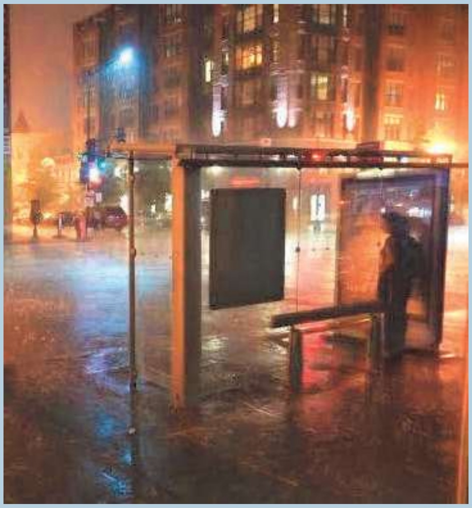
NATIONAL CAPITAL REGION TRANSPORTATION SYSTEM CLIMATE VULNERABILITY ASSESSMENT

May 2024



National Capital Region
Transportation Planning Board

TRANSPORTATION CLIMATE VULNERABILITY ASSESSMENT
Published on May 24, 2024. Updated November 2024.

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CREDITS
This report was prepared for the Metropolitan Washington Council of Governments (COG) Transportation Planning Board (TPB) by ICF. This project was led by Katherine Rainone from TPB and this report was prepared by individuals from ICF including Brenda Dix, Amanda Vargo, Kaitlyn Cyr, Eva Burgos, and Katrina Starbird in close collaboration with TPB.

COVER PHOTO CREDITS
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Glossary

- **Exposure** refers to whether an asset is located in an area that is affected by climate hazards. Assets are more likely to be affected by climate hazards if they have high exposure.

- **Sensitivity** is the degree to which an asset is affected by exposure to a climate hazard. If an asset has high sensitivity to a climate hazard, it will experience more significant impacts from the hazard than assets with low sensitivity.

- **Criticality** refers to the importance of an asset to the transportation system. Criteria to evaluate an asset's criticality may include functional classification and whether or not the asset is located in an Equity Emphasis Area (EEA). EEAs are census tracts that COG has identified as containing high concentrations of low-income individuals and/or traditionally disadvantaged racial and ethnic population groups.

- **Vulnerability** is the degree to which an asset is unable to cope with adverse climate impacts. Vulnerability can be used to understand how susceptible or at-risk an asset is to a climate hazard. In this assessment, exposure and criticality are used to determine an asset's vulnerability, with high exposure and criticality indicating high vulnerability or high risk to the asset.

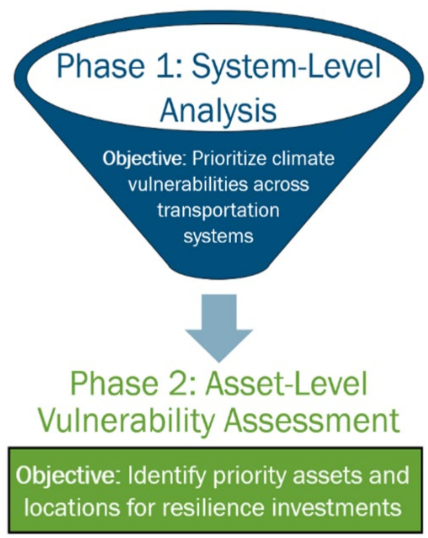
Introduction

The Metropolitan Washington Council of Governments (COG) Transportation Planning Board (TPB) is striving to improve the climate resilience of the transportation system in the metropolitan Washington region. TPB is the federally designated Metropolitan Planning Organization for the region and plays an important role as the regional forum for transportation planning. TPB has undertaken a range of regional transportation resilience assessment and planning initiatives to support the region's climate resilience goals. In 2020, the COG Board of Directors adopted greenhouse gas (GHG) emission reduction goals that emphasize the importance of climate mitigation and climate resilience efforts, including in long range transportation planning. COG Board Resolution R45-2020 established:

- The climate mitigation goal of 50% GHG reductions below 2005 levels by 2030;
- The climate resilience goal of becoming a Climate Ready Region and making significant progress to be a Climate Resilient Region by 2030; and
- The need to incorporate equity principles and expand education on climate change into COG's Climate Energy & Environment Policy Committee and its members' actions to reach the climate mitigation and resiliency goals.

The region's local jurisdictions, supported by TPB, must continue to assess current and future climate risks, and integrate climate planning across government plans, operations, and communications to help meet the Climate Ready and Climate Resilient Region goals. The key objective of this vulnerability assessment is to build on the strong foundation of resilience work undertaken by TPB to assess the vulnerabilities of the region's transportation system and identify priority areas for resilience investments. The assessment will also inform a Transportation Resilience Improvement Plan (TRIP) that will contribute to member organizations' understanding of climate risk to improve resilience planning; identify priorities for investments in resilience; and better position TPB and its members for federal funding and match reduction under the Promoting Resilient Operations for the Transformative, Efficient, and Cost-Saving Transportation (PROTECT) Program.

Figure 1. Overview of Phase 1 and Phase 2.



The climate vulnerability assessment provides a systemic look at risks to the transportation network for the region. The assessment identifies areas and assets across the metropolitan Washington region with the highest vulnerability to climate hazards and will be used to inform climate resilience and transportation planning.[1] The assessment was conducted in two phases. Phase 1 used a system-level sensitivity analysis to identify priority transportation asset/climate hazard (asset/hazard) pairs that are highly sensitive to climate hazards. Phase 2 further analyzed the priority asset/hazard pairs from Phase 1 through quantitative and qualitative analyses. This included an indicator-based, asset-level vulnerability assessment for specific individual assets to provide a deeper understanding of the region's vulnerabilities and priorities

[1] As of February 21, 2024, after the completion of this vulnerability analysis, Fauquier County is no longer a TPB member. Following the 2020 Census, Fauquier County's urban areas were redefined and are no longer contiguous to those in Prince William County. Fauquier County is now entirely outside of the Washington DC-VA-MD urban area for which the TPB is the designated MPO.

for resilience investments. Figure 1 summarizes the Phase 1 and Phase 2 objectives and illustrates how the system-level assessment informed the asset-level analysis. This report describes the methodology and results of the vulnerability assessment.

Phase 1: System-Level Analysis

Phase 1 aimed to understand the sensitivity of each asset type to each hazard and rate them on a high-to-low sensitivity scale. The results of the Phase 1 analysis include a selection of asset/hazard pairs that moved on to Phase 2 for further analysis. The Phase 1 analysis was based on a literature review that consolidated information from existing climate vulnerability and resilience studies in the region to identify regionally relevant transportation asset groups and climate hazards. The climate hazards included in Phase 1 were defined using regionally relevant weather and climate considerations for the scope of this high-level sensitivity screening. The assessment considered the following transportation asset groups and climate hazards:

Key Term

Sensitivity is the degree to which an asset is affected by exposure to a climate hazard. If an asset has high sensitivity to a climate hazard, it will experience more significant impacts from the hazard than assets with low sensitivity.

Table 1. Transportation Asset Groups Included in Phase 1

Transportation Asset Groups
Roads and highways: Paved surfaces and embankments that are part of roads used for vehicle travel (infrastructure) and the ability to utilize road and highways (service).
Bridges: Paved surfaces, supporting structures, foundation, and joints of bridge structures (infrastructure) and the ability to utilize bridge infrastructure (service).
Public transit: Bus, rail, other transit fleet vehicles, and their associated public use stations (infrastructure) and the ability to utilize or access public transit / the established schedule for transit service (service).
Active transportation: Paved surfaces used for pedestrian, bicycle, or other non-motorized transportation (infrastructure) and ability to utilize active transportation (service).
Airports: Airfields and surrounding areas, runways, airport facilities and buildings (infrastructure) and ability to utilize air travel (service).
Maritime: Port structures and equipment (infrastructure) and operations of maritime travel (service).
Stormwater: Culvert crossings and stormwater systems including tunnels, pipes, gutters, and embankments (infrastructure) and the ability to convey stormwater (service).

Table 2. Climate Hazards Included in Phase 1

Climate Hazards
Extreme heat: Includes "heat emergency days" when the heat index exceeds 95°F. The impact of an extreme heat event on physical infrastructure depends on the number of consecutive "heat emergency days," though the service impacts may result after only one day.
Temporary flooding (coastal and riverine): Includes 100-year and 500-year floods. This definition is based on FEMA floodplains data, with a note that local records indicate prevalence of urban flooding issues outside of these floodplains.
Permanent flooding (sea level rise): Includes 4 to 8 feet of sea level rise by 2100 compared to 2012, an increase in nuisance flooding along the Potomac and Anacostia riverfronts and significant shoreline erosion, and coastal storm surge.
Extreme winter conditions: Includes heavy snow, heavy precipitation with at or below freezing temperatures, and dangerous wind chills.
Extreme wind: Includes extreme storms with high winds, such as hurricanes and tropical storms.

Phase 1 Vulnerability Assessment Rubric

The assessment scored sensitivity for infrastructure and customers and services on a high-to-low scale. As transportation systems can be impeded by failures in the physical infrastructure and barriers to usability, the assessment used scoring rubrics for both. The consideration of impacts to infrastructure and services enabled a fuller picture of transportation vulnerabilities. For many hazards, the actual impacts to an asset depend on the severity and duration of the hazard event. Phase 1 analysis erred on the side of higher sensitivity to capture the range of potential risks.

Impacts to Physical Infrastructure:

Low	When exposed to the hazard, the asset suffers minor to no damage and maintains functionality.
Medium	When exposed to the hazard, the asset suffers damage requiring repairs to resume full functionality.
High	When exposed to the hazard, the asset is damaged beyond repair or destroyed, and cannot resume normal function until replaced.

Impacts to Customers and Services:

Low	When exposed to the hazard, there is minimal to no impact to service or discomfort to customers.
Medium	When exposed to the hazard, service is disrupted or suspended for up to a day OR hazard exposure causes discomfort for customers (e.g., waiting at a bus stop in high heat).
High	When exposed to the hazard, service is suspended for more than 24 hours and disruptions may continue for days to weeks after the event as infrastructure repairs are made OR hazard exposure poses a safety risk to customers (e.g., unsafe driving conditions due to flood depth or health risks due to extreme heat). Customers must find alternative travel options.

Phase 1 System-level Results Summary

Phase 1 provided a system-level overview of the sensitivity of key transportation assets to the climate hazards that exist in the region. This assessment did not consider an explicit timeframe or the potential increasing sensitivity of assets from impacts of hazards over several years or decades. The assessment acknowledges that time considerations may be more significant for some of the climate hazards as extreme weather events are expected to increase. Figure 2 overviews the sensitivity scores of the asset/hazard pairs examined in Phase 1. Asset/hazard pairs with highest scores have the most significant impacts to infrastructure and services. Some hazards had little to no impact on the asset's ability to function, while some impeded just the infrastructure or the quality of service. Several hazards had high sensitivity scores based on both infrastructure and service considerations.

Figure 2. System-level analysis results (Infrastructure impacts on left; service and customer impacts on right).

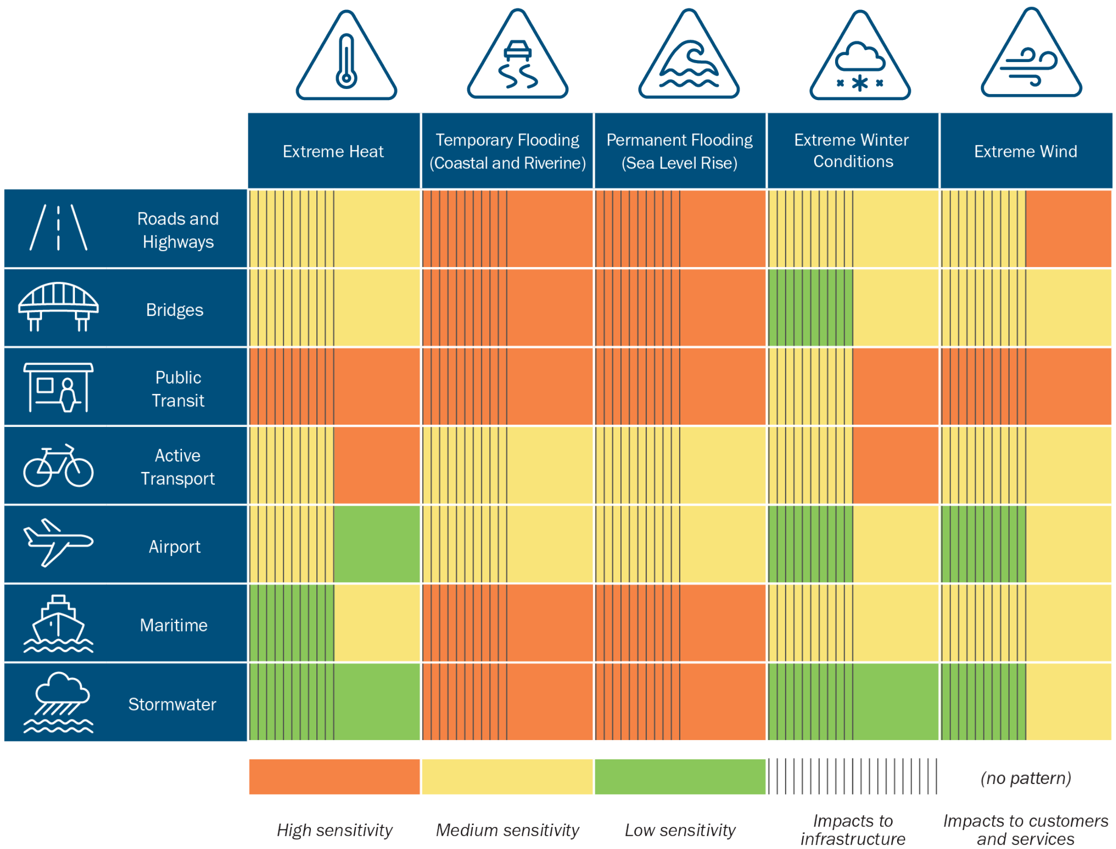


Table 3 summarizes the highly sensitive pairs that moved forward for further analysis in Phase 2. These pairs were determined to be regionally significant based on the literature review and stakeholder feedback from member agencies.

Table 3. Highly Sensitive Asset/Hazard Pairs

Hazard	Asset Groups					
	Roads and Highways	*Bridges*	*Public Transit*	*Active Transportation*	*Maritime*	*Stormwater*
Extreme Heat			✓	✓		
Temporary Flooding (Coastal and Riverine)	✓	✓	✓		✓	✓
Permanent Flooding (Sea Level Rise)	✓	✓	✓		✓	✓
Extreme Winter			✓	✓		
Extreme Wind	✓		✓			

Phase 2: Asset-Level Analysis

The overall objective of Phase 2 was to further understand where there are vulnerabilities and risks to the transportation network in the region and to identify priority assets and locations for resilience investments. Due to data limitations, an indicator-based, asset-level vulnerability assessment could not be completed for all highly sensitive pairs identified in Phase 1. Phase 2 therefore included three tiers of analysis: an indicator-based vulnerability assessment, overlaying the identified sensitive assets from Phase 1 with climate data to identify individual assets that are highly vulnerable to each hazard; a map layer to visualize potential risks to health and safety; and a literature review for asset/hazard pairs lacking geospatial data. Table 4 summarizes the three tiers of the Phase 2 analysis.

Table 4. Three-Tiered Approach to Phase 2

Tier	Type of Analysis	Description	Relevant Pairs
1	**Asset-level, indicator-based vulnerability assessment with mapping tool**	For pairs with adequate geospatial data (hazards and assets) and asset data (e.g., location, condition, etc.), the assessment used indicators to evaluate exposure, criticality, and vulnerability for individual assets.	• **Extreme heat:** public transit • **Temporary flooding (coastal and riverine):** roads and highways, bridges, public transit • **Permanent flooding (sea level rise):** roads and highways, bridges, public transit
2	**Map layer**	For pairs with high sensitivity to user health and safety rather than infrastructure, the assessment includes a map layer to visualize potential risks. Pairs from Tier 1 are also visible on the map layer.	• **Extreme heat:** active transportation
3	**Literature review**	All pairs were considered in this tier, though special focus was given to highly sensitive pairs from Phase 1 that lacked adequate geospatial data. This tier includes a qualitative assessment of current and future climate conditions and example impacts to transportation assets.	Pairs with special attention: • **Temporary flooding (coastal and riverine):** stormwater, maritime • **Permanent flooding (sea level rise):** stormwater, maritime • **Extreme winter:** public transit, active transportation • **Extreme wind:** roads and highways, public transit

The following report sections provide more details on the methodologies and results for each tier of analysis. The results of the Tier 1 and Tier 2 analysis can be viewed on the mapping tool produced for this vulnerability analysis and is available at the [TPB Transportation Resiliency Web Application]. Collectively, these results provide a picture of climate vulnerability in the region.

Tier 1: Indicator-based, Asset-level Vulnerability Assessment

Tier 1 applied a Geographic Information System (GIS)-based analysis using exposure and criticality indicators to identify highly vulnerable assets and locations that could be a priority for resilience investments.

The assessment focused on the following asset/hazard pairs:

- **Extreme heat:** public transit
- **Temporary flooding (coastal and riverine):** roads and highways, bridges, public transit
- **Permanent flooding (sea level rise):** roads and highways, bridges, public transit

These pairs received a high sensitivity rating in Phase 1 and had appropriate geospatial and asset data available to complete this level of analysis. Each of these asset/hazard pairs were evaluated to determine an individual asset's vulnerability to the climate hazard. This assessment evaluated the vulnerability of roads and highways, public transit (bus routes, rail stops, and rail lines), and bridges to extreme heat, temporary flooding, and permanent flooding on a low-to-high scale to identify specific assets or areas within the region that are highly vulnerable.

ASSET-LEVEL VULNERABILITY ASSESSMENT METHODOLOGY

The methodology used in this assessment builds on current best practices as outlined in the Federal Highway Administration's (FHWA) Vulnerability Assessment and Adaptation Framework and lessons learned from other transportation agencies to create a defensible and useful vulnerability prioritization process.[2] TPB has identified potential improvements to this methodology that could be utilized for future iterations, described in the Future Improvements section.

Where Phase 1 assessed the sensitivity of asset groups and services to various climate hazards, Phase 2 assesses additional components of climate vulnerability for individual assets. The total vulnerability score for each asset was calculated based on exposure and criticality using the equation below.

$$Vulnerability = (Exposure\ Score \times 0.7) + (Criticality\ Score\ \times\ 0.3)$$

For each asset/hazard pair, exposure and criticality were scored on a scale of 0 to 3, with 3 being the highest possible score. An exposure score of 0 indicates that the asset is not exposed to the climate hazard and therefore also receives a final score of 0. Table 5 shows the vulnerability score thresholds that correspond to high, medium, and low vulnerability ratings for each asset/hazard pair.

Key Terms

Exposure refers to whether an asset is located in an area that is affected by climate hazards. Criticality refers to the importance of an asset to the transportation system. Criteria to evaluate an asset's criticality may include functional classification and whether or not the asset is located in an Equity Emphasis Area (EEA), defined in the Criticality Datasets section below.

Vulnerability is the degree to which an asset is unable to cope with adverse climate impacts. Vulnerability can be used to understand how susceptible or at-risk an asset is to a climate hazard. In this assessment, exposure and criticality are used to determine an asset's vulnerability, with high exposure and criticality indicating high vulnerability or high risk to the asset.

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[2] FHWA. 2017. Vulnerability Assessment and Adaptation Framework. https://www.fhwa.dot.gov/environment/sustainability/resilience/adaptation_framework/.

Table 5. Final Vulnerability Score Thresholds

Final Vulnerability Rating	Vulnerability Score Value
High	2.5 – 3.0
Medium	2.0 – 2.49
Low	0.01 – 1.99
Not exposed	0

Table 6 lists the data sources used in this assessment and indicates whether they were used to determine extreme heat, temporary flooding (coastal and riverine), or permanent flooding (sea level rise) exposure and criticality.

Table 6. Data Sources

Data Source	Extreme Heat Exposure	Temporary Flooding (Coastal and Riverine) Exposure	Permanent Flooding (Sea Level) Exposure	Criticality
Landsat Thermal Infrared Sensor 5-year Median Land Surface Temperature	✓			
FEMA 100-year and 500-year Flood Maps		✓		
NOAA Sea Level Rise Inundation			✓	
National Bridge Inventory (NBI)		✓	✓	✓
COG Equity Emphasis Areas				✓
Functional Classification				✓

For each asset/hazard pair, criticality was evaluated using two indicators: COG Equity Emphasis Areas (EEAs) (for all pairs) and Functional Classification (for roads and highways and bridges). These indicators helped determine the relative importance of the asset to the transportation system as a whole and the potential impact to the transportation system if the asset were affected by the climate hazard. The datasets used for these indicators are described in the following:

- **COG EEAs:** EEAs are census tracts that COG has identified as containing high concentrations of low-income individuals and/or traditionally disadvantaged racial and ethnic population groups. There are 364 EEA designated census tracts out of the 1,300+ census tracts in the region. Populations with high equity scores tend to be more significantly impacted by loss of a transportation option because they often have limited or no access to alternative modes of transportation.
- **Function Classification:** Roads and highways are separated into functional classifications as designated by the FHWA. These distinguish between types of roads based on the degree of mobility

they offer (where roads go and how fast one can travel on them) and how easy it is to access them. For example, interstates, principal roads, and local roads are each a type of functional classification that have decreasing levels of speed and use. Damage to a highly utilized road often causes more issues for the transportation system than damage to a less frequently utilized road.

Equity and Transportation Resilience

Transportation is essential for accessing healthcare, education, employment, and basic services. Low-income and traditionally disadvantaged communities tend to have limited transportation options, and when climate related events occur, their ability to access these services can be further compromised. Investing in transportation resilience ensures that these communities, and their transportation options, are prioritized.

Extreme Heat

PUBLIC TRANSIT

Exposure scores were determined by calculating the median land surface temperature for rail lines and rail and bus stops. For rail lines, the maximum median land surface temperature was applied per rail segment. For stops, the median land surface temperature at the stop location was applied. Each asset was scored on a scale of one (lowest temperatures) to three (highest temperatures) to indicate whether the area has surface temperatures in the highest, middle, or lowest third of all surface temperatures in the region. Criticality was scored using EEAs. Table 7 and Table 8 show the scoring scales used for exposure and criticality, respectively.

Table 7. Exposure Scoring Scale for Extreme Heat and Public Transit

Indicator	Weight	Indicator Value	Score
Land Surface Temperature	70%	Top $\frac{1}{3}$ of surface temperatures	3
		Middle tier of surface temperatures ($\frac{1}{3}$ to $\frac{2}{3}$) experienced in the study area	2
		Bottom $\frac{1}{3}$ of surface temperatures experienced in the study area	1

Table 8. Criticality Scoring Scale for Extreme Heat and Public Transit

Indicator	Weight	Indicator Value	Score
COG Equity Emphasis Area	30%	Located in EEA	3
		Not located in EEA	1

Temporary Flooding (Coastal and Riverine)

ROADS AND HIGHWAYS

Temporary flooding exposure for roads and highways was scored using FEMA 100- and 500-year floodplain maps. The 100-year floodplain indicates a historical 1% annual chance of flooding. The 500-year floodplain indicates a historical 0.2% annual chance of flooding and includes areas in the 100-year floodplain. Although FEMA flood maps are a useful tool to understand flood likelihood at a specific location, these maps are based on historical data and do not consider future climate change. These maps also do not consider additional types of flooding. TPB has identified several potential improvements to the temporary flooding (coastal and riverine) analysis to address the limitations of the floodplain maps, described in the Application of the Assessment section.

The current 500-year floodplain can be used as a proxy to estimate future flood extent due to climate change for the future 100-year floodplain. [3] Additionally, a differential buffer was created to represent an extreme flood scenario. The width of the differential buffer varies based on the floodplain width and can range from 10-200 feet. Criticality was scored using EEAs and functional classification. Table 9 and Table 10 show the scoring scales used for exposure and criticality, respectively.

Table 9. Exposure Scoring Scale for Temporary Flooding and Roads and Highways

Indicator	Weight	Indicator Value	Score
Flood Data (FEMA)	70%	100-yr floodplain	3
		500-yr floodplain	2
		500-yr floodplain + differential buffer	1
		None	0

Table 10. Criticality Scoring Scale for Temporary Flooding and Roads and Highways

Indicator	Weight	Indicator Value	Score
COG Equity Emphasis Area	15%	Located in EEA	3
		Not located in EEA	1
Functional Classification	15%	Interstate, other freeways or expressways	3
		Other principal arterial	2
		Major and minor collector, minor arterial, local	1

PUBLIC TRANSIT

Similar to roads and highways, temporary flooding exposure for public transit assets was scored using FEMA 100- and 500-year floodplain maps.[4] Criticality was scored using EEAs. Table 13 and Table 14 show the scoring scales used for exposure and criticality, respectively.

Table 11. Exposure Scoring Scale for Temporary Flooding and Public Transit

Indicator	Weight	Indicator Value	Score
Flood Data (FEMA)	70%	100-yr floodplain	3
		500-yr floodplain	2
		500-yr floodplain + differential buffer	1
		None	0

Table 12. Criticality Scoring Scale for Temporary Flooding and Public Transit

Indicator	Weight	Indicator Value	Score
COG Equity Emphasis Area	30%	Located in EEA	3
		Not located in EEA	1

BRIDGES

Bridges that cross water were evaluated for flood exposure using condition data, rather than the temporary or permanent flood exposure approaches used for other asset types given these bridges already cross water. Bridges in poor condition may be more likely to be damaged or fail during a flood event. The flooding exposure score for bridges was based on three condition data points from the National Bridge Inventory:

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[3] FEMA. Federal Flood Risk Management Standard. https://www.fema.gov/floodplain-management/intergovernmental/federal-flood-risk-management-standard.

