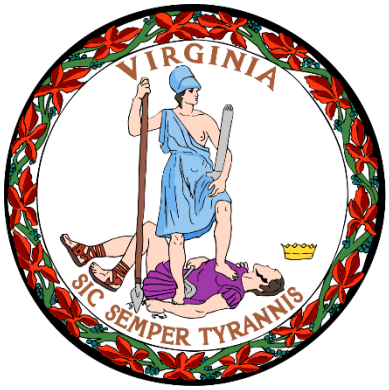

REPORT

Chapter 978 of the 2020 Acts of Assembly
(HB 1217)

January 2022

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ACRONYMS

AHQ	Area Headquarters
CCRFR	Commonwealth Center for Recurrent Flooding Resiliency
CCRM	Center for Coastal Resources Management
CSOI	County Safety and Operational Improvement
DCR	Department of Conservation and Recreation
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
H&H	Hydrologic and Hydraulic
JCOTS	Joint Commission on Science and Technology
NFHL	National Flood Hazard Layer
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NOVA	Northern Virginia (as in VDOT's Northern Virginia District)
OSM	OpenStreetMap
PD8	Planning District 8
VASEM	Virginia Academy of Science, Engineering, and Medicine
VDOT	Virginia Department of Transportation
VIMS	Virginia Institute of Marine Science
VTrans	Virginia Transportation Plan
VTRC	Virginia Transportation Research Council

DEFINITIONS

The following words and terms are provided here for the purposes of this report and have the following meanings unless the context of this document clearly indicates otherwise.

Critical Transportation Infrastructure, for the purposes of this Study, means key facilities and road networks that are necessary to maintain the successful flow of traffic during a flood event.

Deterioration means physical damage to infrastructure after floodwaters recede, reduction in level of service, or limiting access to critical corridors such as evacuation routes.

Planning District 8 or PD8 is comprised of nine localities namely Arlington County, Fairfax County, Loudoun County, Prince William County, City of Alexandria, City of Fairfax, City of Falls Church, City of Manassas, and City of Manassas Park.

Recurrent Flooding means flooding that happens repeatedly in the same area over time, typically leading to economic losses or concerns with emergency access to residents and/or businesses. Recurrent flooding can be due to high intensity rainfall, prolonged precipitation events, tide, storm surge, or sea level rise.

Resiliency is the capability of a transportation project or strategy to anticipate, prepare for, respond to, or recover from significant multi-hazard threats with minimum damage and disruptions through the incorporation of design decisions in both planning and project delivery.

Sea Level refers to the average level of tidal waters, generally measured over a 19-year period. The 19-year cycle is necessary to smooth out variations in water levels caused by seasonal weather fluctuations and the 18.6-year cycle in the moon's orbit. The sea level measured at a particular tide gauge is often referred to as local mean sea level (LMSL).[1]

Sensitive Transportation Infrastructure, for the purposes of this Study, means VDOT facilities that support the operation and maintenance of the roadway system including District Complexes, Residencies, and Area Headquarters (AHQ).

Vulnerability, for the purposes of this Study, means a degree of risk to roadway infrastructure that is susceptible to deterioration, including a reduction in service due to recurrent flooding. The degree of risk is subjective to the type of infrastructure being assessed. The Federal Highway Administration (FHWA) uses three indicators when assessing vulnerability: exposure; sensitivity; and adaptive capacity.

[1] Titus, J.G. et al., 2010. *The Likelihood of Shore Protection along the Atlantic Coast of the United States*. Volume 1: Mid-Atlantic. Report to the U.S. Environmental Protection Agency. Washington, D.C.

Executive Summary

Virginia has been subject to recurrent flooding in recent years, especially in its coastal areas. Chapter 978 of the 2020 Acts of Assembly, introduced as HB 1217, directed the Virginia Department of Transportation (VDOT), in collaboration with the Commonwealth Center for Recurrent Flooding Resiliency (CCRFR), to identify public transportation infrastructure under the jurisdiction of VDOT in Planning District 8 (PD8) that is at risk of deterioration due to recurrent flooding.[2] VDOT was directed to (i) identify the issues related to recurrent flooding and the scope of such issues and (ii) make policy and budget recommendations to alleviate such issues (Study).

In response to HB 1217, VDOT, through the Virginia Transportation Research Council (VTRC), has and is continuing to collaborate with CCRFR consortium member, Virginia Institute of Marine Science (VIMS), and other stakeholders on studies in coastal areas, including PD8. Through this collaboration, the following efforts have been performed and are currently being performed to advance this Study:

a) Overlay of VDOT-maintained roads with the Federal Emergency Management Agency's (FEMA's) flood hazard zones to approximate roadway segments and bridges that are potentially more susceptible to flooding;
b) Assessment of historical road closure frequency and duration due to weather-related flooding incidents from 2008–2019;
c) Evaluation of land cover and other landscape changes and potential relation to flooding; and
d) Analysis of road networks as it relates to recurrent flood frequencies to assess roadways and transportation pathways and the impact of road flooding on access to and from critical and sensitive transportation infrastructure.

As to the identification of at risk public infrastructure, the FEMA overlay analysis indicates that, out of the total 6,638 miles of VDOT-maintained highway network assessed in PD8, 97.3 percent of the network (6,459.4 miles) is within a minimal flood hazard zone; two percent of the network (135.9 miles) is within the most vulnerable flood hazard zone, with a 1% annual chance of flooding; 0.4 percent (24.1 miles) of the network is within the flood hazard zone with a 0.2% annual chance of flooding; and 0.3 percent of the network (18.4 miles) is within an area of undetermined flood hazard zone.

Assessment of the historical (2008-2019) road closure data based on VDOT's 511 operations database further shows that there were a total of 2,912 high water-related road closures, with 2,259 of the incidents resulting from hurricane/flood reports and 653 of the incidents resulting from standing/ponding events. Of the total high water-related road closures, 78 (66 hurricane/flood events and 12 standing/ponding reports) locations reported having experienced high water-related closures more than four times in the twelve-year period between 2008 and 2019. For those

[2] Public transportation infrastructure includes roads and bridges under the jurisdiction of VDOT. PD8 includes Arlington County, Fairfax County, Loudoun County, Prince William County, City of Alexandria, City of Fairfax, City of Fall Church, City of Manassas, and City of Manassas Park.

locations having more than four high water-related road closures during that time, an average closure time of 88 hours for hurricane/flooding incidents and 102 hours for standing/ponding incidents was reported. As described later in this report, there are limitations associated with 511 data that are atrributable to the variety of data sources and circumstances of collection.

Taken with the results of other statewide and regional initiatives and studies that were reviewed as part of this effort, and the discussion with VDOT's Northern Virginia (NOVA) District personnel regarding their firsthand experiences and observations, this Study reaches a number of findings regarding factors related to an increase in recurrent flooding. These factors include:

i) Changes in historical rainfall pattern intensities, duration, and frequencies over several decades has resulted in increased inundation;
ii) Antiquated or limited standards and rainfall records used as the basis for infrastructure selection during the early to mid-20th century resulted in legacy drainage infrastructure that no longer has the capacity to meet the emerging design storm needs of today;
iii) Infill development and higher land use densities resulting from rezoning or existing land use entitlements, as well as drainage pathway modifications, has contributed to drainage-related problems including flooding;
iv) Drainage interconnections to localities and other entities with either old or legacy infrastructure or differing design criteria has caused challenges in designing and providing for adequately sized drainage infrastructure; and
v) Funding availability and mechanisms, and corresponding dedicated administration resources, to repair and/or upgrade existing infrastructure is very limited and has resulted in a diminished ability to appropriately address many, if not all, of the causes of recurrent flooding infrastructure.

The compounding effects of these factors have been identified in this Study as the causes and issues that may lead to the experienced recurrent flooding in PD8.

VDOT recognizes that the causes of recurrent flooding in PD8 are partially due to historical causes, issues related to development over time at the local level, as well as the broader issue of climate change influence that is currently being evaluated by the Commonwealth, statewide and among various state agencies and stakeholders. Through VDOT's active involvement in this and other studies related to climate change and resiliency, VDOT offers the following recommendations:

1. *Support Key Statewide & Regional Studies:* Continue to support the update of the authoritative National Oceanic and Atmospheric Administration's (NOAA) Atlas 14 rainfall records, which are presently current through approximately 2004, to include more recent historical records for the region. At the same time, continue active development, participation, and funding of key regional and statewide studies, such as the statewide expansion of the precipitation study, to estimate future projected rainfall patterns that incorporate climate change influences. Identify data gaps and initiate

applied research to provide information that can be used directly by engineers and designers, such as future projected streamflow estimates for very large drainage systems, and adaptive design standards that can be utilized in future at-risk projects.

2. *Participation and Coordination with Major Commonwealth Efforts*: Actively participate and align efforts and policies with statewide efforts including the Virginia Coastal Resilience Master Planning Framework and the *Virginia Coastal Resilience Master Plan*, and findings from the recently concluded study arising from the Joint Commission on Science and Technology (JCOTS), *The Impact of Climate Change on Virginia's Coastal Areas*, among others.

3. *Continual Improvement and Coordination of Datasets and Tools:* Collaborate with other entities to continually improve, update, and expand existing datasets and tools, or create new ones where needed, related to recurrent flooding to better inform and understand causes and issues related to existing infrastructure as well as aiding in the identification of future potential at-risk infrastructure, both for existing and new, and the evaluation of potential solutions.

4. *Continual Assessment of Transportation Network:* Continue to conduct further assessments with other partners to evaluate the implications and effects of recurrent flooding, climate change, and resiliency with a focus on transportation infrastructure and to evaluate options that will enhance VDOT's ability to mitigate, prepare and respond to these issues.

5. *Enhanced Collaboration and Partnership between State and Localities:* Continue and enhance collaboration and partnership between state and localities in identifying infrastructure subject to recurrent flooding, evaluating potential causes, and aid in identifying and implementing solutions to alleviate the problem.

6. *Funding of Flood-Related Projects:* It is currently premature to make specific funding recommendations, but it is clear that funding will need to be identified for several key activities necessary in the development of a program and strategies to address recurrent flooding and resiliency for transportation infrastructure. Those activities include but are not necessarily limited to: (i) studies; (ii) infrastructure improvement; (iii) tools and technology for flood prone areas; and (iv) capacity building. Sources of funding for these activities will need to be identified for state and local projects and could include both federal and state funds.

I. Introduction

Changes in extreme weather have begun to significantly affect our country and many parts of the world. Virginia is currently experiencing the effects of climate change resulting in increased flooding and precipitation for many areas throughout the Commonwealth. In an effort to address some of these issues and concerns, in 2020 the General Assembly of Virginia passed House Bill 1217 directing VDOT, in collaboration with CCRFR, to identify public infrastructure in PD8 at

risk of deterioration due to recurrent flooding, to identify the issues and scope of recurrent flooding, and to make policy and budget recommendations to improve such issues. An excerpt of the legislation is included below:

> *The Department of Transportation (the Department) shall, in collaboration with the Commonwealth Center for Recurrent Flooding Resiliency, identify public transportation infrastructure in Planning District 8 that is at risk of deterioration due to recurrent flooding. For purposes of this section, "public transportation infrastructure" includes roads and bridges under the jurisdiction of the Department. The Department shall (i) identify the issues related to recurrent flooding and the scope of such issues and (ii) make policy and budget recommendations to alleviate such issues. The Department shall complete its meetings by November 30, 2021, and the Commissioner shall report its findings and recommendations to the Chairs of the House and Senate Committees on Transportation no later than the first day of the 2022 Regular Session of the General Assembly.*

The subsequent sections outline the scope and methodology for the Study, identify VDOT assets and roadway within PD8 and identify those that are at risk for deterioration due to recurrent flooding, discuss factors that contribute to recurrent flooding, and provide recommendations to alleviate issues related to recurrent flooding involving public transportation infrastructure.

II. Background and Methodology

Virginia has been subject to recurrent flooding in recent years including in its coastal regions and certain inland areas of the state. There is a growing recognition that the Commonwealth needs to prepare for these flooding events that put infrastructure at risk to disruption and deterioration, among other safety concerns. As such, the General Assembly has sought to identify public infrastructure that is at risk of flooding and to identify the causes and issues behind it, and to better understand how to mitigate and reduce the number of road closures and disruptions that also may have related evacuation and safety concerns.

The scope of this Study is specific to public transportation infrastructure within PD8 which is located in Northern Virginia and includes Arlington County, Fairfax County, Loudoun County, Prince William County, City of Alexandria, City of Fairfax, City of Falls Church, City of Manassas, and City of Manassas Park. The geographic boundary of PD8 is shown in Figure 1. For purposes of this report, “public transportation infrastructure” includes roads and bridges under the jurisdiction of the Department, but does not include municipally-maintained transportation infrastructure in cities or federal and privately-owned roads and facilities. Figure 2 displays VDOT assets comprising public transportation infrastructure such as bridges and culverts, facilities, park-n-ride locations, VDOT-owned roadways, and intersecting waterways. PD8 aligns with, and encompasses, the same area as VDOT’s NOVA District.

To aid in the identification of public infrastructure that is at risk of deterioration due to recurrent flooding, the VDOT roadways that intersect with, and are located within, Federal

Emergency Management Agency (FEMA)-mapped flood hazard zones were identified for each locality in PD8. Additionally, existing documentation related to recurrent flooding in PD8 was reviewed. Flood and standing water events in PD8 that are logged into VDOT's 511 operations database were reviewed for information on road closures. Specifically, data from the years 2008–2019 was used to determine the location of historical recurrent flooding events and the frequency at each location, also inferring sites at risk of future flooding incidents. As such, an analysis of the 511 information was performed. In addition to the 511 data, VDOT's NOVA District further maintains data regarding frequently flooded roadways through the course of their operations and based on area knowledge for some localities that contributed to this Study. VDOT also leveraged an ongoing study with VIMS[3] to perform a road network analysis to assess the impact of roadway flooding to access to and from critical and sensitive transportation infrastructure. A more detailed discussion of these items can be found in Section III.

To identify the issues related to recurrent flooding, land cover change was evaluated through a study conducted by VIMS and is discussed in Section IV. Additionally, this report includes the results of discussions with VDOT's NOVA District that were performed to aid in the identification and evaluation of issues related to recurrent flooding in PD8. Personnel from VDOT's NOVA District have firsthand knowledge and experience in addressing the issue of recurrent flooding in this region.

As part of this report and as previously mentioned, VDOT has collaborated with several entities, including but not limited to, CCRFR through consortium member VIMS.[4] VDOT participated in bi-monthly coordination meetings with appropriate stakeholders such as VIMS to discuss the status of the efforts associated with elements of this report. The list of meetings and coordination that were held as part of this effort is included in Appendix B.

Policy recommendations are being proposed based on the information gathered from the various sources, the review of various studies and initiatives, and coordination with VDOT's NOVA Maintenance and Hydraulics personnel. The relevant initiatives and studies reviewed include, among others, the *Virginia Coastal Resiliency Master Planning Framework* developed to establish core principles on the best approach to coastal adaptation and protection in coastal Virginia; *The Impact of Climate Change on Virginia's Coastal Areas,* which is the recently concluded study by the Joint Commission on Science and Technology (JCOTS); the draft Virginia Transportation Plan (VTrans) Vulnerability Assessment tool from the Office of Intermodal Planning and Investment, which identifies transportation infrastructure vulnerable to sea level rise, storm surge, and inland riverine flooding; other studies related to the development of updates to

[3] In VDOT's collaboration with VIMS, portions of this report (Section III. A & D) rely on the data, methodology and analysis from: Virginia Institute of Marine Science, Center for Coastal Resources Management, *2021: Virginia Transportation Planning for Sea Level Rise. Interim Report for the Virginia Transportation Research Council.*

[4] Chapter 440 of the 2016 Session of the General Assembly created the Commonwealth Center for Recurrent Flooding Resiliency (CCRFR) to be designated jointly at VIMS, Old Dominion University, and the College of William and Mary in order to serve, advise, and support the Commonwealth by conducting interdisciplinary studies and investigations and provide training, technical and nontechnical services, and outreach in the area of recurrent flooding and resilience research.

rainfall and precipitation data including NOAA's Atlas 14 and future projected rainfall intensity-duration-frequency curves; and VDOT's ongoing resiliency efforts, including VDOT's Structure and Bridge Division's *Considerations of Climate Change and Coastal Storms* and revisions to VDOT's Location and Design Division's *Drainage Manual*, which details how VDOT is implementing new design standards aimed at making future bridges and transportation structures more resistant to the effects of climate change.

