Interior Flooding in Washington, DC

A first look at where it occurs in the District of Columbia

DC Silver Jackets Interior Flooding Task Group

August 25, 2017

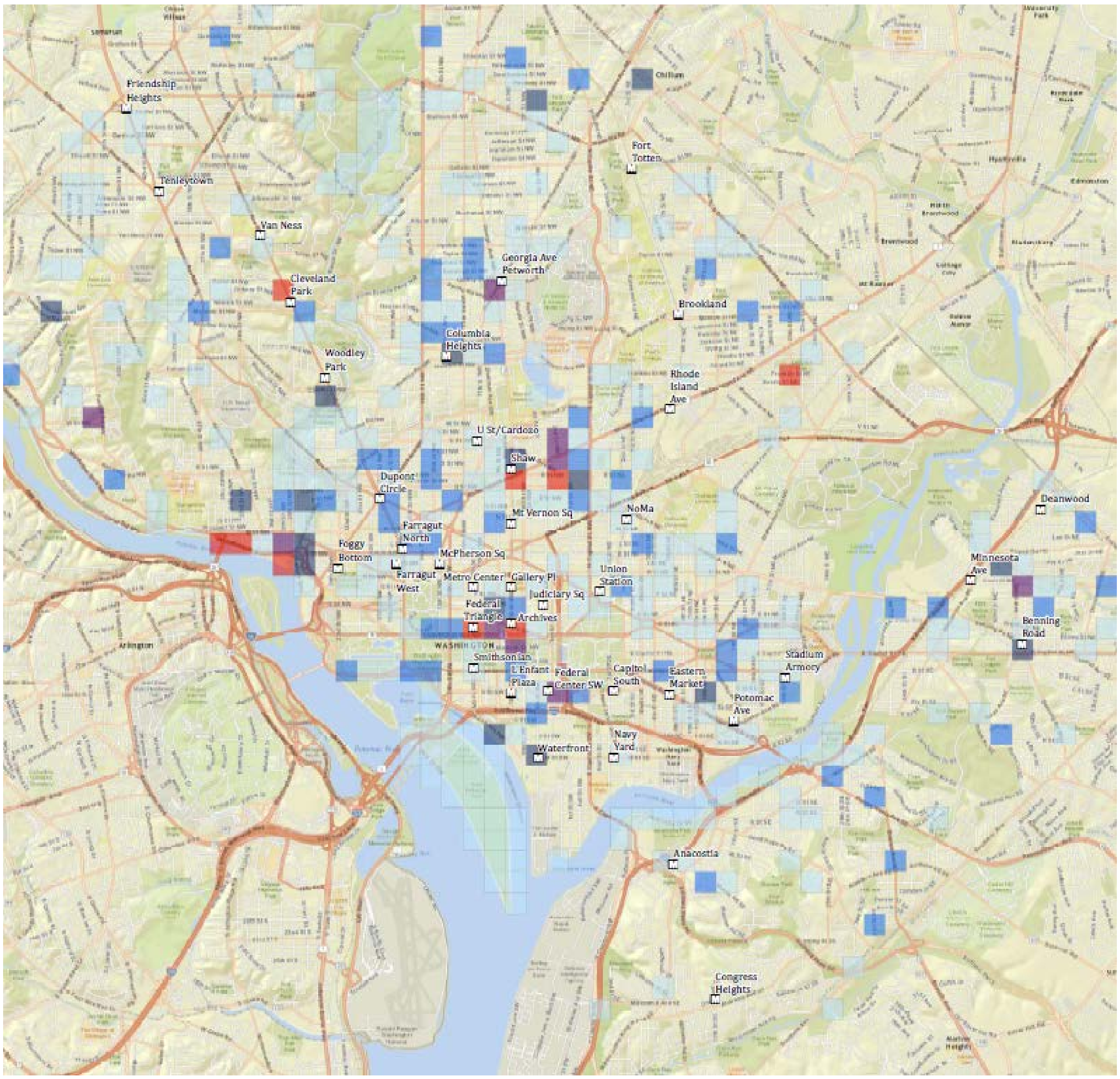

Figure 1: A portion of the map produced by the DC Silver Jackets that is the subject of this paper. The full map is at the end of the document.

Contents

List of Figures

About the DC Silver Jackets

The DC Silver Jackets is an interagency team comprised of members from federal, District of Columbia, and regional agencies, as well as academia. The team leverages resources to identify and implement comprehensive, resilient, and sustainable solutions to reduce flood risk around Washington, DC and to assist local communities in their flood risk mitigation efforts. Flood risk management is critical in the District of Columbia, as it is home to numerous residents and businesses, cultural and historic treasures, and federal assets that if flooded would have both local and national consequences.