[4] Due to data limitations, the flood exposure methodology was applied to all rail stations and rail lines, regardless of whether those assets are located above or below ground. Underground stations and lines may not be as directly exposed to flooding and typically have pump systems in place. The degree of vulnerability to underground infrastructure is at the discretion of the rail owner.

- **Channel condition:** The physical condition associated with the flow of water through the bridge. Includes stream stability.
- **Water adequacy:** Whether the existing bridge opening can handle the water flowing through it.
- **Scour criticality:** Whether part of the bridge foundation is unstable, or may become unstable, due to scour.

For bridges that had all three datapoints available, the categories were weighted evenly. For bridges that did not have all three datapoints, the remaining two datapoints were weighted 35% each. Criticality was scored using EEAs and functional classification. Table 11 and Table 12 show the scoring scales used for exposure and criticality, respectively.

Table 13. Exposure Scoring Scale for Flooding and Bridges

Indicator	Weight	Indicator Value	Score
Channel Condition (NBI)	24%	Severe damage to full channel failure (NBI = 0 to 4)	3
		Minor to major damage (NBI = 5 to 7)	2
		No noticeable or noteworthy deficiencies. Banks are in a stable condition (NBI = 8 or 9)	1
Water Adequacy (NBI)	23%	Intolerable (NBI = 0 to 3)	3
		Meets minimum limits (NBI = 4 to 6)	2
		Better than present criteria (NBI = 7 to 9)	1
Scour Criticality (NBI)	23%	Scour critical (NBI = 0 to 3)	3
		Foundations stable (NBI = 4 or 5)	2
		Not at risk (NBI = 6 to 9, or T)	1

Table 14. Criticality Scoring Scales for Flooding and Bridges

Indicator	Weight	Indicator Value	Score
COG Equity Emphasis Area	15%	Located in EEA	3
		Not located in EEA	1
Functional Classification	15%	Interstate, other freeways or expressways	3
		Other principal arterial	2
		Major and minor collector, minor arterial, local	1

Permanent Flooding (Sea Level Rise)

ROADS AND HIGHWAYS

Permanent flooding exposure for roads and highways was based on expected depth of inundation from the 2060 intermediate-high sea level rise scenario. The permanent flooding analysis focused on identifying assets at risk of permanent inundation from sea level rise. Storm surge during coastal flood events could cause more severe, but temporary inundation to the transportation system. Criticality was scored using EEAs and functional classification. Table 15 and Table 16 show the scoring scales used for exposure and criticality, respectively.

Table 15. Exposure Scoring Scale for Permanent Flooding (Sea Level Rise) and Roads and Highways

Indicator	Weight	Indicator Value	Score
Sea Level Rise Inundation (NOAA)	70%	Inundation of > 1 ft	3
		Inundation of > 0.5 ft and ≤ 1 ft	2
		Inundation of > 0 ft and ≤ 0.5 ft	1
		No Inundation	0

Table 16. Criticality Scoring Scale for Permanent Flooding (Sea Level Rise) and Roads and Highways

Indicator	Weight	Indicator Value	Score
COG Equity Emphasis Area	15%	Located in EEA	3
		Not located in EEA	1
Functional Classification	15%	Interstate, other freeways or expressways	3
		Other principal arterial	2
		Major and minor collector, minor arterial, local	1

PUBLIC TRANSIT

Permanent flooding exposure for public transit assets was based on expected depth of inundation from the 2060 intermediate-high sea level rise scenario.[5] Criticality was scored using EEAs. Table 17 and Table 18 show the scoring scales used for exposure and criticality, respectively.

Table 17. Exposure Scoring Scale for Permanent Flooding (Sea Level Rise) and Public Transit

Indicator	Weight	Indicator Value	Score
Sea Level Rise Inundation (NOAA)	70%	Inundation of > 1 ft	3
		Inundation of > 0.5 ft and ≤ 1 ft	2
		Inundation of > 0 ft and ≤ 0.5 ft	1
		No Inundation	0

Table 18. Criticality Scoring Scale for Permanent Flooding (Sea Level Rise) and Public Transit

Indicator	Weight	Indicator Value	Score
COG Equity Emphasis Area	30%	Located in EEA	3
		Not located in EEA	1

[5] Due to data limitations, the flood exposure methodology was applied to all rail stations and rail lines, regardless of whether those assets are located above or below ground. Underground stations and lines may not be as directly exposed to flooding and typically have pump systems in place. The degree of vulnerability to underground infrastructure is at the discretion of the rail owner.

ASSET-LEVEL VULNERABILITY ASSESSMENT RESULTS

Overall results of the vulnerability assessment are presented in Table 19 and can be interactively explored through the online mapping tool. Rail lines had the greatest percentage of assets with high vulnerability to any hazard (11% highly vulnerable to temporary flooding (coastal and riverine)) followed by roads and highways (5% highly vulnerable to temporary flooding (coastal and riverine)). The score threshold for a high rating was 2.5 or above out of 3.0. This threshold was chosen to highlight the most vulnerable assets that should be a top priority for resilience investments in the region. However, that should not discount the significance of high-end medium scoring assets that could also be considered for resilience improvements. The following sections summarize the vulnerability assessment results for each asset/hazard pair.

Table 19. Vulnerability Score Count by Asset for Extreme Heat, Temporary Flooding (Coastal and Riverine), and Permanent Flooding (Sea Level Rise)

	Extreme Heat				Temporary Flooding (Coastal and Riverine)				Permanent Flooding (Sea Level Rise)			
Asset Type	High	Medium	Low	Not Exposed	High	Medium	Low	Not Exposed	High	Medium	Low	Not Exposed
Roads / Highways (miles)	Not Assessed				1,097 (4.8%)	1,318 (5.8%)	733 (3.2%)	19,754 (86.3%)	50 (0.2%)	17 (0.1%)	14 (0.1%)	22,820 (99.6%)
Bridge	Not Assessed				1 (0.0%)	39 (3.0%)	1,281 (97.0%)	0 (0.0%)	*Bridges were evaluated for flood vulnerability generally based on condition data rather than temporary flooding vs. permanent flooding			
Bus Stops	196 (0.9%)	6,467 (29.1%)	15,560 (70.0%)	0 (0.0%)	173 (0.8%)	336 (1.5%)	377 (1.7%)	21,337 (96.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	22,223 (100.0%)
Rail Stops	0 (0.0%)	53 (33.1%)	107 (66.9%)	0 (0.0%)	1 (0.6%)	6 (3.8%)	4 (2.5%)	149 (93.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	160 (100.0%)
Rail Line (miles)	18 (1.8%)	352 (34.6%)	646 (63.6%)	0 (0.0%)	115 (11.3%)	154 (15.2%)	128 (12.6%)	619 (60.9%)	19 (1.8%)	42 (4.1%)	2 (0.2%)	954 (93.9%)

Certain assets have high vulnerability to more than one hazard. The assessment found 33.5 miles of rail lines and 50.3 miles of roads and highways were susceptible to both temporary flooding (coastal and riverine) and permanent flooding (sea level rise). Two segments of rail line (1 mile) have high vulnerability to all three hazards. Six bus stops have high vulnerability to extreme heat and temporary flooding (coastal and riverine). Table 20 lists the six bus stops that scored high for two or more hazards and the rail lines that scored high for all three hazards.

Table 20. Public Transit Assets that Received High Vulnerability Scores for Multiple Hazards

Type	Stop/Route Name	Owner	Extreme Heat Score	Temporary Flooding (Coastal and Riverine) Score	Permanent Flooding (Sea Level Rise) Score
Bus Stop	3133 Pennsy Drive	Prince George's County TheBus	3	3	0
Bus Stop	Columbia Park Road & Cabin Branch Drive	Prince George's County TheBus	3	3	0
Bus Stop	Columbia Park Road & #5700	Washington Metropolitan Area Transit Authority (WMATA) Metrobus	3	3	0
Bus Stop	Pennsy Drive & #3133	WMATA Metrobus	3	3	0
Bus Stop	South Picket Street & Shilling Street (North)	WMATA Metrobus	3	3	0
Bus Stop	South Picket Street & Shilling Street (South)	WMATA Metrobus	3	3	0
Rail Line	WMATA Orange Line (351) – between Stadium Armory & Minnesota Avenue	WMATA Metrorail	3	3	3
Rail Line	WMATA Blue Line (1731) - between Stadium Armory and Benning Road	WMATA Metrorail	3	3	3

Assets that face medium vulnerability to one climate hazard but high vulnerability to another may also be more vulnerable than other assets. Table 21 identifies the number of assets that have high vulnerability to at least one climate hazard and medium or high vulnerability to all others that they are exposed to.

Table 21. Assets with Medium-High Vulnerability

	Bus Stops	Rail Line	Rail Stop	Roads	Bridges
Number of assets with medium-high vulnerability to multiple hazards	140	13 miles	1	7.3 miles	N/A

The results of each hazard/asset pair are described in more depth below.

Extreme Heat Results

PUBLIC TRANSIT

Extreme heat can cause physical damage to public transit infrastructure in addition to affecting public transit users. For example, extreme heat can create kinks in rail tracks and affect electric bus batteries. Waiting at a bus or rail stop in extreme heat can be intolerable for riders. This analysis evaluated extreme heat vulnerability for bus stops, rail stops, and rail lines throughout the region. As seen in Figure 3, the majority of vulnerable rail lines have low vulnerability to extreme heat.

Figure 3. Breakdown of rail lines with low, medium, and high vulnerability to extreme heat.

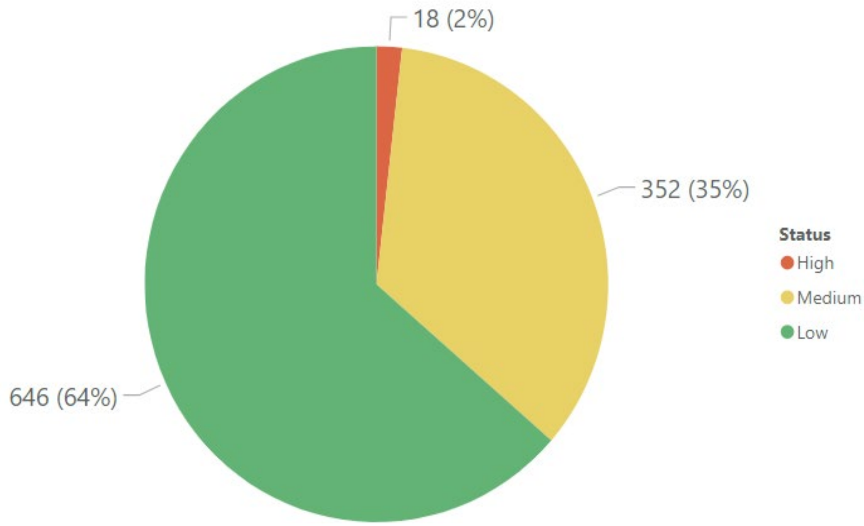


Figure 4 and Figure 5 show the extreme heat vulnerability results by rail operator. Amtrak has the most miles of rail line overall (569.6 miles assessed) and the most that are highly vulnerable to extreme heat (7 miles). This constitutes 1.2% of their total assets, the lowest of any rail line. On the other hand, DC Streetcars has the fewest miles of rail line (4.2 miles) but the highest percentage of highly vulnerable rail lines (23.7%). Virginia Railway Express does not have any assets that face significant extreme heat risk. Only one stop was found to face high extreme heat risk: Brunswick Maryland Area Rail Commuter (MARC) Station in Frederick, Maryland.

Figure 4. Percentage of assets with low, medium, and high vulnerability to extreme heat, by rail operator.

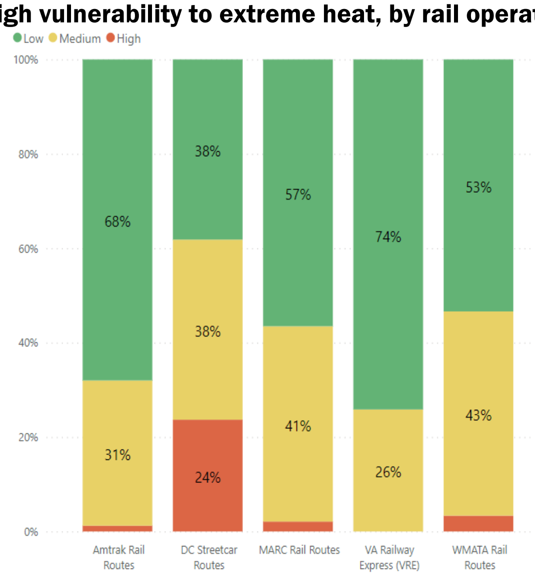
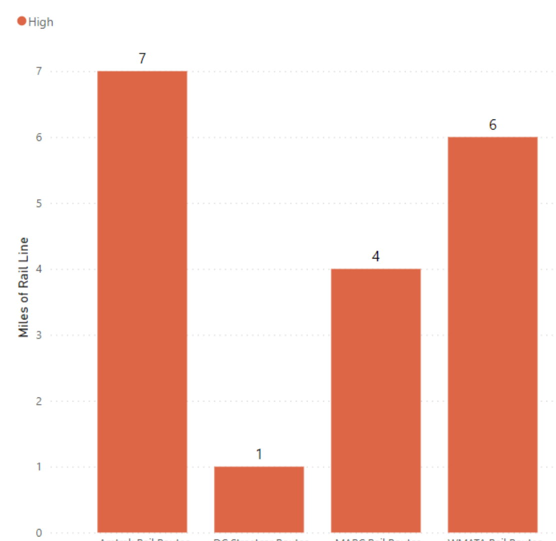


Figure 5. Miles of rail line that are highly vulnerable to extreme heat, by rail line operator.



Of the 22,223 bus stops in the region, only 1% (196 stops) are highly vulnerable to extreme heat (Figure 6). All 196 stops are in an EEA. There are 6,467 bus stops (29%) with medium vulnerability to extreme heat.. Maryland has the highest number of bus stops with high vulnerability to extreme heat (96 stops, or 0.8% of Maryland stops) (Figure 7). Virginia has the highest ratio of highly vulnerable bus stops to total bus stops within the state with 83 highly vulnerable bus stops (1.3% of Virginia stops).

Figure 6. Breakdown of bus stops with low, medium, and high vulnerability to extreme heat.

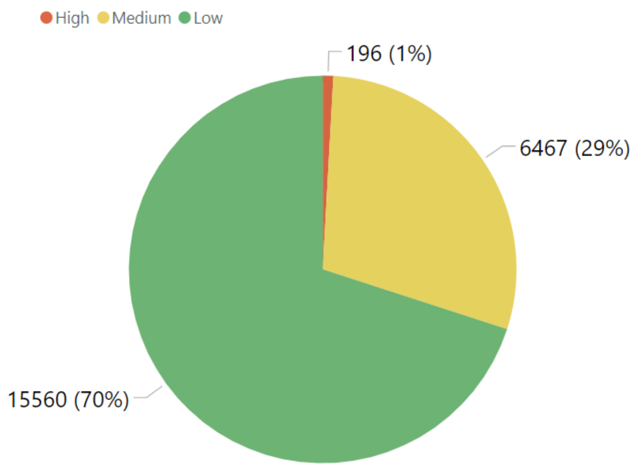
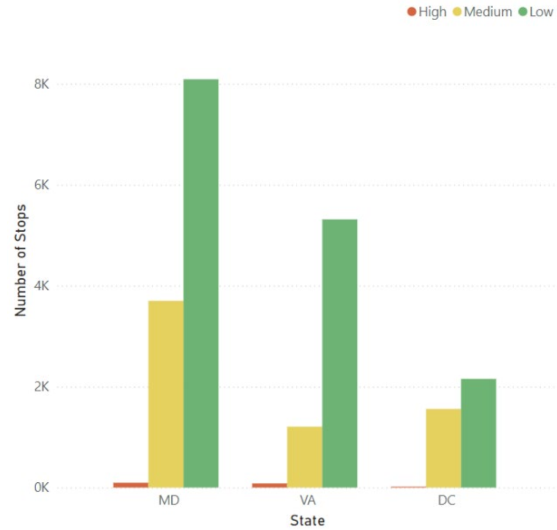


Figure 7. Each region's number of bus stops with each level of vulnerability to extreme heat.

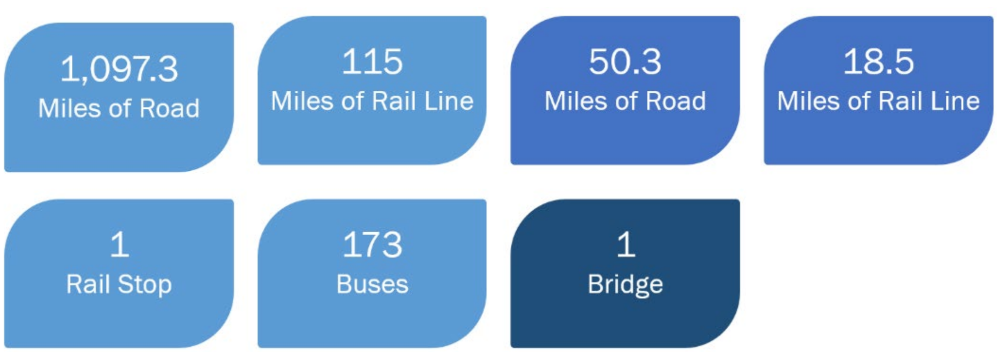


Temporary Flooding (Coastal and Riverine) and Permanent Flooding (Sea Level Rise)

The vulnerability assessment revealed that flooding mainly poses a high vulnerability to roads and highways, buses, and rail lines. As noted in the Temporary Flooding (Coastal and Riverine) methodology section, the flood vulnerability results likely do not capture all locations and assets that are highly vulnerable to flooding. This is largely because the metropolitan Washington region lacks data on regional temporary coastal and riverine flooding and FEMA floodplain maps were the only data available for this analysis. The FEMA maps are not forward-looking, and some may be outdated. Potential future improvements to the flood vulnerability assessment are included in the Application of the Assessment section.

Figure 8 summarizes the assets (in number or mileage as appropriate) that are highly vulnerable to temporary flooding (coastal and riverine) and permanent flooding (sea level rise). Bridge vulnerability was based on bridge condition and susceptibility to failure rather than exposure to temporary and permanent flooding, specifically.

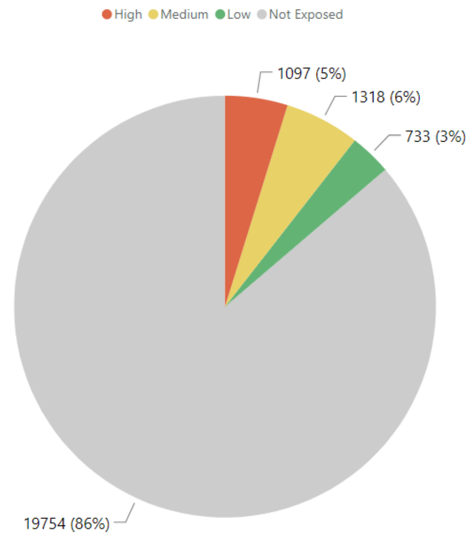
Figure 8. Summary of assets with high vulnerability to temporary flooding (light blue) and permanent flooding (medium blue). Bridge flood vulnerability was based on condition data (dark blue). Some assets are vulnerable to both hazards and are counted in both categories.



ROADS AND HIGHWAYS

High flood risk along roads and highways may create dangerous driving conditions. Flooding may crack and erode road and highway surfaces or wash away the soil beneath a road or highway, thereby compromising the structural integrity of the road. Extreme precipitation and storm surge can create temporary flooding events through coastal, riverine, or urban flooding while rising sea level may pose a permanent coastal flood risk. Temporary flood and permanent flooding may also affect the same assets. A total of 50.1 out of the 50.3 miles of roads and highways with high vulnerability to permanent flooding (sea level rise) also have high vulnerability to temporary flooding (coastal and riverine). These multi-hazard vulnerable roads and highways account for 5% of the total 1,097.3 miles of roads and highways with high temporary flooding vulnerability.

Figure 9. Miles of roads and highways included in the assessment and their respective vulnerability to temporary flooding (coastal and riverine).



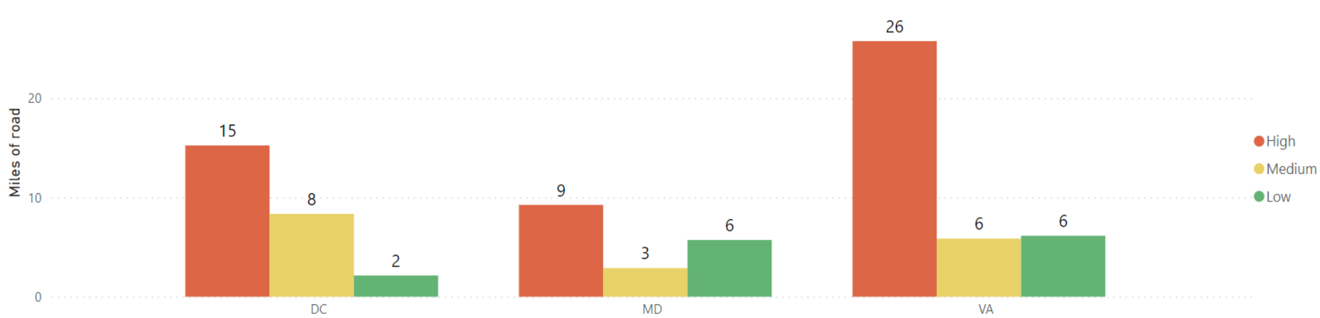
TEMPORARY FLOODING (COASTAL AND RIVERINE)

The assessment identified 1,097 miles of road (5%) with high vulnerability to temporary flooding and 1,318 miles of road (6%) with medium vulnerability (Figure 9). Most roads and highways do not have any identified vulnerability to temporary coastal and riverine flooding. EEAs are very vulnerable to temporary flooding: about 20% of all miles of roads and highways are in an EEA, most of which are in Maryland. While 12% of all roads and highways in an EEA have high vulnerability to temporary coastal and riverine flooding, the same is true for only 1% of all roads and highways not in an EEA.

PERMANENT FLOODING (SEA LEVEL RISE)

Of the 64 miles of roads and highways that are projected to be exposed to permanent flooding from sea level rise, 50 miles have high vulnerability, 17 miles have medium vulnerability, and 14 miles have low vulnerability (Figure 10). The 50 miles of road and highways that were identified as highly vulnerable scored 3 on exposure, meaning they will be inundated by at least one foot of water by 2060. Over half of the roads and highways with high vulnerability to permanent flooding from sea level rise are in Virginia. EEAs are also very vulnerable to permanent flooding: nearly 80% of Maryland's roads and highways with high vulnerability to permanent flooding (sea level rise) are in EEAs. Similarly, 63% of DC's roads and highways with high vulnerability to permanent flooding (sea level rise) are in EEAs.

Figure 10. Miles of road that have some vulnerability to permanent flooding (sea level rise), by location.



BRIDGES

Bridges are generally designed to be able to handle flood events. Only one bridge in the region, located in Washington, DC, shown in Figure 11 with details in Table 22, has high vulnerability to flooding. This bridge's high score is based on its condition data, location in an EEA in Washington, DC, and functional classification as an interstate, freeway, or expressway.

Figure 11. Location of the bridge with high vulnerability to flooding.

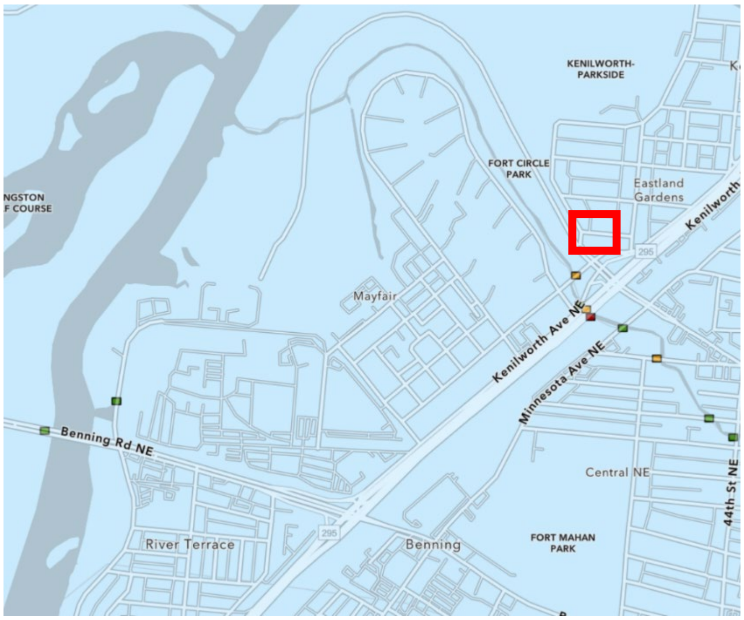


Table 22. Score Components for the Bridge Highly Vulnerable to Flooding

Structure Number	0019-1(LOW)
Functional Class	Interstate, other freeways or expressways
Exposure Score	2.33
EEA	3
Functional Class	3
Overall Risk	2.53

PUBLIC TRANSIT

Floods can limit the functionality of rail lines and buses. Floods can also make it harder to access public transit. Flood risk at bus stops indicates usability issues as it may be hard for pedestrians to get to and wait at bus stops. There are 18.5 miles of rail lines that have high vulnerability to both temporary flooding (coastal and riverine) and permanent flooding (sea level rise).[6]

TEMPORARY FLOODING (COASTAL AND RIVERINE)

A total of 0.8% of all public transit bus stops (173), 11% of rail lines (115 miles), and 0.6% (1) of all rail stops are highly vulnerable to temporary coastal and riverine flooding (Figure 12 and Figure 13). Figure 14 shows the breakdown of high, medium, and low vulnerability by rail line operators and finds that 10-15% of each rail line's assets have high vulnerability to temporary flooding. The rail stop with high temporary coastal or riverine flooding risk is the Brunswick MARC station in Frederick, Maryland, and is within the FEMA 100-year floodplain.