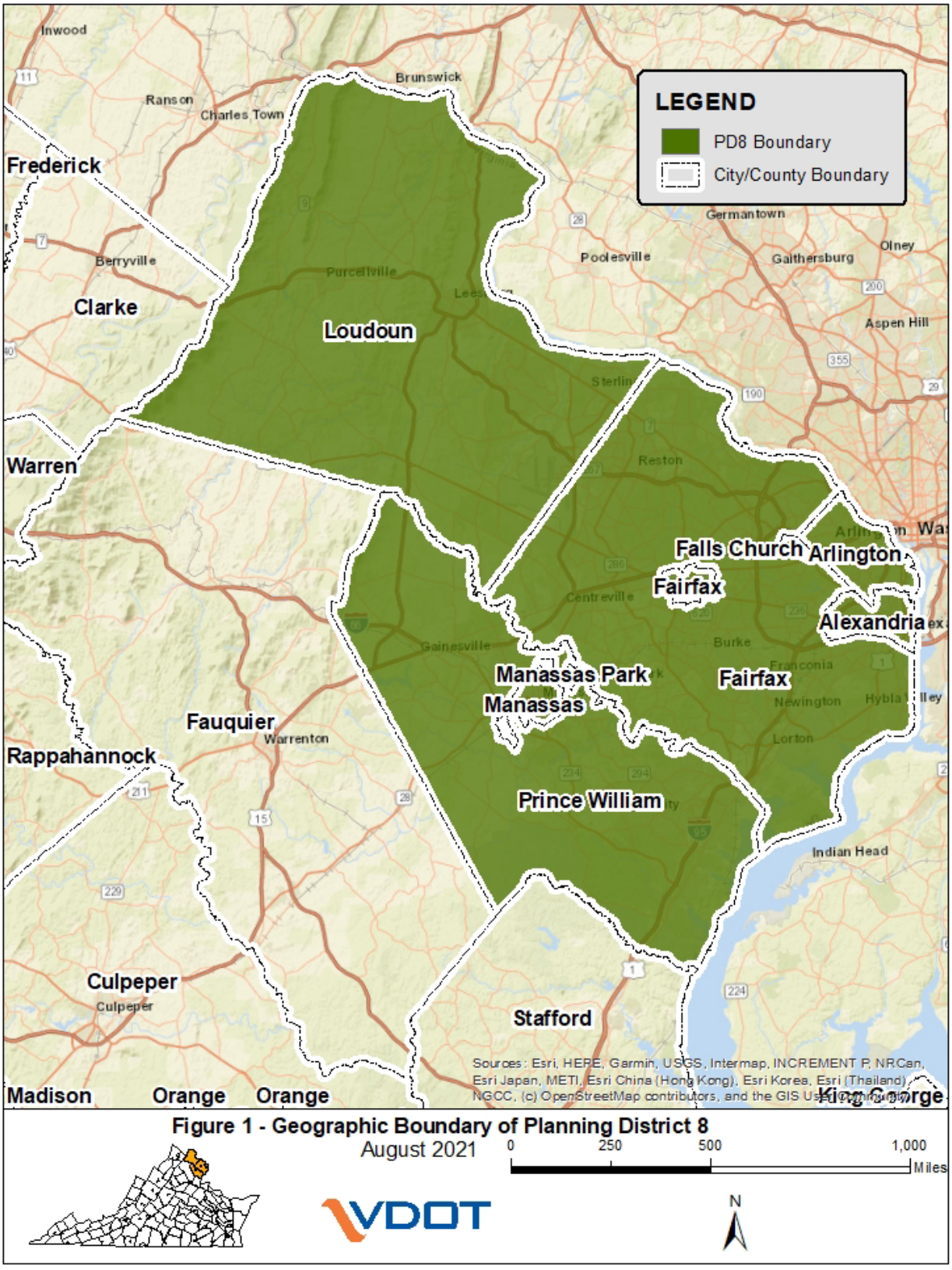


Figure 1 - Geographic Boundary of Planning District 8
August 2021

Figure 1, Geographic Boundary Planning District 8.

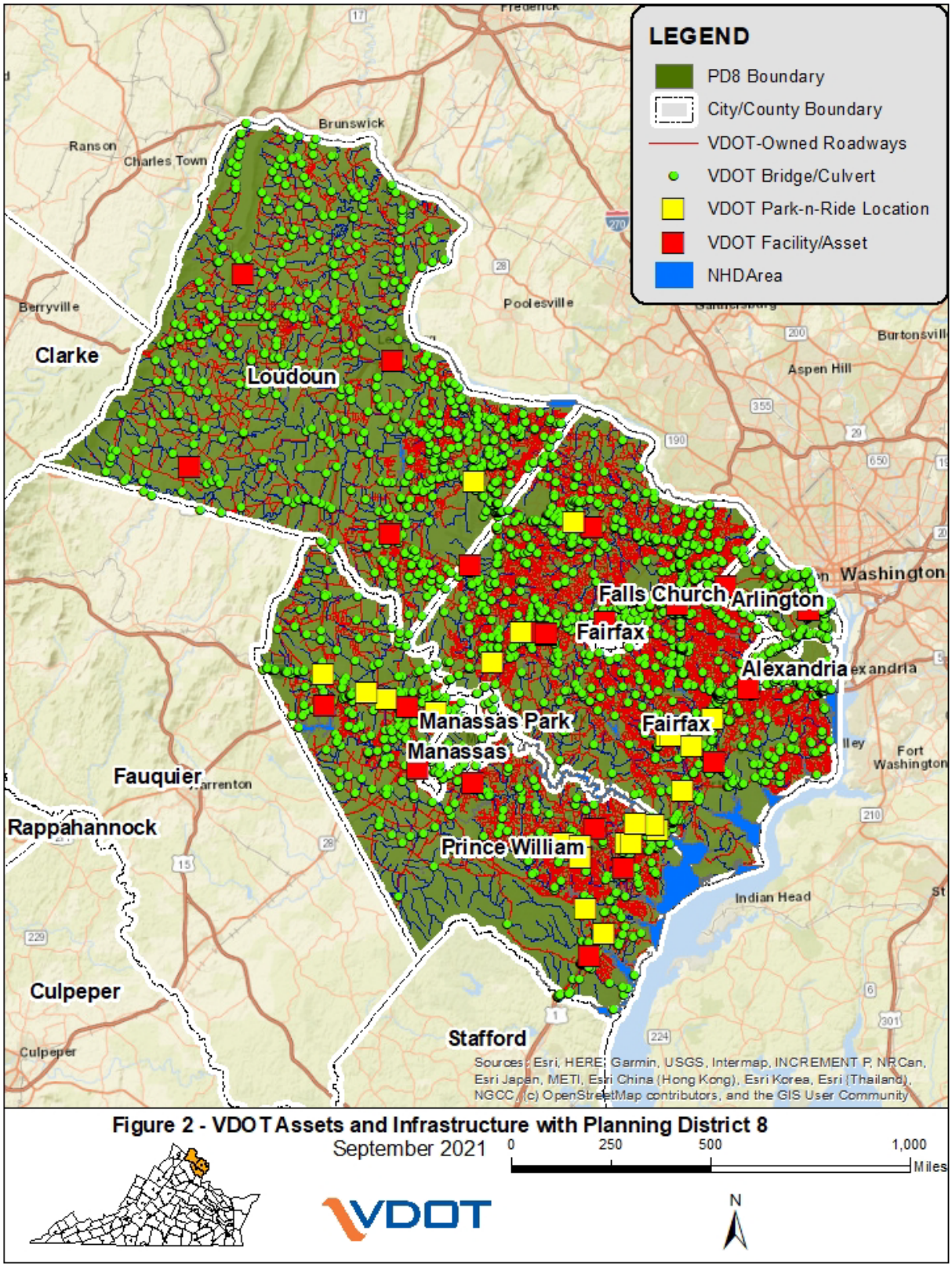


Figure 2 - VDOT Assets and Infrastructure with Planning District 8
September 2021

III. Identification of At Risk Infrastructure

The following sections of the Study detail the research and findings presented by VDOT, in collaboration with VIMS, to address the objectives of the HB 1217.

A. FEMA Flood Hazard Zones

FEMA has designated flood hazard zones that reflect the chance that an area or place will be flooded. The most commonly known 100-year and 500-year flood plains represent zones with flood events that have a 1% chance annually of being equaled or exceeded, and 0.2% chance annually of being equaled or exceeded, respectively. While these zones are most frequently used to assess flood insurance rates or the need for flood insurance coverage, they also provide valuable information for future planning of development and infrastructure with respect to flooding.

This Study uses these zones for a level one (general) assessment of flood risk to public roads and associated infrastructure such as signage, roadside ditches, right-of-way, wharfs, and docks. FEMA designates these zones based on models that consider elevation and exposure to high velocity wave events that may be either tidal, wind, or precipitation driven. The assessment adequately incorporates all VDOT-maintained roads but does not adequately account for bridges since these structures are naturally elevated above the flood zone. In addition, the specific location of features such as ditches, signage, and right-of-way designations are not accounted for but presumed to be within close proximity of the mapped roadway.

FEMA flood zones were overlaid with road centerline data using GIS to assess baseline vulnerability of road networks to flooding. OpenStreetMap (OSM) road network data was used as the base road network for this assessment. VDOT road classifications were transferred to the base road network by applying an 8-meter buffer to VDOT's road network and transferring all VDOT codes to the OSM data. Smaller roads and any VDOT roads not covered by the designated buffers were assigned classifications based on the best match of OSM naming conventions to VDOT naming conventions. Bike trails and pedestrian paths were excluded from the analysis.

The results quantified the road miles and location of roads for a locality that are coincidental with high-risk flood zones. The miles of roadways were calculated by road class that fell within four designated FEMA flood hazard zones: 1% annual chance of flooding (all A and V zones), the 0.2% annual chance of flooding, area of minimal flood hazard, and area of undetermined flood hazard (zone D). The analysis was performed for coastal Virginia but was later expanded to include the non-tidal areas within PD8. The results and findings presented in the subsequent sections only pertain to the VDOT-maintained roadways within the PD8 area.

A total of 6,638 miles of VDOT roadways were assessed in the localities within PD8. The majority of the network (97.3%, 6,459.4 miles) currently resides within the area of minimal flood hazard zone. There are 135.9 miles (2%) of VDOT roadways that fall within the most vulnerable flood hazard zones A and V (1% annual chance of flooding), and 24.1 miles (0.4%) that fall within the flood hazard zone with a 0.2% annual chance of flooding. There are 18.4 miles (0.3%) of roadway that fall within the zone designated by FEMA as an area of undetermined flood hazard.

A summary of the associated flood risks for VDOT-maintained roadways for each locality in PD8, including those VDOT-maintained roadways within municipalities, is shown in Table 1. The FEMA flood hazard vulnerability for VDOT-maintained roads within PD8 is also depicted in Figure 3. This analysis of overlaying flood zones and roadways provides a coarse representation of areas that may be more susceptible to flooding risks. Due to the nature of the high level mapping assessment, however, it does not include other more refined and on the ground information that would be necessary to provide a more comprehensive assessment of flood risk.

Table 1, Overlay of VDOT Roadways within Planning District 8 and Mapped FEMA Flood Zones.[*]

County/City	Road Classification	Total Road Length	1% Annual Chance Flood Hazard (all A and V zones)	0.2% Annual Chance Flood Hazard	Area of Minimal Flood Hazard	Area of Undetermined Flood Hazard
		(miles)	(miles)	(miles)	(miles)	(miles)
Alexandria City	Interstate	16.8	3.0	1.8	12.0	0.0
	Interstate Ramp	13.2	3.0	1.7	8.4	0.0
	Major Collector	0.1	-	0.1	0.1	-
	Minor Arterial	0.5	0.1	0.1	0.3	-
	Other Principal Arterial	1.3	0.3	0.1	0.9	-
	Not Classified	1.6	0.3	0.1	1.1	0.0
	Total for City of Alexandria	**33.5**	**6.7**	**3.9**	**22.8**	**0.0**
Arlington County	Interstate	27.3	0.3	1.4	25.6	0.0
	Interstate Ramp	17.8	0.1	0.5	17.2	0.0
	Major Collector	2.4	-	0.1	2.3	0.0
	Minor Arterial	10.6	0.0	0.6	9.9	0.1
	Minor Arterial Ramp	2.7	-	0.3	2.4	-
	Minor Collector	0.6	0.0	0.0	0.6	-
	Other Freeway or Expressway	8.2	-	0.5	7.5	0.2
	Other Freeway or Expressway Ramp	2.8	-	0.1	2.6	0.1
	Other Principal Arterial	42.3	1.0	2.1	39.1	0.1
	Not Classified	5.4	0.4	0.1	4.9	0.0
	Total for Arlington County	**120.2**	**1.8**	**5.8**	**112.1**	**0.5**
Fairfax City	Interstate Ramp	0.1	-	-	0.0	0.0
	Other Principal Arterial	0.3	-	-	0.1	0.1
	Not Classified	0.5	-	-	0.3	0.3
	Total for City of Fairfax	**0.9**	**0.0**	**0.0**	**0.4**	**0.4**
Fairfax County	Interstate	154.9	5.9	0.1	148.9	0.0
	Interstate Ramp	85.4	3.4	0.0	82.0	0.0

County/City	Road Classification	Total Road Length	1% Annual Chance Flood Hazard (all A and V zones)	0.2% Annual Chance Flood Hazard	Area of Minimal Flood Hazard	Area of Undetermined Flood Hazard
		(miles)	(miles)	(miles)	(miles)	(miles)
	Major Collector	252.5	5.5	0.3	246.7	0.0
	Minor Arterial	444.1	16.1	0.1	427.9	0.0
	Minor Arterial Ramp	32.2	0.6	0.1	31.5	-
	Minor Collector	144.2	5.8	0.0	138.4	0.0
	Other Freeway or Expressway	36.5	0.9	0.0	35.6	-
	Other Freeway or Expressway Ramp	22.0	0.8	0.0	21.2	-
	Other Principal Arterial	233.4	5.5	0.2	227.8	0.0
	Not Classified	1,973.4	18.2	1.1	1,954.0	0.1
	Total for Fairfax County	**3,378.6**	**62.6**	**1.8**	**3,314.0**	**0.1**
Falls Church City	Major Collector	0.0	-	-	0.0	-
	Other Principal Arterial	0.2	-	-	0.2	-
	Not Classified	0.2	0.0	-	0.2	-
	Total for City of Falls Church	**0.4**	**0.0**	**0.0**	**0.4**	**0.0**
Loudoun County	Major Collector	214.6	4.5	1.5	205.2	3.4
	Minor Arterial	162.2	2.7	1.8	156.4	1.2
	Minor Arterial Ramp	6.7	-	-	6.6	0.1
	Minor Collector	113.8	6.4	0.5	104.9	2.0
	Other Freeway or Expressway	43.1	0.8	0.1	42.2	-
	Other Freeway or Expressway Ramp	16.3	0.5	0.1	15.7	-
	Other Principal Arterial	54.1	1.9	0.0	51.8	0.3
	Not Classified	990.4	19.7	2.5	958.1	10.1
	Total for Loudon County	**1,601.1**	**36.6**	**6.5**	**1,540.8**	**17.2**
Manassas City	Major Collector	0.7	-	-	0.7	-
	Minor Arterial	0.7	0.1	0.0	0.6	-
	Minor Arterial Ramp	0.2	-	-	0.2	-
	Minor Collector	0.1	0.0	0.0	0.0	-
	Other Freeway or Expressway	1.0	-	-	1.0	-
	Other Freeway or Expressway Ramp	2.1	0.1	0.3	1.7	-
	Other Principal Arterial	0.3	-	-	0.3	-
	Not Classified	0.7	0.0	0.0	0.7	-

County/City	Road Classification	Total Road Length	1% Annual Chance Flood Hazard (all A and V zones)	0.2% Annual Chance Flood Hazard	Area of Minimal Flood Hazard	Area of Undetermined Flood Hazard
		(miles)	(miles)	(miles)	(miles)	(miles)
	Total for City of Manassas	**5.7**	**0.2**	**0.3**	**5.2**	**0.0**
Manassas Park City	Major Collector	0.0	-	-	0.0	-
	Minor Arterial	0.0	-	-	0.0	-
	Other Principal Arterial	0.6	-	-	0.6	-
	Not Classified	0.2	-	-	0.2	-
	Total for City of Manassas Park	**0.9**	**0.0**	**0.0**	**0.9**	**0.0**
Prince William County	Interstate	65.5	1.8	0.2	63.6	0.0
	Interstate Ramp	31.7	0.1	0.0	31.6	-
	Major Collector	199.2	7.0	1.4	190.7	0.0
	Minor Arterial	126.7	3.3	0.9	122.4	0.0
	Minor Arterial Ramp	7.5	0.1	0.1	7.3	-
	Minor Collector	75.8	2.5	0.3	72.9	0.0
	Other Freeway or Expressway	30.1	0.7	0.0	29.4	-
	Other Freeway or Expressway Ramp	2.1	0.0	0.1	2.0	-
	Other Principal Arterial	94.8	2.9	0.5	91.3	0.0
	Not Classified	863.3	9.6	2.1	851.6	0.1
	Total for Prince William County	**1,496.7**	**28.0**	**5.8**	**1,462.8**	**0.1**
Total for VDOT Roads in PD8		***6,638.0***	***135.9***	***24.1***	***6,459.4***	***18.4***

**All road lengths represent centerline road lengths and are rounded to the nearest tenth place. Cells with "–" indicate no roads in that category.*

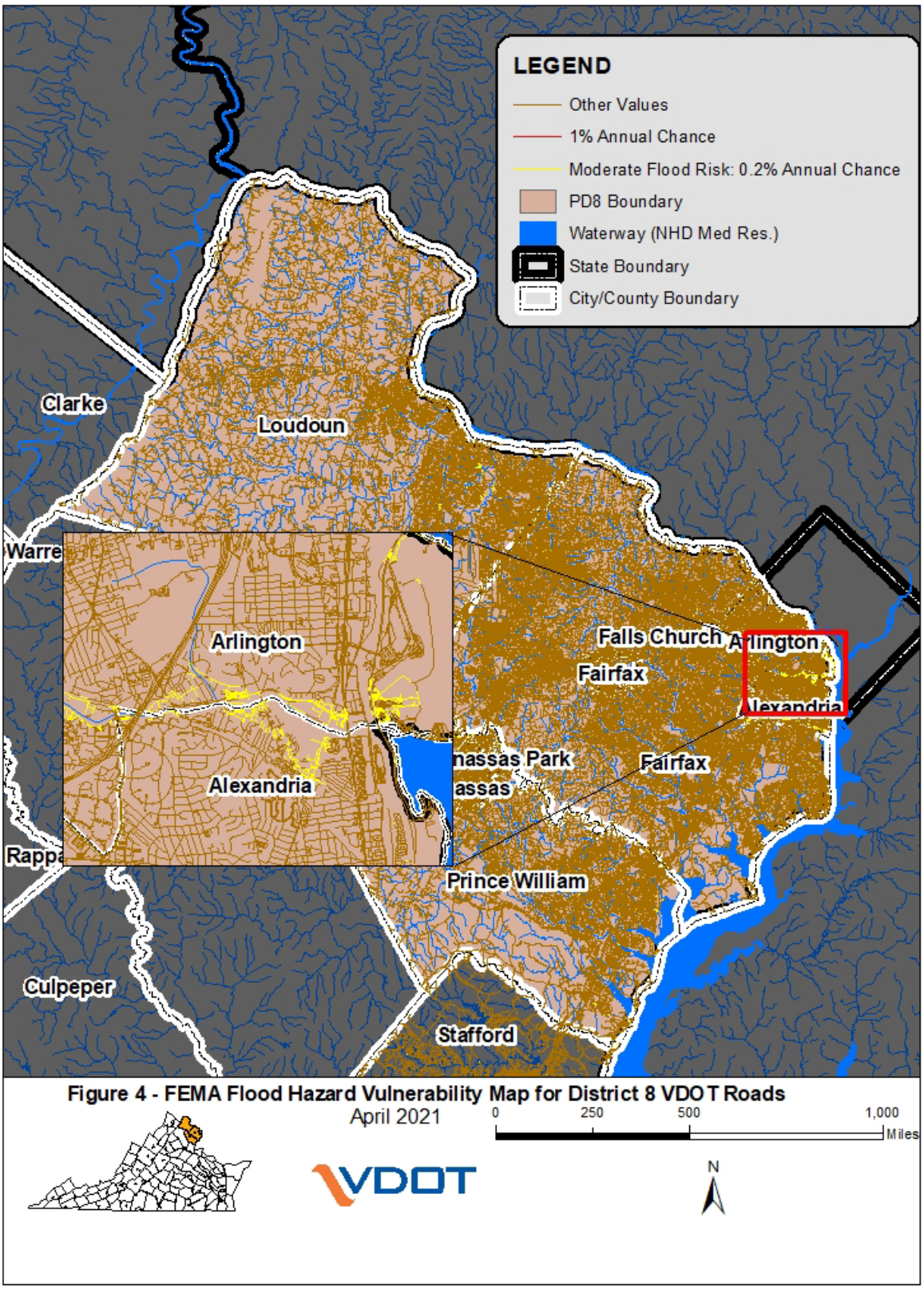


Figure 3, Overlay of VDOT Roadways within Planning District 8 and FEMA Flood Zones.

