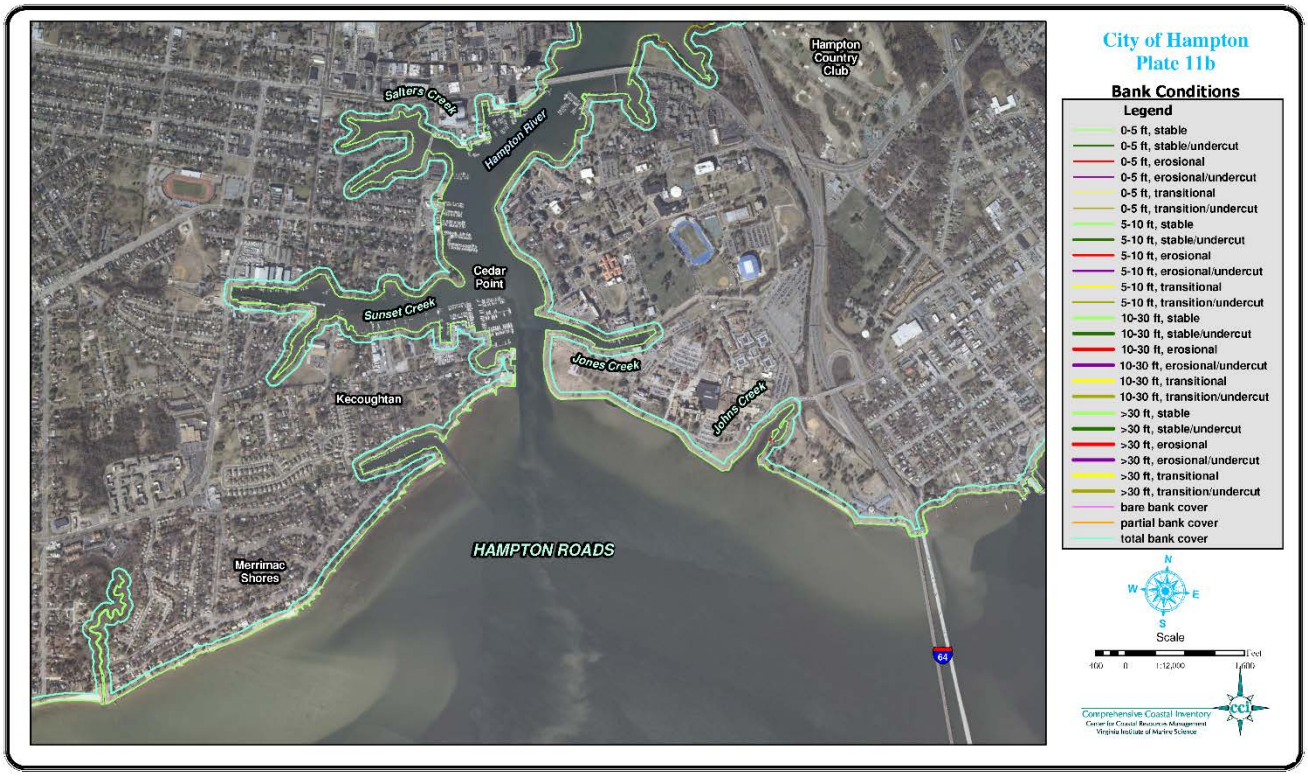
The Comprehensive Coastal Inventory Program (CCI) at VIMS has created a new GIS shoreline database to develop revised Shoreline Situation Reports (SSR) for cities and counties in the region. SSRs were developed by VIMS in the 1970s, and are available online at: http://ccrm.vims.edu/gis_data_maps/index.html. These reports have been the foundation for shoreline management planning in the region for more than 30 years. CCI has developed new protocols for collecting, disseminating, and reporting data relevant to shoreline management issues today. New SSRs are currently available online at: http://ccrm.vims.edu/gis_data_maps/shoreline_inventories/. Southampton County and Franklin are not included in the Chesapeake Bay Shoreline Inventory project.

The data inventory developed for the new SSRs is based on a three-tiered shoreline assessment approach. In most cases this assessment characterizes conditions that can be observed from high resolution imagery. A small boat navigating along the shoreline was used to verify the remotely sensed data and collect features that could not be ascertained from the imagery. The three tiered shoreline assessment approach divides the shore zone into three regions: 1) the immediate riparian zone, evaluated for land use; 2) the bank, evaluated for height, stability, cover and natural protection; and 3) the shoreline, describing the presence of shoreline structures for shore protection and recreational purposes. Final prepared maps are available online at the site noted above. Although the maps alone do not indicate potential loss from erosion, they provide areas for future study and indicate where shoreline structure protection is currently in place to protect against coastal erosion.

Figure 5.18 provides a sample of the maps available in the SSR for the City of Hampton.