Figure 12. Vulnerability of bus stops to temporary flooding (coastal and riverine).

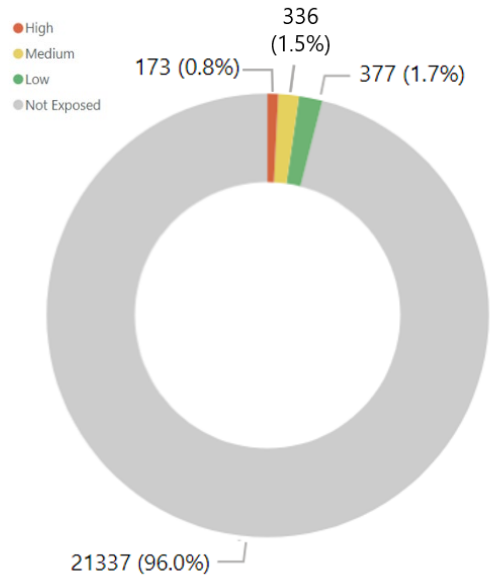


Figure 13. Vulnerability of rail lines to temporary flooding (coastal and riverine).

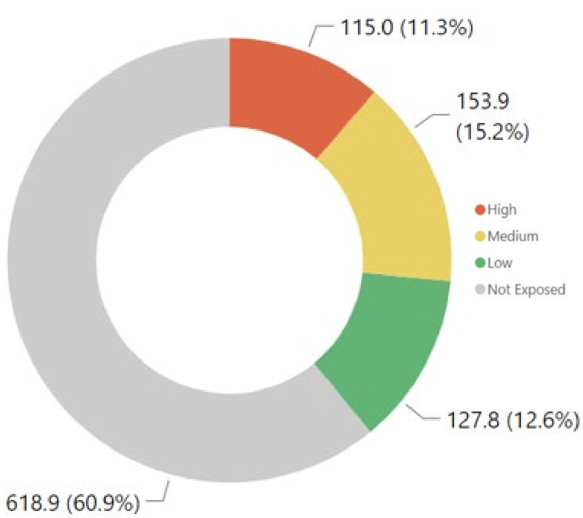
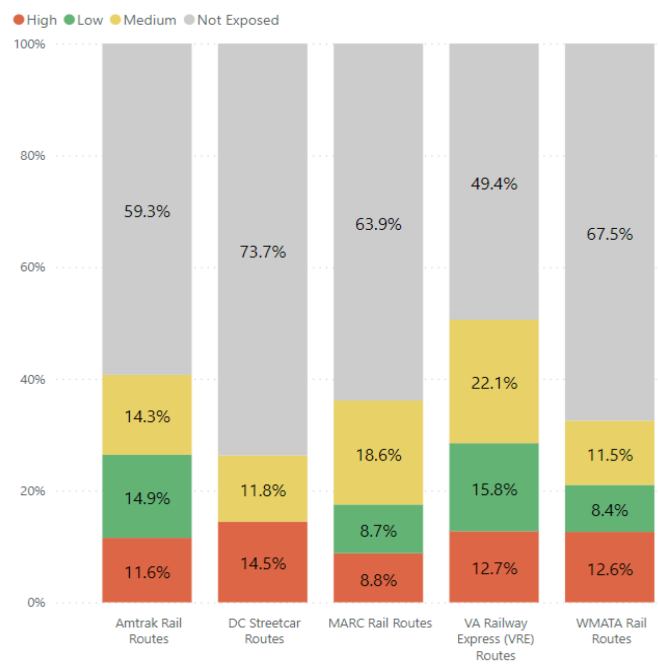


Figure 14. Percentage of assets with high, medium, and low temporary flooding (coastal and riverine) vulnerability, by rail operator.



[6] Due to data limitations, the flood exposure methodology was applied to all rail stations and rail lines, regardless of whether those assets are located above or below ground. Underground stations and lines may not be as directly exposed to flooding and typically have pump systems in place. The degree of vulnerability to underground infrastructure is at the discretion of the rail owner.

PERMANENT FLOODING (SEA LEVEL RISE)

While only 18.5 miles (1.8%) of all rail lines are highly vulnerable to permanent flooding from sea level rise (Figure 15), these 18.5 highly vulnerable miles account for 30% of all exposed rail lines, meaning that when rail lines are exposed, they are often highly vulnerable. One to two percent of each rail line operator's assets have high vulnerability to permanent flooding (sea level rise) (Figure 16). All (100%) of MARC lines that are exposed to permanent flooding (sea level rise) have a high vulnerability (2 miles), as do 44% of WMATA rail lines (4 miles), 25% of Amtrak lines (11 miles), and 21% of Virginia Railway Express (VRE) lines (1.5 miles).

Figure 15. Breakdown of how many miles of rail line have a high, medium, or low permanent flooding (sea level rise) vulnerability.

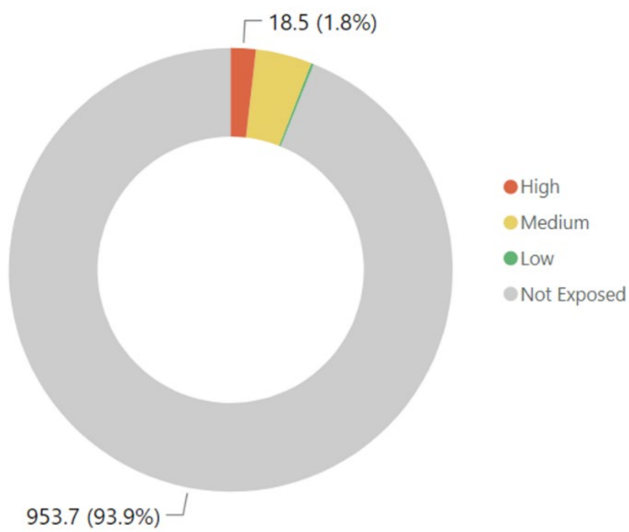
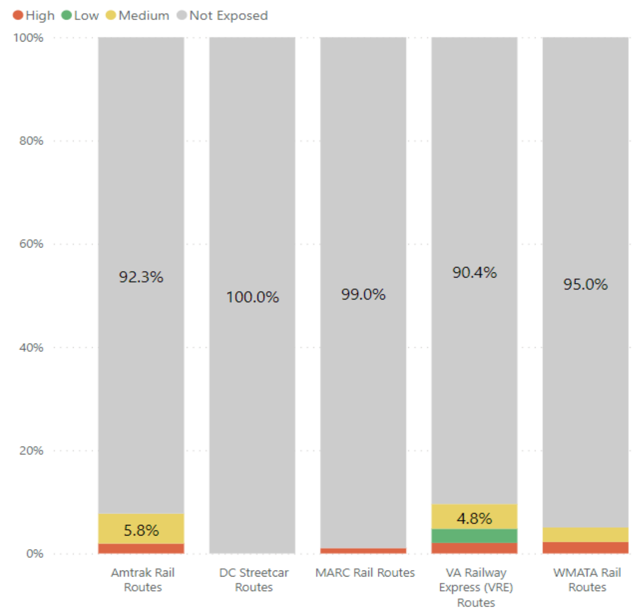


Figure 16. Percent of assets with high, medium, and low permanent flooding (sea level rise) vulnerability by rail operator.



Tier 2: Map Layer

A visual map layer was used to identify potential vulnerabilities for the highly sensitive active transportation and extreme heat pair from Phase 1. This pair indicated high sensitivity to user health and safety rather than infrastructure. Active transportation, including biking and walking, during extreme heat can pose risks to human health and safety. A GIS map layer was created to visualize the potential vulnerabilities to active transportation users and extreme heat. The highest median surface temperatures coincide with densest urban development, indicating that active transportation users are most vulnerable to extreme heat in city centers. This is likely due to the urban heat island effect, where densely built structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat.[7]

Figure 17 shows a bike routes and heat map for the metropolitan Washington region and Figure 18 shows a closer look at the Washington, DC region, overlaying bike routes with the median surface temperature. Bike routes in urbanized areas that may be prone to urban heat island effect could be locations to target for resilience improvements (e.g., adding more shading along routes).

Figure 17. Metropolitan Washington region bike and heat map.

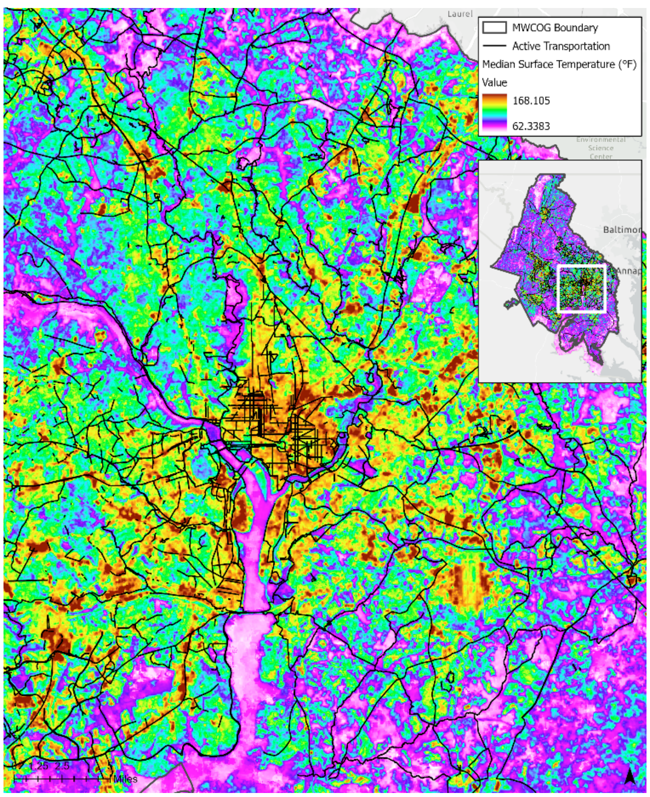
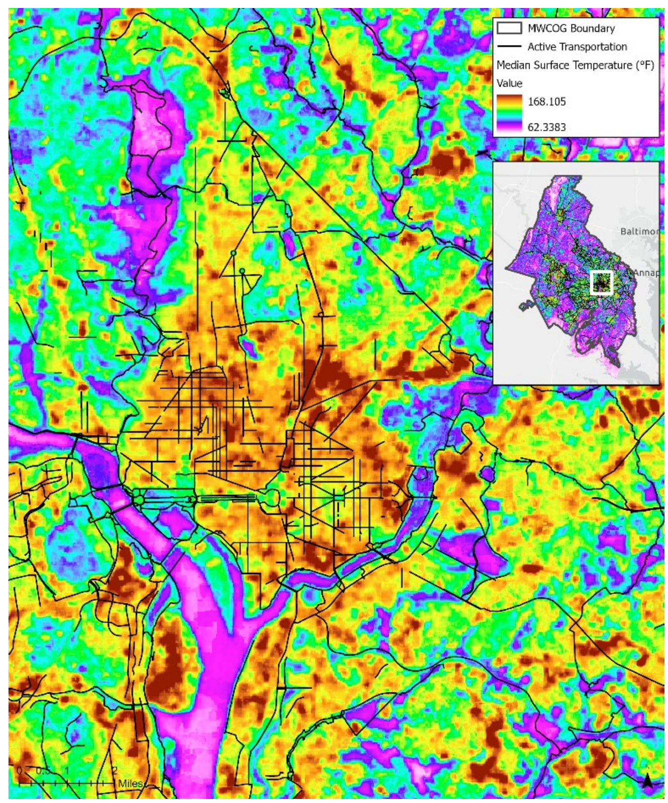


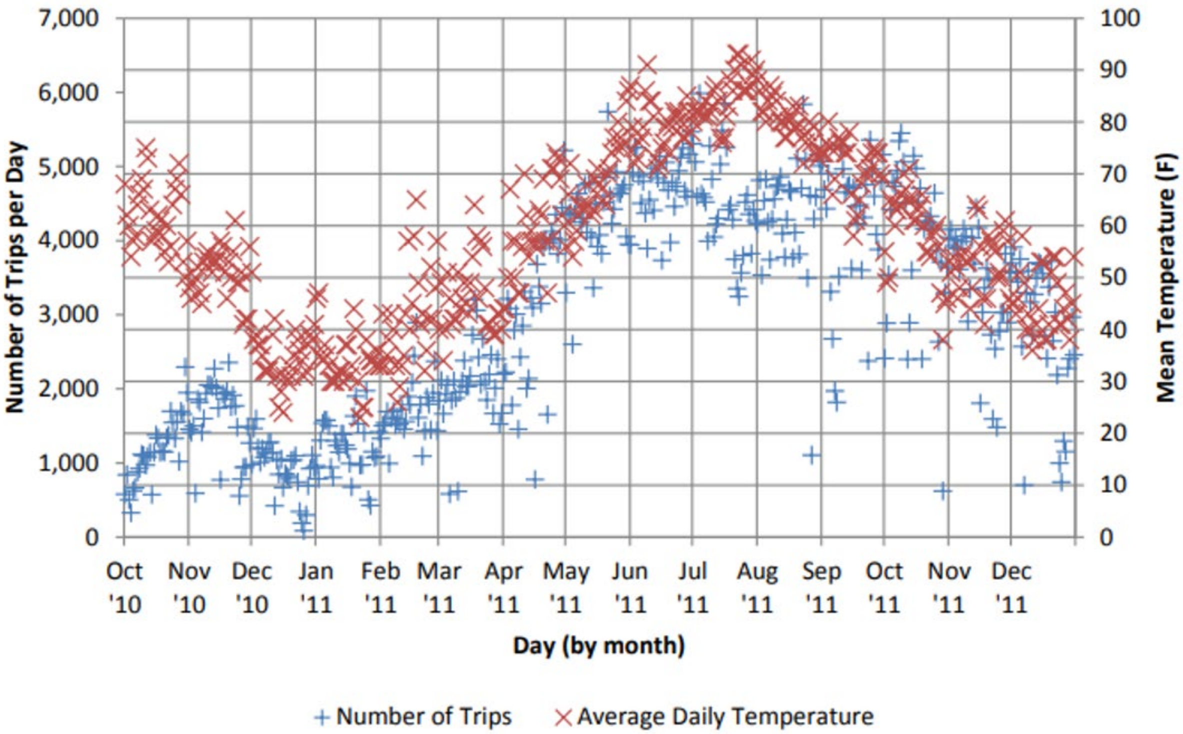
Figure 18. Downtown Washington, DC bike and heat map.



[7] U.S. Environmental Protection Agency: Learn About Heat Islands. Accessed 2023. https://www.epa.gov/heatislands/learn-about-heat-islands#heat-islands

Extreme heat has implications for the accessibility of active transportation options. Figure 19 compares the number of Capital Bikeshare trips per day to the average temperature each day.[8] As temperatures increase, ridership generally increases at a similar rate. However, there is a noticeable stagnation or dip in ridership in July and August when temperatures are at their hottest (above 80°F). This indicates a point at where riders are choosing not to take Capital Bikeshare due to extreme heat and presumably use alternative modes of transportation. Extreme heat has the potential to significantly impact active transportation as a viable transportation mode, particularly in dense urban areas.

Figure 19. Total number of Capital Bikeshare trips per day compared to average temperature per day.



Source: Gehbart and Noland/Transportation

[8] Kyle Gebhart and Robert B Noland. 2014. The impact of weather conditions on bikeshare trips in Washington, DC. https://link.springer.com/article/10.1007/s11116-014-9540-7

Tier 3: Literature Review

The third tier of Phase 2 was a literature review exploring how extreme heat, temporary flooding (coastal and riverine), permanent flooding (sea level rise), extreme winter, and extreme wind events are expected to change over time in the region. The literature review focuses on the asset/hazard pairs that received a high sensitivity rating in the Phase 1 vulnerability assessment, but could not be analyzed for the asset-level, indicator-based vulnerability assessment (Tier 1):

- **Temporary flooding (coastal and riverine):** stormwater, maritime
- **Permanent flooding (sea level rise):** stormwater, maritime
- **Extreme winter:** public transit, active transportation
- **Extreme wind:** roads and highways, public transit

Geospatial data was not available for these asset/hazard pairs to complete a detailed GIS analysis. Each of the following sections includes a summary of historical events and trends, future climate projections as available, and transportation impacts for each highly sensitive pair, including potential disproportionate impacts to certain populations or transportation users.

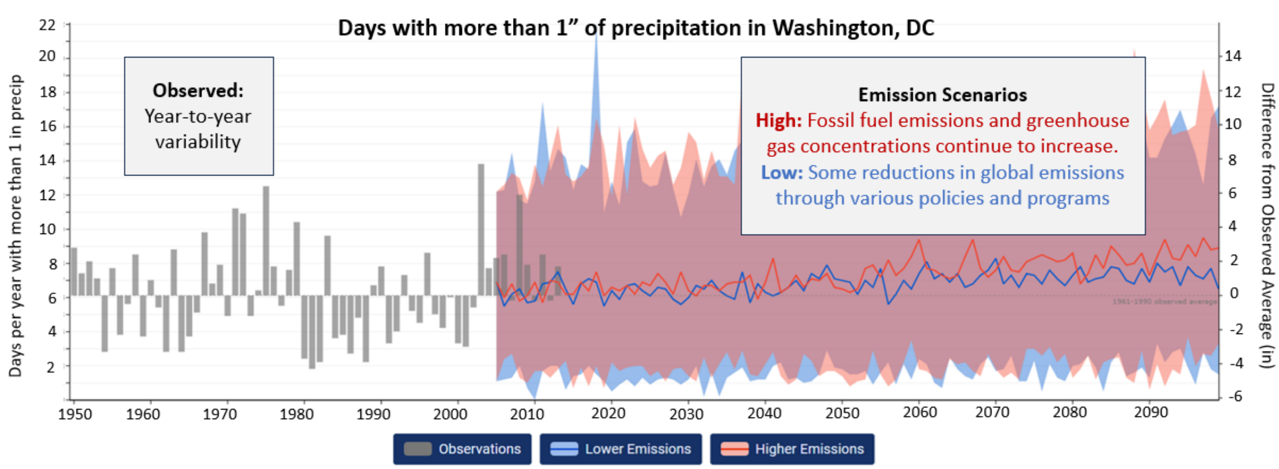
Other Hazards: Wildfire Impacts

While the metropolitan Washington region is not itself at risk from wildfires, the region did experience significant impacts from wildfire smoke in 2023. During this event, outdoor air quality was considered unsafe for everyone and authorities asked people to stay indoors and avoid physical activity. Schools and public outdoor parks closed while flights were delayed.[9]

Hotter temperatures and drier conditions are expected to fuel more wildfires that could continue to impact visibility and air quality in the region during wildfire events. Wildfire smoke would adversely affect active transportation users most.

How to Read Climate Projections Graphs

Throughout this report, graphs showing both observed historical data and future climate projections are used to illustrate how average climate conditions are expected to change over time (see example below). Although changes in average conditions will be gradual, the metropolitan Washington region is still expected to see year-to-year variability through mid- and late-century. Climate projections represent the average values of multiple climate models for both low and high emissions scenarios.



[9] Drew Wilder. 2023. DC-area flights delayed, recess pushed inside due to Canada wildfire smoke. [DC-area flights delayed, recess pushed inside due to Canada wildfire smoke – NBC4 Washington (nbcwashington.com)]

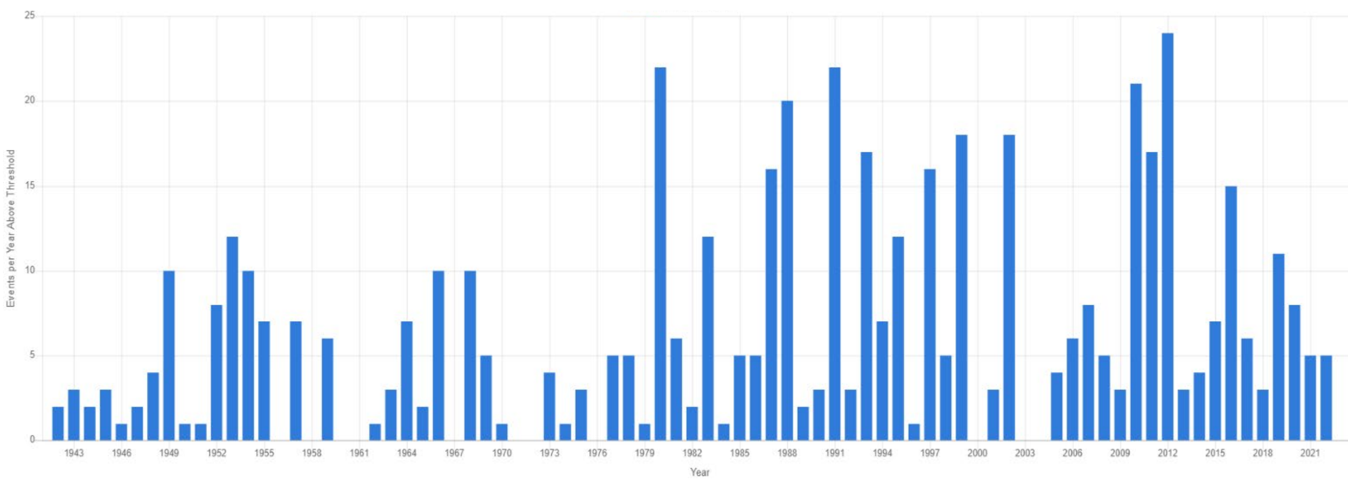
EXTREME HEAT

The Phase 1 vulnerability assessment identified public transit and active transportation as highly sensitive to extreme heat. The Tier 1: Indicator-based, Asset-level Vulnerability Assessment section identifies the extreme heat vulnerability of individual public transit assets in the region and the Tier 2: Map Layer section provides a map of active transportation infrastructure and surface temperatures to help identify higher risk locations.

Historical Trends and Past Events

Temperatures in the metropolitan Washington region have been increasing over time. Heat waves have also become more common. The number of hot days each year has significantly increased since 1980 (Figure 20). Between 1943 and 1972, the metropolitan Washington region experienced an average of 3.8 days per year where maximum temperature was above 95°F. From 1992 to 2022, there were an average of 8.2 days per year where temperature exceeded 95°F.[10]

Figure 20. Time series of number of days where maximum temperature exceeds 95°F from 1942 to 2022.



Source: NOAA Climate Explorer

Extreme heat can cause changes to physical transportation infrastructure as well as decrease the usability of transportation options if conditions are too hot for the human body and pose a health or safety risk. Some examples of regional transportation impacts from extreme heat events include:

- VRE, WMATA, and MARC issue heat orders that limit the speed of passenger trains on warm days or when there is a significant change in temperature. Regularly affected lines include Fredericksburg Line (VRE), Brunswick Line (MARC), and Camden Line (MARC). MARC, for example, imposes restrictions when ambient temperatures are 85°F or higher or when there is a 25°F temperature change within a 24 hour period.[11] These limits ensure that trains do not encounter a "sun kink", a buckled or misshapen part of the rail track that can occur under these conditions. When sun kinks form, single tracking is implemented so that this section of the rail track can be replaced.[12] Heat

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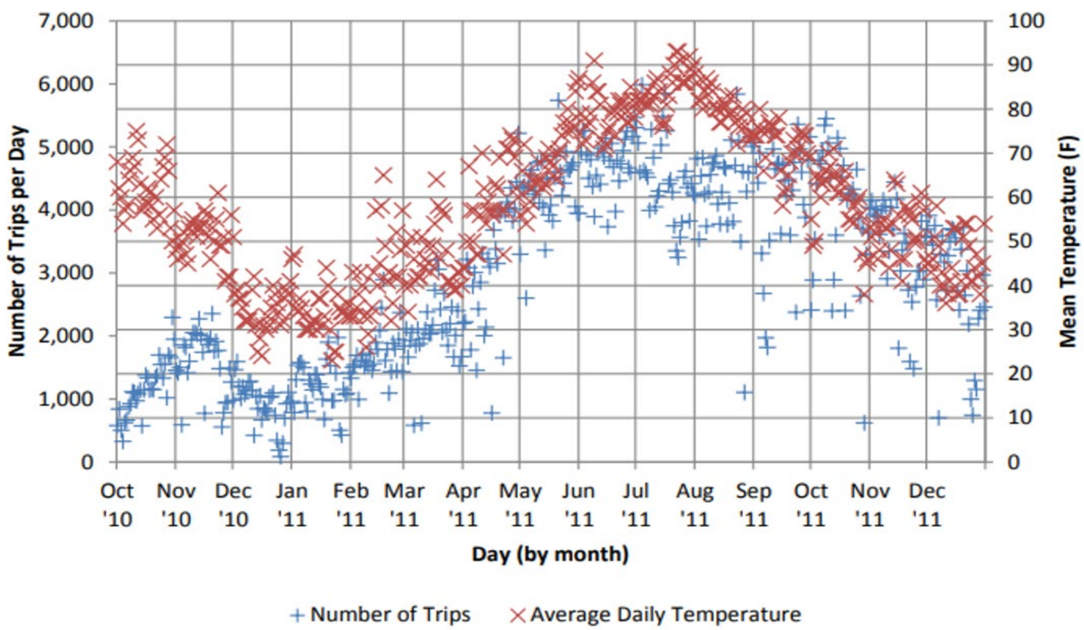
[10] NOAA Climate Explorer: Historical Weather Data. Accessed 2023. https://crt-climate-explorer.nemac.org/historical_weather_data/.
[11] Maryland Department of Transportation. MARC Heat Orders. Accessed 2023. https://www.mta.maryland.gov/marc-heat-orders
[12] Virginia Railway Express. The Need for Heat Restrictions. Accessed 2023. https://www.vre.org/about/blog/understanding-the-need-for-heat-restrictions/?startRow=51&nextNID=C411E30D-8F4E-441E-8A01BC4045A851D8

orders consistently cause delays due to the train speed decrease.