B. Road Closures Due to Flooding/Ponding Incidents (511 Data)

As mentioned in Section II, VDOT analyzed the high water-related data obtained from the 511 database, which includes a record of road closures on state maintained roads. Data from this database for the years 2008–2019 were used to determine where recurrent flooding is occurring and to identify infrastructure that may currently be at risk for deterioration within PD8. The database also provides insight on areas that may have the potential to be continually at risk for future flooding based on prior experience.

The 511 database reported incidents from hurricane/flooding and incidents from standing/ponding water. The analysis of these incidents for the years 2008–2019 shows that there were a total of 2,912 high water-related incidents, with 2,259 reported incidents attributed to hurricane/flooding, and 653 reported incidents attributed to standing/ponding water. Hurricane/flooding incidents are long term weather events where segments of routes are typically affected from one intersection to another but may include point locations as well. Standing/ponding incidents are short term weather events a point locations that are usually the result of heavy rainfall or a precursor to a larger flooding event. It should be noted that the analysis identified a total of 78 locations (66 from hurricane/flooding incidents and 12 from standing/ponding water incidents) that have experienced high water-related events more than four times over the course of the twelve-year period. In addition, those locations with more than four high water-related events and subsequent road closures had an average closure duration of 88 hours for hurricane/flooding incidents, and 102 hours for standing/ponding water incidents. The data for standing/ponding water incidents is summarized and displayed in Figure 4 and the data for incidents reported due to hurricane/flooding is summarized displayed in Figure 5.

It is noted that 511 data is generated from a variety of sources including VDOT safety service patrol and construction crews, traffic cameras, state police, pavement sensors, and reports from the public. The variety of sources result in a varying level of information and completeness for each entry or incident. Two dataset categories used for this study, standing/ponding and flooding/hurricane, relate to the number of reported high-water related incidents and road closures, but did not always report and characterize the cause of the incidents (precipitation or storm surge). Because of these and other limitations, the 511 data as analyzed and presented herein is intended to merely provide insight into past occurrences.

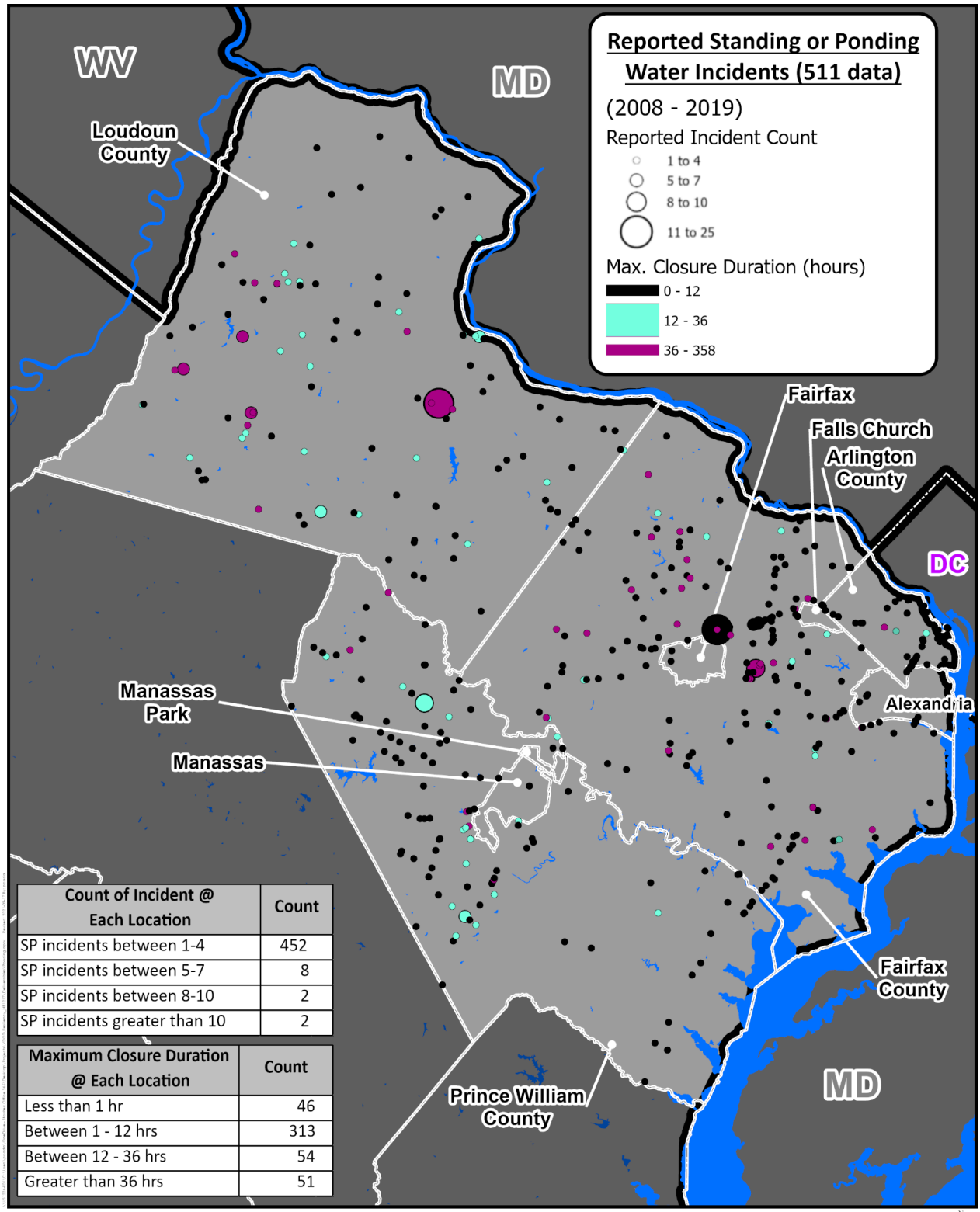
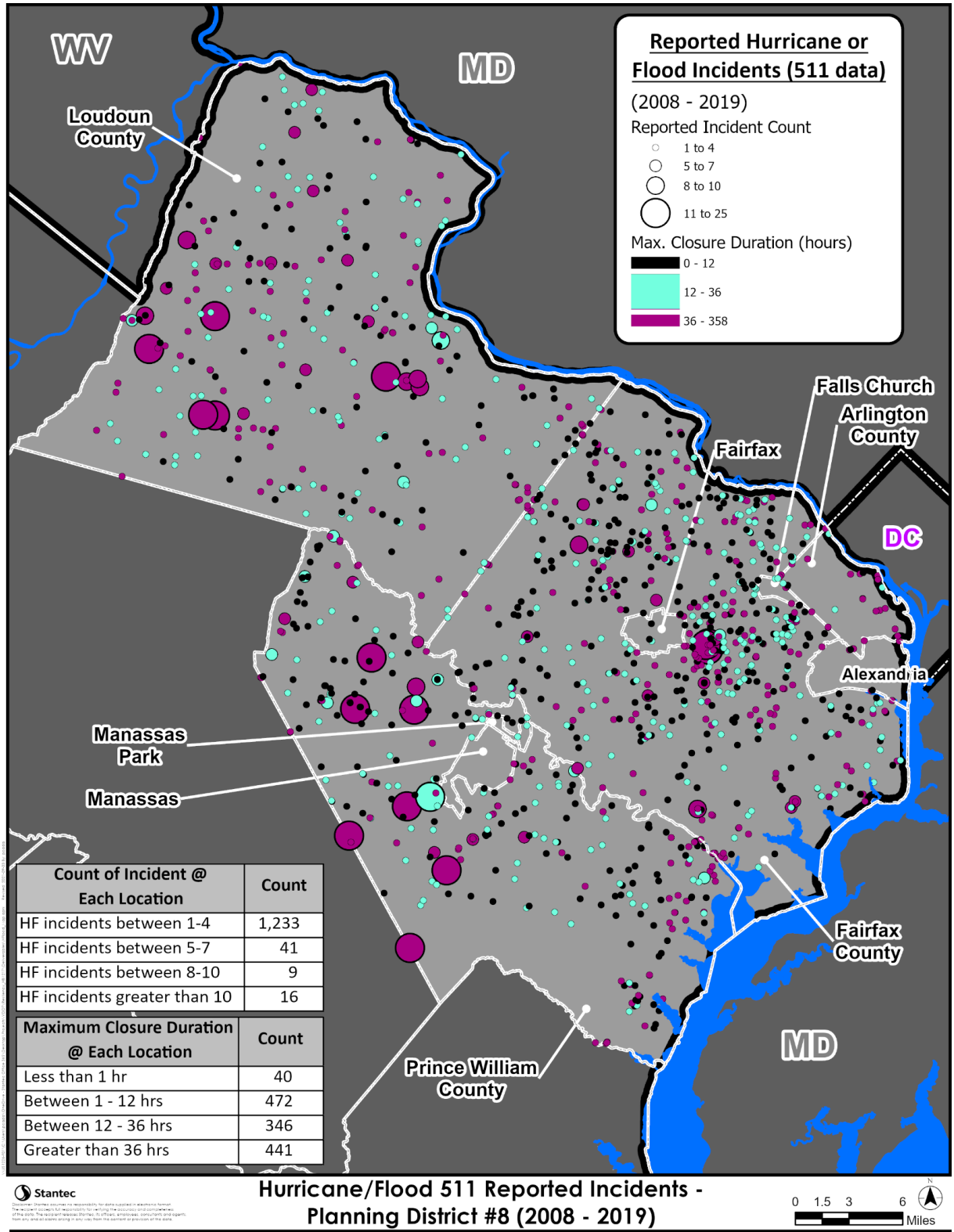


Figure 4, Standing/Ponding Reported Incidents from 511 database from 2008 to 2019.



Count of Incident @ Each Location	Count
HF incidents between 1-4	1,233
HF incidents between 5-7	41
HF incidents between 8-10	9
HF incidents greater than 10	16

Maximum Closure Duration @ Each Location	Count
Less than 1 hr	40
Between 1 - 12 hrs	472
Between 12 - 36 hrs	346
Greater than 36 hrs	441

Figure 5, Hurricane/Flooding Reported Incidents from 511 database from 2008 to 2019.

C. Road Closures and Known High Water Locations in VDOT's NOVA District

In addition to the 511 data, VDOT's NOVA District also documents information regarding flooding on roadways for some localities through the course of their operations and based on area knowledge. VDOT Residencies log this information for Fairfax, Prince William, and Loudoun Counties and this is provided in Appendix A for reference.

VDOT's Fairfax Residency[5] documents high water locations and collects the following information: presence of flip signs, sign wording, sign verification picture, route #, street name, starting point, ending point, GPS location, drainage structure present, structure type, flood cause, and additional notes. Table 2 shows an excerpt of collected data and fields. This table does not display all the fields and information.

Table 2, Excerpt from VDOT's Fairfax Residency Data of Known High Water Locations.

Has Flip Signs	Sign Wording	Route #	Street Name	Starting Point - Street Name	Ending Point - Street Name
Mt. Vernon AHQ					
No Sign	N/A	611	Old Colchester Rd.	Approx. at 9700 Old Colchester Rd.	N/A
No Sign	N/A	611	Old Colchester Rd.	Hassett St.	Greene Dr.
No Sign	N/A	623	Old Mill Rd.	Dogue Dr.	Rosemary Lena Way
McClean AHQ					
No Sign	N/A	2804	Valley Wood Rd.	1901 Valley Wood Rd.	1906 Valley Wood Rd.
No Sign	N/A	689	Chesterbrook Rd.	Maddox Ln.	6034 Chesterbrook Rd.
No Sign	N/A	695	Kirby Rd.	Claiborne Dr.	1358 Kirby Rd.
No Sign	N/A	7	Leesburg Pike	Gallows Rd.	Gallows Rd.
No Sign	N/A	703	Shreve Rd.	Wieland Pl.	Buckelew Dr.
No Sign	N/A	650	Magrity Rd.	Great Falls St.	Great Falls St.
No Sign	N/A	693	Westmoreland St.	Lemon Rd.	Somerville Dr.

In addition, VDOT's Fairfax Residency keeps documentation of identified locations with known flooding issues with notes identifying cause of flooding. An excerpt of this information is displayed in Table 3.

[5] VDOT's NOVA District is composed of the Fairfax, Prince William, Loudoun, and Arlington/Interstate Residencies.

Table 3, Excerpt from VDOT's Fairfax Residency Data of Identified Locations with Known Flooding Issues.

Location	Notes
Brilyn Place & N. West	Curb and gutter improvements needed
Swinks Mill Road at Georgetown Pike	Pipe and ditch improvements needed
Swinks Mill Road (Between Georgetown Pike and Old Dominion)	Crossover pipe on is undersized.
Lawyers Road (east of Hunter Mill	Several undersized and failing crossover pipes.
Browns Mill Road at 1500 Pennycress Lane	Low lying area on Brown Mill Rd. at bridge/culverts for Difficult Run between Windstone Dr. and Rosewood Hill.

VDOT's Prince William Residency also collects information on flooded roadways. The following information is included in their documentation: date, road/intersection, road status, call type/event details, road closure sheet notes, time closed, and time opened. Table 4 shows an excerpt of collected data and fields. This table does not display all the fields and information.

Table 4, Excerpt from VDOT's Prince William Residency Flooded Roadways Data.

Date	Road/Intersection	Road Status	Call Type/Event Details	Road Closure Sheet Notes
5/14/2018	TURNER/ RR	CLOSURE	Flash Flooding due to Severe Thunderstorm	Tracks being flooded
5/31/2018	ADEN RD / PARKGATE DR	CLOSURE	Flash Flooding; Flood Warning due to Severe Thunderstorm	Aden Shut Down between Fitzwater and Parkgate
6/1/2018	OLD CHURCH RD / CROCKETT RD	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain	High Water
6/2/2018	JEFFERSON DAVIS HWY / FULLER RD	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain	Road Closure: Jefferson Davis Hwy @ Fuller Road is completely closed due to very high water
6/3/2018	ADEN RD / PARKGATE DR	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain	Flooded/ Impassable
6/3/2018	OLD CHURCH RD / CROCKETT RD	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain	Impassable; 2.5-3 ft of water; receding slowly
7/21/2018	Fitzwater Dr. / Aden Rd	CLOSURE	Aerial Flood Warning; 2 inches of heavy rain exceeding 1" /hour	Flooded but passable
7/21/2018	Hickerson Lane	CLOSURE	Aerial Flood Warning; 2 inches of heavy rain exceeding 1" /hour	Flooded, unknown if passable
7/21/2018	Carriage Ford Rd from Aden Rd to PSA	CLOSURE	Aerial Flood Warning; 2 inches of heavy rain exceeding 1" /hour	Flooded in numerous places
7/21/2018	Wellington RD between Williams Way / Rollings Ford Rd	CLOSURE	Aerial Flood Warning; 2 inches of heavy rain exceeding 1" /hour	Flooded, impassable

Similarly, VDOT's Loudoun Residency also keeps track of their flooded roadways and collects the following information: location point of reference, latitude and longitude, drainage area, number of events/frequency per year, impacts of flooding, description of events, public safety impacts, and road types. Table 5 shows an excerpt of collected data and fields. This table does not display all the fields and information.

Table 5, Excerpt from VDOT's Loudoun Residency Flooding Hotspots Data.