The DC Silver Jackets has established multiple task groups to help implement the team's mission and goals. Currently, they include: Development of Flood Inundation Mapping/Stream Gauges; Flood Emergency Planning; Interior Flooding; Levee Certification and Accreditation; and Flood Risk Communication. The Interior Flooding Task Group prepared this report.

Introduction

What is Interior Flooding?

Interior floods, also known as flash floods, stormwater floods, or urban drainage floods, are caused by heavy rainfall that accumulates too quickly to be absorbed by the ground, or drained by the storm sewer system. Interior flooding can occur when river elevations are normal. Factors that contribute to interior floods include topography, surface permeability, localized weather, buried streams, high water tables, and the capacity of the storm sewer system.

Why Study Interior Flooding?

Washington, DC is vulnerable to three types of flooding: riverine, coastal, and interior (see Figure 2). Riverine and coastal flooding are the subject of many maps and other research in the region, including federally funded mapping efforts such as the Storm Surge Inundation Maps and the Flood Insurance Rate Maps. Interior flooding and where it occurs in the region, however, is not well understood.

Recent studies in the United States and abroad indicate that flood losses from interior flooding are on the rise.[1] In Washington, DC there were numerous recent and well publicized interior flood events that anecdotally support these findings. Furthermore, interior flooding is expected to escalate as a result of the increased intensity and frequency of severe storms due to climate change. The lack of data, as well as the growing interior flooding risk in Washington, DC, are two primary reasons why the DC Silver Jackets felt further study on interior flooding was necessary.

Report Purpose

This report, and the associated map (located at the end of the document), summarize the current state of knowledge about interior flooding in Washington, DC and presents the first District-wide map of where interior flooding occurs. This report is divided into two sections. The first section, "Background," provides information on interior flooding and previous attempts to map it. The second section, "About the Map," describes the data and methodology behind the map produced by the DC Silver Jackets' Interior Flooding Task Group. The map aggregated the best available interior flooding data at the time, which still only provides a limited picture of the interior flooding problem. As the second section describes, users must be careful not to draw conclusions that the data does not support.

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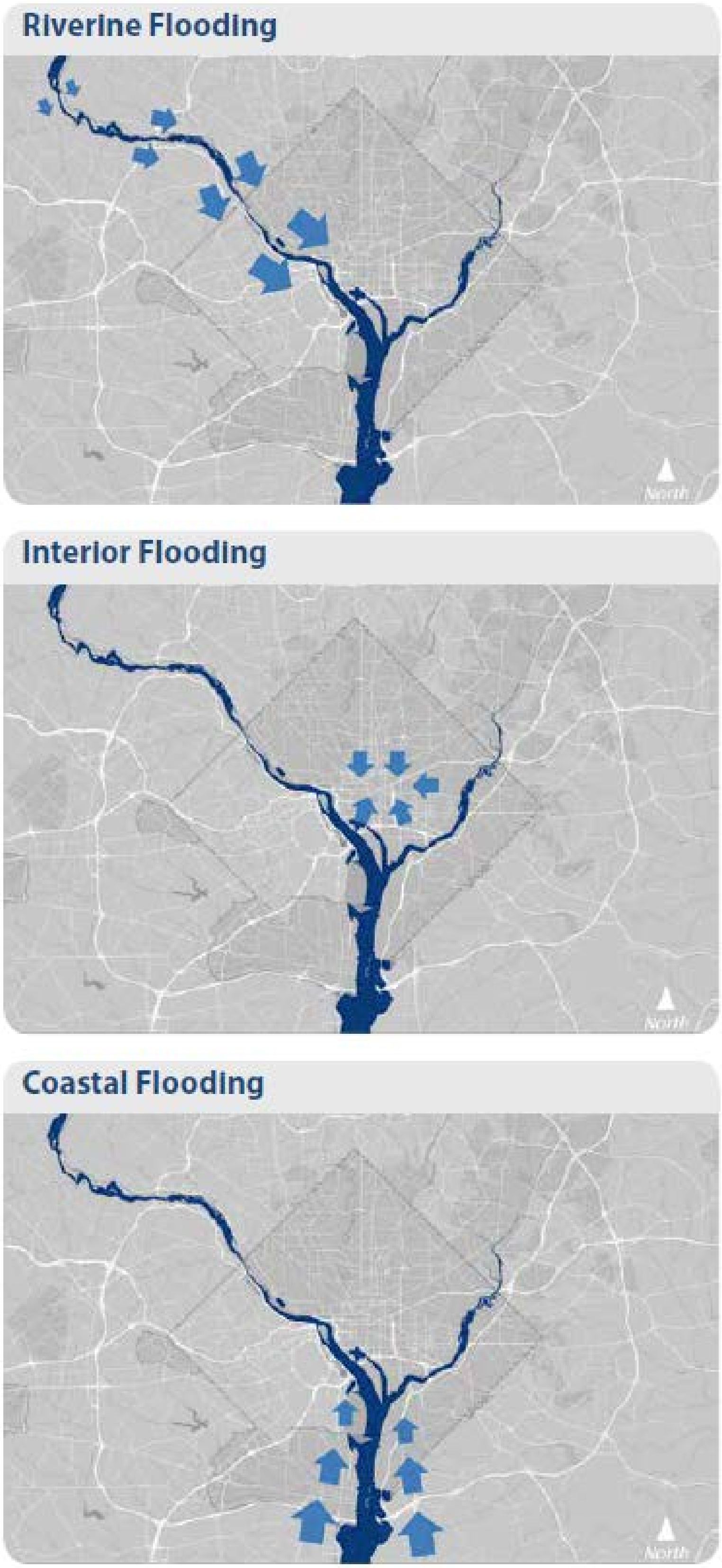
[1] The Center for Texas Beaches and Shores, *Urban Flooding Study*, 2017, April 2017 Newsletter. http://www.tamug.edu/ctbs/newsletter/CTBS_Newsletter_April_2017.pdf