- As discussed in Tier 2: Map Layer, the use of the Capital Bikeshare decreases under hot conditions. Figure 21 compares the number of Capital Bikeshare trips per day to the average temperature each day.[13]

Figure 21. Total number of Capital Bikeshare trips per day compared to average temperature per day.



Source: Gehbart and Noland/Transportation

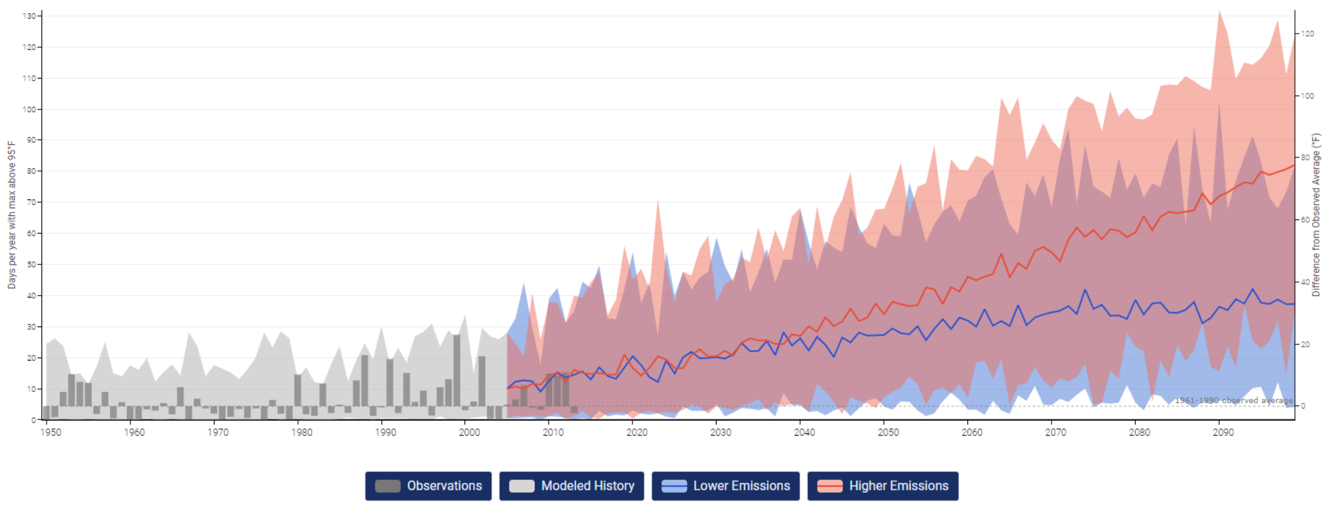
[13] Kyle Gebhart and Robert B Noland. 2014. The impact of weather conditions on bikeshare trips in Washington, DC https://link.springer.com/article/10.1007/s11116-014-9540-7

Future Conditions

MORE FREQUENT EXTREME HEAT

Projections indicate that the number of days with extreme heat will increase. From 1960-1990, there were an average of 4.4 days a year with temperatures above 95°F and 0 days above 105°F. In 2050, climate models project that this will rise to 38.9 days with temperatures above 95°F and 2.3 days above 105°F. By 2100 these numbers will again rise to 77.4 days with temperatures above 95°F and 15.3 days above 105°F (Figure 22). For context, there are almost zero days in the historical record where temperatures pass 105°F. Perceived temperatures are likely to be even higher than this because the human body experiences temperatures to be hotter than they actually are when humidity is present.[14]

Figure 22. Days with extreme heat as identified by days with maximum temperatures above 95°F. Projections given both low and high emissions are shown.



Source: NOAA Climate Explorer

[14] National Weather Service. What is the Heat Index? https://www.weather.gov/ama/heatindex Retrieved 2023.

TEMPORARY FLOODING (COASTAL AND RIVERINE)

The Phase 1 vulnerability assessment identified roads and highways, bridges, public transit, stormwater, and maritime infrastructure as highly sensitive to temporary coastal and riverine flooding. The Tier 1: Indicator-based, Asset-level Vulnerability Assessment section identifies the flood vulnerability of individual roads and highways, bridges, and public transit assets in the region. This section qualitatively evaluates stormwater and maritime infrastructure vulnerability.

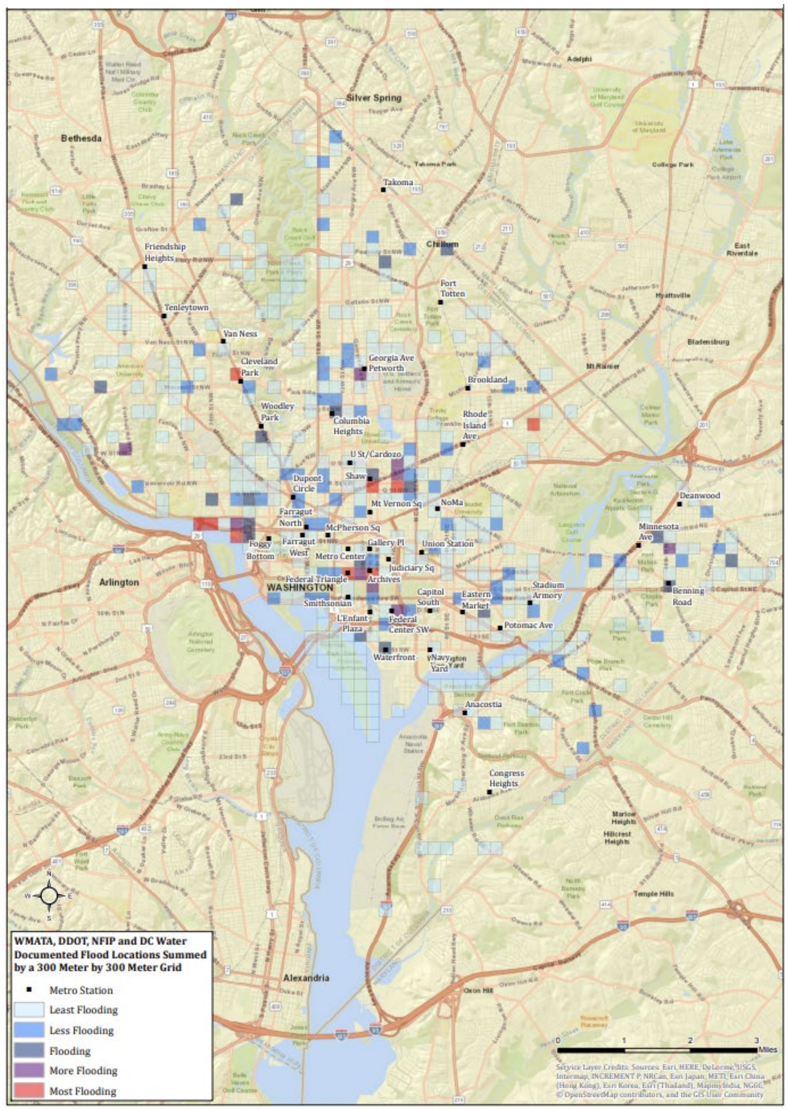
Historical Trends and Past Events

EXTREME PRECIPITATION

The metropolitan Washington region typically receives about 42 inches of rain each year,[15] but annual precipitation has been increasing in the region since 1961.[16,17] For example, Washington, DC saw its wettest year on record in 2018 with over 61 inches of rain.[18] Extreme precipitation events are also increasing in frequency and intensity. From 2006-2017, the region saw double the number of days with extreme precipitation over 3 inches compared to 1976-2005.[19]

Extreme precipitation events can cause temporary coastal and riverine flooding when water accumulates too quickly to be absorbed into the ground or diverted by stormwater infrastructure. Heavy rain events can also cause rivers and channels to overflow their banks. Figure 23

Figure 23. Areas in Washington, DC that have experienced regular urban flooding.



Source: DC Silver Jackets/Task Group Report (2017)

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[15] NOAA. 2021. U.S. Climate Resilience Toolkit Climate Explorer/Total Precipitation in DC https://crt-climate-explorer.nemac.org/.

[16] NOAA. 2021. The new U.S. Climate Normals are here. What do they tell us about climate change? https://www.noaa.gov/news/new-us-climate-normals-are-here-what-do-they-tell-us-about-climate-change.

[17] NOAA Mid-Atlantic RISA. Future Differences from "Normal Temperature." https://www.midatlanticrisa.org/data-tools/climate-data-tools/difference-from-normal-total-annual-precipitation.html.

[18] WUSA9. Here's how 2019 in DC matches up against its wettest year on record. https://www.wusa9.com/article/news/heres-how-2019-in-DC-matches-up-against-its-wettest-year-on-record/65-c7c4e7a0-0c7f-43db-b5f9-acb02ae63907.

[19] NOAA Mid-Atlantic RISA. N.d. Changes in Extreme Precipitation from 1976 to Present. https://www.midatlanticrisa.org/data-tools/climate-data-tools/extreme-precipitation-historic.html.

shows areas in Washington, DC that experience regular urban flooding.[20]

Some examples of transportation and stormwater infrastructure impacts from past heavy rainfall and temporary flooding events include:

- In 2006, heavy showers and thunderstorms caused a flash flood in Washington, DC (Figure 24). Washington National Airport recorded almost 8 inches of rain in just 24 hours. [21] Daily precipitation would usually average 0.14 inches.[22] The flooding event overwhelmed the city's stormwater drainage system and caused an estimated $10 million in property damage.[23] A stormwater drainage study of the event indicated that all pumps and facilities in the area operated as intended.[24] However, the magnitude of the rainfall event exceeded the capacity of the sewer system, resulting in severe flash flooding. Some sewers also accumulated sediment, further reducing their capacity.[25] The event also caused numerous road closures and power outages. VRE commuter rail did not operate and much of the Metro system was shut down due to flooding in underground tunnels. Up to 4 feet of water was reported in some tunnels in DC.[26]
- In 2019, a cloudburst in the metropolitan Washington region produced nearly a month's worth of rain (4-6 inches) in just an hour.[27] This record-breaking storm overwhelmed stormwater systems and caused severe flash flooding (Figure 25). Major roads were completely inundated, and some roads caved in, resulting in large sinkholes.[28] A portion of one road in Maryland completely collapsed due

Figure 24. Flooding near the Federal Triangle, 2006.

Source: Comprehensive Flood Risk Management

Figure 25. School bus pushes through floodwaters in Washington, DC 2019.

Source: Washington Post

[20] This map is based on the following data sources: locations where DC Water received multiple calls about flooding (2009-2015), District Department of Transportation areas prone to flooding, National Flood Insurance Program flood insurance claim locations (1977-2015), and areas where water has entered Washington Metro Area Transit Administration (WMATA) facilities.
[21] NOAA. N.d. Remembering the June 26-28, 2006 Flooding across the Baltimore and Washington, DC region. https://noaa.maps.arcgis.com/apps/MapJournal/index.html?appid=d91f870682374ab281eda95056ec4c09#map.
[22] NWS. DCA Norms, Means, and Extremes. https://www.weather.gov/lwx/dcanme#jun. Retrieved 2023.
[23] Ibid.
[24] DC Water. 2011. Federal Triangle Stormwater Drainage Study. https://www.ncpc.gov/docs/Federal_Triangle_Stormwater_Drainage_Study_Jul2011.pdf.
[25] Ibid.
[26] NOAA. N.d. Remembering the June 26-28, 2006 Flooding across the Baltimore and Washington, DC region.
[27] Samenow, J. et al. 2019. How and why the DC area was deluged by a month's worth of rain in an hour Monday. https://www.washingtonpost.com/weather/2019/07/08/washington-D.C.-flash-flood-how-why-area-was-deluged-by-months-worth-rain-an-hour-monday/.
[28] Ibid.

to floodwaters.[29] Fairfax County emergency response teams performed 56 swift water rescues.[30] The public transit system was also affected, with water pouring into Metro stations and underground tunnels. Amtrak was also forced to suspend its service in and around DC.[31]

- In 2020, heavy rainfall in Prince George's County and Montgomery County produced 4-6 inches of rain (Figure 26). Streams rose up to 8 feet in an hour and inundated major roads.[32] Route 50 was closed for 6 hours due to high-water conditions.[33] Vehicles along many roads in Prince George's County, Montgomery County, and Washington, DC were abandoned.[34] Montgomery County Fire and Rescue received 50 emergency phone calls with request for high-water rescue.[35] High floodwaters also prevented regional trains from conducting normal operations.[36]
- In 2021, parts of the region saw a month's worth of rain from slow moving thunderstorms. Rain was most severe near the cities of Alexandria and Manassas where 5 inches of precipitation fell in two hours. Blacklick Run rose 6 feet in less than 30 minutes.[37] Precipitation inundated low-lying areas, forcing multiple road closures and trapping at least two vehicles. The torrential downpour caused several stoplights to malfunction and downed multiple trees.[38]

Figure 26. Route 50 in Prince George's County under water in September 2020.

Source: Dave Dildine/WTOP News

Figure 27. Vehicle in Washington, DC stuck in flash flood, 2019.

Source: Alex Brandon/Associated Press

[29] Stack, L. and E. Rueb. 2019. Washington Area Hit by Heavy Rains and Flash Floods. https://www.nytimes.com/2019/07/08/us/washington-DC-weather-rain.html.
[30] Woolsey, A. 2019. The numbers are in: Fairfax County sustained at least $2 million in damages after July 8 rainstorm. https://www.fairfaxtimes.com/articles/the-numbers-are-in-fairfax-county-sustained-at-least-2-million-in-damages-after-july/article_bd454a1a-b561-11e9-852d-0b2f115d24dd.html.
[31] Ibid.
[32] Samenow, J and Streit, D. 2020. Torrential rain triggers widespread flooding in D.C. area, inundating roads, stranding motorists. https://www.washingtonpost.com/weather/2020/09/10/DC-area-forecast-tropical-downpours-today-could-produce-areas-flooding/
[33] Moore, J. 2020. Why was Route 50 flooding in Prince George's County so extreme? https://wtop.com/weather-news/2020/09/why-was-route-50-flooding-in-prince-georges-county-so-extreme/#:~:text=At%20the%20height%20of%20the%20flooding%2C%20shortly%20after,for%20about%20six%20hours%20Thursday%20afternoon%2C%20Felix%20added.
[34] Samenow, J and Streit, D. 2020. Torrential rain triggers widespread flooding in DC area, inundating roads, stranding motorists. https://www.washingtonpost.com/weather/2020/09/10/D.C.-area-forecast-tropical-downpours-today-could-produce-areas-flooding/
[35] Ibid.
[36] Moore, J, Alim, T, and Gelman, S. Dramatic rescues after heavy rain drenches DC area. https://wtop.com/weather-news/2020/09/DC-region-under-flash-flood-watch-through-thursday-night/
[37] Walker, A. and Samenow, J. 2021. Torrential rain produces flash flooding around Alexandria. https://www.washingtonpost.com/weather/2021/08/14/pm-update-strong-severe-storms-possible-into-this-evening/
[38] Rosenzweig-Ziff, D. and Samenow, J. 2021. Flash flooding in Alexandria and the region overnight damages homes, roadways. https://www.washingtonpost.com/local/alexandria-flash-flood/2021/08/15/7c05d54a-fD.C.d-11eb-a664-4f6de3e17ff0_story.html

- In 2023, intense rain from thunderstorms led to three feet of flooding in northeast Washington, DC near Rhode Island Avenue.[39] The area has also flooded in 2022 and 2021.[40,41] In each case, trees have fallen over, downing power lines and blocking roads. Flood waters have affected businesses, leading some to consider relocation.[42]

COASTAL STORMS

Sea level rise will exacerbate damage done by coastal storms. Coastal storms such as hurricanes, tropical storms, and tropical depressions can bring intense rainfall, high winds, and coastal flooding to the region. The region has experienced many coastal storms that have caused extensive flooding along the Anacostia and Potomac Rivers (Figure 30). Four storms have reached the DC Metro area as hurricanes, 22 as tropical storms, 11 as tropical depressions, and 19 as extratropical storms.[43] Some examples of transportation and stormwater infrastructure impacts from past coastal flooding events include:

- In 2003, Hurricane Isabel produced winds of 105 mph and caused severe tidal flooding and storm surge.[44] At the Washington, DC Southwest Waterfront, the sea level reached 10.1 feet. This is 4.8 feet above the height at which the area starts to flood.[45, 46] In Charles County, Maryland, the tidal surge rose 5 feet above average levels. Isabel caused $2 million in damage to roads in the county. Many piers were also damaged or lost along the shore (Figure 31).[47] Marinas were also damaged along the Anacostia River in Maryland. Hurricane Isabel brought down thousands of trees and damaged or destroyed numerous buildings across the region. Many were also left without power.[48]

Figure 28. High water mark at the Wharf identifying the height of historic and possible future flood events.

Source: NOAA Tides and Currents

Figure 29. Hurricane Isabel destroyed Romancoke Pier in Maryland.

Source: MyEasternShore

[39] WTOP News. 2023. Torrential rain, strong storms lead to flooded roadways, water rescues in DC area. https://wtop.com/weather-news/2023/08/steamy-and-stormy-start-to-D.C.-regions-workweek/
[40] Washington Post. 2022. Storms unleash up to 2 to 4 inches of rain, flooding in DC area. https://www.bing.com/search?q=rhode+island+avenue+flood+august+2022&qs=n&form=QBRE&sp=-1&lq=0&pq=rhode+island+avenue+flood+august+2022&sc=0-37&sk=&cvid=433FC6A16E9A46C58230F4084D556077&ghsh=0&ghacc=0&ghpl=
[41] WTOP. 2022. Storms flood roads, down trees in DC region. https://wtop.com/weather-news/2021/07/storms-flood-roads-down-trees-in-D.C.-area/
[42] ABC News. 2022. Owner of DC's District Dogs considering relocation following rash of severe flooding. https://wjla.com/news/local/D.C.-district-dogs-flooding-weather-washington-bowser-rain-relocating-business-underwater-flood-northeast-rhode-island-avenue-jacob-hensley
[43] NOAA. 2022. Historical Hurricane Tracks. https://coast.noaa.gov/hurricanes/#map=4/32/-80.
[44] Ambrose, K. 2013. Remembering Hurricane Isabel, 10 years later. https://www.washingtonpost.com/news/capital-weather-gang/wp/2013/09/18/remembering-hurricane-isabel-10-years-later-photos/.
[45] Wang, et al. 2015. Modeling Storm Surge and Inundation in Washington, DC, during Hurricane Isabel and the 1936 Potomac River Great Flood. https://scholarworks.wm.edu/vimsarticles/235.
[46] NOAA. 2023. Storm Events Database. https://www.ncD.C..noaa.gov/stormevents/details.jsp.
[47] Charles County Government. 2003. Demographic Trends Newsletter. https://wayback.archive-it.org/all/20070628171904/http://www.charlescounty.org/pgm/planning/publications/demotrends/vol7_4.pdf.
[48] Ambrose, K. 2013. Remembering Hurricane Isabel, 10 years later.

Figure 30. King Street under water following tidal flooding in Alexandria in 2021.

Source: Alexandria Living Magazine

- In 2011, Tropical Storm Irene produced widespread, heavy rain across the metropolitan Washington region, causing significant flooding. More than two million people were left without power in Virginia and some MARC station tunnels were also flooded in Maryland.[49] Many major roads were impassable, including the temporary closure of the Harry W. Nice Memorial Bridge in Charles County.[50,51]
- In 2021, a storm system along the East Coast caused significant flooding in the metropolitan Washington region. This event raised the water level along the Chesapeake Bay and Potomac River, flooding parts of DC with 2-3 feet of water at high tide.[52] Old Town Alexandria saw the highest tide and worst flooding since Hurricane Isabel in 2003 when the Potomac River reached almost 6 feet above sea level (Figure 32).[53] This caused severe tidal flooding, that led to thousands of people losing power. Many buildings and roads were submerged.[54]

Future Conditions

MORE VARIABLE SEASONAL/MONTHLY PRECIPITATION

Precipitation is expected to become more variable each year, with some years receiving much more precipitation than other years. Historically, the metropolitan Washington region has seen 42 inches of annual precipitation (1961-1990). This is projected to increase by approximately 2 inches by 2050 and 7 inches by 2080 under a high emissions scenario.[55] The greatest increases in seasonal precipitation are expected in winter and spring.[56] Monthly precipitation in the metropolitan Washington region is projected to be approximately 1 inch greater for December through April by 2080 under a high emissions scenario, relative to a historical baseline of 1971-2000.[57]

MORE HEAVY PRECIPITATION

Heavy rainfall events are expected to become more frequent and intense, leading to flooding. The number of days each year where more than one inch of precipitation falls can be a useful variable to understand future precipitation patterns. From 1961-1990, there was an average of 5.5 days each year that received more than one inch of precipitation.[58] As shown by the observed data in Figure 28, these heavy precipitation days have varied greatly on a year-to-year basis. By 2080, the number of days each year with

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[49] Ibid.

[50] CBS News. 2011. Impacts from Irene, state by state. https://www.cbsnews.com/news/impacts-from-irene-state-by-state/.

[51] CBS News. 2011. Irene Batters Md.: Roads Closed, Many Trees Down, Thousands Without Power. https://www.cbsnews.com/baltimore/news/hurricane-irene-batters-maryland/.

[52] WUSA9. 2021. Worst sea level rise event in 10 to 20 years expected in DC region today. https://www.wusa9.com/article/weather/weather-watchers/coastal-flooding-october-2021/65-f5f9eaf6-fc60-448b-a64c-3b7d6ef62c19.

[53] Alexandria Living Magazine. 2021. Photos: Old Town Alexandria Sees Worst Flooding in Years. https://alexandrialivingmagazine.com/news/old-town-alexandria-va-flooding-in-years-oct-29-2021/.

[54] Hedgpeth, D. et al. 2021. Potent storm drenches Washington region with heavy downpour and powerful winds. https://www.washingtonpost.com/D.C.-md-va/2021/10/29/flooding-roads-closed/.

[55] NOAA. 2021. U.S. Climate Resilience Toolkit Climate Explorer/Total Precipitation in DC

[56] Dupigny-Giroux, L.A., et al. 2018. Northeast. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program, Washington, DC, USA, pp. 669–742. doi: 10.7930/NCA4.2018.CH18

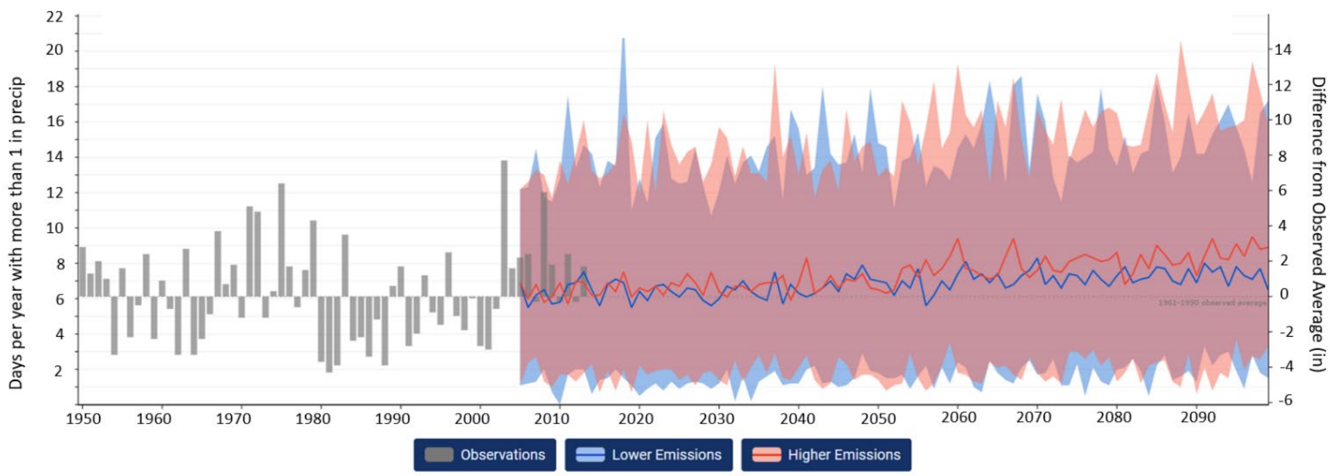
[57] Ibid.

[58] NOAA. 2021. U.S. Climate Resilience Toolkit Climate Explorer/Days with More Than One Inch of Precipitation in DC

more than one inch of precipitation could increase to 7.3 to 9.0 days. [59] The projections in Figure 28 represent an average of climate model projections, showing a gradual increase in the number of days each year with more than one inch of precipitation. It is likely that the general upward trend will persist, but some years will have many days with more than one inch of precipitation and others will have far fewer.

The frequency and intensity of large storms events is also projected to increase. These high-volume precipitation events have a low annual percent change of occurrence each year. For example, the 100-year storm (8.1 inches of rain) has a 1% annual chance of occurrence, meaning there is a 1% chance each year of DC receiving 8.1 inches of rain in 24-hours.[60] These heavy rainfall events are expected to become more frequent and intense in the future. The Department of Energy and the Environment estimates that the historic 100-year event will become the future 15-year event by 2080. This means the same 8.1 inches of rainfall will now have a 6.67% chance of occurring each year. By 2080, the amount of rain falling during the 100-year event is projected to increase to 14 inches. [61]

Figure 31. Days with more than one inch of precipitation based on low and high emissions scenarios.