The Atlantic Ocean shorelines in Virginia Beach and Norfolk are the most vulnerable areas of Hampton Roads with regard to coastal shoreline erosion. The fetch for tropical storms and nor'easters is sufficient to create wind-driven waves that cause significant damage on a regular basis as shown in Table 4.8. The Chesapeake Bay shorelines of Hampton, Poquoson and Norfolk are also susceptible to wind-driven wave action that causes coastal shoreline erosion. The James River and York River are deep and wide enough to cause some shoreline erosion in Suffolk, Isle of Wight, Newport News, York County and James City County. Riverine erosion in Franklin and Southampton County, while not as dangerous to people and homes, creates limited vulnerability to infrastructure.

FIGURE 5.18: BANK CONDITIONS, HAMPTON RIVER



FUTURE VULNERABILITY AND LAND USE

It is difficult to assess future vulnerability and land use in regard to this hazard. Generally speaking, future vulnerability will depend greatly on appropriate local site planning and permitting, as well as each community's approach to sea level rise and associated flooding problems.

TORNADO

Historical evidence shows that the Hampton Roads region is vulnerable to tornado activity, which is often associated with other severe weather events such as thunderstorm or tropical cyclone activity.

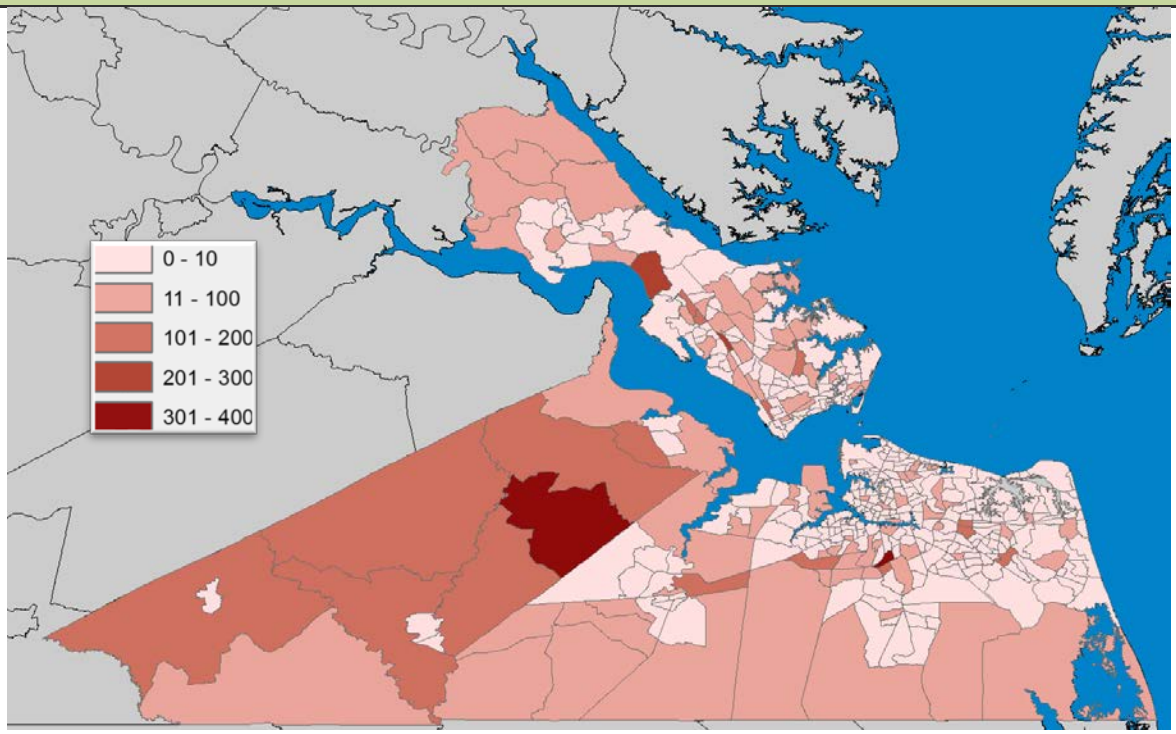
ESTIMATES OF POTENTIAL LOSSES

Because it cannot be predicted where a tornado may strike, it is not possible to map geographic boundaries for this hazard or produce detailed loss estimates. Therefore, the total dollar exposure figure of $197 billion for all buildings and contents within the region is considered to be exposed and could potentially be impacted on some level by the tornado hazard.

Low-intensity tornadoes may not completely destroy a well-constructed building, although even the most well-constructed buildings are vulnerable to the effects of a more intense (F2 or higher) tornado. The statewide building code provides a reasonable level of protection for newly constructed buildings, while structures built before the code went into effect are most vulnerable to damage.

Because manufactured homes are particularly vulnerable to damage from tornadoes, HAZUS was used to show geographic concentrations of manufactured homes in the study area. **Figure 5.19** is a map showing the number of manufactured homes by Census tract from the 2010 Census data generated by HAZUS.