Location Point of Reference	Latitude	Longitude	# of Events/ Frequency Per Year	Impacts of Flooding	Description of Events	Public Safety Impacts	Road Types
36789 Snickersville Turnpike	39.0628	-77.7467	1 to 3	Road floods during heavy rain due to stream	Road floods	Roads is closed until water recedes.	Paved
39990 Oatlands Mill Road	39.0318	-77.6175	2 to 3	Road floods during heavy rain due to stream	Road floods	Roads is closed until water recedes.	Paved/Gravel
Alder School Road just west of Berlin Turnpike	39.159	-77.6986	1 to 2	Road floods during heavy rain due to stream	pipes under road get overwhelmed on a heavy rain	Roads is closed until water recedes.	Paved/Gravel

D. Road Network & Systems Analysis

As mentioned in Section I, VDOT is collaborating with CCRFR consortium member VIMS on a road network and systems analysis. This analysis focuses on land areas where road closures due to frequency of recurrent flooding result in the increased vulnerability of communities and their critical and sensitive transportation infrastructure, and the ability of VDOT to provide services to the community. The road network analysis will provide critical information to VDOT that may further inform and identify vulnerable infrastructure requiring mitigation in order to adapt to present or future conditions due to sea level rise. PD8 was designated as one of the focal areas for the initial analysis, which centered on identifying vulnerable infrastructure within PD8 localities. Due to time constraints, the results and findings of the aforementioned study were not available or finalized prior to the submission of this report at the start of the 2022 Session of the General Assembly.

Current and projected frequency of water levels at different elevations are currently being developed for PD8. Flood frequencies are being calculated from NOAA tide gauge data and the mean future sea levels are being based on Sea Level Report Card projections (VIMS) until 2050

and the NOAA (2017) sea level rise analysis[6] for time periods after 2050. Concurrently, a road network with land elevations based on the North American Vertical Datum of 1988 (NAVD88) is also being developed for this PD8 analysis. Road networks and road centerline data acquired from the OSM database are being utilized and correlated to VDOT roadways. Elevations are being mapped to the roads using high resolution land use and light detecting and radar (LiDAR) data available through the Virginia Geographic Information Network (VGIN).

Using raster processing and network analysis tools in ArcGIS Desktop 8.0, the network analysis will be performed with an anticipated delivery date of June 2023. The current and projected flood frequencies and water levels will be tied to road elevations and routing information to assess the impact of road flooding on access to and from target areas. The analysis is intended to assess roadways and transportation pathways and how traffic can move to and from a node if a barrier (i.e. a flooded road) were encountered and whether alternate or redundant routes are available for passage or whether the target area is single access dependent and becomes isolated. Nodes that are anticipated to be utilized for this analysis will include critical and sensitive transportation infrastructure such as VDOT Area Headquarters, Residency, and District Complexes, and entrances to major arteries or evacuation routes.

IV. Identification of Issues Related to Recurrent Flooding

There are a number of potential causes and suspected issues including factors such as increases in present day precipitation over historical rainfall, legacy infrastructure installed decades ago designed to different conditions and standards, infill and rezoning leading to denser developments and larger building footprints with associated land cover changes such as compacted soils and increased impervious surfaces, past standards and designs based on conditions that existed decades ago, and funding availability. This section provides details on some of the identified issues and causes such as land cover and use change, which were evaluated through a study conducted by VIMS, and other likely contributing factors to recurrent flooding based on observations and experiences from VDOT's NOVA District personnel.

A. Rainfall/Precipitation Increase

Increased rainfall intensity, duration, and frequency is likely a contributing factor to flooding. From 1950 to 2015, the annual maximum daily rainfall total has seen an increasing trend of approximately 2 inches/century (VTRC 2019). Similarly, as documented by NOAA's Mid-Atlantic Regional Integrated Sciences and Assessments Program (MARISA), there has been a 27% increase in the heaviest precipitation events (defined as the heaviest 1% of all daily events each year) from 1958 to 2012.[7] Finally, DeGaetano (2009) documented how a 2% annual recurrence (50-year storm event) based on using historical rainfall records from 1950 to 1979 would become

[6] National Oceanic and Atmospheric Administration, *2017: Global and Regional Sea Level Rise Scenarios for United States*.
[7] *Chesapeake Bay Watershed Climate Impacts Summary and Outlook for 2018*, MARISA, https://www.midatlanticrisa.org/climate-summaries/2018/11.html, (accessed 7 April 2021

more likely to occur (equating to a 3% annual recurrence or 33-year storm) using the more recent rainfall records from the time period from 1980 to 2009.[8]

These increases have also been observed in PD8 with VDOT's NOVA District personnel indicating that an increase in rainfall events appears to be contributing to flooding issues throughout the area. It was also indicated that observed increases in precipitation varied from locality to locality and that some localities, such as the Town of Leesburg, have recently modified their intensity-duration-frequency curves, which serve as a basis for drainage design, to accommodate for increases in precipitation in their design of drainage systems.

B. Legacy Drainage Infrastructure, and Antiquated or Limited Standards

1. Legacy Infrastructure

Legacy infrastructure was also identified as a likely cause contributing to recurrent flooding in the area. For instance, legacy infrastructure installed in the early to mid-20th century was built to different (now considered antiquated) standards and has not kept up with the current built conditions and increasing precipitation. Additionally, roads that were brought into the secondary systems in the 1930's were based on limited standards or simply constructed using practical experience and existing construction best practices or techniques. Moreover, historical rainfall records relied on much older data as well as past methods such as *Technical Paper No. 40* (TP-40)[9]. In 2004, NOAA Atlas 14 was published for the mid-Atlantic region which provided updated annual recurrence intervals (i.e. 2-year, 10-year storm events) based on more recent rainfall records. For comparison, a 10-year rainfall intensity utilizing TP-40 may have been 3 inches/hour, versus 4 inches/hour based on Atlas 14. For drainage infrastructure that utilizes rainfall as an input, the antiquated data has an effect on sizing. The consequences are an issue for all entities (localities, state, federal, private) that have undertaken development or built infrastructure over the past several decades. Routine maintenance work can provide in kind replacement of these structures as needed, however, there may be instances where upgrades to drainage systems are necessary but not completed due to various factors and limited funding, which is discussed in more detail in the subsequent section.

2. Interconnections with Localities and Other Entities

Interconnection of VDOT drainage systems to localities may also be a contributing factor to recurrent flooding in some cases. VDOT may have adequately sized drainage infrastructure but flooding issues can occur when connecting to locality-owned infrastructure, which may have been built long ago and designed to older standards, effectively becoming undersized for current day conditions. Conversely, in some instances, there are also issues associated with interconnection of localities and HOA infrastructure discharging to VDOT drainage infrastructure, where it is necessary to ensure the discharge occurs appropriately without causing any other issues such as

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[8] DeGaetano, Arthur T., *2009: Time-Dependent Changes in Extreme-Precipitation Return-Period Amounts in the Continental United States*. J. Appl. Meteor. Climatol., 48, 2086– 2099.

[9] U.S. Department of Commerce, Weather Bureau, *1961: Technical Paper No. 40. Rainfall Frequency Atlas of the Unites States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years.*

erosion. VDOT is continuously interacting with the localities to improve identified drainage problems, however, funding and the associated administration capacity for the improvement projects has always been a challenge to implementation. Similar to the issues with connecting to locality-owed drainage systems, VDOT has experienced difficulty making adequate connections and discharges to historical areas and properties, and other federally-owned properties and areas due to site specific regulatory constraints.

C. Increase in Runoff from Land Cover and Use Changes

Consistent with the directive of this Study to work with CCRFR, VDOT has requested VIMS to assist in responding in order to leverage other statewide efforts, including a similar initiative to examine road vulnerability to sea-level rise and recurrent flooding in Virginia's coastal zone, as described in Section V. Since a portion of PD8 is outside of the coastal zone, however, and includes non-tidal areas where recurrent flooding is driven primarily from precipitation events in low lying areas, a supplemental study[10] was conducted to encompass PD8.

Through their prior working relationship in conducting remote sensing-related transportation research, VDOT has requested that VIMS's Center for Coastal Resources Management (CCRM) review the transportation and development pattern data available through various geospatial resources to determine the amount of development that has occurred in recent history throughout the nine localities of PD8, and determine if increased recurrent flooding can be attributed to the increase in developed surfaces, and by extension impervious surfaces, through intensive runoff.

Changes in surface area development were mapped and computed using two time steps from the National Land Cover Database (NLCD) data (using inventories from 2001, and the latest available data from 2016). Developed surfaces were then classified further into land cover type sub-classes to aid in identifying roadways and rooftops, versus other types of developed lands (i.e., high-density, medium-density, low-density). The increase in developed surfaces and the increase in intensity for each locality within PD8 is summarized in Table 6 and shown on Figures 6 and 7.

[10] Virginia Institute of Marine Science, Center for Coastal Resources Management, *2021: Land Use Change and Recurrent Flooding Issue in Northern Virginia. Report for the Virginia Transportation Research Council.*

Table 6, Increase in Developed Surfaces and Development Intensity Increase in Localities within Planning District 8.

Locality	Increase in Developed Surfaces				
	Natural Land Converted to Development (in acres)				Increased Intensity of Existing Development (in acres)
	To Open Development	To Low Intensity Development	To Medium Intensity Development	To High Intensity Development	
Alexandria	22.7	20.5	23.8	23.1	202.7
Arlington	43.4	31	17.8	2.9	315
Falls Church	5.1	4	0.2	0.2	19.3
Fairfax	2703.8	1,730.3	1,561.6	462.4	3,129.8
Loudoun	5,558.7	5,573.3	5,712.5	1,260.2	2,024.8
Manassas	36.7	30.6	54.1	9.9	300.4
Manassas Park	16.9	31.5	49.9	7.9	35.3
Prince William	4,917.4	4,997.7	3,989.3	782.8	1,864.1
TOTAL	**13,307.7**	**12,418.9**	**11,409.2**	**2,549.4**	**7891.4**

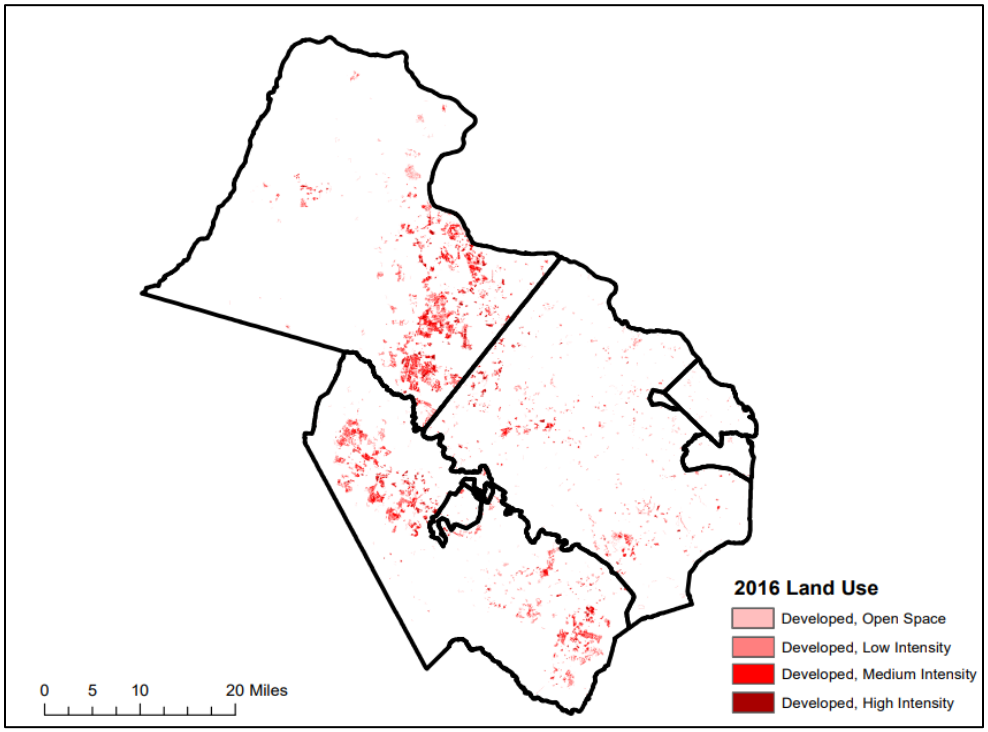

Figure 6, Change in Development from 2001 to 2016 in Planning District 8.

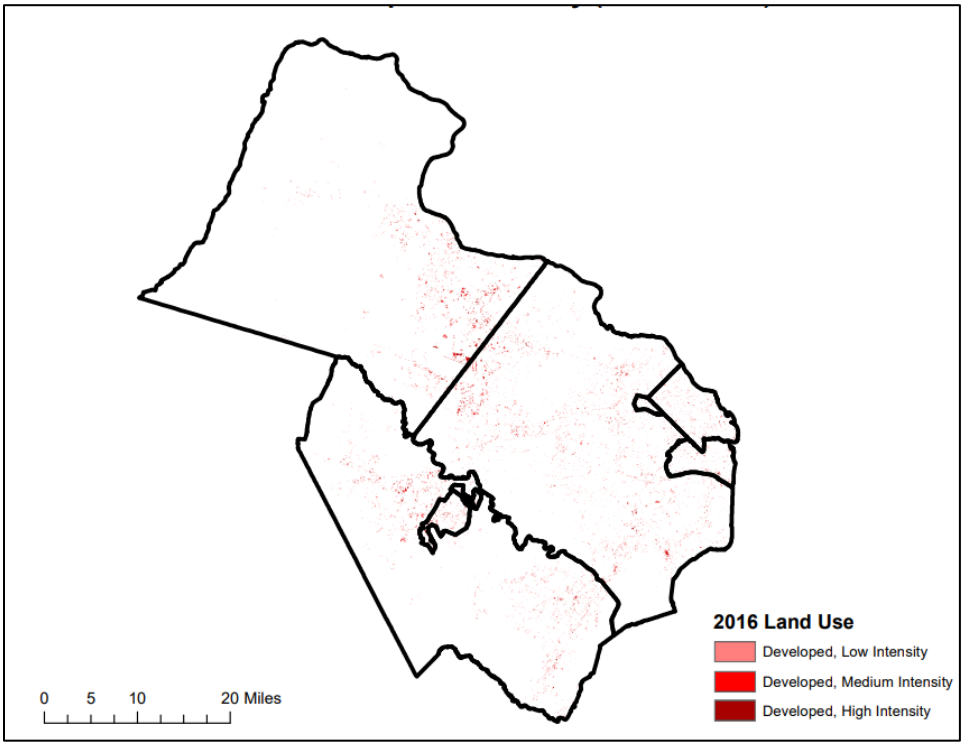

Figure 7, Increase in Intensity of Development from 2001 to 2016 in Planning District 8.

The data regarding change in developed surfaces, development intensity, and associated impervious surfaces, was further analyzed by identifying areas where these changes were occurring in flood prone areas as identified by FEMA'S National Flood Hazard Layer (NFHL) within the 100-year and 500-year floodplains. The high-risk flood prone areas are identified by the Virginia Flood Risk Information System, co-developed by CCRM and the state's Flood Plain Management Division of the Department of Conservation and Recreation (DCR). Tables 7 and 8 summarize the results of the analysis.

Table 7, Increase in Developed Surfaces and Development Intensity Increase within the 100-year Floodplain in PD8.

Locality	Increase in Developed Surfaces (100-Year Floodplain)				
	Natural Land Converted to Development (acres)				Increased Intensity of Existing Development (acres)
	To Open Development	To Low Intensity Development	To Medium Intensity Development	To High Intensity Development	
Alexandria	4.4	6.2	11	15.6	26
Arlington	4.2	1.1	0.9	0.2	26.2
Falls Church	0	0	0	0	0
Fairfax	151.8	58.1	27.3	7.7	93.9
Loudoun	294.4	107.6	57.9	11.4	48
Manassas	4.8	4.4	0.7	0.2	26.2
Manassas Park	3.3	1.5	0.9	0	4.4
Prince William	195.1	88.4	40.5	3.5	55.2
TOTAL	**658**	**267.3**	**139.2**	**38.6**	**279.9**

Table 8, Increase in Developed Surfaces and Development Intensity Increase within the 500-year Floodplain in Planning District 8.

Locality	Increase in Developed Surfaces (500-Year Floodplain)				
	Natural Land Converted to Development (acres)				Increased Intensity of Existing Development (acres)
	To Open Development	To Low Intensity Development	To Medium Intensity Development	To High Intensity Development	
Alexandria	0	0	1.1	0.7	8.6
Arlington	1.3	0	0.4	0	22
Falls Church	0	0	0	0	0
Fairfax	2.9	0.9	2.6	0.2	4.2
Loudoun	33.7	22.7	21.1	3.7	4.6
Manassas	0.4	0.2	0.4	0	10.3
Manassas Park	0	0	0	0	0
Prince William	27.3	16.1	11.7	0.9	26.6
TOTAL	**65.6**	**39.9**	**37.3**	**5.5**	**76.3**

In addition, slope analyses and an elevation risk assessment were performed to identify any significant topographic changes that simulate drainage away from pavement. A flow accumulation analysis was also performed for facilities and roadways to identify areas where flow accumulation is highest, which indicates greater flow to the given area. The results of these analyses were combined with the change in developed surfaces and development intensity in flood prone areas to assist in identifying the five areas of greatest risk for each locality in PD8, according to the methodology described here.

First, three areas were selected where a change in slope of greater than 15 degrees occurred between 2006 and 2016 (slope calculations by locality). Then, within each locality, those highest slope change areas (plus or minus 25 degrees) were converted to vector polygons. The overlay of many areas with the flow accumulation information and the change detection in floodplains among these steepest changes in gradient were then used to determine the five areas of greatest potential flood risk by locality. The highest values for flow accumulation in each locality were prioritized above those with less accumulation within 5 meters of VDOT-maintained roads, and were ranked as the second most important input for this combined evaluation metric. Finally, areas within PD8 with increased changes towards more developed lands since 2000 within FEMA's NFHL were considered in this combined analysis. Increases in developed land cover changes in the currently recognized 100-year and 500-year floodplains in Virginia already are known to result in increased rainwater runoff due to the addition of impervious surface areas. These layers identified areas with the greatest change towards highest density urban development over those areas where less significant development was detected. VIMS has noted that flood frequency is expected to become worse as FEMA continues to update the NFHL and as coastal sea levels are projected to continue to rise. Most of the five resulting locations for this combined analysis had at least two of these layers overlapping.