Source: NOAA Climate Explorer

HIGHER INTENSITY COASTAL STORMS

Increases in storm intensity coupled with higher sea level rise is likely to increase coastal flooding in the metropolitan Washington region. Although the total number of hurricanes, tropical storms, and tropical depressions are projected to remain approximately the same or even decrease, the intensity of these storms is expected to increase along the East Coast.[62] Coupled with sea level rise and storm surge, the extent of coastal flooding is expected to increase. For example, one study predicts that if an equivalent storm to Hurricane Isabel (2003) occurred in 2100, 47-62% more land area surrounding the Chesapeake Bay, which includes the metropolitan Washington region, would flood.[63] Another study finds that while a sea level rise of 6 feet above mean high water in Washington, DC has only occurred once in the last 70

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[59] Ibid.
[60] DOEE. 2015. Climate Projections & Scenario Development. https://doee.D.C..gov/sites/default/files/D.C./sites/ddoe/publication/attachments/150828_AREA_Research_Report_Small.pdf.
[61] Ibid.
[62] Chung, Maya, et al. 2021. Climate change is probably increasing the intensity of tropical cyclones. Climate.gov. https://www.climate.gov/news-features/understanding-climate/climate-change-probably-increasing-intensity-tropical-cyclones
[63] Zhang, F. et al. 2020. Assessing storm surge impacts on coastal inundation due to climate change: case studies of Baltimore and Dorchester County in Maryland. https://doi.org/10.1007/s11069-020-04096-4

years, the likelihood of a flood reaching this level is greater than 50% by 2030 under a low sea level rise projection. A 6-foot flood would affect $4.6 billion in property value and 21 miles of road.[64]

Transportation Impacts: Stormwater

As demonstrated by the past events profiled above, more frequent and intense rainfall events could significantly affect stormwater infrastructure in the region. Urbanized areas with high impervious surface area have higher amounts of runoff, which can overwhelm stormwater infrastructure if there is insufficient capacity. For example, in cities like Washington, DC, rainfall during large storms cannot drain through pipes and out of the city quickly enough, causing further flooding.[65] This was the case during the 2006 flash flood. Overwhelmed stormwater infrastructure can result in standing or flowing water on driving surfaces, bike lanes, and sidewalks. Insufficient stormwater infrastructure capacity can also cause combined sewer overflows during flooding events, which can have public health implications. Flooding can also lead to debris and sediment accumulation at culvert crossings, limiting drainage capacity, and compromising pavement and embankments.

Transportation Impacts: Maritime

Coastal storms can significantly affect maritime infrastructure and services. While there are currently no ports in the COG area, any potential new port and other maritime infrastructure will have to consider these impacts. Tourism and ferry taxi services will also be affected.

Waves and flooding from coastal storms can dislodge containers and cargo from open storage areas at ports, move debris, and cause damage to port structures, pavement, and equipment. Strong wave action can wash away fender system timbers and leave berths inoperable. Severe coastal storms can result in reduced visibility, posing a safety risk to operators and users at maritime facilities. Significant temporary flooding from strong storms can increase erosion, sedimentation, and runoff. This may reduce channel depth and limit access to coastal infrastructure, weaken port support structures, and scour pier supports. In addition, barrier islands can also be destroyed by severe storms, eliminating some waterway systems entirely. Flooding from coastal storms would increase operational disruptions and maintenance requirements.

[64] Strauss, B. et al. 2014. Washington, DC and the Surging Sea: A vulnerability assessment with projections for sea level rise and coastal flood risk. https://sealevel.climatecentral.org/uploads/ssrf/D.C.-Report.pdf
[65] NCPC. 2018. Flood Risk Management Planning Resources for Washington, D.C. https://www.ncpc.gov/docs/Flood_Risk_Management_Planning_Resources_January_2018.pdf.

PERMANENT FLOODING (SEA LEVEL RISE)

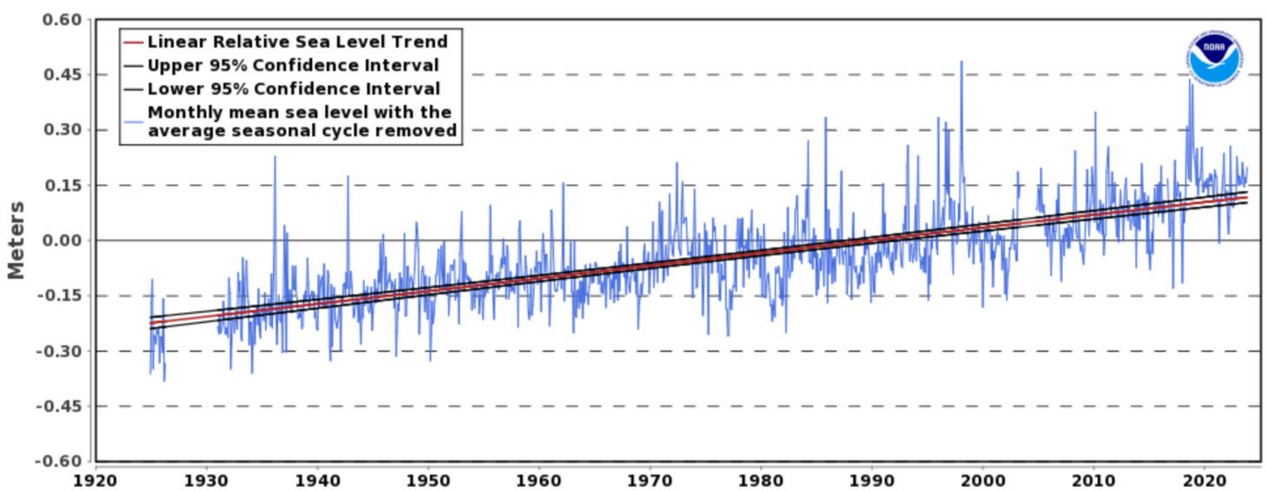
The Phase 1 vulnerability assessment identified roads and highways, bridges, public transit, stormwater, and maritime infrastructure as highly sensitive to permanent flooding (sea level rise). The Tier 1: Indicator-based, Asset-level Vulnerability Assessment section identifies the permanent flooding (sea level rise) vulnerability of individual roads and highways, bridges, and public transit assets in the region. This section qualitatively reflects on stormwater and maritime infrastructure vulnerability.

Historical Trends and Past Events

The metropolitan Washington region experiences permanent flooding due to sea level rise, and the sea level in the Mid-Atlantic is rising faster than any other region along the East Coast.[66] Tide gauges reveal that sea level in the Chesapeake Bay has been rising at twice the global average rate for the last 60 years.[67] This is due to both sea level rise and the fact that the land under the Chesapeake Bay is rapidly sinking, and could sink an additional 6 inches by the end of the century.[68] Sea level has risen over 1 foot in the metropolitan Washington region since 1920 at a rate of 3.43 mm/year (Figure 29).[69] Sea level is measured by relative mean sea level, or the height of the sea level relative to land.[70]

Sea level rise can increase the rate of sunny day tidal flooding known as nuisance flooding, seen in Figure 33, which can eventually lead to permanent inundation of low-lying areas and infrastructure.[71] There have been 55 reports of nuisance flooding in Washington, DC alone since 2010. Coastal Virginia and Maryland also experience regular nuisance flooding:

Figure 32. Relative sea level trend in Washington, DC.



NOAA Tides and Currents

[66] Fritz, A. 2015. Why sea level in the DC region is rising faster than anywhere else on the East Coast. https://www.washingtonpost.com/news/capital-weather-gang/wp/2015/07/29/why-sea-level-in-the-d-c-region-is-rising-faster-than-anywhere-else-on-the-east-coast/.
[67] Brown, J. 2015. Washington, DC, Sinking Fast, Adding to Threat of Sea-Level Rise. https://www.uvm.edu/news/story/washington-D.C.-sinking-fast-adding-threat-sea-level-rise.
[68] Fritz, A. 2015. Why sea level in the DC region is rising faster than anywhere else on the East Coast.
[69] NOAA. 2022. Relative Sea Level Trend in Washington, DC https://tidesanD.C.urrents.noaa.gov/sltrends/sltrends_station.shtml?id=8594900.
[70] NOAA. 2022. Relative Sea Level Trend in Washington, DC https://tidesanD.C.urrents.noaa.gov/sltrends/sltrends_station.shtml?id=8594900.
[71] NCPC. 2018. Flood Risk Management Planning Resources for Washington, DC

- In 2019, coastal communities in Virginia saw two to five times more nuisance flooding than the national average.[72]
- In Charles County, the approach to the bridge to Cobb Island is subject to regular nuisance flooding from the Neale Sound. The crab houses on either side of the road frequently sustain damage from the nuisance floods.[73]
- In Old Town Alexandria, high tides prevent effective stormwater drainage on Strand, King, and Union Streets.[74]

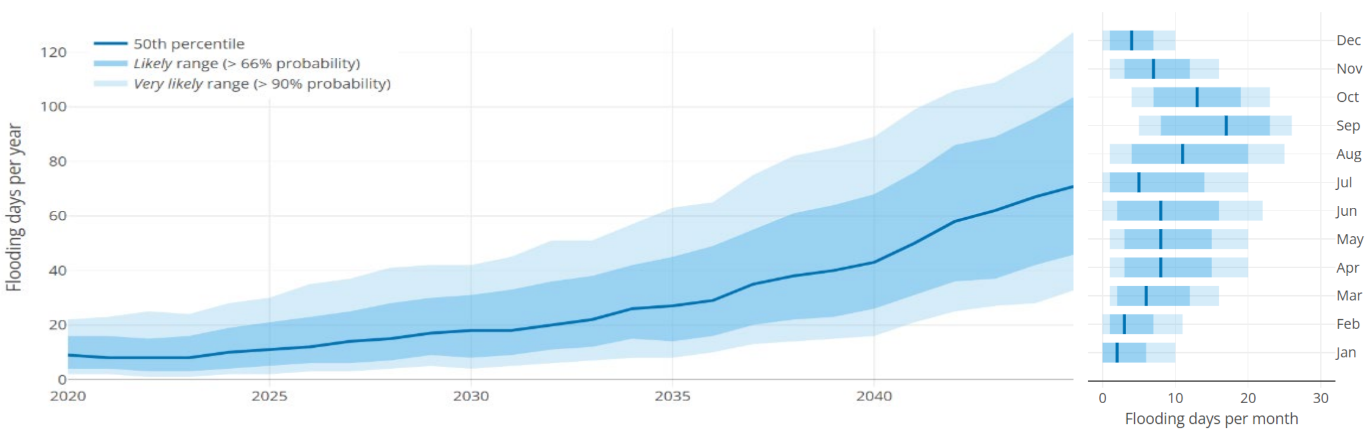
Figure 33. Flooding during high tide at the Tidal Basin in Washington, DC.

Source: WTOP News

Future Conditions

Sea level rise is projected to increase and contribute to more nuisance and coastal flooding events. Sea level is projected to rise by approximately 1.3-1.5 ft by 2050 and 2.5-5.2 ft by 2100.[75, 76] Sea level rise would increase the number of days that nuisance flooding occurs in the DC Metro Area. Flooding days per year are estimated to reach 71 flooding days per year by 2050 (Figure 33).[77]

Figure 34. Flooding days per year (left) and flooding days per month in 2050 (right).



Source: NASA Flooding Analysis Tool

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[72] Vogelsong, S. 2020. Virginia's coast saw two to five times more nuisance floods in 2019 than the national average. https://www.virginiamercury.com/2020/07/17/virginias-coast-saw-two-to-five-times-more-nuisance-floods-in-2019-than-the-national-average/.

[73] Charles County Nuisance & Urban Flood Plan. 2017. https://www.charlescountymd.gov/services/emergency-services/emergency-preparedness/nuisance-and-urban-flooding

[74] City of Alexandria, Parks and Recreation. 2012. King, Strand, and Union Streets Flood Mitigation Project Update. https://media.alexandriava.gov/docs-archives/recreation/info/kingstrandunionstreetsfloodmitigationprojectupdate.pdf

[75] NOAA. 2023. Sea Level Rise Viewer. https://coast.noaa.gov/slr/,

[76] Intermediate low and intermediate high sea leave rise scenarios were used to provide a range of future sea level rise using the NOAA Sea Level Rise Viewer.

[77] NASA Sea Level Change Team. 2023. Flooding Analysis Tool. https://sealevel.nasa.gov/flooding-analysis-tool/projected-flooding?station-id=8594900.

Transportation Impacts: Stormwater

Rising sea level could significantly affect stormwater infrastructure in the metropolitan Washington region. Water levels can overwhelm stormwater infrastructure if there is insufficient capacity. For example, in the City of Alexandria high tides can prevent effective stormwater drainage on waterfront streets. Overwhelmed stormwater infrastructure can result in standing or flowing water on driving surfaces, bike lanes, and sidewalks. Flooding can also lead to debris and sediment accumulation at culvert crossings, limiting drainage capacity and compromising pavement and embankments.

Transportation Impacts: Maritime

Permanent flooding (sea level rise) can affect maritime infrastructure and services including shipping, tourism, or a ferry taxi service. While there are currently no ports in the COG area, any potential new port and other maritime infrastructure will have to consider these impacts. Higher sea levels can permanently inundate coastal facilities and infrastructure in the future and corrode metal port equipment. Coastal areas may be more exposed to higher energy wave action that cause changes in coastal erosion and deposition rates. Over time, erosion may reduce channel depth. Permanent flooding (sea level rise) can also lead to service disruptions or delays, as well as safety risks. For example, sea level rise can reduce bridge clearance, limiting the movement of large vessels.

EXTREME WINTER

Historical Trends and Past Events

Winters have warmed in the Mid-Atlantic, leading to later snowfall and earlier snowmelt.[78] Annual average snowfall has also decreased in the Mid-Atlantic.[79] In Washington, DC, for example, snowfall from 1981 to 2010 averaged 15.4 inches per year. This dropped to 13.8 inches for the period from 1991 to 2020.[80] In winter of 2022-2023, most of the Mid-Atlantic experienced temperatures 4-6°F above normal, and the southern half of the region received less than 25% of normal winter season snowfall.[81]

Extreme and unpredictable winter weather events will occur with warming winters. Some studies link the weakening of global weather systems to extreme weather events in the mid-latitudes.[82] The metropolitan Washington region has had several significant winter storms in the recent past. From 1996 to 2015, there were 97 winter storms in Arlington County/City of Alexandria/City of Falls Church, which caused $460,000 in property damage.[83] Some examples of transportation infrastructure impacts from past winter storms include:

- Public transit services in the metropolitan Washington region tend to be delayed or suspended during snow events. For example, escalators and elevator service to the Metro may go out of service in the case of snow events and winter icing.[84] Additionally, Metro alters service depending on the amount of snowfall. Precipitation of 1-2 inches of snow, freezing rain, or ice results in modified service, and 2-8 inches results in reduced service.[85] If more than 8 inches of snow falls, aboveground Metro services may need to be suspended.[86]
- Active transportation is also affected during snow events. District Department of Transportation faces challenges in plowing bike lanes after snowfall. Some bike lanes are plowed, though they can often be covered up again if other snowplows follow behind and do not plow the bike lanes. There is an additional challenge for plowing unprotected bike lanes as snowplows try to stay farther from the edge to avoid damaging parked cars. After a major winter storm in 2022, the DC bikeshare program remained a viable method of public transit when other transit services were shut down (Figure 34).[87]

Figure 35. Vehicles and drivers stranded in Arlington, VA during a snowstorm in 2022.

Source: New York Times

[78] Dupigny-Giroux, L.A., et al. 2018. Northeast. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program, Washington, DC, USA, pp. 669–742. doi: 10.7930/NCA4.2018.CH18
[79] Livingston, I. 2021. Washington's 'normal' snowfall is about to fall further. https://www.washingtonpost.com/weather/2021/03/04/washington-D.C.-normal-average-snowfall/.
[80] Ibid.
[81] NOAA Mid-Atlantic RISA. 2023. Mid-Atlantic Regional Climate Impacts Summary and Outlook: Winter 2022-2023. https://www.midatlanticrisa.org/climate-summaries/2023/03.html.
[82] Francis, J., Skific, N. Evidence linking rapid Arctic warming to mid-latitude weather patterns. Philosophical Translations. Royal Society Publishing. 2015. https://royalsocietypublishing.org/doi/10.1098/rsta.2014.0170.
[83] Northern Virginia Hazard Mitigation Plan. 2017. http://arlington.granicus.com/MetaViewer.php?view_id=2&event_id=1101&meta_id=163110.
[84] WMATA. n.d. Why are elevators/escalators out of service for repair? https://wmata.com/service/elevators-escalators/outage-types.cfm.
[85] WMATA. n.d. Severe Weather. https://www.wmata.com/rider-guide/weather/.
[86] Ibid.
[87] Ibid.

- In 2010, the region experienced a heavy snowstorm followed by a nor'easter five days later. The original snowstorm, now known as "Snowmageddon," produced between 1 and 3 feet of snow across the region (Figure 35). Together, these storm events broke all-time seasonal snowfall records, with Reagan National Airport recording a total of over 4.5 feet of snow.[88] These events made the winter of 2009-2010 the snowiest on record in Washington, DC.[89] Roads and other transportation facilities were obstructed for days or weeks by excessive snow, downed trees, and abandoned vehicles. The storm caused vehicle accidents and widespread loss of power.[90] Metro bus and rail service were shut down, and in Maryland, special snow trains were used on heavy rail and light rail lines to keep tracks clear. Amtrak shut down much of their service in the Mid-Atlantic region, and MARC and the VRE shut down operations for several days as well.[91]
- In 2016, a major blizzard called 'Snowzilla' produced more than 2 feet of snow across most of Washington, DC, and parts of Maryland saw almost 3.5 feet of snow in some areas (Figure 36). The storm caused half a billion dollars in damages nationally and left over 100,000 people without power in the metropolitan Washington region. [92] The blizzard was ranked a Category 4 or 'Crippling' winter storm on NOAA's Northeast Snowfall Impact Scale.[93] Washington, DC shut down its entire mass transit system over the weekend of the storm, making it the longest such shutdown in the agency's history.[94] People were encouraged to stay home and off the roads due to severe snow and ice conditions, leaving most active transportation routes inaccessible until the snow was

Figure 36. A road covered in snow in Reston, VA during Snowmageddon in 2010.

Source: WTOP News

Figure 37. Winter weather on I-95 trapping travelers in Virginia.

Source: Virginia Mercury

[88] Dildine, D. 2018. A look back at 'Snowmageddon' 8 years later. https://wtop.com/weather-news/2018/02/look-back-snowmageddon-8-years-later/.
[89] ABC7. 2023. Monday marks 13th anniversary of DC's blockbuster 'Snowmageddon' storm. https://wjla.com/weather/first-alert-weather-blog/D.C.-snowmageddon-anniversary-blizzard-mid-atlantic-region-17-inches-snow-2010-washington-district-government-schools-shutdown-power-snowzilla-2016-dulles-airport-washington-winter-forecast.
[90] COG. Metropolitan Washington 2030 Climate and Energy Action Plan. 2020. https://www.COG.org/documents/2020/11/18/metropolitan-washington-2030-climate-and-energy-action-plan/.
[91] NBC Washington. 2010 .Above-Ground Metro Stations to Stay Closed Thursday. https://www.nbcwashington.com/news/local/some-above-ground-stations-reopen-as-metro-braces-for-next-storm/1844420/
[92] Thomas, M. and J. Colucci. 2023. A timeline of the snowiest blizzards in DC, Maryland and Virginia history. https://www.fox5D.C..com/weather/a-timeline-of-the-snowiest-blizzards-in-D.C.-maryland-and-virginia-history-snow-2016-2003-1996-blizzard.
[93] WUSA9. 2016. 'Snowzilla' clobbered the DMV January 2016. https://www.wusa9.com/article/weather/blizzard-2016-anniversary/65-4a440853-1015-4292-92f5-1b1e8a4ee227.
[94] Washington Metropolitan Area Transit Authority. 2016. Metro to suspend service during blizzard. https://web.archive.org/web/20160123194140/http://www.wmata.com/about_metro/news/PressReleaseDetail.cfm?ReleaseID=6029.

cleared.[95] The blizzard required significant snow removal efforts across the region, with DC spending a total of $41 million dollars on snow removal from the storm.[96]

- In 2022, a winter storm delivering up to one foot of snow and icing over roads resulted in 650 crashes and 600 stranded vehicles in Virginia.[97] The storm trapped motorists in their cars on I-95. Drivers reported being stuck in their vehicles for between 7 and 21 hours.[98] Amtrak returned a northbound train back to an earlier station after downed trees blocked the tracks.[99]

Future Conditions

Changes in snowfall and winter storm events are difficult for climate scientists to project. There is uncertainty about how these events may change over time, especially in specific areas. General trends for the Mid-Atlantic suggest:

- As the climate warms, the frequency of winter conditions (i.e., snow, ice) across the Mid-Atlantic could decrease. The region will experience fewer days each year below freezing (32°F) which will cause precipitation to fall more often as rain rather than snow. This could lead to shorter snow seasons and decreased snow depth.[100, 101]
- Although the frequency of winter conditions may decrease, when winter storms do occur, they are projected to be more severe and produce greater snowfall.[102] Warmer temperatures increase the atmosphere's ability to hold moisture and thus produce more snow.

In 2016, Snowzilla struck the metropolitan Washington region during one of its **warmest winters on record**, dumping up to 3.5 feet of snow in some areas. Although winter temperatures are warming, severe snowstorms like Snowzilla are expected to become more intense in the future.

FEWER DAYS WITH TEMPERATURES BELOW FREEZING

The metropolitan Washington region will experience fewer days each year with temperatures below freezing (32°F). Historically, the region has experienced about 91 days each year where daily low temperatures dip below 32°F. The number of days with minimum temperatures below freezing is expected to decrease to 58 days by 2050 and 37 days by 2080 under a high emissions scenario (Figure 37).[103]

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95 Halsey, A. et al. 2016. A blizzard for the ages shuts down Washington area. https://www.washingtonpost.com/local/double-digit-snowfall-blankets-the-D.C.-region-with-more-to-come/2016/01/23/30b7a46e-c1bb-11e5-bcda-62a36b394160_story.html.

96 WUSA9. 2016. 'Snowzilla' clobbered the DMV January 2016.

97 New York Times. 2022. Heavy Winter Storm Hits DC Area and Knocks Out Power Across Southeast. https://www.nytimes.com/2022/01/03/us/sleet-snow-forecast.html

98 New York Magazine. 2022. Drivers Were Stranded on I-95 for Almost a Full Day. https://nymag.com/intelligencer/2022/01/storm-leaves-drivers-stuck-i95-for-19-hours.html#:~:text=A%20Monday%20storm%20that%20delivered%20more%20than%20a,trapped%20in%20their%20cars%20overnight%20in%20below-freezing%20temperatures.

99 USA Today. 2022. 27-hour commute: Virginia officials pelted with questions after hundreds of drivers were stuck on I-95 overnight. https://www.usatoday.com/story/news/nation/2022/01/04/winter-storm-power-outages-interstate-95-virginia/9087146002/

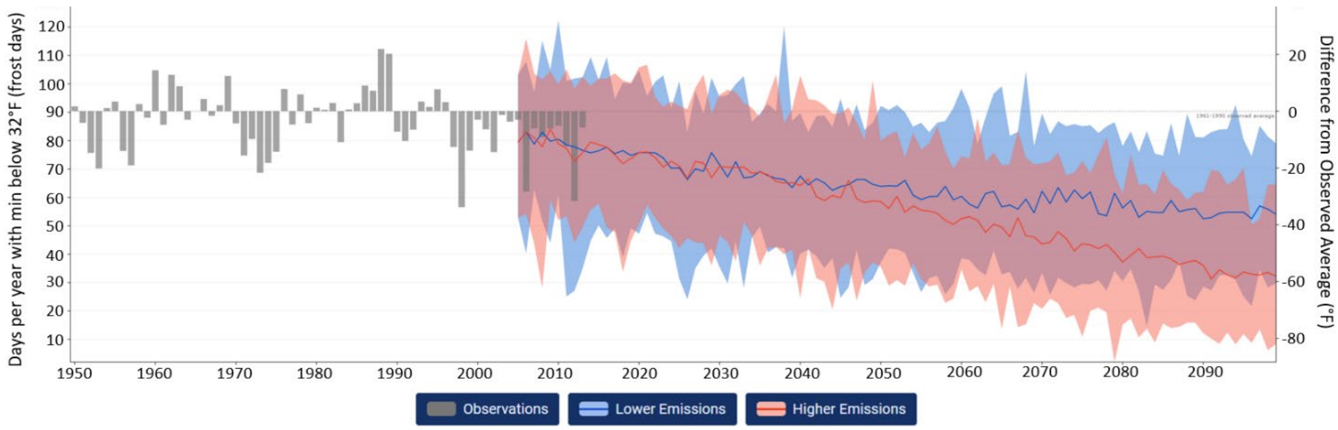
100 Zarzycki, C. M. 2018. Projecting Changes in Societally Impactful Northeastern U.S. Snowstorms. Geophysical Research Letters, 45(21), 12,067-12,075. https://doi.org/10.1029/2018GL079820

101 Demaria, E. M. C., Roundy, J. K., Wi, S., & Palmer, R. N. 2016. The Effects of Climate Change on Seasonal Snowpack and the Hydrology of the Northeastern and Upper Midwest United States, Journal of Climate, 29(18), 6527-6541. Retrieved Jan 18, 2023, from https://journals.ametsoc.org/view/journals/clim/29/18/jcli-d-15-0632.1.xml

102 Dupigny-Giroux, L.A., et al. 2018. Northeast. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program, Washington, DC, USA, pp. 669–742. doi: 10.7930/NCA4.2018.CH18

103 U.S. Federal Government. NOAA. 2021. U.S. Climate Resilience Toolkit Climate Explorer/Days each year with minimum daily temperatures below 32 degrees Fahrenheit in Dutchess County, NY. https://crt-climate-explorer.nemac.org/.

Figure 38. Days per year with minimum daily temperatures below 32°F based on low emissions and high emissions scenarios.