Riverine, or freshwater flooding, refers to overbank flooding on the Potomac River caused by its inability to contain the water collected in the Potomac River Basin. Heavy rainfall or snowmelt upstream can cause increased water levels downstream on the Potomac River hours or days later that also can cause backwater flooding on the Anacostia River.

Examples: Floods in 1936, 1942, 1985, and 2010

Interior floods, also known as flash floods, are caused by heavy rainfall that cannot be absorbed by the ground and then overwhelm the drainage system. Interior flooding can occur when river elevations are normal because interior floods are attributed to topography, development, localized weather, and the capacity of stormwater systems.

Examples: 2006 Federal Triangle Flood, and 2012 Bloomingdale Floods

Coastal floods, refer to inundation caused by the Potomac and Anacostia Rivers' connection to the Chesapeake Bay and ultimately to the Atlantic Ocean. Coastal flooding includes inundation resulting from high tides (often called tidal, nuisance, or sunny day flooding), but also from coastal storms like hurricanes that drive storm surge and waves up the Potomac River and into Washington, DC.

Examples: Nuisance floods, Hurricane Isabel

Figure 2: Types of flooding in Washington, DC.

Background

Recent Interior Flood Events

Interior floods can have a significant impact on facilities and operations in the region. The 2006 Federal Triangle flood, for example, destroyed critical parts of the Internal Revenue Service headquarters' electrical and mechanical equipment and submerged the basement level under five feet of water. This resulted in millions of dollars of damage and required the building's 2,000 plus employees to be relocated for almost six months.[2] The 2006 flood also had significant impacts to other buildings including the Department of Commerce, the Department of Justice, the National Archives, and several Smithsonian museums. In addition, the Washington Metropolitan Area Transit Authority (WMATA) shut down its Federal Triangle Metrorail Station for four days, and spent millions of dollars to clean and replace critical train control and communication equipment.

The 2012 floods in the Bloomingdale neighborhood are examples of interior flooding and the devastation it can cause residential communities. Over the span of six weeks, the neighborhood experienced four interior floods.[3] An inadequate combined storm sewer system could not handle the amount of rain. This, combined with the lack of backflow prevention devices in many homes, led to stormwater and raw sewage backups into basements. Residents were displaced and homeowners and landlords still had to pay their mortgages without compensation from the local governments in addition to paying for repairs that were necessary before residents could come back into their homes. This localized flooding event left a significant strain on the neighborhood. Since then, DC Water has made significant improvements to the neighborhood to mitigate interior flooding,[4] including the completion of the First Street Tunnel that can store 8 million gallons of stormwater and wastewater during intense rainstorms.

In 2017, isolated heavy rains in Northwest Washington, DC resulted in a cascade of water into the Cleveland Park Metro Station, causing the station to close for a few hours during the evening commute.[5] WMATA, in partnership with DC Water and the District Department of Transportation, has since begun the process of constructing permanent flood protection for this station, as well as other Metro locations that frequently experience interior flooding.