The five areas of greatest risk, according to the methodology used in this VIMS analysis for each of the localities in PD8 are identified and shown in Figure 8. Many of the areas at most

risk were either naturally adjacent to the Potomac River and its tributaries, or areas where the slope gradient has experienced a large change towards the extremes. Table 9 also summarizes the roadways and VDOT facilities that are within the identified areas of most risk per the analysis. One of the limitations of this analysis is that the NLCD compared land cover data from the year 2001 to 2016, which does not capture changes occurring from the early or mid-1900's through 2000, including the presence of older infrastructure already that was already in place. The short window of the analysis, nevertheless, does provide insight on changes over the last two decades and yields a sense of the magnitude of change in these localities. VDOT is still evaluating the results of this VIMS analysis, including as it relates, or contrasts to, past historical road closures, Residency information, and feedback provided from District personnel based on local knowledge and experiences.

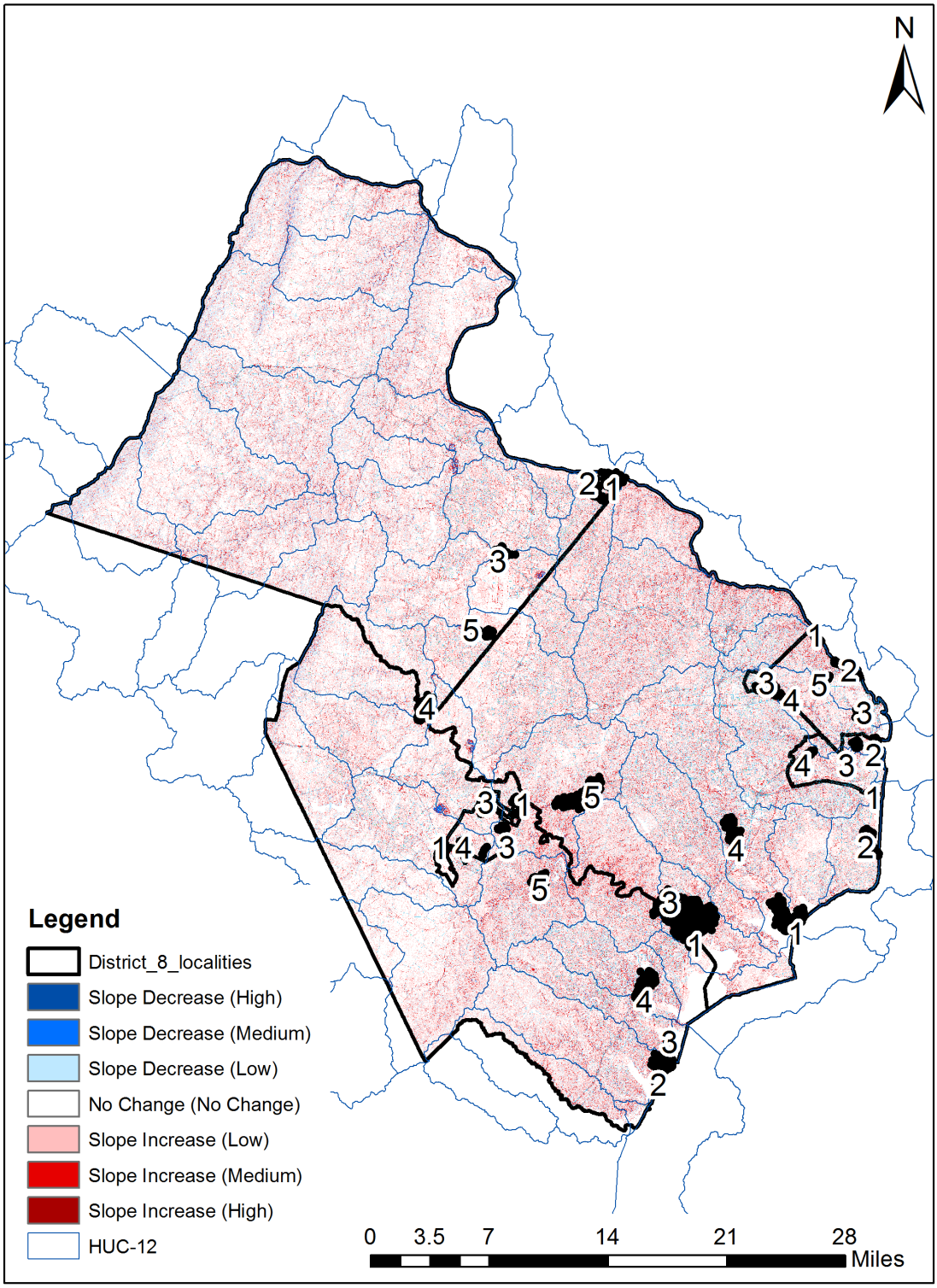

Figure 8, Areas of Most Risk according to the VIMS analysis for Flooding in Each Locality in Planning District 8.

			Streets Affected			
Locality	Rank	HUC-12	Street 1	Street 2	Street 3	VDOT Facility
City of Alexandria	1	20700100302	Rt1 Nb Ramp To I95 Nb Local Ramp	I95 Sb Local Ramp To Rt1 Nb Ramp	S Patrick St	WOODROW WILSON BRIDGE
City of Alexandria	2	20700100301	George Washington Memorial Parkway	Jefferson Davis Highway	Potomac Avenue	
City of Alexandria	3	20700100302	King Street	Chinquapin Drive	Scroggins Road	
City of Alexandria	4	20700100302	Henry G. Shirley Memorial Highway	North Van Dorn Street		
City of Alexandria	5	20700100301	Old Dominion Boulevard	Canyon Drive	Alabama Avenue	
City of Arlington	1	20700100103	Chain Bridge Road	North Glebe Road	George Washington Mem. Pkwy	
City of Arlington	2	20700100103	George Washington Memorial Parkway	Spout Run Parkway	22nd Street North	
City of Arlington	3	20700100103	Washington Boulevard	Army Navy Drive	South Arlington Ridge Road	COLUMBIA PIKE MAINT/OPER COMPLEX
City of Arlington	4	20700100103	Arlington Boulevard	North Fort Myer Drive	17th Street North	
City of Arlington	5	20700100103	Custis Memorial Parkway	North Kirkwood Road	North Johnson Street	
Fairfax County and City of Fairfax	1	20700100402	Patrick Road	Putnam Road	Sultan Loop	
Fairfax County and City of Fairfax	2	20700100307	George Washington Memorial Parkway	Fort Hunt Road	Morningside Lane	
Fairfax County and City of Fairfax	3	20700100803	Lorton Road	Ox Road	Henry G. Shirley Memorial Highway	
Fairfax County and City of Fairfax	4	20700100402	Franconia-Springfield Parkway	Barta Road	Rockledge Court	NEWINGTON AREA HDQTRS
Fairfax County and City of Fairfax	5	20700100705	Chapel Road	Fairfax Station Road	Colchester Road	
City of Falls Church	1	20700100302	S Washington Avenue	S Maple Avenue	W Westmoreland Road	
City of Falls Church	2	20700100301	N Van Buren Street	E Jefferson Street		
City of Falls Church	3	20700100301	Little Falls Street	W Columbia Street		
City of Falls Church	4	20700100301	Roosevelt Boulevard			
City of Falls Church	5	20700100302	East Broad Street			
Loudoun County	1	20700080905	Watermark Place	Center Brook Square	Sinegar Place	
Loudoun County	2	20700080905	Algonkian Parkway	Middle Bluff Place	River Bank Street	
Loudoun County	3	20700080902	Dulles Greenway Ramp	Old Ox Road	Moran Road	
Loudoun County	4	20700100701	Gum Spring Road	Cedar Ridge Boulevard		
Loudoun County	5	20700100704	West Perimeter Road	Willard Road	Tanners Lane	CHANTILLY AREA HDQTRS
City of Manassas	1	20700100504	Prince William Parkway	Gateway Boulevard		NORTHERN VA DISTRICT RESIDENCY OFFICE
City of Manassas	2	20700100703	Stonewall Road	Tillett Loop		
City of Manassas	3	20700100705	Liberia Avenue	Quarry Road	Richmond Avenue	
City of Manassas	4	20700100504	Central Park Drive			
City of Manassas	5	20700100504	Dumfries Road	Hastings Drive	Orchard Lane	
City of Manassas Park	1	20700100705	Enterprise Court	Industry Drive		
City of Manassas Park	2	20700100705	Corbett Place	Pickens Place		
City of Manassas Park	3	20700100703	Moseby Drive	Kirby Street		
City of Manassas Park	4	20700100705	Oak Street	Leighlex Court	Glade Bank Drive	
City of Manassas Park	5	20700100703	Kent Drive	Holden Drive	Colfax Drive	
Prince William County	1	20700100803	Gordon Boulevard	Union Street	Mill Street	
Prince William County	2	20700110106	Cockpit Point Road	River Heritage Boulevard		
Prince William County	3	20700110106	Harbor Station Parkway	Cherry Hill Road		
Prince William County	4	20700100804	I95 SB	River Rock Way	Landings Point Loop	DALE CITY AHQ (TAMS)
Prince William County	5	20700100801	Prince William Parkway	Stonebrook Drive	Sandal Wood Lane	

Increase in runoff related to development and urbanization in general is contributing to flooding but, in particular intensifying infill development plays a significant role. Infill development typically occurs in urban areas and refers to development of unused or underutilized lands within existing development patterns.

VDOT's NOVA District personnel stated, during discussions related to the problem of recurrent flooding, that while some of the drainage infrastructure was built in past decades, there is newer infill development occurring at high densities through rezoning, additional entitlements, and/or by right. The infill development increases impervious surfaces whereby larger house/building footprints replace existing smaller house/building footprints. As a result, the installed legacy infrastructure that was not designed for such intensities becomes overwhelmed. Although the newer development is designed using newer standards, the legacy infrastructure receiving drainage from the newer development is often not adequately sized to receive the aggregate of increased flows.

VDOT personnel also noted that, in some cases, drainage pathways are being filled to accommodate development such as driveway culverts or roadside ditches to make way for on-street parking. Historical development within floodplains and surrounding areas are known to be contributing to the drainage problems and recurrent flooding experienced in this area. Additionally, personnel raised concerns about development in the area in general and whether adequate watershed modeling is being performed to ensure drainage and flooding issues are properly addressed and incorporated in the development. One of the concerns is that infill development is generally assessed on an individual project by project basis instead of at the larger watershed scale to understand the cumulative impacts.

D. Limited Funding Availability and Mechanisms

Funding, and the associated administrative capacity to implement funding goals, remains the primary and biggest challenge in addressing flooding issues. Funding levels directly affect the ability of the VDOT's NOVA District and localities to provide necessary upgrades to drainage infrastructure in identified areas of recurrent flooding. Related to funding is the administration of and support staff needed to carry out and deliver any additional projects that would be enabled should funding become available.

Maintenance is routinely performed for VDOT assets that are in areas where recurrent flooding and resultant damage occurs. As previously mentioned, routine maintenance typically consists of in kind replacement, whereby replacement is accomplished through the installation of a comparable structure. While a hydrologic and hydraulic (H&H) study could be performed to determine whether an in kind replacement would provide adequate drainage for today's conditions and alleviate flooding, circumstances may not always allow. This is particularly the case when considering time-sensitive emergency repairs needed to restore service. In other non-emergency circumstances, there may be limited funding available for the Commonwealth's maintenance needs. The scope of drainage improvement projects requiring more detailed H&H analysis and design efforts are generally considered to be beyond routine maintenance through in kind replacement.

In addition to longer timelines, more extensive maintenance protocols inclusive of detailed H&H studies are likely to incur increased design and construction costs, such as the cost of right-of-way acquisitions and utility adjustment, which can be very expensive, especially in Northern Virginia. As previously mentioned, the availability of funding for localities to address drainage issues and improvements is limited as well. Currently, VDOT and some localities (i.e. Fairfax County) have utilized the County Safety and Operational Improvement (CSOI) program to fund projects associated with flooding and drainage improvements.

E. Compounding Effects

It is evident that there is an interplay of a number of contributing causes and issues to recurrent flooding in PD8. The land use and cover change study conducted by VIMS shows that development and urbanization leads to an increase in impervious surface, which in turn leads to an increase in intense runoff that directly contributes to recurrent flooding. Additionally, rainfall variability over time, legacy infrastructure designed to now-outdated standards and built conditions decades ago, funding and administrative availability, and other factors as discussed in this Study have been found to be contributing to recurrent flooding in PD8.

V. Policy Recommendations

VDOT recognizes that the causes of recurrent flooding in PD8 are partially due to historical causes, development over time at the local level, as well as the broader impacts of climate change currently being evaluated by the Commonwealth at multiple levels. As such, VDOT is actively involved in several ongoing studies and initiatives related to climate change and resiliency that

inform how issues related to recurrent flooding and at risk infrastructure can be addressed. Based on the foregoing, a discussion of the recommendations are presented below.

A. Support Key Statewide and Regional Studies

As previously stated, there are a number of ongoing studies and initiatives regarding climate change, resiliency, and flooding risks at the state, regional, and local levels. Support for key statewide and regional studies is recommended. Key studies include, among others, the update to the authoritative NOAA Atlas 14 rainfall records, which currently only includes data through 2004, to include more recent historical records for the state and improve accuracy. In addition, active development, participation, and funding is recommended to be continued for key studies such as the statewide expansion of the precipitation study to estimate future projected rainfall patterns. VDOT also recommends the identification of data gaps and the initiation of applied research to be directly used by engineers and designers. Examples could include future projected streamflow estimates for very large drainage systems and adaptive design standards that can be utilized in future at risk projects.

B. Participation and Coordination with Major Commonwealth Efforts

Active participation and alignment efforts and policies with major statewide efforts such as the *Virginia Coastal Resilience Master Planning Framework* and the future Coastal Resiliency Master Plan document, as well as JCOT's report on the *Impact of Climate Change on Virginia's Coastal Areas*, among others, is recommended, as well as continued collaboration with other entities and stakeholders. The following section outlines the primary goals of the *Virginia Coastal Resilience Master Planning Framework* as well as the recommendations from the JCOT's report.

1. Virginia Coastal Resilience Master Planning Framework

Released in October 2020, the *Virginia Coastal Master Planning Framework* set out to establish fundamental principles on the best ways to approach and tackle coastal adaptation and protection in coastal Virginia. By the end of 2021, the Commonwealth intends to begin the implementation of the future Coastal Resilience Master Plan, which has as one of its primary objectives the Commonwealth's resiliency and adaptability to sea level rise. The Master Plan also observes an increase in nuisance flooding and more frequent and intense storms, which are attributed to climate change. Listed below are the *Virginia Coastal Master Planning Framework* primary goals and guiding principles.

<u>Master Planning Framework Primary Goals:</u>

1. Identify priority projects to increase the resilience of coastal communities, including both built and natural assets at risk due to sea level rise and flooding;
2. Establish a financing strategy, informed by regional differences and equity considerations, to support execution of the plan;
3. Effectively incorporate climate change projections into all of the Commonwealth's programs addressing coastal zone built and natural infrastructure at risk due to sea level rise and flooding; and

4. Coordinate all state, federal, regional, and local coastal adaptation and protection efforts in accordance with the guiding principles of the Framework.

Master Planning Framework Guiding Principles:

1. Acknowledge climate change and its consequences, and base decision-making on the best available science;
2. Identify and address socioeconomic inequities and work to enhance equity through coastal adaptation and protection efforts;
3. Recognize the importance of protecting and enhancing green infrastructure like natural coastal barriers and fish and wildlife habitat by prioritizing nature-based solutions;
4. Utilize community and regional scale planning to the maximum extent possible, seeking region-specific approaches tailored to the needs of individual communities; and
5. Understand fiscal realities and focus on the most cost-effective solutions for protection and adaptation of our communities, businesses and critical and sensitive transportation infrastructure.

With the challenges currently being faced in the Commonwealth, the *Virginia Coastal Resilience Master Planning Framework* is presented as an opportunity for the Commonwealth to comprehensively address climate change and prioritize resiliency.

2. The Impact of Climate Change on Virginia's Coastal Areas (VASEM & JCOTS)

The Virginia General Assembly directed JCOTS to study and to accept any scientific and technical assistance provided by the nonpartisan, volunteer Virginia Academy of Science, Engineering, and Medicine (VASEM) to evaluate the safety, quality of life, and economic consequences of weather and climate-related events on coastal areas in Virginia.[11]

The report submitted by VASEM outlines the science, research, and other efforts conducted to accomplish the directives given by the Virginia General Assembly. The report finds that climate change will have an increasingly disruptive effect on people living in Virginia's coastal areas during the 21st century—and that these disruptions will have repercussions across the Commonwealth. The report further details the physical forces driving climate change, an analysis of the current and projected effects of climate change on the Commonwealth, the perspectives that legislators might consider as they face these challenges, and recommendations that could help Virginia implement more productive and effective strategies to address them.[12]

The JCOTS report provides four recommendations to improve the state's response to climate change and its impact on coastal areas as follows:

1. Establish a structure for more effective collaboration and coordination;
2. Address gaps in policy and procedure;

[11] Virginia Academy of Science, Engineering, and Medicine, *2021: The Impact of Climate Change on Virginia's Coastal Areas*.
[12] Ibid.

3. Create a body to coordinate and support critical data collection and technology transfer across the Commonwealth; and
4. Provide meaningful economic innovation and incentives to build a resilience economy in Virginia.