Source: NOAA Climate Explorer

The region has historically experienced an average of 8 days each year where daily high temperatures remain below 32°F. The number of days with maximum temperatures below 32°F is also projected to decrease to 2 days by 2050 and 1 day by 2080 under a high emissions scenario.

Transportation Impacts: Public Transit and Active Transportation

More intense winter storms with greater snowfall and more frequent ice conditions could significantly affect public transit and active transportation in the metropolitan Washington region. Aboveground rail tracks can ice over during severe storms, and snow and ice conditions can make rail yards impassable. Ice formation and snow removal can also deteriorate pavement, causing potholes and cracking. These impacts can result in service delays or shutdowns on both rail and bus lines. Additionally, buses may only run on major streets during severe snow events, reducing access to bus services in remote locations. Severe cold and icy conditions can also present safety and health risks to transit passengers waiting at outdoor stops and traveling to and from transit stops.

Customers with limited transportation options, a particular concern for EEAs, will be disproportionately impacted by loss or reduction of transit service options. Heavy snow can also create delays in clearing sidewalks and bikeways, and black ice can cause dangerous conditions for pedestrians and cyclists. Bikeways and other active transportation routes can also become inaccessible due to snow plowing. Extreme winter events can make it more difficult for people to choose active transportation (particularly if they have other options). Conversely, for those without other options, extreme winter conditions can limit mobility.

EXTREME WIND

Historical Trends and Past Events

The region has had multiple reports of high sustained wind speeds and wind gusts from past storm events, such as thunderstorms, extratropical cyclones, and tropical systems. The National Weather Service defines damaging high wind as sustained wind speeds of 40-50 mph.[104]

Some specific examples of transportation impacts from severe wind events include:

- Tropical Storm Irene in 2011 recorded wind speeds of 65 mph, and strong wind gusts up to 80 mph in some areas. The storm caused many downed trees and power lines across the region, resulting in road closures. [105] More than 2 million people were left without power in Virginia and many major roads were impassible.[106] MARC Penn line ran a limited service and recommended that travelers bring flashlights to deal with power outages at several stations.[107] Harry W. Nice Memorial Bridge in Charles County was temporarily closed due to high windspeeds.[108] Maryland also closed the Chesapeake Bay Bridge due to high winds.[109]
- Hurricane Sandy in 2012 recorded wind speeds of 60-70 mph and caused severe wind damage. A State of Emergency was issued in Washington, DC, Virginia, and Maryland. High winds brought trees down across the metropolitan Washington region, resulting in road closures.[110] In Maryland, mass transit service was suspended.[111] In Washington, DC, both VRE and MARC service were suspended.[112]
- In 2023, a severe storm recorded intense winds that exceeded 80 mph and caused severe damage (Figure 38). Power lines and very large trees were downed across Washington, DC, damaging homes and vehicles and blocking some major roads.[113] Metro and VRE service was also suspended on some lines due to downed trees and power lines, and some stations were bypassed due to power outages.[114]
- In 2012, a derecho storm recorded hurricane-force winds up to 82 mph in the region. Tracks were damaged along the Amtrak route between Philadelphia and Washington, forcing Amtrak to halt service for repairs. VRE canceled service for a day to address damage to their tracks and

Figure 39. Fallen trees and broken power lines after the severe storm in 2023.

Source: Washington Post

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[104] National Weather Service. 2022. Wind. https://www.weather.gov/safety/wind
[105] Washington American University Radio (WAMU). 2011. Irene Leaves Fallen Trees And Wires, Thousands Without Power In DC Area. https://wamu.org/story/11/08/28/irene_leaves_fallen_trees_and_wires_thousands_without_power_in_D.C._area/.
[106] CBS News. 2011. Impacts from Irene, state by state. https://www.cbsnews.com/news/impacts-from-irene-state-by-state/.
[107] Washington Post. 2011. After Hurricane Irene, Cleanup Begins.https://www.washingtonpost.com/local/cleanup-begins-after-irenes-weekend-of-destruction/2011/08/28/gIQAiujslJ_story.html
[108] CBS News. 2011. Irene Batters Md.: Roads Closed, Many Trees Down, Thousands Without Power. https://www.cbsnews.com/baltimore/news/hurricane-irene-batters-maryland/.
[109] The Washington Post. 2011. Hurricane Irene aftermath: Dispatches from Virginia, Maryland, Delaware and the District. https://www.washingtonpost.com/blogs/post_now/post/hurricane-irene-aftermath-dispatches-from-virginia-marland-delaware-and-the-district/2011/08/28/gIQArS2gkJ_blog.html.
[110] Cornwell, S. and S. Heavy. 2012. Washington DC escapes worst of storm Sandy. https://www.reuters.com/article/us-storm-sandy-washington/washington-d-c-escapes-worst-of-storm-sandy-idUSBRE89T1C620121030.
[111] CNN. 2012. Sandy's impact: State by state. https://www.cnn.com/2012/10/30/us/tropical-weather-state-by-state/index.html.
[112] Gartner, L. 2012. Hurricane Sandy shutters DC area. https://www.washingtonexaminer.com/hurricane-sandy-shutters-D.C.-area.
[113] Latson, S. et al. 2023. Huge cleanup, thousands without power after storms pummel DC region. https://www.washingtonpost.com/DC-md-va/2023/07/30/severe-storm-damage-day-after/?%20va._1.
[114] CNN. 2023. Thunderstorms cause damage in DC area. https://www.cnn.com/2023/07/29/weather/thunderstorms-D.C.-damage/index.html.

trains.[115] The Metro was also affected, with delays on all lines, suspended rail service on some lines due to a power outage, and single tracking on other lines due to downed trees obstructing the railway. There were also several reports of downed trees and power lines blocking roads in the area, which led to significant traffic on roadways and service delays for Metrobuses. More than 1.5 million people were left without power.[116]

Future Conditions

Average and extreme wind speeds are difficult to project due to the localized scale at which they occur.[117] Existing literature on average wind speeds for the Mid-Atlantic does not suggest significant expected changes. However, existing literature does support an increase in the intensity of hurricanes, tropical storms, and tropical depressions along the East Coast.[118] These events are defined by wind speed and atmospheric pressure, so it is possible that hurricanes, tropical storms, and tropical depressions could result in higher wind speeds and gusts in the metropolitan Washington region.[119] A recent modeling study confirms that Tropical Cyclone wind risk is projected to increase along the East Coast, and projects that the Mid-Atlantic will see the largest increase in maximum wind speeds.[120]

Transportation Impacts: Roadways and Highways and Public Transit

More intense wind events in the metropolitan Washington region could significantly affect roadways and highways and public transit. Extreme wind can create and move debris and bring down trees and power lines, resulting in service delays and detours, power outages, and in some cases, physical infrastructure damage. Power outages can affect stoplights on roads and highways and all forms of public transportation. It can also be dangerous for high-profile vehicles (e.g., buses and rail cars) to drive during extreme wind events, which can create additional disruptions or delays in service. Customers with limited transportation options will be disproportionately impacted by loss or reduction of transit service options.

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[115] WUSA. 2020. VRE service canceled Friday for repairs after severe weather damage on tracks. https://www.wusa9.com/article/traffic/vre-train-service-canceled-friday-after-severe-storms-thursday/65-754c13f8-6a08-4644-b133-a59da09203cd

[116] NBC Washington. 2012. More Than 1.5 Million Without Power; 4 Killed. https://www.nbcwashington.com/news/local/records-could-be-broken-as-D.C.-heats-up/1921095/.

[117] Komurcu, M. and S. Paltsev. 2021. Toward resilient energy infrastructure: Understanding the effects of changes in the climate mean and extreme events in the Northeastern United States. Joint Program Report Series Report 352, June, 16 p. http://globalchange.mit.edu/publication/17608

[118] Chung, Maya, et al. 2021. Climate change is probably increasing the intensity of tropical cyclones. Climate.gov. https://www.climate.gov/news-features/understanding-climate/climate-change-probably-increasing-intensity-tropical-cyclones

[119] Seneviratne, S.I., et al. 2021. Weather and Climate Extreme Events in a Changing Climate. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1513–1766, doi:10.1017/9781009157896.013

[120] First Street Foundation. 2023. Highlights from "Worsening Winds." https://firststreet.org/research-lab/published-research/article-highlights-from-worsening-winds/.

Application of the Assessment

The overall purpose of the two-phase climate vulnerability assessment is to support transportation resilience planning in the metropolitan Washington region. The below section identifies how the results of this assessment will be used to support this aim and proposes improvements to the assessment methodology to enhance future analyses and resilience planning efforts.

Resilience Criteria

The results of the vulnerability assessment have been integrated into a publicly accessible Transportation Resiliency Planning Interactive Map to allow regional agencies to evaluate highly vulnerable assets and identify priority projects to submit for inclusion in the TRIP. The Resilience Criteria were developed to help establish the bounds of what constitutes a good/reasonable resilience project and to help COG member agencies evaluate transportation resilience projects.

Table 23. Resilience Criteria

Resilience Criteria	Description
Eligible transportation asset	TPB is collecting proposed projects for inclusion in in the TRIP for the following transportation assets: roads and highways, bridges, public transit infrastructure, active transportation infrastructure, airports, maritime infrastructure, and stormwater infrastructure. Note, PROTECT discretionary grants can only be awarded to eligible highway projects, transportation facilities or services, intercity passenger rail facilities or services, and port facilities.
Qualifying project type for PROTECT	There are four types of grants that can be used for the following project types: 1) **Resilience Planning** – Resilience planning activities, capacity building, and evacuation planning and preparation. 2) **Resilience Improvements** – Projects that make existing surface transportation infrastructure more resilient such as improving drainage, upgrades to meet or exceed design standards, relocating roadways, or elevating bridges. 3) **Community Resilience and Evacuation Routes** – Improvements to make evacuation routes more resilient or add capacity and redundant evacuation routes. 4) **At-Risk Coastal Infrastructure** – Projects that protect, strengthen, or relocate coastal highway and non-rail infrastructure.
Targets high priority risks	The proposed project protects the most vulnerable and critical assets/services identified via the TPB Climate Vulnerability Assessment or identified through local studies and assessments, or areas with historic evidence of natural hazard damage. While projects that protect the identified highly vulnerable critical assets/services may be prioritized, any resilience project for a transportation system(s) can be submitted.
Reduces climate risks	The proposed project reduces the risks associated with one or more climate hazards: extreme heat, temporary flooding (coastal and riverine), permanent flooding (sea level rise), extreme winter conditions, and extreme wind. In addressing climate risks, the proposed project ensures the continuity and/or reliability of the transportation service/system.

Future Improvements

TPB is invested in continuous improvement of its vulnerability assessments and identification of resilience priorities. For example, while some localities may have more granular flood data available, FEMA floodplain maps were the only floodplain mapping dataset available across all metropolitan Washington regions. Therefore, the FEMA maps were used to consistently evaluate flood risk across the region. Potential enhancement for future updates to the vulnerability assessment, include:

- Improving the flood risk mapping for the whole region. Ideally, the flood risk mapping would include one or more of the following enhancements:
  - Integration of forward-looking changes in precipitation due to climate change and the impacts of those changes on riverine floodplains.
  - Consideration of pluvial flooding (i.e., when heavy rainfall overwhelms drainage systems and natural water pathways). Current FEMA maps only represent fluvial flooding (i.e., flooding around rivers, streams, and lakes).
  - Integration of known areas with a history of flooding. This may require developing a mapping survey/interactive tool to collect member agency and public input on where there have been flooding (or other climate hazard) events in the region.
  - Integrated modeling of the combined impacts of sea level rise and changes in precipitation.

- Enhancing consideration of equity impacts. Conducting an analysis that considers not just where an asset is located relative to disadvantaged populations, but who the actual users of the asset are, would provide much more accurate insights on the equity implications of potential damage.

- Moving toward a monetized understanding of the risks posed by climate change. While the current indexed scores provide insight on relative vulnerabilities, a dollar-based value would allow for better comparison with other, non-climate risks. Ideally, this analysis would account for both the agency (e.g., costs to repair damage) and user (e.g., lost time due to detours) costs.

- Incorporating additional systems thinking into the analysis that considers cross-modal and cross-asset redundancy in the system.

- Compiling or creating asset elevation data to refine the understanding of flood risks based on projected depth of flooding.

- Moving from a point-based bridge inventory to a better representation of the bridge locations to facilitate calculation of whether or not the bridge approaches will flood in the future.

- Integrating connectivity to critical community facilities (e.g., hospitals, police/fire stations, schools) into the criticality scoring to capture the importance of those routes.

- Conducting deeper-dive asset-level analysis for select pilot locations to determine how to refine the understanding of vulnerability and develop cost-effective adaptation solutions.

Appendix: High Vulnerability Asset List

This appendix lists assets that scored 2.5 or higher indicating high vulnerability to extreme heat, temporary flooding (coastal and riverine), or permanent flooding (sea level rise).

Extreme Heat

BUS STOPS

Table 24. High Vulnerability Bus Stops for Extreme Heat

Bus Stop Intersection	Longitude	Latitude	Extreme Heat Score	Equity Score	Final Score
Pennsy Dr & 3133 Pennsy Dr	-76.8877	38.9330	3	3	3
Columbia Park Rd & Cabin Branch Dr	-76.9070	38.9169	3	3	3
Columbia Park Rd & 5700 Columbia Park Rd	-76.9082	38.9167	3	3	3
Pennsy Dr & 3133 Pennsy Dr	-76.8877	38.9329	3	3	3
S Pickett St & Shilling St	-77.1321	38.8044	3	3	3
S Pickett St & Shilling St	-77.1320	38.8046	3	3	3
Mt Vernon Ave & Russell Rd	-77.0629	38.8405	3	3	3
Mt Vernon Ave & Russell Rd	-77.0629	38.8401	3	3	3
S Pickett St & 600 S Pickett St	-77.1303	38.8059	3	3	3
S Pickett St & 600 S Pickett St	-77.1301	38.8059	3	3	3
Army Navy Dr Eb & S Joyce St Fs	-77.0618	38.8657	3	3	3
N Glebe Rd Eb & N Piedmont St Fs	-77.1029	38.8721	3	3	3
Amherst Ave & Springfield Blvd	-77.1852	38.7777	3	3	3
Amherst Ave & Springfield Boulevard	-77.1855	38.7777	3	3	3
Annandale & Pine	-77.1966	38.8315	3	3	3
Backlick Rd & Spring Garden Dr	-77.1841	38.7731	3	3	3
Commerce St & Amherst Ave	-77.1877	38.7826	3	3	3
Commerce St & Brandon Ave	-77.1833	38.7824	3	3	3
Fordson Rd & Huntley Meadows Plz	-77.0840	38.7510	3	3	3
Fordson Rd & Richmond Hwy	-77.0842	38.7509	3	3	3
John Marr Dr & Little River Tpke	-77.1902	38.8290	3	3	3
Little River & Annandale	-77.1981	38.8309	3	3	3
Little River & John Marr	-77.1895	38.8292	3	3	3
Little River & Oasis	-77.1422	38.8178	3	3	3
Little River Tnpk & Backlick R	-77.1935	38.8299	3	3	3
Little River Tnpk & Markham St	-77.1992	38.8309	3	3	3
Mt Vernon Square Apartments	-77.0776	38.7576	3	3	3
Richmond Hwy & Dawn Dr	-77.0809	38.7752	3	3	3
Richmond Hwy & Fordson Rd	-77.0832	38.7491	3	3	3
Richmond Hwy & Lukens Ln	-77.1200	38.7233	3	3	3
Richmond Hwy & Russell Rd	-77.0994	38.7338	3	3	3
Richmond Hwy & Southgate Dr	-77.0813	38.7735	3	3	3
Richmond Hwy & Woodlawn Ter	-77.0831	38.7511	3	3	3
Richmond Hwy & Woodlawn Ter	-77.0834	38.7514	3	3	3
Saint Germain Dr & Abelia Ave	-77.4416	38.8370	3	3	3
Southgate Dr & Richmond Hwy	-77.0828	38.7744	3	3	3
Southgate Dr & Richmond Hwy	-77.0828	38.7742	3	3	3
Frederick Shopping Center North	-77.4166	39.4322	3	3	3
Frederick Shopping Center South (Giant Eagle)	-77.4191	39.4311	3	3	3
Opossumtown Pike & Thomas Johnson Drive	-77.4106	39.4400	3	3	3
Walkers Village Shopping Center (Safeway)	-77.3415	39.4849	3	3	3
Westridge Plaza & Gmart	-77.4462	39.4189	3	3	3
Westridge Plaza & Payless	-77.4448	39.4189	3	3	3
Briggs Chaney Rd & Outlet Dr	-76.9471	39.0818	3	3	3
Lockwood Dr & 1209 Lockwood Dr	-76.9879	39.0410	3	3	3
Lockwood Dr & New Hampshire Ave	-76.9892	39.0403	3	3	3
Lockwood Dr & New Hampshire Ave	-76.9894	39.0404	3	3	3

Bus Stop Intersection	Longitude	Latitude	Extreme Heat Score	Equity Score	Final Score
Parklawn Dr & 12224 Parklawn Dr	-77.1104	39.0579	3	3	3
Perry Pkw & 200 Perry Pkw	-77.2095	39.1420	3	3	3
Perry Pkw & 202 Perry Pkw	-77.2106	39.1432	3	3	3
Perry Pkw & 205 Perry Pkw	-77.2094	39.1424	3	3	3
Piney Branch Rd & Greenwood Ave	-77.0028	38.9984	3	3	3
Centreville Rd & Phoenix Dr	-77.4572	38.7651	3	3	3
Liberia Ave & Euclid Ave	-77.4560	38.7595	3	3	3
Manassas Mall Departures	-77.5067	38.7723	3	3	3
Minnieville Rd & Elm Farm Rd	-77.3131	38.6536	3	3	3
Minnieville Rd & Prince William Pkwy	-77.3143	38.6530	3	3	3
Old Triangle Rd & Kearsarge Dr	-77.3237	38.5631	3	3	3
Potomac Festival After Omniride	-77.2965	38.6359	3	3	3
Potomac Festival Before Omniride	-77.2961	38.6366	3	3	3
Potomac Mills Commuter Lot	-77.2937	38.6404	3	3	3
Potomac Mills Mall & Buy Buy Baby	-77.2924	38.6457	3	3	3
Potomac Mills Rd & Gideon Dr	-77.2939	38.6401	3	3	3
Potomac Mills Rd & Gideon Dr	-77.2939	38.6400	3	3	3
Route 1 & Dumfries Rd	-77.3156	38.5738	3	3	3
Route 1 & Featherstone Dr	-77.2692	38.6370	3	3	3
Route 1 & Marys Way	-77.2558	38.6528	3	3	3
Route 1 & Mt Pleasant Dr	-77.2556	38.6525	3	3	3
Route 234 Commuter Lot	-77.3158	38.5768	3	3	3
Smoketown Plaza Shopping Center	-77.3078	38.6541	3	3	3
Smoketown Rd & Nazarene Way	-77.3014	38.6437	3	3	3
Smoketown Rd & Nazarene Way	-77.3013	38.6443	3	3	3
Telegraph Rd & Prince William Pkwy	-77.2905	38.6535	3	3	3
Worth Ave & Prince William Pkwy	-77.2949	38.6488	3	3	3
Worth Ave & Prince William Pkwy	-77.2953	38.6498	3	3	3
3300 75th Ave & 75th Ave	-76.8829	38.9330	3	3	3
3300 Pennsy Dr & Pennsy Dr	-76.8844	38.9364	3	3	3
3301 Pennsy Dr & Pennsy Dr	-76.8844	38.9362	3	3	3
Bladensburg Rd & 38th Ave	-76.9503	38.9351	3	3	3
Columbia Park Rd & Clarkson Way	-76.9033	38.9176	3	3	3
Columbia Park Rd & Stanford Ct	-76.9007	38.9181	3	3	3
Donnell Dr & Marlboro Pike	-76.8853	38.8489	3	3	3
Donnell Dr & Marlboro Pike	-76.8850	38.8488	3	3	3
Donnell Dr & Pennsylvania Ave	-76.8849	38.8446	3	3	3
Donnell Dr & Pennsylvania Ave	-76.8846	38.8446	3	3	3
East-West Hwy & Pg Plaza	-76.9582	38.9670	3	3	3
Forest Village Park Mall	-76.8852	38.8476	3	3	3
Maxwell Dr & Morris Ave	-76.8961	38.8153	3	3	3
Morris Ave & Maxwell Dr	-76.8964	38.8151	3	3	3
Penn-Mar Shopping Center	-76.8850	38.8477	3	3	3
Pennsy Dr & 75th Ave	-76.8829	38.9358	3	3	3
University Blvd & Riggs Rd	-76.9777	38.9834	3	3	3
Baltimore Ave / Southard Dr (Northbound)	-76.9117	39.0317	3	3	3
Baltimore Ave / Southard Dr (Southbound)	-76.9118	39.0319	3	3	3
Contee Rd / Baltimore Ave (Eastbound)	-76.8695	39.0764	3	3	3
Contee Rd / Baltimore Ave (Westbound)	-76.8700	39.0768	3	3	3
26th St NE & Bladensburg Rd NE	-76.9699	38.9223	3	3	3
908 W Glebe Rd & Valley Dr	-77.0731	38.8420	3	3	3
Amherst Ave & Commerce St	-77.1869	38.7826	3	3	3
Arlington Blvd & Graham Rd	-77.1947	38.8665	3	3	3
Arlington Blvd & Graham Rd	-77.1944	38.8662	3	3	3
Arlington Blvd & Loemanns Plaza	-77.1975	38.8660	3	3	3
Army Navy Dr & S Joyce St	-77.0618	38.8657	3	3	3
Audrey Ln & Eastover Park & Ride Lot	-77.0016	38.8185	3	3	3
Baltimore Ave & Southard Dr	-76.9118	39.0319	3	3	3

Bus Stop Intersection	Longitude	Latitude	Extreme Heat Score	Equity Score	Final Score
Baltimore Ave & Southard Dr	-76.9117	39.0318	3	3	3
Beltway Plaza & Cunningham Dr Entr	-76.9087	38.9981	3	3	3
Beltway Plaza & Cunningham Dr Exit	-76.9096	38.9984	3	3	3
Beltway Plaza & Main Rdwy In Frt Of Stores	-76.9075	38.9986	3	3	3
Benning Rd NE & 17th St NE	-76.9795	38.8993	3	3	3
Bladensburg Division & Employee Shuttle Stop	-76.9694	38.9232	3	3	3
Bladensburg Rd & 38th Ave	-76.9503	38.9351	3	3	3
Bladensburg Rd NE & Channing St NE	-76.9684	38.9225	3	3	3
Branch Ave & Marlow Heights Shopping Center	-76.9432	38.8348	3	3	3
Brentwood Rd NE & T St NE	-76.9946	38.9164	3	3	3
Brentwood Rd NE & V St NE	-76.9936	38.9176	3	3	3
Brentwood Rd NE & W St NE	-76.9912	38.9196	3	3	3
Carlin Springs Rd & Leesburg Pike	-77.1253	38.8474	3	3	3
Carmen Turner Facility & Main Entrance	-76.8764	38.9387	3	3	3
Columbia Park Rd & Clarkson Way	-76.9033	38.9176	3	3	3
Columbia Park Rd & Stanford Ct	-76.9007	38.9181	3	3	3
Commerce St & Amherst Ave	-77.1877	38.7826	3	3	3
Dallas Pl & Princeton Estates Apartments	-76.9485	38.8257	3	3	3
Donnell Dr & Forest Vil Pk Mall	-76.8852	38.8476	3	3	3
Donnell Dr & Marlboro Pk	-76.8850	38.8489	3	3	3
Donnell Dr & Marlboro Pk	-76.8853	38.8489	3	3	3
Donnell Dr & MD-4	-76.8846	38.8446	3	3	3
Donnell Dr & MD-4	-76.8849	38.8446	3	3	3
Donnell Dr & Penn-Mar Shoping Ctr	-76.8850	38.8478	3	3	3
East-West Hwy & Entr To Mall At Prince George's	-76.9582	38.9670	3	3	3
Eastover Shopping Center & 5035b	-77.0027	38.8191	3	3	3
Eastover Shopping Center & Dollar Tree Store	-77.0035	38.8177	3	3	3
Edsall Rd & S Van Dorn St	-77.1320	38.8077	3	3	3
Greenbelt Rd & Cherrywood Ln	-76.9117	38.9981	3	3	3
H St NW & 4th St NW	-77.0171	38.8997	3	3	3
Jefferson Ave & Ardwick Ardmore Rd	-76.8700	38.9415	3	3	3
Jefferson Ave & Ardwick Ardmore Rd	-76.8697	38.9418	3	3	3
John Marr Dr & Little River Tpke	-77.1904	38.8291	3	3	3
Kenilworth Ave & 52nd Ave	-76.9315	38.9298	3	3	3
Landover Rd & Kilmer St	-76.9028	38.9323	3	3	3
Landover Rd & Kilmer St	-76.9015	38.9322	3	3	3
Lee Hwy & Windsor Dr	-77.2095	38.8753	3	3	3
Leesburg Pike & Crossroads Center Way	-77.1322	38.8518	3	3	3
Leesburg Pike & Gorham St	-77.1235	38.8478	3	3	3
Leesburg Pike & Patrick Henry Dr	-77.1512	38.8666	3	3	3
Little River Tpke & Annandale Rd	-77.1981	38.8309	3	3	3
Little River Tpke & Backlick Rd	-77.1935	38.8299	3	3	3
Little River Tpke & John Marr Dr	-77.1895	38.8293	3	3	3
Little River Tpke & Markham St	-77.1992	38.8309	3	3	3
Little River Tpke & Oasis Dr	-77.1422	38.8178	3	3	3
Livingston Rd & Oxon Hill Rd	-76.9890	38.8028	3	3	3
Lockwood Dr & New Hampshire Ave	-76.9893	39.0402	3	3	3
Lockwood Dr & New Hampshire Ave	-76.9894	39.0404	3	3	3
Lockwood Dr & White Oak S/C	-76.9878	39.0409	3	3	3
Lockwood Dr & White Oak Shopping Center	-76.9879	39.0410	3	3	3
Market St NE & Costco Store	-76.9523	38.9210	3	3	3
Market St NE & Lowes Store	-76.9540	38.9203	3	3	3
Marlboro Pike & Boones Hill Rd	-76.9313	38.8735	3	3	3
Marlboro Pike & Boones Hill Rd	-76.9311	38.8736	3	3	3
Marlboro Pike & Boones Hill Rd	-76.9320	38.8737	3	3	3
Marlboro Pike & Edgewick Ave	-76.9295	38.8731	3	3	3
Marlboro Pike & Edgewick Ave	-76.9298	38.8734	3	3	3
Marlow Heights Shopping Center & Macys	-76.9444	38.8347	3	3	3