How Future Interior Flood Risks May Change

Future interior flood risk is expected to increase primarily as a result of changes in precipitation. These changes include both an increase in average annual rainfall and an increase in the intensity and frequency of severe storms. The 2015 District of Columbia report, Climate Projections and Scenario Development, outlines these precipitation projections. The report includes data on expected annual rainfall changes, and how the frequency and severity of storms will change over time. For example, today's 100-year storm is projected to be equivalent to a 15-year storm by the 2080s.[6]

Sea level rise is also expected to make interior flooding more frequent and severe. As sea levels rise, the fresh water table also rises,[7] decreasing the capacity of the soil to absorb stormwater runoff. With higher sea levels and more frequent nuisance flooding events, there will also be more days when the storm sewer outlets are below the water surface elevation of the Potomac and Anacostia Rivers. When this occurs, stormwater that

[2] Government Accountability Office (GAO), *IRS Emergency Planning* (2007), 4-5. http://www.gao.gov/new.items/d07579.pdf
[3] Floods occurred on July 10, 18, 19, and September 2, 2012 according to the Flood Prevention Task Force.
[4] DC Water, *The Northeast Boundary Neighborhood Protection Project.* https://www.dcwater.com/projects/northeast-boundary-neighborhood-protection-project
[5] Hensley, Sarah Beth, *Cleveland Park Metro station reopens after flooding (photos)* (2016). http://wtop.com/sprawl-crawl/2016/06/flooding-closes-cleveland-park-metro-station-photos/slide/1/
[6] Department of Energy and Environment (DOEE), *Climate Projections and Scenario Development* (2015). http://doee.dc.gov/sites/default/files/dc/sites/ddoe/publication/attachments/150828_AREA_Research_Report_Small.pdf
[7] USGS, *Coastal Groundwater Systems* (2014). http://wh.er.usgs.gov/slr/coastalgroundwater.html

normally drains through pipes connected directly to the rivers (in MS4 areas)[8] will be trapped. If heavy rains happen at the same time as elevated water surface levels, interior flooding may occur in areas of the City that are connected to these pipes because of their inability to drain into the rivers.

Interior flooding is heavily influenced by the built environment, which includes changes in land use. Changes in the amount of pervious surface in a storm sewer drainage area can significantly impact the quantity and timing of water entering the storm sewer system. The addition of green infrastructure features, such as green roofs and sidewalk stormwater infrastructure, or improvements to existing infrastructure (i.e. enlarging pipes to increase capacity) will help reduce interior flood risk, but will not completely eliminate it. Alternatively, adding more impervious surfaces such as pavement and concrete will likely increase interior flood risk because of the reduction of permeability.

Data for Interior Flooding

There is a scarcity of maps that show where interior flooding occurs in Washington, DC. The primary reasons are that modeling and mapping interior flooding is complex, resource intensive, and no comprehensive or uniform collection of relevant District-wide data exists. Without models or comprehensive data, proxy data to approximate the locations of interior flooding must be used.

The Complexity of Modeling Interior Flooding

Currently, there is an information gap that hinders the ability to fully evaluate interior flood risk in Washington, DC. Aside from specific mapping done in the Federal Triangle as a result of the 2006 flood,[9] studies of interior flooding in Washington, DC are scarce. Interior flooding is often difficult to map because it requires hydrologic modelling and a hydraulic model of the storm sewer infrastructure. This is necessary because interior flooding is impacted by the flow of water over the surface, and its interaction with the storm sewer system. In many cases, interior flooding occurs as a result of rainfall overwhelming the storm sewer system. A hydraulic model to predict interior flooding should contain information on the location and size of storm sewer inlets and pipes, as well as how the pipes are connected to other areas of the city. Since data on public utilities and infrastructure can be sensitive, it is generally not publicly available.

The lack of data on interior flooding should not be mistaken for a lack of risk. In Federal Triangle, the one area in Washington, DC that was modeled, the likelihood of interior flooding is greater than that of riverine or coastal flooding, because of the 17th Street Levee Closure.[10] Many other areas of Washington, DC, including the Bloomingdale neighborhood, are known areas of interior flooding but have not been officially mapped.

Collecting Interior Flooding Data

Without the available data and resources to model the entire District of Columbia and identify all the areas where interior floods may occur, we must use proxy data in order to map interior flooding. Proxy data refers to data that does not directly measure the desired data points (locations of interior flooding), but measures data points that are closely related. In the case of interior flooding, one example of proxy data is DC Water's data on calls for service due to standing water. These data points can serve as a proxy for interior flooding locations. When the locations of the service calls are plotted on a map it can be a useful, though unscientific, proxy for where interior flooding occurs in the region. Like all proxy data, users must be careful not to make conclusions that the data does not support.