FIGURE 5.19: NUMBER OF MANUFACTURED HOMES BY CENSUS TRACT



Source: HAZUS-MH and 2010 U.S. Census

Based on historic property damages for the 21-year period between 1995 and 2015 as shown in *Section 4, Hazard Identification and Risk Analysis*, there were 54 tornado events with an annualized loss estimate of $2.1 million and annual probability of 2.7% percent.

While Figure 4.24, Historical Tornado Hazard Frequency, and Figure 5.19, Number of Manufactured Homes by Census Tract are useful for seeing where tornadoes have historically struck and where they could potentially damage a specific type of structure, the figures do not show measured differences in vulnerability among study area communities. As tornadoes are driven by larger scale air masses and storm systems and these storm systems affect the Hampton Roads region uniformly, the region's vulnerability to tornadoes is quite uniform. The population concentrations in the urbanized areas of the Peninsula and Southside Hampton Roads may experience more damage as a result of a similar event in the more rural areas of Southampton County or Isle of Wight County, for example, but the vulnerability to tornado strike is uniform throughout the study area.

FUTURE VULNERABILITY AND LAND USE

All future structures built in Hampton Roads are likely to be exposed to the tornado hazard.

WINTER STORM

Historical evidence shows that the Hampton Roads region is vulnerable to winter storm activity and the wind-related impacts of nor'easters, including heavy snow, ice, extreme cold, freezing rain, and sleet.

ESTIMATES OF POTENTIAL LOSSES

Because winter storms typically affect large areas beyond county and municipal boundaries, it is not possible to map geographic locations at specific risk from this hazard or produce detailed loss estimates. Therefore, the total dollar exposure figure of $197 billion for all buildings and contents within the region is considered to be exposed and could potentially be impacted by the winter storm hazard. Based on historic property damages for the past 20 years (1996 to 2015), an annualized loss estimate of $959,000 and annual probability of 100% was generated for the winter storm hazard. Potential losses may be inflated by factors such as the costs associated with the removal of snow from roadways, debris clean-up, indirect losses from power outages, and the tendency of the NCDC data to combine metropolitan regional damages.

Structures built prior to Virginia's statewide building code are somewhat more vulnerable to damage from severe winter storms where snow and ice may accumulate on rooftops, especially if snow loads were not accounted for in the original structure design.

Because manufactured or mobile homes are also very susceptible to damage of roof collapse or additional damage due to their design features, HAZUS was used to show geographic concentrations of manufactured homes in the study area. **Figure 5.19** is a map showing manufactured homes by Census tract from the 2010 Census data generated by HAZUS.

Due to the consistency in the study area's basic geographic characteristics, winter storms can be expected to affect Hampton Roads' communities in a similar way. However, warm ocean currents offshore of Virginia Beach can occasionally diminish the effects of winter storms on the communities adjacent to larger bodies of water, including Virginia Beach, Norfolk, Hampton, and Poquoson. Temperature differences of a few degrees in these eastern communities can cause faster melting of snow and ice, and may result in a "snow line" that bisects the study area into areas of snow versus areas of rain associated with eastward moving systems. Such differences can result in dramatically different storm impacts in the study area.

FUTURE VULNERABILITY AND LAND USE

Because of the geographic location, all future structures built in Hampton Roads are likely to be exposed to the winter storm hazard and may experience damage not accounted for in the estimated losses presented in this section.

EARTHQUAKE

The annual probability of an earthquake epicenter within 65 miles of Hampton Roads is estimated at less than 1% based on historical data. While the probability of an earthquake occurrence is relatively low, moderate losses, should a significant earthquake event occur, are possible.

ESTIMATES OF POTENTIAL LOSSES

Table 5.10 provides generalized building damage estimates by jurisdiction for the 1,000-year return period based on probabilistic scenarios using HAZUS-MH.

TABLE 5.10: ESTIMATES OF POTENTIAL BUILDING DAMAGE – EARTHQUAKE WITH 1,000-YEAR RETURN PERIOD

SUBREGION	COMMUNITY	BUILDING DAMAGE	NON-STRUCTURAL, CONTENTS & INVENTORY DAMAGE	TOTAL*
Peninsula	Hampton	$4,614,000	$4,664,000	$20,172,000
	Newport News	$6,840,000	$7,658,000	$31,661,000
	Poquoson	$535,000	$355,000	$2,097,000
	Williamsburg	$825,000	$1,200,000	$4,409,000
	James City County	$4,396,000	$3,799,000	$19,609,000
	York County	$3,167,000	$2,610,000	$13,386,000
Southside	Norfolk	$8,393,000	$18,849,000	$36,396,000
	Portsmouth	$2,906,000	$6,632,000	$12,771,000
	Suffolk	$3,067,000	$6,868,000	$12,617,000
	Virginia Beach	$13,530,000	$27,488,000	$53,882,000
	Chesapeake	$7,246,000	$15,124,000	$28,734,000
Western Tidewater	Isle of Wight County	$1,587,000	$3,705,000	$6,576,000
	Franklin	$337,000	$481,000	$1,706,000
	Southampton County	$780,000	$685,000	$3,314,000
Totals		**$58,223,000**	**$100,118,000**	**$247,330,000**