C. Continual Improvement and Coordination of Datasets and Tools

It is recommended that VDOT continue to collaborate with other entities to improve, update, and expand existing datasets and tools, or create new ones where needed, related to recurrent flooding. As an example, VIMS has been assigned the task of developing a portal with meaningful tools that ultimately enhance the ability of VDOT to address recurrent flooding and the resulting vulnerability of the transportation infrastructure and the impacted ecosystem throughout the Tidewater area, which includes the tidal communities in PD8 region. Within the portal, VDOT and local governments will be able to link to documents, maps, and data. The ArcGIS platform will have an important role through interactive management tools that display geospatial data and model output enabling end users to proactively manage and plan for these impacts and mitigation challenges. The anticipated delivery date of such portal is in June 2024.

There are a number of other concurrent efforts directed at resiliency preparation, such as data gathering on areas of recurrent flooding, risk and vulnerability assessments for flood prone areas, flooding frequencies, and water level projections for high risk and vulnerable areas. It is important to recognize that collaboration is needed in order to leverage these efforts effectively. It is also important to note that there will be an ongoing need to refine and update the datasets and tools as better data, methodology, and technology become available.

D. Continual Assessment of Transportation Network

It is recommended that VDOT continue to assess recurrent flooding issues through the participation and support in the transportation focused efforts and studies outlined below:

1. VTrans Vulnerability Assessment

VTrans, the statewide transportation plan, created an assessment that examines the vulnerability of Virginia's transportation system to climate change. The assessment informs the development of VTrans' Midterm and Long Range Transportation Plans and focuses on vulnerabilities from sea level rise, storm surge, and inland/riverine flooding. Both primary (e.g., major highways, bridges on major highways) and secondary (e.g., passenger rail, transit, ports, airports) transportation assets are included in the assessment.

The primary assets were assessed in a quantitative manner through an indicator-based methodology that was based on FHWA's Vulnerability Scoring Tool for VTrans' primary transportation assets across the state. This approach uses data on asset location and other key attributes to serve as indicators of each of the three components of vulnerability which are exposure, sensitivity, and adaptive capacity. The study is ongoing.

2. Project Atlantis

VDOT's Office of Strategic Innovation conducted literature reviews on flooding in Virginia, specifically Fredericksburg, to determine what research has been performed in the areas of flood mitigation and its relationship to changes in weather conditions. The project was focused on identifying maintenance activities and recommended mitigation techniques alleviating flooding and evaluating methodologies and approaches for modeling and measuring changes in flood zones, frequency, and analyzing other flood and infrastructure characteristics. The study is currently underway.

3. Climate Adaptation of Transportation Infrastructure

VIMS, in collaboration with VDOT's VTRC, has an ongoing project to assist VDOT in understanding and addressing sea level rise, land subsidence and recurrent flooding impacts on existing and planned road infrastructure and to assess how that infrastructure will impact natural ecosystems in Virginia's coastal zone. The project incorporates three fundamental elements that any major public service agency must address when considering climate change impacts: science, management and policy. Portions of this project are referenced in Section III (A), Section III (D), and Section V (C) of this report. The remaining tasks include an evaluation and modeling of impacts of sea level rise to habitats and threatened and endangered species and policy analysis on road abandonment as it relates to recurrent flooding.

4. VDOT's Structure and Bridge Division's Considerations of Climate Change and Coastal Storms and Location and Design Division's Drainage Manual Revisions

VDOT's Structure and Bridge Division developed Chapter 33 of the *Manual of Structure and Bridge Division*, "Considerations of Climate Change and Coastal Storms," which details how VDOT is implementing new design standards aimed to make bridges and transportation structures more resistant to the effects of climate change. The Structure and Bridge Division identified temperature change, salinity, precipitation or rainfall intensity, and SLR as four factors that may affect bridges. The guidelines of Chapter 33 direct engineers and designers to account for those four factors in an effort to make the lifespan of a bridge last more than 100 years.

This new Chapter 33 includes (i) material considerations to address salinity and temperature changes; (ii) adjustments to deck drainage, scour, stream pressure, and buoyancy design parameters to address increased rainfall intensity and discharge; and (iii) bridge layout and profile adjustments and design considerations for abutment and riprap, erosion, slope stability, and selection of materials to address sea level rise. VDOT has also made conforming revisions throughout the Location and Design Division's *Drainage Manual* to ensure consistency with the provisions in Chapter 33, including revisions to Chapter 6 on "Hydrology" (in order to compute 200-year stream flows needed for scour computations) and Chapter 12 on "Riverine Analysis" (to add bridge scour computations associated with the 200-year streamflow discharge event). Additional changes to VDOT's *Drainage Manual* are anticipated to accommodate relevant findings of studies and evaluations regarding key climatic changes that may affect drainage design.

E. Enhanced Collaboration and Partnership between State and Localities

The Commonwealth and its localities should continue to enhance their collaboration and partnership in identifying infrastructure subject to recurrent flooding, evaluating potential causes, and implementing solutions to alleviate the problem. Since the problem of recurrent flooding knows no boundaries, political or geographical, it is important to recognize that solutions entail coordination and collaboration between the state and localities. As presented in this Study, certain contributing challenges to recurrent flooding problems may be resolved by addressing interconnection issues between state and localities, and aligning design criteria for drainage structures, to ensure consistency and prevent areas of drainage failures. Although there is current collaboration between the state and localities, the dialog will need to be enhanced in order to address the widespread problem of recurrent flooding

F. Funding of Flood-Related Projects

While it is currently premature to make specific funding recommendations, it is clear that funding for several key activities necessary in the development of a program and strategies to address recurrent flooding and resiliency in transportation infrastructure will need to be identified. Those activities include but are not necessarily limited to:

Funding for Studies that will lead to (i) the more precise identification of vulnerable assets, robust assessment of risk, accurate cost benefit analysis and prioritization for proposed improvements to infrastructure experiencing recurrent flooding and (ii) development of design standards and measures to ensure resilience in existing and new infrastructure.

Funding for Infrastructure Improvements that would be used to address existing infrastructure that is prone to recurrent flooding, based on established priorities.

Funding for Tools and Technology for Flood Prone Areas that could be used at the state and local level in identifying, developing, enhancing, and implementing tools and technology to mitigate risks for areas currently prone to recurrent flooding. These tools and technologies can be useful for existing flood-prone areas while waiting for funds to be made available for the necessary capital improvements.

Funding for Capacity Building that would assist the state and localities in capacity building and managing their resiliency efforts. Developing a solutions toolbox or a flooding resiliency clearinghouse to share solutions and act as a central repository, for instance, would foster and accelerate the adoption of best practices across the Commonwealth.

Sources of funding for these activities will need to be identified for state and local projects, and could include both federal and state funds, which in turn would include programmatic/formula-based funding as well as discretionary grant programs. The Infrastructure Investment and Jobs Act, recently enacted into law (P.L. 117-58), may serve as a source of funding for resilience planning and resilience-related improvements through both formula driven apportionments and competitive grants. There are also existing funding opportunities for

stormwater-related and flooding improvement projects in the form of grants such as the Building Resilient Infrastructure and Communities (BRIC) grant administered by FEMA, and the Community Flood Preparedness Fund (CFPF) administered by DCR. A limitation to consider with grant funding may be that such monies typically support the development of individual projects and cannot be relied upon as a recurring source of funds. Also, the grant application and management process can be time-intensive and competitive. Hence, additional funding dedicated for capital improvements to address at risk infrastructure, through the expansion of the current CSOI, or a creation of a new funding mechanism could serve as a reliable backstop to grant funding opportunities and to make matching funds accessible when other grants become available.

VI. Appendices

Appendix A – Northern Virginia District Data on Flooded VDOT Roadways

Prince William County Data

Date	Road/Intersection	Road Status	Call Type/Event Details	Road Closure Sheet Notes	Time Closed	Time Opened
2/11/2018	JEFFERSON DAVIS HWY/ MOUNT PLEASANT DR	CLOSURE	FLOOD; Flood Warning; 2 inches in 1 hour		622	822
3/20/2018	15605 JOPLIN RD	CLOSURE	FLOOD		1530	1605
3/22/2018	PORTNER AVE / SUDLEY RD	CLOSURE	FLOOD		835	1225
4/16/2018	MINE RD / CAMERON ST	CLOSURE	FLOOD		210	240
4/16/2018	ARTEMUS RD / PAGELAND LN	CLOSURE	FLOOD		905	1455
4/16/2018	ADEN RD / CEDAR RUN DR	CLOSURE	FLOOD		1135	1630
4/16/2018	PIPER LN / RR (TRACKS)	CLOSURE	FLOOD; Areal Flood Warning		1145	2040
4/16/2018	15595 FLEETWOOD DR	CLOSURE	FLOOD		1625	2040
5/14/2018	Turner/ RR	CLOSURE	Flash Flooding due to Severe Thunderstorm	Tracks being flooded		
5/19/2018	PIPER LN / RR (TRACKS)	CLOSURE	FLOOD; Areal Flooding Warning			
5/31/2018	PURCELL RD / HUNTERS GROVE RD	CLOSURE	Flash Flooding; Flood Warning due to Severe Thunderstorm			2013
5/31/2018	UNION ST / MILL ST	CLOSURE	Flash Flooding; Flood Warning due to Severe Thunderstorm			2013
5/31/2018	JEFFERSON DAVIS HWY / MARYS WAY	CLOSURE	Flash Flooding; Flood Warning due to Severe Thunderstorm			2013
5/31/2018	ADEN RD / PARKGATE DR	CLOSURE	Flash Flooding; Flood Warning due to Severe Thunderstorm	Aden Shut Down between Fitzwater and Parkgate		1217
5/31/2018	Dale Blvd/ Forestdale Plaza	CLOSURE	Flash Flooding; Flood Warning due to Severe Thunderstorm			2013
6/1/2018	OLD CHURCH RD / CROCKETT RD	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain	High Water	1249	0538
6/2/2018	Jefferson Davis HWY/ Russell Rd	CLOSURE	Flooding		1548	

Date	Road/Intersection	Road Status	Call Type/Event Details	Road Closure Sheet Notes	Time Closed	Time Opened
6/2/2018	JEFFERSON DAVIS HWY / FULLER RD	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain	Road Closure: Jefferson Davis Hwy @ Fuller Road is completely closed due to very high water.	1628	
6/3/2018	PURCELL RD / ROCKY BROOKE CT	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain	Closed between Purcell/Rocky Brooke and Purcell/234//high water	1530	
6/3/2018	Prince William Pkwy/County Complex	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain	Right lane W/B Pr. Wm Py. shut down at County Complex Ct due to high water	1530	
6/3/2018	ADEN RD / PARKGATE DR	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain	Flooded/ Impassable	1530	
6/3/2018	10911 REID LN	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain			
6/3/2018	11507 VALLEY VIEW DR	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain	Impassable	1530	
6/3/2018	OLD CHURCH RD / CROCKETT RD	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain	Impassable; 2.5-3 ft of water; receding slowly		
6/3/2018	15300 FLEETWOOD DR to Slate View	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain	Passable with caution; Starting to flood from Aden Dr. to Slate View	1530	6/4; 1421
6/3/2018	Wellington Rd/Cellar Door Drive	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain	High Water but passable	1530	
6/3/2018	Joplin @ MM17	CLOSURE	Flood Warning/Flash Flooding Warnings due to extended periods of rain	Minor Flooding; Passable		

Date	Road/Intersection	Road Status	Call Type/Event Details	Road Closure Sheet Notes	Time Closed	Time Opened
6/23/2018	Sudley Manor Dr/Vint Hill Rd and Darnick CT	CLOSURE	Flash Flooding due to Severe Thunderstorm	High Water - Down to 1 Lane	1911	2335
6/23/2018	11507 VALLEY VIEW DR	CLOSURE	Flash Flooding due to Severe Thunderstorm	High Water- 2 Ft over Road	2101	0355
6/23/2018	Jefferson Davis HWY/ East Longview Dr and Mt. Pleasant Dr	CLOSURE	Flash Flooding due to Severe Thunderstorm	High Water/ Passable (2135) 2 Vehicles in water (1900)	1911	1950
6/24/2018	Piper Lane/RR	CLOSURE	Flash Flooding due to Severe Thunderstorm		805	2250
7/6/2018	Jeff Davis Hwy / Mary's Way	CLOSURE	Flooding	NB Route 1 shut down @ Mary's Way/ SB shut down to one lane/ Motor units en route to set up cones/ KB	643	718
7/21/2018	Fitzwater Dr. / Aden Rd	CLOSURE	Aerial Flood Warning; 2 inches of heavy rain exceeding 1" /hour	Flooded but passable	1753	7/22/18 529
7/21/2018	Hickerson Lane	CLOSURE	Aerial Flood Warning; 2 inches of heavy rain exceeding 1" /hour	Flooded, unknown if passible	1753	7/22/18 529
7/21/2018	Carriage Ford Rd from Aden Rd to PSA	CLOSURE	Aerial Flood Warning; 2 inches of heavy rain exceeding 1" /hour	Flooded in numerous places	1753	7/22/18 529
7/21/2018	Wellington RD between Williams Way / Rollings Ford Rd	CLOSURE	Aerial Flood Warning; 2 inches of heavy rain exceeding 1" /hour	Flooded, impassable	1753	7/22/18 529
7/21/2018	ADEN RD / PARKGATE DR	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 3-4 inches of heavy rain exceeding 1" /hour	Impassable	1914	7/22/18 1530
7/21/2018	Easy St. / Jefferson Davis Highway	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 3-4 inches of heavy rain exceeding 1" /hour	Impassable	1914	7/22/18 529
7/21/2018	Glenkirk Rd / Linton Hall Rd.	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 3-4 inches of heavy rain exceeding 1" /hour	High but passable	1914	7/22/18 529
7/21/2018	Glenkirk Rd / Sterling Point	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 3-4 inches of heavy rain exceeding 1" /hour	High but passable	1914	7/22/18 529

Date	Road/Intersection	Road Status	Call Type/Event Details	Road Closure Sheet Notes	Time Closed	Time Opened
7/21/2018	Lee Highway / Featherbed Lane between Pageland Dr.	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 3-4 inches of heavy rain exceeding 1" /hour	Closed	1914	7/22/18 1016
7/21/2018	Carriage Ford Rd / Hazelwood Drive	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 3-4 inches of heavy rain exceeding 1" /hour	Flooded, impassable	1914	7/22/18 529
7/21/2018	ARTEMUS RD / PAGELAND LN	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 3-4 inches of heavy rain exceeding 1" /hour	Flooded	2012	7/22/18 1016
7/21/2018	Valleyview at Valleyview Dr.	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 3-4 inches of heavy rain exceeding 1" /hour	Flooded	2012	7/22/18 1016
7/21/2018	Sudley Dr. / Lee Hwy	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 3-4 inches of heavy rain exceeding 1" /hour	Officers on Scene blocking roads; Swiftwater rescue	2012	7/22/18 1016
7/21/2018	Aden Rd / Fleetwood	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 3-4 inches of heavy rain exceeding 1" /hour	Impassable	1914	7/22/18 529
7/21/2018	12705 Old Church Rd	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 4-6 inches of heavy rain exceeding 1" /hour	Old Church between bridge and Parkgate completely inaccessible; Swiftwater Rescue on 7/21/18	2126	7/23/18 1302
7/21/2018	Piper Lane	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 4-6 inches of heavy rain exceeding 1" /hour	Piper between Nokesville and Observation Closed	2126	7/22/18 1530
7/21/2018	Vint Hill Rd / Glenkirk	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 4-6 inches of heavy rain exceeding 1" /hour	High Water - Still passable	2235	7/22/18 529
7/21/2018	Aden Rd / Nokesville Rd	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 4-6 inches of heavy rain exceeding 1" /hour			7/22/18 645
7/21/2018	Aden Rd / Marstellrar Dr	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 4-6 inches of heavy rain exceeding 1" /hour			7/22/18 646

Date	Road/Intersection	Road Status	Call Type/Event Details	Road Closure Sheet Notes	Time Closed	Time Opened
7/22/2018	Leland Dr / Lake Dr	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 4-6 inches of heavy rain exceeding 1" /hour	Impassable. Cones set out	1016	7/23/18 1302
7/22/2018	Lake Dr / Pine St	CLOSURE	Aerial Flood Warning/Flash Flooding Warning; 4-6 inches of heavy rain exceeding 1" /hour	High Water. Cones set out	1244	7/23/18 558
7/24/2018	US 1 / Jefferson Plaza Near Easy St.	CLOSURE	Areal Flood Warning; 1 inch of heavy rain	Right lane blocked by flooding/NB lanes open	625	1056
7/25/2018	Logmill Rd / James Madison Hwy	CLOSURE	Flash Flood Warning; Heavy rain	High Water - Closed from Rt 15 to Youngs Dr	1834	2124
7/25/2018	Bethlehem Rd / Sudley Manor Dr	CLOSURE	Flash Flood Warning; Heavy rain	High Water - 1 lane closed	1834	2124
7/25/2018	11913 Cotton Mill Dr	CLOSURE	Flash Flood Warning; Heavy rain	High water and debris	1936	2124
7/25/2018	Sanders Ln / Loudon Co Line at Bull Run Creek	CLOSURE	Flash Flood Warning; Heavy rain	High water causing roadway to erode underneath; Closed	2003	2223
7/25/2018	3465 Ingram Dr	CLOSURE	Flash Flood Warning; Heavy rain	High water; cones set up	2003	2223
7/25/2018	Mine Rd / Main St	CLOSURE	Flash Flood Warning; Heavy rain	High Water from Main St. to Fairfax St.	2126	7/26/18 0101
7/30/2018	Aden between Highland Farms & Hunting Grove	CLOSURE	Flash Flood Warning; Heavy rain	High Water but passable	1836	7/31/18 1217
7/30/2018	Aden between Fleetwood Dr and Parkgate	CLOSURE	Flash Flood Warning; Heavy rain	High Water but passable	1836	7/31/18 1217
7/30/2018	Vint Hill Rd / Sudley Manor	CLOSURE	Flash Flood Warning; Heavy rain	High Water but passable	1836	7/31/18 1217
7/30/2018	Valleyview at Park/Golf Course	CLOSURE	Flash Flood Warning; Heavy rain	High Water but passable	1948	
7/30/2018	Jiffy Lube Live area	CLOSURE	Flash Flood Warning; Heavy rain	Up to 8" water on surrounding roads	1948	7/31/18 1217
7/30/2018	Wellington / Bethlehem	CLOSURE	Flash Flood Warning; Heavy rain	High Water but passable	1948	7/31/18 1217