Bus Stop Intersection	Longitude	Latitude	Extreme Heat Score	Equity Score	Final Score
Maryland Ave NE & Neal St NE	-76.9810	38.9010	3	3	3
Maxwell Dr & Morris Ave	-76.8961	38.8152	3	3	3
Minnesota Ave NE & Benning Rd NE	-76.9496	38.8947	3	3	3
Minnesota Ave NE & Clay Pl NE	-76.9506	38.8933	3	3	3
Minnesota Ave NE & Dix St NE	-76.9499	38.8941	3	3	3
N Glebe Rd & 2nd St N	-77.1029	38.8721	3	3	3
N Pershing Dr & N Glebe Rd	-77.1055	38.8736	3	3	3
N Pershing Dr & N Glebe Rd	-77.1056	38.8737	3	3	3
Old Branch Ave & Ourisman Used Cars	-76.9341	38.8312	3	3	3
3020 Penn-Mar Shopping Center	-76.8830	38.8485	3	3	3
3200 Penn-Mar Shopping Center	-76.8828	38.8470	3	3	3
3314 Penn-Mar Shopping Center	-76.8831	38.8457	3	3	3
Pennsy Dr & 3301 Pennsy Dr	-76.8844	38.9362	3	3	3
Pennsy Dr & 75th Ave	-76.8829	38.9358	3	3	3
Pennsy Dr & 75th Ave	-76.8828	38.9357	3	3	3
Pennsy Dr & Metrobus Station	-76.8768	38.9371	3	3	3
Pennsy Dr & Metrobus Station	-76.8764	38.9374	3	3	3
Piney Branch Rd & Greenwood Ave	-77.0028	38.9984	3	3	3
Rhode Island Ave NE & 610 Rhode Island Ave NE	-76.9978	38.9209	3	3	3
Rhode Island Ave NE & 5th St NE	-76.9993	38.9203	3	3	3
Richmond Hwy & Lukens Ln	-77.1200	38.7233	3	3	3
Richmond Hwy & Southgate Dr	-77.0813	38.7735	3	3	3
S Reynolds St & Edsall Rd	-77.1298	38.8081	3	3	3
Southern Ave & Bowen Rd SE	-76.9343	38.8736	3	3	3
St Barnabas Rd & Clifton Rd	-76.9452	38.8267	3	3	3
St Barnabas Rd & Clifton Rd	-76.9455	38.8261	3	3	3
St Barnabas Rd & Pohanka Pl	-76.9468	38.8251	3	3	3
St Barnabas Rd & Pohanka Pl	-76.9467	38.8254	3	3	3
St Barnabas Rd & Stamp Rd	-76.9442	38.8272	3	3	3
St Barnabas Rd & Stamp Rd	-76.9439	38.8279	3	3	3
Stevenson Ave & S Van Dorn St	-77.1327	38.8115	3	3	3
University Blvd E & MD-212	-76.9777	38.9834	3	3	3
W. Glebe Rd & Valley Dr	-77.0734	38.8422	3	3	3

RAIL LINES

Table 25. High Vulnerability Rail Lines for Extreme Heat

Segment ID	Rail Route Name	Extreme Heat Score	Equity Score	Final Score
2042	Amtrak NEC	3	3	3
1975	MARC Brunswick	3	3	3
1952	MARC Brunswick	3	3	3
1888	Amtrak Silver Service/Palmetto	3	3	3
1887	Amtrak Silver Service/Palmetto	3	3	3
1768	WMATA Red Line	3	3	3
1767	WMATA Red Line	3	3	3
1748	WMATA Red Line	3	3	3
1732	WMATA Blue Line	3	3	3
1731	WMATA Blue Line	3	3	3
1729	WMATA Blue Line	3	3	3
1561	Amtrak Cardinal	3	3	3
1366	Amtrak Acela	3	3	3
1355	DC Streetcar Union Station - Benning Rd	3	3	3
1253	Amtrak Crescent	3	3	3
1223	MARC Penn	3	3	3
1190	DC Streetcar Union Station - Benning Rd	3	3	3
1134	Amtrak Regional	3	3	3
1133	Amtrak Regional	3	3	3

Segment ID	Rail Route Name	Extreme Heat Score	Equity Score	Final Score
1031	WMATA Yellow Line	3	3	3
1003	MARC Penn	3	3	3
931	Amtrak Carolinian	3	3	3
930	Amtrak Carolinian	3	3	3
834	MARC Camden	3	3	3
715	Amtrak Vermonter	3	3	3
544	MARC Brunswick	3	3	3
521	MARC Brunswick	3	3	3
351	WMATA Orange Line	3	3	3
349	WMATA Orange Line	3	3	3
292	Amtrak Capitol Limited	3	3	3
291	Amtrak Capitol Limited	3	3	3
229	Amtrak Capitol Limited	3	3	3
123	WMATA Silver Line	3	3	3
122	WMATA Silver Line	3	3	3
120	WMATA Silver Line	3	3	3
92	MARC Camden	3	3	3

Flooding

BRIDGES

Table 26. High Vulnerability Bridge For Flooding

Structure Number	Longitude	Latitude	Channel Condition Score	Water Adequacy Score	Scour Criticality Score	Equity Score	Functional Score	Final Score
0019-1(LOW)	-76.9445	38.9015	2	2	3	3	3	2.53

Temporary Flooding (Coastal and Riverine)

BUS STOPS

Table 27. High Vulnerability Bus Stops For Temporary Flooding (Coastal and Riverine)

Bus Stop Intersection	Longitude	Latitude	Flood Score	Equity Score	Final Score
Pennsy Dr & 3133 Pennsy Dr	-76.8877	38.9330	3	3	3
Columbia Park Rd & Cabin Branch Dr	-76.9070	38.9169	3	3	3
Columbia Park Rd & 5700 Columbia Park Rd	-76.9082	38.9167	3	3	3
Pennsy Dr & 3133 Pennsy Dr	-76.8877	38.9329	3	3	3
S Pickett St & Shilling St	-77.1321	38.8044	3	3	3
S Pickett St & Shilling St	-77.1320	38.8046	3	3	3
28th St S Nb & 26th St S Ns	-77.0742	38.8488	3	3	3
28th St S Sb & 26th St S Fs	-77.0743	38.8486	3	3	3
S Four Mile Run Dr Eb & S Walter Reed Dr Ns	-77.0954	38.8473	3	3	3
S Four Mile Run Dr Nb & 16th St S Ns	-77.1024	38.8523	3	3	3
S Four Mile Run Dr Sb & S George Mason Dr Fs	-77.1029	38.8525	3	3	3
S George Mason Dr Nb At 1401	-77.1017	38.8537	3	3	3
S Glebe Rd Eb & S Meade St Ns	-77.0715	38.8443	3	3	3
S Glebe Rd Eb & W Glebe Rd Fs	-77.0758	38.8439	3	3	3
S Glebe Rd Wb & S Meade St Fs	-77.0714	38.8445	3	3	3
S Glebe Rd Wb & S Wayne St Ns	-77.0747	38.8442	3	3	3
Pennsylvania Ave & 6th St NW	-77.0199	38.8928	3	3	3
Edsall Rd & Winter View Dr	-77.1446	38.8043	3	3	3
Frederick Towne Mall & Boscov's West Entrance	-77.4596	39.4206	3	3	3
Key Parkway & Mccain Drive	-77.4536	39.4225	3	3	3
Waverley Drive & Waverley Center	-77.4600	39.4223	3	3	3

Bus Stop Intersection	Longitude	Latitude	Flood Score	Equity Score	Final Score
Waverly Drive & Steps To Strip Mall (Ollie's)	-77.4599	39.4222	3	3	3
Clopper Rd & Firstfield Rd	-77.2243	39.1438	3	3	3
Clopper Rd & Firstfield Rd	-77.2235	39.1436	3	3	3
East-West Hwy & Meadowbrook Dr	-77.0604	38.9926	3	3	3
East-West Hwy & Meadowbrook La	-77.0601	38.9924	3	3	3
Firstfield Rd & Clopper Rd	-77.2234	39.1440	3	3	3
Firstfield Rd & Clopper Rd	-77.2238	39.1439	3	3	3
N Frederick Ave & Professional Dr	-77.2262	39.1632	3	3	3
Perry Pkw & 584 Perry Pkw	-77.2126	39.1487	3	3	3
Perry Pkw & 620 Perry Pkw	-77.2134	39.1486	3	3	3
Quince Orchard Blv & Firstfield Rd	-77.2269	39.1346	3	3	3
23rd Ave & Sheridan St	-76.9727	38.9697	3	3	3
23rd Ave & Sheridan St	-76.9728	38.9698	3	3	3
3101 Pennsy Dr & Pennsy Dr	-76.8890	38.9322	3	3	3
3133 Pennsy Dr & Pennsy Dr	-76.8879	38.9330	3	3	3
5718 Columbia Park Rd & Columbia Park Rd	-76.9082	38.9167	3	3	3
Ager Rd & Nicholson St	-76.9695	38.9621	3	3	3
Ager Rd & Nicholson St	-76.9696	38.9618	3	3	3
Ager Rd & Oglethorpe St	-76.9718	38.9639	3	3	3
Annapolis Rd & 46th St	-76.9401	38.9393	3	3	3
Annapolis Rd & 46th St	-76.9399	38.9390	3	3	3
Auburn Ave & Riverdale Rd	-76.8965	38.9650	3	3	3
Baltimore Ave & Berwyn House Rd	-76.9334	38.9923	3	3	3
Baltimore Ave & Berwyn House Rd	-76.9332	38.9923	3	3	3
Baltimore Ave & Lakeland Rd	-76.9341	38.9902	3	3	3
Baltimore Ave & Lakeland Rd	-76.9342	38.9905	3	3	3
Capital Crossing Apartments	-76.9477	38.8604	3	3	3
Chillum Shopping Center	-76.9692	38.9520	3	3	3
Chillum Shopping Center	-76.9692	38.9522	3	3	3
Columbia Park Rd & 64th Ave	-76.9105	38.9165	3	3	3
Columbia Park Rd & 64th Ave	-76.9105	38.9166	3	3	3
Kenilworth Ave & Sarvis Ave	-76.9164	38.9700	3	3	3
Landover Rd & Pinebrook Rd	-76.8906	38.9272	3	3	3
Landover Rd & Pinebrook Rd	-76.8898	38.9272	3	3	3
Old Landover Rd & Landover Rd	-76.8918	38.9287	3	3	3
Old Landover Rd & Landover Rd	-76.8920	38.9286	3	3	3
Southern Ave & 6th St SE	-76.9992	38.8228	3	3	3
Southern Ave & 6th St SE	-76.9997	38.8226	3	3	3
2nd St & Main St	-76.8424	39.1035	3	3	3
8th St & Laurel Park Apartments	-76.8580	39.1004	3	3	3
8 th St & Laurelton Court Apartments	-76.8578	39.1005	3	3	3
Baltimore Ave & Lincoln Ave (Northbound)	-76.9021	39.0448	3	3	3
Baltimore Ave & Lincoln Ave (Southbound)	-76.9022	39.0451	3	3	3
Laurel Bowie Rd & Morris Dr (Northbound)	-76.8434	39.0933	3	3	3
Laurel Bowie Rd & Morris Dr (Southbound)	-76.8439	39.0931	3	3	3
23rd Ave & Sheridan St	-76.9727	38.9698	3	3	3
23rd Ave & Sheridan St	-76.9728	38.9698	3	3	3
Ager Rd & Nicholson St	-76.9695	38.9622	3	3	3
Ager Rd & Nicholson St	-76.9696	38.9618	3	3	3
Ager Rd & Oglethorpe St	-76.9718	38.9639	3	3	3
Annapolis Rd & 46th St	-76.9401	38.9393	3	3	3
Annapolis Rd & 46th St	-76.9399	38.9391	3	3	3
Auburn Ave & Riverdale Rd	-76.8965	38.9650	3	3	3
Baltimore Ave & 4319 Baltimore Ave	-76.9409	38.9419	3	3	3
Baltimore Ave & Bowie Rd	-76.8500	39.0966	3	3	3
Baltimore Ave & Lakeland Rd	-76.9342	38.9906	3	3	3
Baltimore Ave & Lakeland Rd	-76.9341	38.9902	3	3	3
Baltimore Ave & Lincoln Ave	-76.9021	39.0448	3	3	3

Bus Stop Intersection	Longitude	Latitude	Flood Score	Equity Score	Final Score
Baltimore Ave & Lincoln Ave	-76.9022	39.0451	3	3	3
Baltimore Ave & Navahoe St	-76.9334	38.9924	3	3	3
Baltimore Ave & Navahoe St	-76.9331	38.9924	3	3	3
Cipriano Rd & Tuckerman St	-76.8545	38.9769	3	3	3
Cipriano Rd & Tuckerman St	-76.8547	38.9768	3	3	3
Columbia Park Rd & 64th Ave	-76.9106	38.9165	3	3	3
Columbia Park Rd & 64th Ave	-76.9105	38.9166	3	3	3
Division Ave NE & Fitch Pl NE	-76.9263	38.8968	3	3	3
East-West Hwy & Meadowbrook Ln	-77.0604	38.9926	3	3	3
East-West Hwy & Meadowbrook Ln	-77.0601	38.9924	3	3	3
Hayes St NE & 3704-3710 Hayes St NE	-76.9517	38.9044	3	3	3
Indian Run Pky & Bren Mar Dr	-77.1496	38.7998	3	3	3
Jay St NE & 3733-3741 Jay St NE	-76.9483	38.9048	3	3	3
Jay St NE & 3763-3773 Jay St NE	-76.9473	38.9040	3	3	3
Kenilworth Ave & Sarvis Ave	-76.9164	38.9700	3	3	3
Landover Rd & Pinebrook Ave	-76.8898	38.9272	3	3	3
Landover Rd & Pinebrook Ave	-76.8906	38.9272	3	3	3
Lanham Severn Rd & Glenn Dale Rd	-76.8208	38.9868	3	3	3
Laurel Bowie Rd & Morris Dr	-76.8439	39.0931	3	3	3
Laurel Bowie Rd & Morris Dr	-76.8433	39.0933	3	3	3
Mayfair Ter NE & 3531-3537 Mayfair Ter NE	-76.9498	38.9069	3	3	3
Mayfair Ter NE & 3547-3553 Mayfair Ter NE	-76.9510	38.9075	3	3	3
Mayfair Ter NE & 3576-3582 Mayfair Ter NE	-76.9525	38.9071	3	3	3
Mayfair Ter NE & 3592-3598 Mayfair Ter NE	-76.9528	38.9058	3	3	3
Mayfair Ter NE & 3675-3691 Mayfair Ter NE	-76.9493	38.9058	3	3	3
MD-212 & East-West Hwy	-76.9803	38.9716	3	3	3
Minnesota Ave NE & Nannie Helen Burroughs Ave NE	-76.9432	38.9016	3	3	3
Minnesota Ave NE & Nannie Helen Burroughs Ave NE	-76.9422	38.9022	3	3	3
Mt Vernon Ave & Executive Ave	-77.0635	38.8420	3	3	3
Mt Vernon Ave & Executive Ave	-77.0638	38.8422	3	3	3
Mt Vernon Ave & Four Mile Rd	-77.0640	38.8432	3	3	3
Nannie Helen Burroughs Ave NE & 44th St NE	-76.9395	38.9006	3	3	3
Nannie Helen Burroughs Ave NE & 44th St NE	-76.9390	38.9006	3	3	3
Nannie Helen Burroughs Ave NE & 49th St NE	-76.9320	38.8986	3	3	3
Nannie Helen Burroughs Ave NE & 49th St NE	-76.9315	38.8987	3	3	3
Nannie Helen Burroughs Ave NE & 50th St NE	-76.9294	38.8985	3	3	3
Nannie Helen Burroughs Ave NE & 50th St NE	-76.9294	38.8983	3	3	3
Nannie Helen Burroughs Ave NE & Hayes St NE	-76.9376	38.8999	3	3	3
Nannie Helen Burroughs Ave NE & Minnesota Ave NE	-76.9423	38.9017	3	3	3
Old Landover Rd & Old Landover Rd	-76.8920	38.9286	3	3	3
Old Landover Rd & Old Landover Rd	-76.8918	38.9287	3	3	3
Pennsy Dr & 3100 Pennsy Dr	-76.8889	38.9322	3	3	3
Pennsy Dr & 3133 Pennsy Dr	-76.8879	38.9330	3	3	3
Queens Chapel Rd & Chillum Rd	-76.9668	38.9520	3	3	3
S Capitol St SE & 1st St SE	-77.0061	38.8243	3	3	3
S Four Mile Run Dr & 16th St S	-77.1025	38.8523	3	3	3
S Four Mile Run Dr & S George Mason Dr	-77.1029	38.8525	3	3	3
S Four Mile Run Dr & S Walter Reed Dr	-77.0954	38.8473	3	3	3
S Four Mile Run Dr & W Village Of Shirlington	-77.1009	38.8509	3	3	3
Seat Pleasant Dr & 71st Ave	-76.8996	38.8976	3	3	3
Seat Pleasant Dr & Ashleaf Ave	-76.8991	38.8976	3	3	3
Sheriff Rd NE & Minnesota Ave NE	-76.9409	38.9030	3	3	3
Southern Ave & 6th St SE	-76.9997	38.8226	3	3	3
Southern Ave & S Capitol St SW	-77.0006	38.8217	3	3	3
Southern Ave SE & 6th St SE	-76.9992	38.8228	3	3	3

Bus Stop Intersection	Longitude	Latitude	Flood Score	Equity Score	Final Score
Southern Ave SE & S Capitol St SE	-77.0001	38.8221	3	3	3
Southern Ave SE & S Capitol St SE	-77.0011	38.8216	3	3	3
Tuxedo Rd & 5400 Tuxedo Rd	-76.9262	38.9180	3	3	3
Tuxedo Rd & 5400 Tuxedo Rd	-76.9265	38.9180	3	3	3
Tuxedo Rd & Kenilworth Ave	-76.9298	38.9190	3	3	3
Tuxedo Rd & Kenilworth Ave	-76.9301	38.9189	3	3	3
V St SW & 1st St SW	-77.0129	38.8646	3	3	3
VA-120 & S Adams St	-77.0747	38.8442	3	3	3
VA-120 & S Adams St	-77.0746	38.8440	3	3	3
VA-120 & S Troy St	-77.0715	38.8446	3	3	3
VA-120 & S Troy St	-77.0715	38.8443	3	3	3
Soapstone Dr & Hearthstone Ct (North)	-77.3463	38.9306	3	3	3
Telegraph Rd & Belvoir View Pl	-77.1884	38.7220	3	3	3
Old Camp Road & Ballfield	-77.4658	39.4231	3	3	3
Old Camp Road Across From Ballfield	-77.4657	39.4229	3	3	3
Quince Orchard Blv & Firstfield Rd	-77.2264	39.1346	3	3	3
Sligo Creek Pkw & Colesville Rd	-77.0206	39.0079	3	3	3
Watkins Mill Rd & Travis Ave	-77.2145	39.1617	3	3	3
38th Ave & Gaines Pl	-76.9561	38.9501	3	3	3
Cherrywood Ln & Springhill Dr	-76.9052	39.0085	3	3	3
Greenbelt Metro Dr & Cherrywood Ln	-76.9043	39.0114	3	3	3
Owens Rd & Kennebec St	-76.9882	38.8205	3	3	3
Owens Rd & Kennebec St	-76.9880	38.8206	3	3	3
Riverdale Rd & Calvert Park Apartments	-76.9268	38.9608	3	3	3
Cherrywood Ln / Springhill Dr	-76.9052	39.0085	3	3	3
Greenbelt Metro Dr / Cherrywood Ln (Northbound)	-76.9043	39.0114	3	3	3
38th Ave & Gaines Aly	-76.9561	38.9502	3	3	3
Ager Rd & Oglethorpe St	-76.9717	38.9641	3	3	3
Ammendale Rd & Baltimore Ave	-76.8976	39.0512	3	3	3
Barlowe Rd & Landover Rd	-76.8653	38.9202	3	3	3
Barlowe Rd & Landover Rd	-76.8650	38.9202	3	3	3
Cherrywood Ln & Springhill Dr	-76.9052	39.0085	3	3	3
Corporate Dr & Garden City Dr	-76.8683	38.9473	3	3	3
Corporate Dr & Garden City Dr	-76.8685	38.9472	3	3	3
Good Luck Rd & Cipriano Rd	-76.8539	38.9779	3	3	3
Greenbelt Metro Dr & Cherrywood Ln	-76.9043	39.0114	3	3	3
Owens Rd & Kennebec St	-76.9880	38.8207	3	3	3
Owens Rd & Kennebec St	-76.9882	38.8206	3	3	3
Riverdale Rd & Calvert Park Apartments	-76.9268	38.9608	3	3	3

RAIL STOPS

Table 28. High Vulnerability Rail Stop For Temporary Flooding (Coastal and Riverine)

Rail Stop Name	Flood Score	Equity Score	Final Score
Brunswick MARC Station	3	3	3

RAIL LINES

Table 29. High Vulnerability Rail Lines For Temporary Flooding (Coastal and Riverine)

Segment ID	Rail Route Name	Flood Score	Equity Score	Final Score
122	WMATA Silver	3	3	3
1729	WMATA Blue	3	3	3
349	WMATA Orange	3	3	3
719	Amtrak Vermonter	3	3	3
621	Amtrak DC - Richmond	3	3	3
56	VRE Manassas	3	3	3

Segment ID	Rail Route Name	Flood Score	Equity Score	Final Score
1106	Amtrak Regional	3	3	3
672	WMATA Green	3	3	3
833	MARC Camden	3	3	3
961	Amtrak Carolinian	3	3	3
620	Amtrak DC - Richmond	3	3	3
1565	Amtrak Cardinal	3	3	3
15	VRE Manassas	3	3	3
1043	WMATA Yellow	3	3	3
1428	VRE Fredericksburg	3	3	3
686	WMATA Green	3	3	3
448	MARC Brunswick	3	3	3
726	Amtrak Vermonter	3	3	3
1138	Amtrak Regional	3	3	3
934	Amtrak Carolinian	3	3	3
1466	VRE Fredericksburg	3	3	3
1448	VRE Fredericksburg	3	3	3
415	Amtrak DC - Norfolk	3	3	3
449	MARC Brunswick	3	3	3
1358	Amtrak Acela	3	3	3
904	Amtrak Carolinian	3	3	3
1841	Amtrak Silver_Service/Palmetto	3	3	3
1489	Amtrak DC - Lynchburg - Roanoke	3	3	3
1124	Amtrak Regional	3	3	3
1218	MARC Penn	3	3	3
1051	WMATA Yellow	3	3	3
993	MARC Penn	3	3	3
1893	Amtrak Silver_Service/Palmetto	3	3	3
130	WMATA Silver	3	3	3
1566	Amtrak Cardinal	3	3	3
1139	Amtrak Regional	3	3	3
74	VRE Manassas	3	3	3
113	WMATA Silver	3	3	3
353	WMATA Orange	3	3	3
1137	Amtrak Regional	3	3	3
796	Amtrak DC - Newport News	3	3	3
1669	Amtrak Cardinal	3	3	3
1879	Amtrak Silver_Service/Palmetto	3	3	3
1341	Amtrak Crescent	3	3	3
1370	Amtrak Acela	3	3	3
699	WMATA Green	3	3	3
1934	MARC Brunswick	3	3	3
1555	Amtrak DC - Lynchburg - Roanoke	3	3	3
57	VRE Manassas	3	3	3
1679	Amtrak Cardinal	3	3	3
1220	MARC Penn	3	3	3
342	WMATA Orange	3	3	3
1935	MARC Brunswick	3	3	3
1044	WMATA Yellow	3	3	3
1357	DC Streetcar Union Station to Benning Rd	3	3	3
1860	Amtrak Silver_Service/Palmetto	3	3	3
935	Amtrak Carolinian	3	3	3
1518	Amtrak DC - Lynchburg - Roanoke	3	3	3
999	MARC Penn	3	3	3
3	VRE Manassas	3	3	3
1372	Amtrak Acela	3	3	3
1695	WMATA Blue	3	3	3
2046	Amtrak NEC	3	3	3
797	Amtrak DC - Newport News	3	3	3
1376	Amtrak Acela	3	3	3