* Also includes income losses from relocation, lost wages, and lost rental income.
Source: HAZUS-MH

HAZUS-MH (Level 1 analysis) was also used to produce building damage estimates based on percentage of damage (by damage state) for the 1,000-year return period (**Table 5.11**). According to the HAZUS-MH model assumptions, there should be no building damage from the 100-year earthquake event.

TABLE 5.11: ESTIMATES OF POTENTIAL BUILDINGS DAMAGED BY DAMAGE STATE[3]– EARTHQUAKE WITH 1,000-YEAR RETURN PERIOD			
SLIGHT	MODERATE	EXTENSIVE	COMPLETE
10,723	3,092	367	33

Source: HAZUS-MH

Due to the consistency in the geographic characteristics and soils of the study area, earthquakes are expected to affect the Hampton Roads region communities in a similar manner.

FUTURE VULNERABILITY AND LAND USE

All future structures built in Hampton Roads will be vulnerable to seismic events to a limited degree, and may also experience damage not accounted for in the estimated losses presented in this section.

[3] For more detailed description of the four damage states, please refer to the *HAZUS-MH User Manual* for the Earthquake Model.

WILDFIRE

Historical data indicate that the Hampton Roads region of Virginia is vulnerable to wildfire, particularly in the western portion of the study area. Figure 4.29 provides a graphical overview of wildfire vulnerability in the region.

ESTIMATES OF POTENTIAL LOSSES

As shown in the *Hazard Identification and Analysis* section, VDOF documented an average of 26 wildfire events per year between 2002 and 2013, with total property damages of $163,250 reported for the 231 events between 2002 and 2008. Annualized losses for state-response wildfires are, therefore, estimated to be $27,208.

FUTURE VULNERABILITY AND LAND USE

In cities and counties throughout the U.S., population concentration increase has resulted in rapid development in the outlying metropolitan areas and in rural areas, both of which are areas already occupied by dense forests. Wildfire risk can increase when new developments are built in close proximity to large and dense stands of forest. Wildland Urban Interface (WUI) risk is not limited to new developments in large natural areas. Occasionally, forest and brushlands can grow up over time and engulf previously developed areas. Regardless of how the risk arises, the WUI creates an environment in which fire can move readily between structural and vegetative fuels. Expansion of the WUI over time has increased the likelihood that wildfires will threaten structures and people.

The Southern Group of State Foresters has created an online portal for wildfire risk assessment at http://www.southernwildfirerisk.com/map/index/public. The portal provides mapping to help determine future vulnerability to WUI fire in Hampton Roads and to provide planners a sense of where fire mitigation should be focused for the best reduction in vulnerability. Community Protection Zones (CPZs) with both primary and secondary levels of importance are depicted in **Figures 5.20 through 5.22**. The zones are based on an analysis of the “Where People Live” housing density data and surrounding fire behavior potential. Primary CPZs reflect areas with a predefined housing density appropriate to the region. Rate of Spread data is used to determine the areas of concern around populated areas that are within a 2-hour fire spread distance. This is referred to as the Secondary CPZ.

The online portal for wildfire risk assessment also allows users to highlight a neighborhood or street and determine the wildfire characteristics of that area, such as the Wildfire Urban Interface Risk Index, the wildfire ignition density and the fire intensity scale.

The CPZs in the Hampton Roads area, where wildfire vulnerability is highest, are clustered in the lower Peninsula (Hampton, Newport News and Poquoson), James City County, Suffolk, and north Chesapeake. There are sporadic pockets of vulnerability scattered through eastern Isle of Wight County, parts of Virginia Beach, Norfolk and Portsmouth that make these areas perhaps slightly less vulnerable. The Great Dismal Swamp is not mapped as part of this effort as it is Federal land, but there is also high risk of wildfire in that region actively managed by the Great Dismal Swamp Fire Program.