Date	Road/Intersection	Road Status	Call Type/Event Details	Road Closure Sheet Notes	Time Closed	Time Opened
8/1/2018	Sudley Rd / NVCC Campus	CLOSURE	Flash Flood Warning; Heavy rain	High water in 234 in front of NVCC Campus	340	1048
8/1/2018	Aden Rd / Fitzwater Dr	CLOSURE	Flash Flood Warning; Heavy rain	Was high, receding and now passable	340	535
8/1/2018	Lee Highway / Groventon & 234	CLOSURE	Flash Flood Warning; Heavy rain	CLOSED 234 bridge over Youngs Branch Creek to Lee Hwy bridge by Stonehouse at the Mnss Battlefield	340	535
8/1/2018	Pageland Ln / Artemus Rd	CLOSURE	Flash Flood Warning; Heavy rain	High Water but passable	340	1048
8/1/2018	Wellington Rd / Cellar Door	CLOSURE	Flash Flood Warning; Heavy rain	Wellington in front of Jiffy Lube Live - High water but passable	340	1048
8/1/2018	Linton Hall / Glenkirk	CLOSURE	Flash Flood Warning; Heavy rain	High/standing water but passable	340	1048
8/1/2018	Aden / Fleetwood & Brookfield	CLOSURE	Flash Flood Warning; Heavy rain	High Water but passable; Closed at 1322	340	2220
8/1/2018	Yorkshire / Bull Run Rd	CLOSURE	Flash Flood Warning; Heavy rain	High / standing water, still passable Yorkshire west of Bull Run Rd	340	1048
8/1/2018	Rolling Rd / Thomas Dr & Sudley Rd	CLOSURE	Flash Flood Warning; Heavy rain	Rolling Rd closed - high water	340	1048
8/1/2018	Featherbed Rd / General Trimbles & Sudley	CLOSURE	Flash Flood Warning; Heavy rain	Featherbed impassable	340	1322
8/1/2018	Valley View / Kettle Run	CLOSURE	Flash Flood Warning; Heavy rain	Valley View closed from Crocket Rd to Stainsby Ct	535	1322
8/1/2018	Parkgate Dr / Fleetwood Dr	CLOSURE	Flash Flood Warning; Heavy rain	High water / impassable	535	1048
8/1/2018	Aden Rd / Parkgate Dr / Flory RD	CLOSURE	Flash Flood Warning; Heavy rain	High water	535	2151

Date	Road/Intersection	Road Status	Call Type/Event Details	Road Closure Sheet Notes	Time Closed	Time Opened
8/1/2018	Old Church Rd @ Slate Run Bridge	CLOSURE	Flash Flood Warning; Heavy rain	Impassable at bridge over Slate Run	535	
8/1/2018	Fleetwood Dr / MCB 3	CLOSURE	Flash Flood Warning; Heavy rain	High Water impassable	724	2151
8/1/2018	Piper Lane / RR	CLOSURE	Flash Flood Warning; Heavy rain	High Water impassable	1048	1322
8/1/2018	14130 ADEN RD / Parkgate	CLOSURE	Flash Flood Warning; Heavy rain	Closed		
8/1/2018	ADEN RD / CEDAR RUN DR	CLOSURE	Flash Flood Warning; Heavy rain	Closed		
8/2/2018	Occoquan Bridge / Gordon Blvd	CLOSURE	Flash Flood Warning; Heavy rain	High water/ Right ln blocked/ 2 lanes still passable	1508	
8/2/2018	Prince William Pkwy/County Complex	CLOSURE	Flash Flood Warning; Heavy rain	High Water but passable	1508	
8/6/2018	MARYS WAY / JEFFERSON DAVIS HWY	CLOSURE	Flash Flooding			
8/21/2018	Pageland Ln / Artemus Rd	CLOSURE	Flash Flooding; 2 inches of rain in 1 hour	Closed high water	1350	8/22 0548
8/21/2018	Lomond Dr /Ashland	CLOSURE	Flash Flooding; 2 inches of rain in 1 hour	High Water, 1 lane closed	1350	2105
8/21/2018	Wellington Rd / Cellar Door	CLOSURE	Flash Flooding; 2 inches of rain in 1 hour	Closed high water	1350	1609
8/21/2018	Linton Hall / Lee	CLOSURE	Flash Flooding; 2 inches of rain in 1 hour	EB Lee ramp closed high water	1350	8/22 0003
8/21/2018	Piper Lane / RR	CLOSURE	Flash Flooding; 2 inches of rain in 1 hour	Closed - High Water - 3 ft high	1938	
8/21/2018	MARYS WAY / JEFFERSON DAVIS HWY	CLOSURE	Flash Flooding; 2 inches of rain in 1 hour	High Water but still passable	1938	8/22 0003
8/22/2018	Featherbed Rd / General Trimbles & Sudley	CLOSURE	Flash Flooding; 2 inches of rain in 1 hour	Closed to Through Traffic by VDOT for repairs	548	

Fairfax County Data

Known High Water Areas

Has Flip Signs	Sign Wording	Sign Verification (Picture)	Route #	Street Name	Starting Point - Street Name	Ending Point - Street Name	GPS Location	Drainage Structure Present	Structure Type (DI, Pipe, Bridge, Creek)	Flood Cause (Low Spot in Road, No Drain Present, Topography, Old Drainage/Needs Upgrade)	Additional Notes
Merrifield AHQ											
Flip	Watch For Standing Water		699	Prosperity Ave.	Arlington Blvd.	Little River Turnpike	Accotink Creek	Yes	Bridge	Low Point in Roadway Over Creek	
Flip	Watch For Standing Water		699	Prosperity Ave.	Arlington Blvd.	Little River Turnpike	Crook Branch	Yes	Bridge	Low Point in Roadway Over Creek	
No Sign	N/A	N/A	978	Morningside Dr.	Chandler St.	Woodhill Pl.	Crook Branch	Yes	Bridge	Low Point in Roadway Over Creek	
Flip	Watch For Water Over Road		709	Woodburn Rd.	Robey Ave.	Spicewood Dr.	Accotink Creek	Yes	Bridge	Low Point in Roadway Over Creek	
No Sign	N/A	N/A	2310	Barret Rd.	Annandale Rd.	Cofer Rd.	Runs Parallel to Tripps Run	Yes	DI	Creek Backs Up Into DI's Then Into Roadway	
Chantilly AHQ											
Flip	Watch for Standing Water	Yes	665	Fox Mill Rd.	Thoroughbred Rd.	Loveless Ln.	2818 Fox Mill (Cross-Pipe)	Yes	Pipe	Low Spot in Road	
Flip	Watch for Standing Water	Yes	673	Lawyers Rd.	Whippoolwill Rd.	Galloping Way	Stream Crossing (Cross-Pipe)	Yes	Pipe	Low Spot in Road	

Has Flip Signs	Sign Wording	Sign Verification (Picture)	Route #	Street Name	Starting Point - Street Name	Ending Point - Street Name	GPS Location	Drainage Structure Present	Structure Type (DI, Pipe, Bridge, Creek)	Flood Cause (Low Spot in Road, No Drain Present, Topography, Old Drainage/Needs Upgrade)	Additional Notes
No Sign	N/A	N/A	673	Lawyers Rd.	Helmwood Ct .	Gunnel Farms Dr.	Large Cross-Pipe	Yes	Pipe	Low Spot in Road	
Flip	Watch for Standing Water	Yes	674	Hunter Mill Rd.	Cedar Pond Rd .	Hunter Station Dr.	(Low Water Bridge)	Yes	Bridge	Low Spot in Road	
Flip	Watch for Standing Water	Yes	677	Hunter Station Rd.	Hunters Den Ln.	Hunter Mill Rd.	(Bridge)	Yes	Bridge	Low Spot in Road	
No Sign	N/A	N/A	671	Stuart Mill Rd.	Birdfoot Ln.	Twin Mill Ln.	(Bridge Over Little Difficult Run)	Yes	Bridge	Low Spot in Road	
Clifton AHQ											
Flip			661	Old Lee Road	Stonecroft Blvd.	N/A	Bridge	No	N/A	Low Spot Before Bridge	
No Sign	N/A	N/A	660	Fairfax Station Road	Moon Patterns Trail	Moon Pattern Trail	Stream Crossing (Cross-Pipe)	Yes	Pipe	Private Road Pipe Failure	
No Sign	N/A	N/A	641	Chapel Road	Water Street	N/A	Cross-Pipe	Yes	Pipe	No Tail Ditch for Pipe to Drain	
No Sign	N/A	N/A	620	Braddock Road	Old Lee	Starry Night Lane	N/A	Yes	Bridge	Flood Plain Area	
No Sign	N/A	N/A	661	Old Lee Road	Braddock Road	15100 Old Lee Road	(Bridge)	No	N/A	Low Spot/Flood Plain	
No Sign	N/A	N/A	612	Colchester Road.	Fairfax Station Road	N/A	Dead End Near Railroad Tracks	Yes	Bridge	Bridge Opening Too Narrow.	Catches Debris. Stops Up and Floods

Has Flip Signs	Sign Wording	Sign Verification (Picture)	Route #	Street Name	Starting Point - Street Name	Ending Point - Street Name	GPS Location	Drainage Structure Present	Structure Type (DI, Pipe, Bridge, Creek)	Flood Cause (Low Spot in Road, No Drain Present, Topography, Old Drainage/Needs Upgrade)	Additional Notes
No Sign	N/A	N/A	641	Chapel Road	Chapel Road Park	Chapel Road Park	N/A	Yes	Pipe	Low Spot Near Creek	Pipes Not A Problem. Flood Plain
No Sign	N/A	N/A	660	Fairfax Station Road	West of Innisvale Drive	N/A	Box Culvert Near 11800 Fairfax Station Road	Yes	Box Culvert	Flood Plain	
No Sign	N/A	N/A	660	Fairfax Station Road	East of Innisvale Drive	N/A	At Bridge	Yes	Bridge	Flood Plain	Catches Debris
No Sign	N/A	N/A	654	Popes Head Road	Pocol Drive	N/A	Near Sub-Station	Yes	Pipe	Needs Upgraded	
No Sign	N/A	N/A	658	Compton Road	West of Balmoral Forest Drive	N/A	Near Box Culvert and Bamboo Orchard/Johnny Moore Creek	Yes	Box Culvert	Flood Plain	Low Area
No Sign	N/A	N/A	658	Compton Road	East of Bay Valley	Little Rocky Run Bridge	N/A	Yes	Bridge	Bridge Needs Upgrade	
No Sign	N/A	N/A	29	Lee Highway	Clifton Road	Sandy Point	N/A	Yes	DI	Flood Plain Area	
No Sign	N/A	N/A	621	Bull Run Post Office Road	N/A	N/A	Field of Dreams Park	Yes	Pipe	Triple Barrel/Upgrade Culvert	Catches Debris
No Sign	N/A	N/A	658	Compton Road	West of I-66 Bridge			Yes	Pipe	Upgrade Culvert	Catches Debris
Van Dorn AHQ											

Has Flip Signs	Sign Wording	Sign Verification (Picture)	Route #	Street Name	Starting Point - Street Name	Ending Point - Street Name	GPS Location	Drainage Structure Present	Structure Type (DI, Pipe, Bridge, Creek)	Flood Cause (Low Spot in Road, No Drain Present, Topography, Old Drainage/Needs Upgrade)	Additional Notes
No Sign	N/A	N/A	2246	Cherokee Ave.	1/4 Mile North of the Bridge	Navaho Dr.	Indian Run Creek	Yes	Creek	Low Spot in Road	
Flip			2735	Industrial Dr.	Vulcan Material Plant	Electronic Dr	N/A	Yes	Creek	Low Spot in Road	
Flip			2735	Industrial Dr.	Edsall Rd.	Vulcan Concrete Plant	N/A	Yes	Pipe	Old Drainage. Needs Upgrade	
Flip			2461	4200 Woodlark Dr.	Rte 236	Mockingbird Dr.	N/A	Yes	Creek	Low Spot in Road	
Flip			236	Little River Turnpike	Lee Pl.	Wakefield Chapel Rd.	Eastbound	Yes	Pipe	Old Drainage. Needs Upgrade	
Lorton AHQ											
No Sign	N/A	N/A	1	Richmond Hwy/North Bound	Mims St.	CSX Bridge	N/A	Yes	Creek	Low Spot in Road	
No Sign	N/A	N/A	789	Loisdale Rd.	IOMAX Building	Newington Rd.	N/A	Yes	Pipe	Old Drainage. Needs Upgrade	
No Sign	N/A	N/A	286	Fairfax County Parkway	Old Latern Way	Innisfree Rd.	N/A	Yes	Creek	Low Spot in Road	
No Sign	N/A	N/A	289	Franconia/ Springfield Parkway	Bonnie Mill	Beverly Park Dr.	N/A	Yes	Creek	Low Spot in Road	
Mt. Vernon AHQ											

Has Flip Signs	Sign Wording	Sign Verification (Picture)	Route #	Street Name	Starting Point - Street Name	Ending Point - Street Name	GPS Location	Drainage Structure Present	Structure Type (DI, Pipe, Bridge, Creek)	Flood Cause (Low Spot in Road, No Drain Present, Topography, Old Drainage/Needs Upgrade)	Additional Notes
No Sign	N/A	N/A	611	Old Colchester Rd.	Approx. at 9700 Old Colchester Rd.	N/A	Pohick Creek Bridge	Yes	Bridge/Creek	Old Drainage /Needs Upgrade	
No Sign	N/A	N/A	611	Old Colchester Rd.	Hassett St.	Greene Dr.	Bridge South of Hassett St.	Yes	Bridge/Creek	Old Drainage /Needs Upgrade	
No Sign	N/A	N/A	623	Old Mill Rd.	Dogue Dr.	Rosemary Lena Way	Dogue Creek	Yes	Pipe	Low Spot in Road	
McClean AHQ											
No Sign	N/A	N/A	2804	Valley Wood Rd	1901 Valley Wood Rd	1906 Valley Wood Rd	N/A	Yes	Creek	Old Drainage. Needs Upgrade	
No Sign	N/A	N/A	689	Chesterbrook Rd	Maddox Ln	6034 Chesterbrook Rd	N/A	Yes	Creek	Topography	
No Sign	N/A	N/A	695	Kirby Rd	Claiborne Dr	1358 Kirby Rd	N/A	Yes	Creek	Topography	
No Sign	N/A	N/A	7	Leesburg Pike	Gallows Rd	Gallows Rd	Left Turning Lane on RTE 7 WB Turning Onto Gallows Rd	Yes	Pipe	Old Drainage. Needs Upgrade	
No Sign	N/A	N/A	703	Shreve Rd	Wieland Pl	Buckelew Dr	Intersection of Bucklew Dr.	Yes	Creek	Topography	
No Sign	N/A	N/A	650	Magrity Rd	Great Falls St	Great Falls St	Intersection of Great Falls St.	Yes	Creek	Low Spot in Road	

Has Flip Signs	Sign Wording	Sign Verification (Picture)	Route #	Street Name	Starting Point - Street Name	Ending Point - Street Name	GPS Location	Drainage Structure Present	Structure Type (DI, Pipe, Bridge, Creek)	Flood Cause (Low Spot in Road, No Drain Present, Topography, Old Drainage/Needs Upgrade)	Additional Notes
No Sign	N/A	N/A	693	Westmoreland St	Lemon Rd	Somerville Dr	Intersection of Lemon Rd.	Yes		Topography	
Reston AHQ											
Permanent				Browns Mill Rd	Wind Stone Dr	Rosewood Hill Dr				low area	
No Sign				Leesburg Pike	Colvin Run	Faulkner Dr				low area excessive run off	
No Sign				Beulah Rd	@ Browns Mill Rd		Intersection of Browns Mill Rd.			low area excessive run off	
No Sign				Old Courthouse Rd	Besley Rd		Intersection of Besley Rd.			low area excessive run off	
No Sign				Lewinsville Rd	Mayhurst Blvd	Lewinsville Mew CT				low area excessive run off	
No Sign				Spring Hill Rd	Georgetown Pike	Greenwich Woods Dr				low area excessive run off	
No Sign				Bellview Rd	Union Church	Old dominion Dr				low area	
No Sign				Colvin Run Rd	@ Leesburg Pike		Intersection of Leesburg Pike			excessive run off	
No Sign				Walker Rd @ Sunnbrook	Park Royal	Walker Mill Rd				low area excessive run off	
No Sign				Beach Mill Rd	@ Club View Dr		Intersection of Club View Dr.			excessive run off	

Has Flip Signs	Sign Wording	Sign Verification (Picture)	Route #	Street Name	Starting Point - Street Name	Ending Point - Street Name	GPS Location	Drainage Structure Present	Structure Type (DI, Pipe, Bridge, Creek)	Flood Cause (Low Spot in Road, No Drain Present, Topography, Old Drainage/Needs Upgrade)	Additional Notes
No Sign				Riverbend Rd	@ Mine Run Dr		Intersection of Mine Run Dr.			low area excessive run off	
No Sign				Springvale Rd	Leesburg Pike	Brevity Dr				low area excessive run off	
No Sign				Utterback Store Rd	Wolfe Hill La	Bechman Way				low area excessive run off	
No Sign				Kentland Rd	Parrish Farm La					low area excessive run off	
No Sign				Shaker Wood Rd	1007 Shaker Wood Rd						
No Sign				Wiehle Ave	Inlet Ct					low area	
No Sign				Sunset Hills Rd	Isaac Newton Sq.						
No Sign				Hunter Mill Rd	Mount Sunapee	Chamberlain Dr				low area	
				Sunset Hills Rd	Micheal Faraday						
Burke AHQ											
Flip	WATCH FOR STANDING WATER		645	Burke Lake Road	Kilkenny Lane	Jeremiah Court	Flooding Occurs Where Road Crosses Burke Lake	Yes	Pipe	Low Spot/Drainage Needs Upgrade/Roads Needs To Be Elevated	Low Lying Area Where Road Crosses Burke Lake. Water Level In Lake