Segment ID	Rail Route Name	Flood Score	Equity Score	Final Score
2053	Amtrak NEC	3	3	3
688	WMATA Green	3	3	3
1730	WMATA Blue	3	3	3
1571	Amtrak Cardinal	3	3	3
1189	DC Streetcar Union Station to Benning Rd	3	3	3
2048	Amtrak NEC	3	3	3
2052	Amtrak NEC	3	3	3
362	WMATA Orange	3	3	3
52	VRE Manassas	3	3	3
1000	MARC Penn	3	3	3
1447	VRE Fredericksburg	3	3	3
725	Amtrak Vermonter	3	3	3
1607	Amtrak Cardinal	3	3	3
356	WMATA Orange	3	3	3
1694	WMATA Blue	3	3	3
51	VRE Manassas	3	3	3
1351	Amtrak Crescent	3	3	3
721	Amtrak Vermonter	3	3	3
395	Amtrak DC - Norfolk	3	3	3
1632	Amtrak Cardinal	3	3	3
1861	Amtrak Silver_Service/Palmetto	3	3	3
814	Amtrak DC - Newport News	3	3	3
921	Amtrak Carolinian	3	3	3
4	VRE Manassas	3	3	3
1371	Amtrak Acela	3	3	3
1891	Amtrak Silver_Service/Palmetto	3	3	3
1219	MARC Penn	3	3	3
852	MARC Camden	3	3	3
1377	Amtrak Acela	3	3	3
1675	Amtrak Cardinal	3	3	3
2047	Amtrak NEC	3	3	3
603	Amtrak DC - Richmond	3	3	3
202	Amtrak Capitol Limited	3	3	3
602	Amtrak DC - Richmond	3	3	3
1258	Amtrak Crescent	3	3	3
815	Amtrak DC - Newport News	3	3	3
1263	Amtrak Crescent	3	3	3
344	WMATA Orange	3	3	3
1606	Amtrak Cardinal	3	3	3
851	MARC Camden	3	3	3
1125	Amtrak Regional	3	3	3
1673	Amtrak Cardinal	3	3	3
129	WMATA Silver	3	3	3
1480	Amtrak DC - Lynchburg - Roanoke	3	3	3
205	Amtrak Capitol Limited	3	3	3
357	WMATA Orange	3	3	3
1564	Amtrak Cardinal	3	3	3
204	Amtrak Capitol Limited	3	3	3
1933	MARC Brunswick	3	3	3
311	WMATA Orange	3	3	3
1045	WMATA Yellow	3	3	3
1144	Amtrak Regional	3	3	3
1892	Amtrak Silver_Service/Palmetto	3	3	3
1465	VRE Fredericksburg	3	3	3
1488	Amtrak DC - Lynchburg - Roanoke	3	3	3
1724	WMATA Blue	3	3	3
962	Amtrak Carolinian	3	3	3
201	Amtrak Capitol Limited	3	3	3
842	MARC Camden	3	3	3

Segment ID	Rail Route Name	Flood Score	Equity Score	Final Score
1257	Amtrak Crescent	3	3	3
313	WMATA Orange	3	3	3
450	MARC Brunswick	3	3	3
998	MARC Penn	3	3	3
1244	Amtrak Crescent	3	3	3
1107	Amtrak Regional	3	3	3
203	Amtrak Capitol Limited	3	3	3
903	Amtrak Carolinian	3	3	3
2034	Amtrak NEC	3	3	3
922	Amtrak Carolinian	3	3	3
936	Amtrak Carolinian	3	3	3
1936	MARC Brunswick	3	3	3
361	WMATA Orange	3	3	3
670	WMATA Green	3	3	3
664	WMATA Green	3	3	3
433	Amtrak DC - Norfolk	3	3	3
432	Amtrak DC - Norfolk	3	3	3
1479	Amtrak DC - Lynchburg - Roanoke	3	3	3
671	WMATA Green	3	3	3
1304	Amtrak Crescent	3	3	3
84	MARC Camden	3	3	3
85	MARC Camden	3	3	3
1878	Amtrak Silver_Service/Palmetto	3	3	3
1259	Amtrak Crescent	3	3	3
1245	Amtrak Crescent	3	3	3
1213	MARC Penn	3	3	3
720	Amtrak Vermonter	3	3	3
941	Amtrak Carolinian	3	3	3
1087	Amtrak Regional	3	3	3
1345	Amtrak Crescent	3	3	3
343	WMATA Orange	3	3	3
94	MARC Camden	3	3	3
414	Amtrak DC - Norfolk	3	3	3
128	WMATA Silver	3	3	3
1898	Amtrak Silver_Service/Palmetto	3	3	3
1738	WMATA Blue	3	3	3
884	Amtrak Carolinian	3	3	3
1347	Amtrak Crescent	3	3	3
695	WMATA Green	3	3	3
1723	WMATA Blue	3	3	3
1264	Amtrak Crescent	3	3	3
707	Amtrak Vermonter	3	3	3
583	Amtrak DC - Richmond	3	3	3
777	Amtrak DC - Newport News	3	3	3
76	MARC Camden	3	3	3
1481	Amtrak DC - Lynchburg - Roanoke	3	3	3
75	MARC Camden	3	3	3
452	MARC Brunswick	3	3	3
200	Amtrak Capitol Limited	3	3	3
2045	Amtrak NEC	3	3	3
252	Amtrak Capitol Limited	3	3	3
498	MARC Brunswick	3	3	3
1369	Amtrak Acela	3	3	3
453	MARC Brunswick	3	3	3
1932	MARC Brunswick	3	3	3
1998	MARC Brunswick	3	3	3
704	WMATA Green	3	3	3
50	VRE Manassas	3	3	3
718	Amtrak Vermonter	3	3	3

Segment ID	Rail Route Name	Flood Score	Equity Score	Final Score
451	MARC Brunswick	3	3	3
73	VRE Manassas	3	3	3
1464	VRE Fredericksburg	3	3	3
1877	Amtrak Silver_Service/Palmetto	3	3	3
813	Amtrak DC - Newport News	3	3	3
920	Amtrak Carolinian	3	3	3
431	Amtrak DC - Norfolk	3	3	3
1243	Amtrak Crescent	3	3	3
1605	Amtrak Cardinal	3	3	3
1123	Amtrak Regional	3	3	3
619	Amtrak DC - Richmond	3	3	3
350	WMATA Orange	3	3	3
1478	Amtrak DC - Lynchburg - Roanoke	3	3	3
351	WMATA Orange	3	3	3
1731	WMATA Blue	3	3	3
1059	Amtrak Regional	3	3	3
691	WMATA Green	3	3	3
1717	WMATA Blue	3	3	3
1400	VRE Fredericksburg	3	3	3
555	Amtrak DC - Richmond	3	3	3
121	WMATA Silver	3	3	3
630	Amtrak Auto Train	3	3	3
856	Amtrak Carolinian	3	3	3
1027	WMATA Yellow	3	3	3
367	Amtrak DC - Norfolk	3	3	3
749	Amtrak DC - Newport News	3	3	3
1813	Amtrak Silver_Service/Palmetto	3	3	3
337	WMATA Orange	3	3	3
100	MARC Camden	3	3	3
135	WMATA Silver	3	3	3
827	MARC Camden	3	3	3
1001	MARC Penn	3	3	3
1060	Amtrak Regional	3	3	3
368	Amtrak DC - Norfolk	3	3	3
1890	Amtrak Silver_Service/Palmetto	3	3	3
1563	Amtrak Cardinal	3	3	3
1814	Amtrak Silver_Service/Palmetto	3	3	3
1412	VRE Fredericksburg	3	3	3
1368	Amtrak Acela	3	3	3
857	Amtrak Carolinian	3	3	3
1256	Amtrak Crescent	3	3	3
1221	MARC Penn	3	3	3
556	Amtrak DC - Richmond	3	3	3
717	Amtrak Vermonter	3	3	3
631	Amtrak Auto Train	3	3	3
1401	VRE Fredericksburg	3	3	3
750	Amtrak DC - Newport News	3	3	3
933	Amtrak Carolinian	3	3	3
2044	Amtrak NEC	3	3	3
1136	Amtrak Regional	3	3	3

ROADS AND HIGHWAYS

Given the volume of high scoring roads and highways, Table 30 only lists the top scoring segments that received a 3 out of 3 vulnerability rating. There are over 2,000 high vulnerability road and highway segments that scored above 2.5.

Table 30. Highest Vulnerability Roads and Highways for Temporary Flooding (Coastal and Riverine) (scoring 3 out of 3)

Segment ID	Road Name	Flood Score	Functional Score	Equity Score	Final Score
44	12th Expy SW	3	3	3	3
45	12th Expy SW	3	3	3	3
1138	9th St SW	3	3	3	3
2751	I 295 I Bn	3	3	3	3
2762	I 295 I Bn	3	3	3	3
2774	I 395 Bn	3	3	3	3
2775	I 395 Bn	3	3	3	3
2776	I 395 Bn	3	3	3	3
2777	I 395 Bn	3	3	3	3
2778	I 395 Bn	3	3	3	3
2780	I 395 Bn	3	3	3	3
2781	I 395 Bn	3	3	3	3
2782	I 395 Bn	3	3	3	3
2783	I 395 Bn	3	3	3	3
2784	I 395 Bn	3	3	3	3
2787	I 66 Bn	3	3	3	3
2790	I 66 Bn	3	3	3	3
2794	I 66 Bn	3	3	3	3
2796	I 695 I Bn	3	3	3	3
2799	I 695 I Bn	3	3	3	3
2804	I 695 I Bn	3	3	3	3
2805	I 695 I Bn	3	3	3	3
2806	I 95 Bn	3	3	3	3
2941	Kenilworth Ave NE	3	3	3	3
2946	Kenilworth Ave NE	3	3	3	3
3495	New York Ave NE	3	3	3	3
3992	Ramp-36000312	3	3	3	3
4023	Ramp-36000642	3	3	3	3
4031	Ramp-36000732	3	3	3	3
4034	Ramp-36000782	3	3	3	3
4035	Ramp-36000792	3	3	3	3
4042	Ramp-36000862	3	3	3	3
4090	Ramp-36001392	3	3	3	3
4131	Ramp-36001872	3	3	3	3
4145	Ramp-36002012	3	3	3	3
4147	Ramp-36002052	3	3	3	3
4148	Ramp-36002082	3	3	3	3
4194	Ramp-36002582	3	3	3	3
4199	Ramp-36002642	3	3	3	3
4234	Ramp-36003022	3	3	3	3
4290	Ramp-36003702	3	3	3	3
4317	Ramp-36004002	3	3	3	3
4322	Ramp-36004052	3	3	3	3
4341	Ramp-36004282	3	3	3	3
4401	Ramp-36005032	3	3	3	3
4439	Ramp-36005432	3	3	3	3
4440	Ramp-36005432	3	3	3	3
4446	Ramp-36005492	3	3	3	3
4448	Ramp-36005512	3	3	3	3
4454	Ramp-36005562	3	3	3	3

Segment ID	Road Name	Flood Score	Functional Score	Equity Score	Final Score
4455	Ramp-36005572	3	3	3	3
4456	Ramp-36005582	3	3	3	3
4853	Suitland Pkwy SE	3	3	3	3
5275	Whitehurst Fwy NW	3	3	3	3
5276	Whitehurst Fwy NW	3	3	3	3
7134	Anacostia Fr	3	3	3	3
7135	Anacostia Fr	3	3	3	3
8287	Baltimore Washington Pkwy	3	3	3	3
8303	Baltimore Washington Pkwy	3	3	3	3
8304	Baltimore Washington Pkwy	3	3	3	3
8312	Baltimore Washington Pkwy (SB Local)	3	3	3	3
8319	Baltimore Washington Pkwy (SB Local)	3	3	3	3
8328	Baltimore Washington Pkwy (SB Local)	3	3	3	3
8343	Balto National Pike	3	3	3	3
8412	Balto National Pike (WB Local)	3	3	3	3
11999	Capital Beltway	3	3	3	3
12019	Capital Beltway	3	3	3	3
12070	Capital Beltway	3	3	3	3
12074	Capital Beltway	3	3	3	3
12078	Capital Beltway	3	3	3	3
12085	Capital Beltway (NB Local)	3	3	3	3
12096	Capital Beltway (SB Local)	3	3	3	3
12097	Capital Beltway (SB Local)	3	3	3	3
12098	Capital Beltway (SB Local)	3	3	3	3
12104	Capital Beltway (SB Local)	3	3	3	3
12131	Capital Beltway (SB Local)	3	3	3	3
12150	Capital Beltway (SB Local)	3	3	3	3
12647	Catoctin Mountain Hwy	3	3	3	3
12651	Catoctin Mountain Hwy	3	3	3	3
12652	Catoctin Mountain Hwy	3	3	3	3
12653	Catoctin Mountain Hwy	3	3	3	3
14292	Columbia Pike	3	3	3	3
14322	Columbia Pike (SB Local)	3	3	3	3
17624	Edmonston Ave (SB Local)	3	3	3	3
17717	Eisenhower Memorial Hwy	3	3	3	3
17718	Eisenhower Memorial Hwy	3	3	3	3
17720	Eisenhower Memorial Hwy	3	3	3	3
17721	Eisenhower Memorial Hwy	3	3	3	3
17722	Eisenhower Memorial Hwy	3	3	3	3
17724	Eisenhower Memorial Hwy	3	3	3	3
17833	Eisenhower Memorial Hwy (SB Local)	3	3	3	3
17835	Eisenhower Memorial Hwy (SB Local)	3	3	3	3
17836	Eisenhower Memorial Hwy (SB Local)	3	3	3	3
17837	Eisenhower Memorial Hwy (SB Local)	3	3	3	3
17839	Eisenhower Memorial Hwy (SB Local)	3	3	3	3
17840	Eisenhower Memorial Hwy (SB Local)	3	3	3	3
19565	Fort Meade Rd (WB Local)	3	3	3	3
19858	Frederick Fr	3	3	3	3
19862	Frederick Fr	3	3	3	3
19863	Frederick Fr	3	3	3	3
19868	Frederick Fr (SB Local)	3	3	3	3
19871	Frederick Fr (WB Local)	3	3	3	3
23762	Indian Head Hwy	3	3	3	3
23763	Indian Head Hwy	3	3	3	3
23766	Indian Head Hwy	3	3	3	3
23786	Indian Head Hwy (SB Local)	3	3	3	3
23787	Indian Head Hwy (SB Local)	3	3	3	3
23789	Indian Head Hwy (SB Local)	3	3	3	3

Segment ID	Road Name	Flood Score	Functional Score	Equity Score	Final Score
23790	Indian Head Hwy (SB Local)	3	3	3	3
23791	Indian Head Hwy (SB Local)	3	3	3	3
23932	Intercounty Connector	3	3	3	3
23937	Intercounty Connector	3	3	3	3
23949	Intercounty Connector (WB Local)	3	3	3	3
23954	Intercounty Connector (WB Local)	3	3	3	3
24088	I 270 Local Lanes (NB Local)	3	3	3	3
24091	I 270 Local Lanes (NB Local)	3	3	3	3
24092	I 270 Local Lanes (NB Local)	3	3	3	3
24093	I 270 Local Lanes (NB Local)	3	3	3	3
24622	John Hanson Hwy	3	3	3	3
24623	John Hanson Hwy	3	3	3	3
24624	John Hanson Hwy	3	3	3	3
24659	John Hanson Hwy (WB Local)	3	3	3	3
24660	John Hanson Hwy (WB Local)	3	3	3	3
24661	John Hanson Hwy (WB Local)	3	3	3	3
24662	John Hanson Hwy (WB Local)	3	3	3	3
25057	Kenilworth Ave	3	3	3	3
25075	Kenilworth Ave (SB Local)	3	3	3	3
31409	No Name (SB Local)	3	3	3	3
31410	No Name (SB Local)	3	3	3	3
33665	Pennsylvania Ave	3	3	3	3
33666	Pennsylvania Ave	3	3	3	3
33667	Pennsylvania Ave	3	3	3	3
35487	Ramp 1 Fr MD 201 (NB) to MD 459 (WB)	3	3	3	3
35502	Ramp 1 Fr MD 5 (NB) to Suitland Pkwy (WB)	3	3	3	3
35506	Ramp 1 Fr MD 704 to Ramp 8 (to I 595)	3	3	3	3
35544	Ramp 1 Fr Rosemont Ave to Ramp 8	3	3	3	3
35573	Ramp 10 Fr MD 704 to Ramp 9 (to MD 950)	3	3	3	3
35585	Ramp 10 Fr US 50 (WB) to MD 459	3	3	3	3
35587	Ramp 11 Fr MD 210 (NB) to I 295 (NB)	3	3	3	3
35591	Ramp 11 Fr Rp 1 (MD 201 (NB) to MD 459 (EB))	3	3	3	3
35599	Ramp 12 Fr I 295 (SB) to MD 210 (SB)	3	3	3	3
35621	Ramp 2 Fr Columbia Pk Rd (NB) to US 50 (EB)	3	3	3	3
35626	Ramp 2 Fr I 370 (WB) to I 270 (NB)	3	3	3	3
35640	Ramp 2 Fr I 95 Ls to I 295 (NB)	3	3	3	3
35648	Ramp 2 Fr MD 124 (WB) to I 270 (NB)	3	3	3	3
35661	Ramp 2 Fr MD 201 (WB) to MD 295 (NB)	3	3	3	3
35706	Ramp 2 Fr Ramp 7 to Rosemont Ave	3	3	3	3
35716	Ramp 2 Fr Suitland Pkwy (WB) to MD 5 (NB)	3	3	3	3
35726	Ramp 2 Fr US 50 (WB) to Garden City Dr	3	3	3	3
35761	Ramp 3 Fr I 95 Ln to Rp 2 (to I 295 (NB))	3	3	3	3
35768	Ramp 3 Fr MD 124 (EB) to I 270 (NB)	3	3	3	3
35843	Ramp 3 Fr US 50 (EB) to MD 201 (NB)	3	3	3	3
35851	Ramp 4 Fr I 270 (NB) to MD 124 (EB)	3	3	3	3
35891	Ramp 4 Fr MD 201 (NB) to US 50 (EB)	3	3	3	3
35974	Ramp 5 Fr I 270 (SB) to I 370 (EB)	3	3	3	3
36196	Ramp 6 Fr US 50 (EB) to MD 410 (SB)	3	3	3	3
36198	Ramp 7 Fr Allentown Rd (WB) to MD 5 (SB)	3	3	3	3
36216	Ramp 7 Fr I 95 (WB) to I 95x (SB)	3	3	3	3

Segment ID	Road Name	Flood Score	Functional Score	Equity Score	Final Score
36223	Ramp 7 Fr MD 117 (WB) to Ramp 6 (to I 270)	3	3	3	3
36297	Ramp 7 Fr US 15 (SB) to Rosemont Ave	3	3	3	3
36298	Ramp 7 Fr US 15 (SB) to US 40 (EB)	3	3	3	3
36312	Ramp 8 Fr I 270 (SB) to MD 124	3	3	3	3
36316	Ramp 8 Fr I 270 (SB) to Watkins Mill Rd	3	3	3	3
36318	Ramp 8 Fr I 295 (SB) to I 95 Ls	3	3	3	3
36349	Ramp 8 Fr MD 201 (SB) to MD 459 (WB)	3	3	3	3
36375	Ramp 8 Fr MD 704 (SB) to I 595 (WB)	3	3	3	3
36403	Ramp 8 Fr Rosemont Ave to US 15 (SB)	3	3	3	3
36424	Ramp 8 Fr US 40/15 to Ramp 9 (to US 15)	3	3	3	3
36425	Ramp 8 Fr US 50pa (SB) to US 50 (WB)	3	3	3	3
36448	Ramp 9 Fr MD 459 to US 50 (WB)	3	3	3	3
41022	Suitland Pkwy	3	3	3	3
41032	Suitland Pkwy	3	3	3	3
41037	Suitland Pkwy (WB Local)	3	3	3	3
41048	Suitland Pkwy (WB Local)	3	3	3	3
62752	Fairfax County Pkwy	3	3	3	3
70580	I 395 Hov	3	3	3	3
70583	I 395 Hov	3	3	3	3
70596	I 395 Hov (SB) Ramp to I 95 (SB)	3	3	3	3
70613	I 495 Hov Ramp (SB) to I 95 Hov (SB)	3	3	3	3
70614	I 495 Hov (SB) Ramp to I 395 Hov (NB)	3	3	3	3
70617	I 495 Hov (SB) Ramp to I 95 Hov (NB)	3	3	3	3
70618	I 495 Hov (SB) Ramp to I 95 Hov (SB)	3	3	3	3
70619	I 495 Hov (SB) Ramp to I 95 (NB)	3	3	3	3
70658	I 66 Express	3	3	3	3
70660	I 66 Express	3	3	3	3
70734	I 95 Hov	3	3	3	3
70735	I 95 Hov	3	3	3	3
70762	I 95 Hov	3	3	3	3
70798	I 95 Hov Hwy	3	3	3	3
70825	I 95 Hov Hwy	3	3	3	3
70852	I 95 Hov (NB) Ramp to I 495 Hov Ramp (NB)	3	3	3	3
70855	I 95 Hov (NB) Ramp to I 495 (NB)	3	3	3	3
70859	I 95 Hov Ramp (SB) Ramp to I 95 Hov (SB)	3	3	3	3
70864	I 95 Hov (SB) Ramp to I 495 Hov (NB)	3	3	3	3
70879	I 95 (NB Local) Local Hwy	3	3	3	3
71576	I 295	3	3	3	3
71578	I 295	3	3	3	3
71583	I 395	3	3	3	3
71584	I 395	3	3	3	3
71587	I 395	3	3	3	3
71643	I 395 (NB)	3	3	3	3
71652	I 395 (SB)	3	3	3	3
71672	I 495	3	3	3	3
71674	I 495	3	3	3	3
71675	I 495	3	3	3	3
71693	I 495 (NB)	3	3	3	3
71737	I 495 (SB)	3	3	3	3
71793	I 66 (EB)	3	3	3	3
71896	I 695	3	3	3	3
71897	I 695	3	3	3	3
71900	I 695	3	3	3	3

Segment ID	Road Name	Flood Score	Functional Score	Equity Score	Final Score
71904	I 695	3	3	3	3
71905	I 695	3	3	3	3
71913	I 95 (NB)	3	3	3	3
71939	I 95 (NB)	3	3	3	3
71940	I 95 (NB)	3	3	3	3
71966	I 95 (NB) - I 495 (EB)	3	3	3	3
71974	I 95 (SB)	3	3	3	3
72015	I 95 (SB) - I 495 (WB)	3	3	3	3

Permanent Flooding (Sea Level Rise)

RAIL LINES

Table 31. High Vulnerability Rail Lines For Permanent Flooding (Sea Level Rise)

Segment ID	Rail Route Name	Flood Score	Equity Score	Final Score
351	WMATA Orange	3	3	3
1731	WMATA Blue	3	3	3
1059	Amtrak Regional	3	3	3
691	WMATA Green	3	3	3
1717	WMATA Blue	3	3	3
1400	VRE Fredericksburg	3	3	3
555	Amtrak DC - Richmond	3	3	3
121	WMATA Silver	3	3	3
630	Amtrak Auto Train	3	3	3
856	Amtrak Carolinian	3	3	3
1027	WMATA Yellow	3	3	3
367	Amtrak DC - Norfolk	3	3	3
749	Amtrak DC - Newport News	3	3	3
1813	Amtrak Silver Service/Palmetto	3	3	3
337	WMATA Orange	3	3	3
100	MARC Camden	3	3	3
135	WMATA Silver	3	3	3
827	MARC Camden	3	3	3
1001	MARC Penn	3	3	3
1060	Amtrak Regional	3	3	3
368	Amtrak DC - Norfolk	3	3	3
1890	Amtrak Silver Service/Palmetto	3	3	3
1563	Amtrak Cardinal	3	3	3
1814	Amtrak Silver Service/Palmetto	3	3	3
1412	VRE Fredericksburg	3	3	3
1368	Amtrak Acela	3	3	3
857	Amtrak Carolinian	3	3	3
1256	Amtrak Crescent	3	3	3
1221	MARC Penn	3	3	3
556	Amtrak DC - Richmond	3	3	3
717	Amtrak Vermonter	3	3	3
631	Amtrak Auto Train	3	3	3
1401	VRE Fredericksburg	3	3	3
750	Amtrak DC - Newport News	3	3	3
933	Amtrak Carolinian	3	3	3
2044	Amtrak NEC	3	3	3
1136	Amtrak Regional	3	3	3

ROADS AND HIGHWAYS

Given the volume of high scoring roads and highways, Table 32 only lists the top scoring segments that received a 3 out of 3 vulnerability rating. There are over 120 high vulnerability road and highway segments that scored above 2.5.

Table 32. Highest Vulnerability Roads and Highways for Permanent Flooding (Sea Level Rise) (scoring 3 out of 3)

Segment ID	Road Name	Flood Score	Functional Score	Equity Score	Final Score
45	12th Expy SW	3	3	3	3
2751	I 295 I Bn	3	3	3	3
2762	I 295 I Bn	3	3	3	3
2774	I 395 Bn	3	3	3	3
2780	I 395 Bn	3	3	3	3
2787	I 66 Bn	3	3	3	3
2794	I 66 Bn	3	3	3	3
2799	I 695 I Bn	3	3	3	3
2804	I 695 I Bn	3	3	3	3
3495	New York Ave NE	3	3	3	3
4448	Ramp-36005512	3	3	3	3
4456	Ramp-36005582	3	3	3	3
11999	Capital Beltway	3	3	3	3
12085	Capital Beltway (NB Local)	3	3	3	3
12096	Capital Beltway (SB Local)	3	3	3	3
12098	Capital Beltway (SB Local)	3	3	3	3
70879	I 95 (NB Local) Local Hwy	3	3	3	3
71576	I 295	3	3	3	3
71578	I 295	3	3	3	3
71583	I 395	3	3	3	3
71587	I 395	3	3	3	3
71674	I 495	3	3	3	3
71896	I 695	3	3	3	3
71904	I 695	3	3	3	3
71905	I 695	3	3	3	3
71966	I 95 (NB) - I 495 (EB)	3	3	3	3
72015	I 95 (SB) - I 495 (WB)	3	3	3	3

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