FIGURE 5.20: COMMUNITY PROTECTION ZONES FOR WILDFIRE, PENINSULA

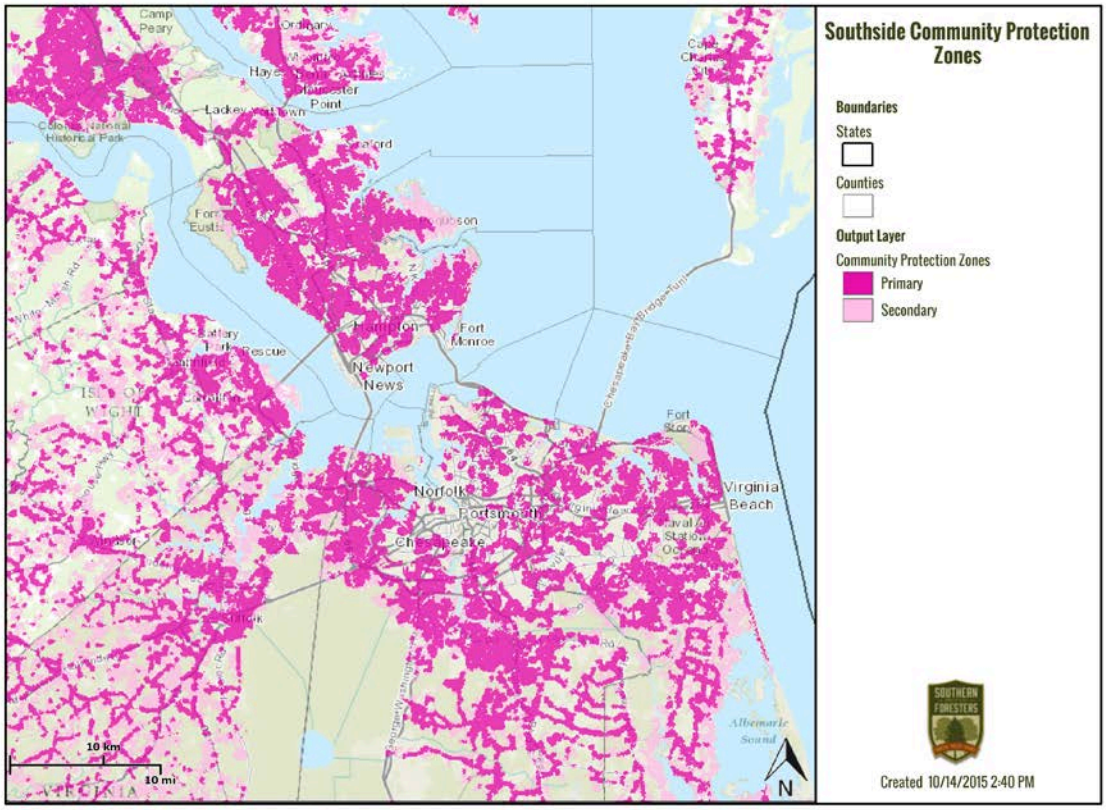


FIGURE 5.21: COMMUNITY PROTECTION ZONES FOR WILDFIRE, SOUTHSIDE

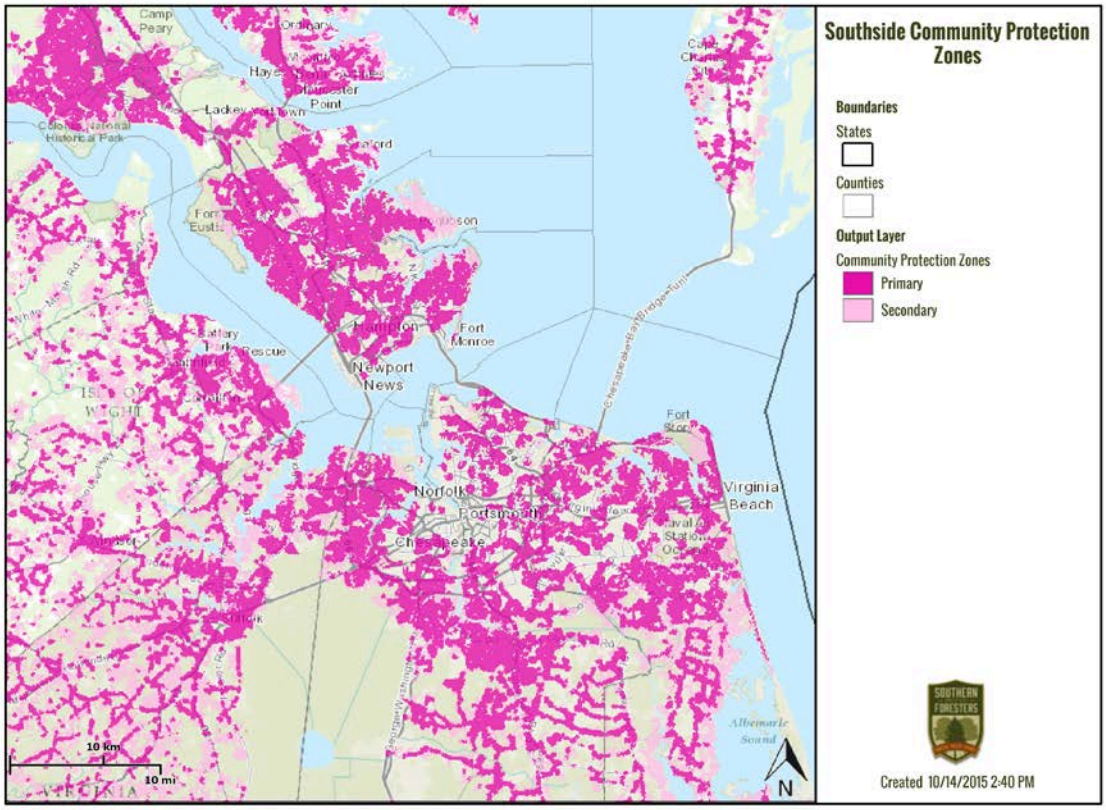
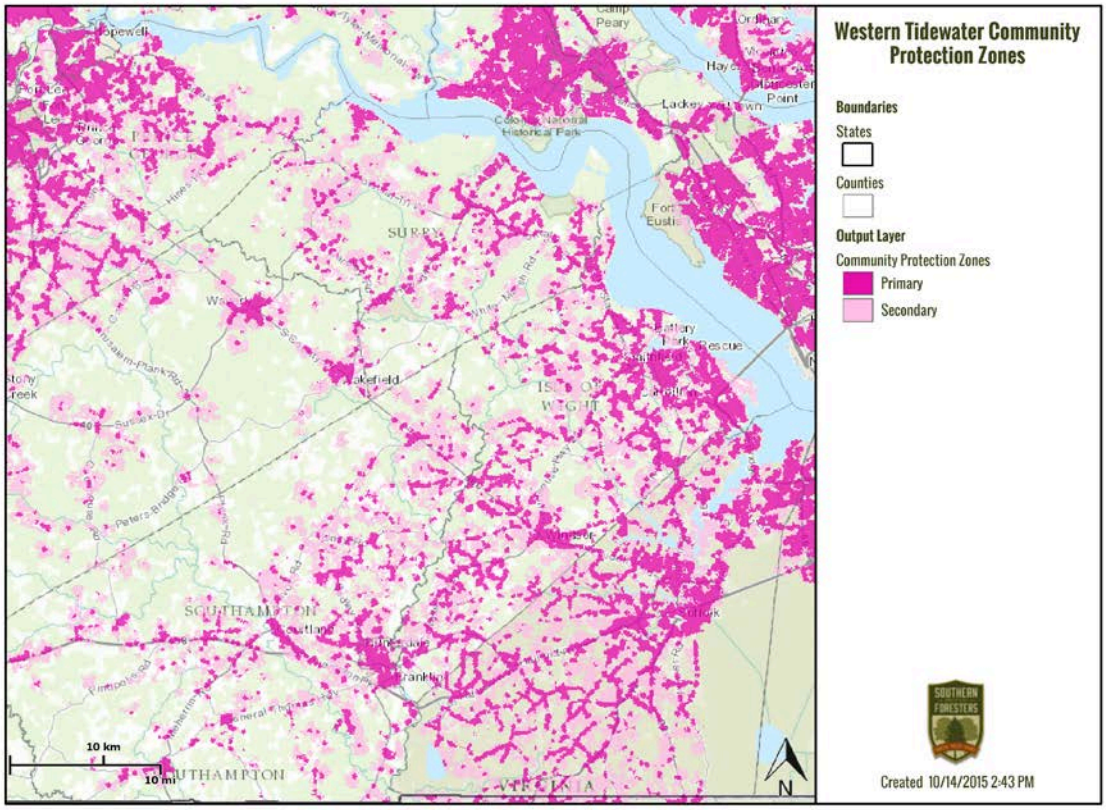


FIGURE 5.22: COMMUNITY PROTECTION ZONES FOR WILDFIRE, WESTERN TIDEWATER



DROUGHTS

Droughts can impact natural systems and the ability of cities, towns and neighborhoods to function effectively. Specific effects may include a reduction in the production of food grains and other crops, the size and quality of livestock and fish, available forage for livestock and wildlife, and the availability of water supplies needed by communities and industry. As evidenced by previous occurrences, the Hampton Roads region is vulnerable to the drought hazard.

ESTIMATES OF POTENTIAL LOSSES

While drought impacts agricultural, recreational, and manufacturing industries, estimating losses to the built environment is difficult because drought causes little documented physical damage to the built environment. In 2006, this plan included an annualized drought loss estimate of $2,215,839 for Isle of Wight County, Suffolk and Virginia Beach; however, the methodology regarding how this loss estimate was developed is not clear. Annualized damages appear to have been based on changes in total harvested cropland; however, losses in harvested cropland or the market value of crops cannot be attributed entirely to drought or other weather-related conditions, especially in rural parts of the planning area that are rapidly developing. Data on drought damages from the NCDC are incomplete and, when available, apply to a very large area including jurisdictions outside of the planning region. As a result, the estimation of annualized damages due to drought was discontinued in previous updates.