Has Flip Signs	Sign Wording	Sign Verification (Picture)	Route #	Street Name	Starting Point - Street Name	Ending Point - Street Name	GPS Location	Drainage Structure Present	Structure Type (DI, Pipe, Bridge, Creek)	Flood Cause (Low Spot in Road, No Drain Present, Topography, Old Drainage/Needs Upgrade)	Additional Notes
											Causes Water To Backup Over Road. Only One Sign On 123 Side of Burke Lake.
No Sign	N/A	N/A	652	Burke Road	Heritage Square Drive	Liberty Bell Court	Flooding Occurs Where Road Crosses Creek	Yes	Pipe	Pipe Was Replaced 2014/2015 Needs Upgrade	Water Volume From Live Stream Exceeds Capacity of Pipe
No Sign	N/A	N/A	286 SB	Fairfax PKWY	Ramp to 123	Ramp to 123	N/A	Yes	DI	DI Grate Clogs w/ Debris	
No Sign	N/A	N/A	286 NB	Fairfax PKWY	Ramp to 123	Ramp to 123	N/A	Yes	DI	DI Grate Clogs w/ Debris	

Identified Locations with Known Flooding Issues

Location	Notes
Brilyn Place & N. West	Curb and gutter improvements needed
1584 Forest Villa Lane	
11224-11226 and 10710 Beach Mill Road	
Swinks Mill Road at Georgetown Pike:	Pipe and ditch improvements needed.
Swinks Mill Road (Between Georgetown Pike and Old Dominion)	Cross over pipe on is undersized.
Lawyers Road (east of Hunter Mill	Several undersized and failing cross over pipes.
Browns Mill Road at 1500 Pennycress Lane	Low lying area on Brown Mill Rd @ bridge/culverts for Difficult Run between Windstone Dr. and Rosewood Hill.
Intersections of Martha Washington Street and Ashton Street at Lawrence Street	
Loisdale Road (north of Fairfax County Parkway)	Water stands in bend of road after heavy rains. Drainage improvement needed.
Chowan Avenue	Drainage improvement needed.
Cherokee Avenue and Navajo Drive	
Columbia Pike Service Road near Whispering Lane	
Annandale Acres - Auburn St/Beverly St/Calvert St/Clemons Ct	Drainage improvement needed.

Lake Barcroft area streets	
Woodburn Road	Potential bridge replacement and roadway improvement needed.
Old Colchester Road near Hassett Street (bridge over Giles Run)	Bridge floods frequently. Creek bed consistently requires dredging due to sediment build-up. Bridge group cleans out on a routine maintenance schedule.
Hunter Estates: Higham, Franklin, Bulkley, Catskill, Newington, and Ona Roads. (Possibly Accotink and Hamilton will be added to this list.)	No curb and gutter. Instead, community has ditches and swales that are now too shallow to carry runoff. During a heavy rain, the storm water exceeds the capacity of the ditches and overflows the streets and floods neighborhood yards.
Woodlawn Manor - Stillwell Avenue & McNair Drive	
Fort Hunt Rd and Route 1 East side	Box culverts consistently get blocked with sediment and vegetation, large debris. Bridge group cleans out on routine maintenance schedule.
7135 Tyler Avenue	One undersized drop inlet for a distance of approximately 900 linear feet, unable to handle flow in heavy rain events.
Morningside Drive just south of Chandler Street	Existing box culvert under road is undersized and overtopping during heavy rain events.
Woodford Road at Woodford Court	Water stands year round at subdivision entrance; no inlets or ditches and nowhere for the water to drain
Prosperity Ave @ Accotink Creek	Potential bridge replacement and road improvement needed. Two existing bridges that is being cleaned out on routine maintenance schedule.
Oak Street and Providence Street	Water doesn't drain and ditches are already very deep.
Fairfax Station Road	Two culverts (S&B) in low lying area in constant flood plain. Potential roadway and drainage improvements needed.
Dead end of Colchester Rd. S. of Tunnel	Potential road and bridge improvements.
Compton Rd between Paradise Mill Rd and Dalemar Dr	Located in the flood plain. Potential roadway and bridge improvement. Confirmed consistent flooding.

Fox Mill Rd just S of Hunt Road	
Woodway Drive/Gum Street/Edison Drive	Potential drainage improvements needed. None of these driveway entrances have culvert pipes. Entire neighborhood lacks drainage infrastructure.
Burke Lake Road between Routes 123 and 286	Road floods
Flooding on Barrett Road, Falls church	Flood Plain area.
Elmwood - Burgundy Village	By Cameron Run. Dense older neighborhood.

Loudoun County Data

Loudoun County Flooding Hotspots

Location Point of Reference	**Latitude**	**Longitude**	**Revised Latitude**	**Revised Longitude**	**Drainage Area**	**# of Events/Frequency Per Year**	**Impacts of Flooding**	**Description of Events**	**Public Safety Impacts**	**Road Types**
36789 Snickersville Turnpike	39.0628	-77.7467				1 to 3	Road floods during Heavy rain due to stream	Road floods	Roads is closed until water recedes.	paved
39990 Oatlands Mill Road	39.0318	-77.6175				**2 To 3**	Road floods during Heavy rain due to stream	Road floods	Roads is closed until water recedes.	Paved/Gravel

Location Point of Reference	Latitude	Longitude	Revised Latitude	Revised Longitude	Drainage Area	# of Events/Frequency Per Year	Impacts of Flooding	Description of Events	Public Safety Impacts	Road Types
42843 Edwards Ferry Road	39.1139	-77.5205	39.1139	-77.5206		**5-Mar**	Roadway is shut down to traffic	Pipe under driveway not on ROW gets clogged and causes creek to over flow driveway on to road. Water flows out in road way and down the road to the creek crossing.	Traffic goes around road closed signs and try to cross high water and fast current	Paved
Alder School Road just west of Berlin Turnpike	39.159	-77.6986				1 to 2	Road floods during Heavy rain due to stream	pipes under road get overwhelmed on a heavy rain	Roads is closed until water recedes.	Paved/gravel
Aldie Dam Road Just South of John Mosby Highway	38.9777	-77.6512				2	Road floods during Heavy rain due to stream	pipes under road get overwhelmed on a heavy rain	Roads is closed until water recedes.	Gravel
Appalachian Trail Road just west of Woodgrove Road	39.1765	-77.7721					Roadway is closed to traffic	water overtops bridge	Roads is closed until water recedes.	Gravel
Auburn Farm Road @ Prince	38.8897	-77.5702				1	Roadway is closed to traffic	water overtops bridge	Roads is closed	

Location Point of Reference	Latitude	Longitude	Revised Latitude	Revised Longitude	Drainage Area	# of Events/Frequency Per Year	Impacts of Flooding	Description of Events	Public Safety Impacts	Road Types
William County line									until water recedes.	
Beaverdam Bridge Road	39.044	-77.746				Crossing has been closed for 2 years due to unsafe condition	Bridge is inadequate to handle existing water flow .New bridge structure needed.	High water flow tops existing structure.	Bridge remains closed.	Gravel
Braddock Road	38.93617	-77.603736				2 to 3	Road has standing water on it	Road floods during heavy rain	High water on road	
Braddock Road	38.9291	-77.587962				2 to 3	Road has standing water on it	Road floods during heavy rain	High water on road	
Charles Town Pike near Harpers Ferry Road	39.2146	-77.7454				2 to 3	Road has standing water on it	Road floods during heavy rain	High water on road	
Clarkes Gap Road between Charles Town Pike and Waterford	39.1902	-77.6122				2	Water floods road	Road floods during heavy rains	Unsafe driving conditions	

Location Point of Reference	Latitude	Longitude	Revised Latitude	Revised Longitude	Drainage Area	# of Events/Frequency Per Year	Impacts of Flooding	Description of Events	Public Safety Impacts	Road Types
Cochran Mill Road just north of Sycolin Road	39.0627	-77.548	39.0628	-77.5482		2	Road is shut down to traffic	River runs beside road way heavy rains cause the river to rise and jump the banks	Road is closed until water recedes	Gravel
Cobb House Road	38.9906	-77.6683				2 to 3	Road is shut down to traffic	water overtops pipes	Road is closed until water recedes	
Crooked Bridge Lane @ Lime Kiln Road	39.0376	-77.6399				3 tp 4 times per year	Road is shut down to traffic	High water from Goosecreek floods road	Road is closed until water recedes	
Crooked Bridge Lane just south of Lime Kiln Road	39.0312	-77.6447				3 tp 4 times per year	Road is shut down to traffic	High water from Goosecreek floods road	Road is closed until water recedes	Asphalt
Dry Mill Road near Thomas Mill Road	39.1144	-77.603				1or2	Road is shut down to traffic	water overtops pipes	Road closed to traffic	Asphalt
Dutchman's Creek	39.307	-77.6512				3 to 4 per year	High water overtops road and washes section of road and stream bank out	River runs beside road way heavy rains cause the river to rise and jump the banks	Road closed to traffic road needs extensive repair after heavy rains	Gravel

Location Point of Reference	Latitude	Longitude	Revised Latitude	Revised Longitude	Drainage Area	# of Events/Frequency Per Year	Impacts of Flooding	Description of Events	Public Safety Impacts	Road Types
Edwards Ferry Rd NE / River Creek Parkway	39.1106	-77.5056				1 to 2	Road is shut down to traffic	During heavy rain Water overtops road at stream crossing	Road closed to traffic	Asphalt
Edwards Ferry Road just east of Battlefield Parkway	39.1139	-77.5208				1 to 2	Road is shut down to traffic	During heavy rain Water overtops road at stream crossing	Road closed to traffic	Asphalt
Edwards Ferry Road NE/Battery Terrace	39.114	-77.5281				1 to 2	Road is shut down to traffic	During heavy rain Water overtops road at stream crossing	Road closed to traffic	Asphalt
Edwards Ferry Road/ Battery Terrace NE	30.1139	-77.5299				1 to 2	Road is shut down to traffic	During heavy rain Water overtops road at stream crossing	Road closed to traffic	Asphalt
Evergreen Mill (South of Shreve Mill Road & North of	39.0555	-77.5765				1 to 2	Road is shut down to traffic	During heavy rain Water overtops road	Road closed to traffic	Asphalt
Trailhead Dr						2 to 3	Road closed to traffic	Pipes cannot handle heavy water flow from storms due to development	Road closed to traffic	Asphalt

Location Point of Reference	Latitude	Longitude	Revised Latitude	Revised Longitude	Drainage Area	# of Events/Frequency Per Year	Impacts of Flooding	Description of Events	Public Safety Impacts	Road Types
Fleetwood Road between Everygreen Mills Rd and John Mosby Highway	38.9584	-77.5676				1 to 2	During heavy rain Water overtops road at stream crossing		Road closed till water recedes	asphalt
Forest Mills Road / Oakland Green Road	39.0921	-77.6825				3 time year	Bridge floods	Bridge floods when debris blocks pipes and water flow washes out approaches to bridge	Bridge is impassable to traffic	Gravel
Gant Lane	39.0617	-77.5413	39.06174	-77.5413		5-Mar	Road is shut down to traffic	Bridge is too small to handle water flow with heavy rains	Road is impassable to traffic	Gravel
Goshen Road Between Braddock Road and John Mosby Highway	38.9351	-77.5679				1	Road is shut down to traffic	water overtops pipes	road closed to traffic	Gravel
Hibbs Bridge Road just south of Snickersville Turnpike	39.0366	-77.7227				3 to 5	Road is impassable	Road needs complete reengineering	Road is impassable to traffic	Gravel
Harmony Church Road just west of James	39.0802	-77.6526				2 to 3	Road is shut down to traffic	creek cannot handle amount of	Road is impassable to traffic	Asphalt

Location Point of Reference	Latitude	Longitude	Revised Latitude	Revised Longitude	Drainage Area	# of Events/Frequency Per Year	Impacts of Flooding	Description of Events	Public Safety Impacts	Road Types
Monroe Highway								water floods road		
Harpers Ferry Road just north of Commmuntiy Center	39.3111	-77.7186				2 to 3	Road is shut down to traffic	Road floods due to heavy rains	Road is shut down to traffic	Asphalt
Hibler Road	39.1903	-77.4989	39.19123	-77.4945		**5-Mar**	Road is shut down to traffic, Road washes out	Out fall of pipe cannot release water due to over grown brush on private property, and silt that has built up	Residents that live beyond this point are unable to leave or return to their homes. Dead end road	Gravel
Hollow Oak Rd/ Yellow School House Road	39.091	-77.8128				**2 to 3**	Road is shut down to traffic	Water flow has been displaced off of state ROW which has caused widespread flooding on the road	Road is impassable to traffic	Gravel
Hillsboro Road	39.1671	-77.7288				2 to 3	Road Floods during Heavy Rain	Road Floods	Caution High water Signs or Road Closed	Paved

Location Point of Reference	Latitude	Longitude	Revised Latitude	Revised Longitude	Drainage Area	# of Events/Frequency Per Year	Impacts of Flooding	Description of Events	Public Safety Impacts	Road Types
									until water recedes.	
Hillsboro Road	39.1789	-77.7232				2 to 3	Road Floods during Heavy Rain	Road floods	Caution High water Signs or Road Closed until water recedes.	Paved
Hillsboro Road	39.1814	-77.7224				2 to 3	Road Floods during Heavy Rain	Road floods	Caution High water Signs or Road Closed until water recedes.	Paved
James Monroe Highway @ Goose Creek Bridge	39.007	-77.6148				1	Road is shut down to flooding	Goose creek overspills it banks	Road closed	Asphalt
James Monroe Highway @ Limestone Branch	39.1681	-77.5366				1	Floods Rt. 15	During Major Heavy rain	Road becomes impassable	Asphalt

Location Point of Reference	Latitude	Longitude	Revised Latitude	Revised Longitude	Drainage Area	# of Events/Frequency Per Year	Impacts of Flooding	Description of Events	Public Safety Impacts	Road Types
Jeb Stuart off Silcott Springs Road	39.0674	-77.7508				2	Ford floods during rains	During heavy rains stream crossing is impassable	Ford is impassable	Gravel
John Mosby Highway @ Tail Race Road	38.9753	-77.6399				1 to 2	Road floods during heavy rains	Road is closed to traffic	Road is closed to traffic	Asphalt
Lime Kiln Road	39.0254	-77.6835				2 to 3	Road floods during heavy rains	Road is closed to traffic	Road is closed to traffic	Asphalt
Lime Kiln Road / Steptoe Hill Road	39.0245	-77.6895				2 to 3	Road floods during heavy rains	Road is closed to traffic	Road is closed to traffic	Asphalt
Oatlands Road / James Monroe Highway	39.026	-77.6209				1 to 2	Road is impassable to traffic	During extended rain events Goose creek floods road	Road is closed to traffic	Asphalt/Gravel
Peach Orchard ln / Little River Road @ Prince William County	38.9119	-77.6073				every time it rains	Ford crossing stream is shut down to traffic	Heavy rain increases water level in stream making ford impassable	Road closed to traffic	Gravel

Location Point of Reference	Latitude	Longitude	Revised Latitude	Revised Longitude	Drainage Area	# of Events/Frequency Per Year	Impacts of Flooding	Description of Events	Public Safety Impacts	Road Types
Shreve Mill Road between Sycolin Road and Dulles Greeneay	39.0605	-77.556	39.0604	-77.556		**5**	Road is shut down to traffic	Debris packs up against the pipes causing the water to over flow on to the road	Traffic goes around the road closed signs and try to navigate the high water and fast current	Paved
Thomas Avenue between Richland Acres and Algonkian Parkway	39.0206	-77.3678	39.02058	-77.3678		4-Feb	Road is shut down to through traffic	Debris packs up against bridge and causes water to over flow the bridge and road	Nearby home can flood if water rises high enough	Paved
Newlin Mill Road	39.9164	-77.8004				2 to 4	Road is shut down to through traffic	Low water crossing water overtops crossing	Road closed to traffic	Gravel
Newvalley Church Road	39.2071	-77.543				2 to 3				
Tranquility Road and Lickey Mill Road	39.1166	-77.7499				3 to 4	During rain stream floods crossing	Structure not adequate to handle increased water flow	Road closed	Gravel

Location Point of Reference	Latitude	Longitude	Revised Latitude	Revised Longitude	Drainage Area	# of Events/Frequency Per Year	Impacts of Flooding	Description of Events	Public Safety Impacts	Road Types
Quarter Branch Road	39.2852	-77.6267				3 to 4	Road closed to traffic and road damaged	Water floods road and overtops at stream crossings and pipes causing damage to road	Road closed and damaged	Gravel
Shannondale Road	39.1962	-77.7634				1 to 2	During rain stream floods crossing	Water floods road and overtops at stream crossings and pipes causing damage to road	Road closed	
Orrison Road	39.25169	-77.609173				2 to 3	During rain stream floods crossing	Water floods road and overtops at stream crossings and pipes causing damage to road	Road closed	

Appendix B. List of Meetings Associated with this Effort

Meetings with VIMS, VTRC, and CCRFR

- April 2, 2020
- June 25, 2020
- August 24, 2020
- December 14, 2020
- February 1, 2021
- February 25, 2021
- March 3, 2021
- April 5, 2021
- May 21, 2021
- June 7, 2021
- August 2, 2021
- October 4, 2021

Other Meetings

VDOT NOVA District

- April 6, 2021
- April 21, 2021
- May 5, 2021
- May 11, 2021
- October 28, 2021