Table 5.12 provides a time series of data regarding the total harvested cropland, irrigated land, market value of crops, and percent of non-irrigated land from 2002, 2007 and 2012. Due to a lack of agricultural information, data for many of the cities and towns are not provided.

TABLE 5.12: AGRICULTURAL DATA RELATED TO DROUGHT VULNERABILITY

JURISDICTION	2002		2007		2012	
	TOTAL HARVESTED CROPLAND (acres)	MARKET VALUE OF CROPS ($1,000)	TOTAL HARVESTED CROPLAND (acres)	MARKET VALUE OF CROPS ($1,000)	TOTAL HARVESTED CROPLAND (acres)	MARKET VALUE OF CROPS ($1,000)
James City County	5,258	$2,032	2,367	$1,469	2,698	$1,565
York County	211	$2,607	Withheld	Withheld	Withheld	$2,076
Suffolk	53,954	$35,745	51,203	$51,271	49,693	$58,963
Virginia Beach	21,609	$7,716	20,258	$12,570	20,814	$16,803
Chesapeake	53,188	$33,056	41,391	$30,956	36,269	Withheld
Isle of Wight County	49,373	$13,458	48,230	$13,798	47,868	$33,025
Southampton County	83,449	$21,912	79,449	$27,500	87,902	$67,002
TOTAL	267,042	$116,526	242,898	$137,564	245,244	$179,434

Source: U.S. Department of Agriculture Farm and Ranch Irrigation Survey (2016)

The geography of the study area makes the Hampton Roads region uniformly vulnerable to the effects of drought. However, the impacts would vary across the region with impacts to agriculture and the agricultural economy primarily in Southampton County, as well as James City County, York County, Suffolk, Virginia Beach, Chesapeake, and Isle of Wight County. Social impacts to water utility customers in the cities of Hampton Roads would be more likely during a chronic, prolonged drought that results in water restrictions.

FUTURE VULNERABILITY AND LAND USE

According the USDA Farm and Ranch Irrigation Survey data from 2002 through 2012, the total harvested cropland in Hampton Roads farming communities decreased 9-percent from 2002 to 2007, and then increased again slightly (less than 1-percent) between 2007 and 2012. This is somewhat consistent with the area's largest farming county, Southampton County, which experienced a decrease of 4-percent in the first period and an increase of 10-percent in the later period. These rates may be indicative of past and future changes in land use which may be peripherally related to long-term drought conditions, although the long period between data collection makes it difficult to draw useful conclusions.

EXTREME HEAT

ESTIMATE OF POTENTIAL LOSSES

Based on the previous historical occurrences, annualized losses to the built environment are considered to be negligible (less than $1,000). Loss of human life or health impacts are a greater concern with extreme heat than is property damage.

Hampton Roads is uniformly vulnerable to the effects of extreme heat, with occasional relief to eastern communities such as Virginia Beach, Norfolk, Hampton and Poquoson brought by sea breezes and cooler ocean temperatures that may moderate temperature extremes by a couple of degrees.

FUTURE VULNERABILITY AND LAND USE

All future structures built in the Hampton Roads region will be exposed to extreme heat on a comparable level to existing structures; however, this hazard typically has little to no physical impact on the built environment in terms of substantial damage to structures, essential facilities or infrastructure elements. Given the lesser nature of this hazard within the planning area, it is not expected that significant changes will be seen in the planning or construction of future building stock in response to this hazard.

HAZARDOUS MATERIALS INCIDENTS

ESTIMATES OF POTENTIAL LOSSES

Based on information provided in the *Hazard Identification and Analysis* section, the Hampton Roads region experiences an average of 25 hazardous materials incidents per year with only minor damages (generally less than $10,000 per year) reported. **Table 5.13** shows hazardous materials incidents from 1998 to 2015 in Hampton Roads region (according to the U.S. Department of Transportation) that contribute to an annualized loss estimate of $81,152.

TABLE 5.13: ANNUALIZED LOSSES FOR HAZARDOUS MATERIALS INCIDENTS

SUBREGION	COMMUNITY	NUMBER OF EVENTS	PROPERTY DAMAGE	AVERAGE ANNUAL NUMBER OF EVENTS	ANNUALIZED LOSS
Peninsula	Hampton	6	$9,454	0.35	$556
	Newport News	34	$3,558	2.00	$209
	Poquoson	0	$0	0.00	$0
	Williamsburg	3	$6,845	0.18	$403
	James City County	0	$0	0.00	$0
	York County	2	$0	0.12	$0
Southside	Norfolk	103	$400,522	6.06	$23,560
	Portsmouth	44	$118,693	2.59	$6,982
	Suffolk	12	$292,978	0.71	$17,234
	Virginia Beach	154	$60,557	9.06	$3,562
	Chesapeake	86	$251,589	5.06	$14,799
Western Tidewater	Isle of Wight County	1	$221,000	0.06	$13,000
	Franklin	8	$3,688	0.47	$217
	Southampton County	2	$10,706	0.12	$630

U.S. Department of Transportation, 2015

SOCIAL VULNERABILITY

At-risk populations were estimated using the proximity of structures located within certain ranges of high-risk railway corridors. Potential at-risk structures (populations), as shown in **Table 5.14**, are presented for each jurisdiction.

TABLE 5.14: POTENTIALLY AT-RISK STRUCTURES FOR HAZARDOUS MATERIALS INCIDENTS

SUBREGION	COMMUNITY	STRUCTURES WITHIN 0.1 MILE OF RAILROAD	STRUCTURES WITHIN 0.25 MILE OF RAILROAD	STRUCTURES WITHIN 1 MILE OF RAILROAD
Peninsula	Hampton	1,940	6,277	34,001
	Newport News	4,625	15,121	55,258
	Poquoson	0	0	0
	Williamsburg	491	2,239	5,601
	James City County	1,387	3,529	11,770
	York County	773	1,739	6,362
Southside	Norfolk	7,297	21,634	61,470
	Portsmouth	3,592	10,841	40,017
	Suffolk	6,223	15,126	33,980
	Virginia Beach	3,337	9,687	47,747
	Chesapeake	8,777	23,074	65,051
Western Tidewater	Isle of Wight County	917	1,532	2,969
	Franklin	1,312	2,993	5,805
	Southampton County	1,885	3,763	7,332
Total Structures		13,118	114,562	357,864
Total Estimated Population*		33,451	292,133	912,553

* Rough estimated based on average household size of 2.55 persons per household for Virginia Beach-Norfolk-Newport News, VA-NC Metro Area in *2010 U.S. Census.*
Source: GIS data analysis of local structure data.

Although railroads are not the only transportation method that contribute to hazardous materials incidents, and myriad other constantly changing factors such as vehicle/train speed, weather conditions, number of vehicles/trains in motion, and operator error can cause accidents, railroad incidents vividly highlight surrounding population vulnerabilities. Table 5.14 indicates that the communities in the study area with the lowest vulnerability to hazardous materials incidents based on proximity to railroads are Poquoson, Isle of Wight County, Williamsburg, York County and Franklin. Norfolk, Chesapeake and, to a lesser degree, Suffolk and Newport News have the largest number of structures near the railroads, and thus a higher population is vulnerable to impacts.

FUTURE VULNERABILITY AND LAND USE

Future land use and zoning of structural development as discussed in previous subsections are expected to have less impact on future vulnerability than the protection of human life through administration of proper emergency notification and evacuation planning with regard to potential hazardous material incidents.

CONCLUSIONS ON HAZARD RISK

The vulnerability assessment performed for Hampton Roads provides significant findings that allow committee members to prioritize hazard risks and proposed hazard mitigation strategies and actions. Prior to assigning conclusive risk levels for each hazard, the committee reviewed the results of the assessments shown in the following tables.

Table 5.15 summarizes the degree of risk assigned to each category for all identified hazards in the region based on the application of the voting tool fully introduced in Methodologies Used, Qualitative Methodology at the beginning of this section. Assigned risk levels were based on historical and anecdotal data, as well as input from committee members.

TABLE 5.15: SUMMARY OF QUALITATIVE ASSESSMENT

HAZARD	MITIGATION PRIORITY RANKING
Flooding	$27,925,000
Tropical/Coastal Storm	$25,775,000
Hazardous Materials Incident	$4,800,000
Tornado	$2,925,000
Winter Storm	$2,500,000
Sea Level Rise & Land Subsidence	$2,100,000
Shoreline Erosion	$1,350,000
Earthquake	$1,150,000
Wildfire	$450,000
Drought	$0
Extreme Heat	$0

Source: Mitigation Committee Meeting results

The conclusions drawn from the assessments, combined with final determinations and discussion from the committee, were inserted into three categories for a final summary of hazard risk for the region based on High, Moderate, Low, or Negligible designations (**Table 5.16**). It should be noted that although some hazards are classified as posing Low risk, their occurrence is still possible.

TABLE 5.16: CONCLUSIONS ON HAZARD RISK FOR HAMPTON ROADS	
CRITICAL HAZARD - HIGH RISK	FLOODING TROPICAL/COASTAL STORM
CRITICAL HAZARD - MODERATE RISK	SEA LEVEL RISE AND LAND SUBSIDENCE TORNADO WINTER STORM HAZARDOUS MATERIALS INCIDENT
NONCRITICAL HAZARD - LOW RISK	SHORELINE EROSION EARTHQUAKE WILDFIRE
NEGLIGIBLE	DROUGHT EXTREME HEAT