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[8] MS4 areas, or Municipal Separate Storm Sewer Systems, are areas of the city where stormwater drains through pipes connected directly to the rivers. In other areas of the city, stormwater flows into a combined sewer system that sends both stormwater and sewage through underground tunnels to the Blue Plains Wastewater Treatment Plant.
[9] This mapping effort is described here (PDF) and was also incorporated into the 2010 FEMA Flood Insurance Rate Maps (FIRMs).
[10] This can be seen in the revised FIRMs. With the 17th Street Levee closure now accredited, facilities like the National Archives are protected from the 1 percent annual chance river or coastal flood, but are still vulnerable to the 1 percent annual chance interior flood.

About the Map

This section of the report refers specifically to the map at the end of the document. The map, produced by the DC Silver Jackets Interior Flooding Task Group, is the first District-wide map of where interior flooding occurs.[11] Because this map relies on proxy data, there are limits on the types of conclusions users can draw. The following text describes the data inputs and process of creating the map.

About the Data

Four separate agencies provided the task group with data that can help approximate locations of interior flooding. An explanation of the data that each agency provided is below.

DC Water

As it specifically relates to interior flooding, DC Water tracks data on all calls about issues related to high standing water, blocked storm water catch basins, and blockages in the sewer system. Data points on the map represent specific locations (either intersections or addresses) where three or more flooding complaints were recorded between 2009 and 2015. The complaints used for this map are only those from a work order database that focused on DC Water catch basin complaints and other street flooding issues. This dataset contains an attribute that indicates the number of flood calls for service that have occurred at each location, though this attribute is only used to filter out locations with less than 3 complaints. For example, if intersection A received two complaints about standing water at that intersection, no data point was recorded. If intersection B received six complaints about standing water, one data point was recorded. If intersection C received 60 complaints about standing water, *one* data point was recorded.

District Department of Transportation (DDOT)

The DDOT data comes from a list of areas that are prone to flooding. The locations are identified by street intersections, stretches of road between two intersections as well as larger geographical areas like Hains Point. In cases where a DDOT data point referred to a stretch of road that extended across multiple intersections, a point was placed in each intersection along that section of road. For example, if the one item on DDOT's list read "Constitution Avenue, between 4th and 17th Streets, NW", a point was placed at 4th and Constitution, 5th and Constitution, 6th and Constitution, etc. For the large areas that were simply described, like Hains Point, one point was placed in each 300 meter by 300 meter cell on the grid layer where all the point data is joined.

National Flood Insurance Program

The District of Columbia's Department of Energy and Environment (DOEE), as the National Flood Insurance Program (NFIP) coordinator for *the District of Columbia,* obtained flood claim data as of November 30, 2015 from NFIP BureauNet. Individual information of policy holders has been removed from the NFIP flood claim data used for this purpose. The NFIP flood claim data is a table of locations containing addresses that were all geocoded using DC GIS's MAR Geocoder. The data include all NFIP flood insurance claims in Washington, DC from 1977 until November 30, 2015. This dataset only captures properties that had an active NFIP flood insurance policy at the time of flooding and made a claim that was paid or unpaid.

Washington Metropolitan Area Transit Authority (WMATA)

WMATA data points represent locations where water entered WMATA facilities. Each point represented five to 10 flood incidents at the same location that are shown as one data point. To reduce flood risk, there are a total of 18 Metrorail stations that are being analyzed for design solutions to reduce or eliminate flooding to the interior rail system. Some of the stations are within the 100 and 500-year flood plain. Other stations are subject to localized flooding due to the surrounding grades and an undersized storm sewer system.

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[11] A version of this map was created for the 2016 Flood Summit on September 8, 2016.

About the Mapping Process

Data points for all four agencies were aggregated in 300 by 300 meter grid cells, so that exact locations of data points would not be shown for security reasons. Each cell was assigned a value from least flooding to most flooding based on how many data points were in each grid. The process for counting data points within each grid is described in the diagram below.

With the exception of DC Water's data, data points from the agencies' different data sets were given equal weight. For DC Water data, the group decided that only locations that received three or more calls would be shown as a data point.

All four of these point datasets were merged into one dataset using ESRI's ArcMap. That merged dataset was then spatially joined to a 300 meter by 300 meter grid that covers the entire city, using ArcMap. As part of that process, all of the points that intersected a grid cell were summed together as a count and added to the grid cell. The grid cells were grouped into five different data classes on the map using the "Jenks Natural Breaks," which is a method of data classification available in ArcMap that is designed to minimize the data variance within each data class.

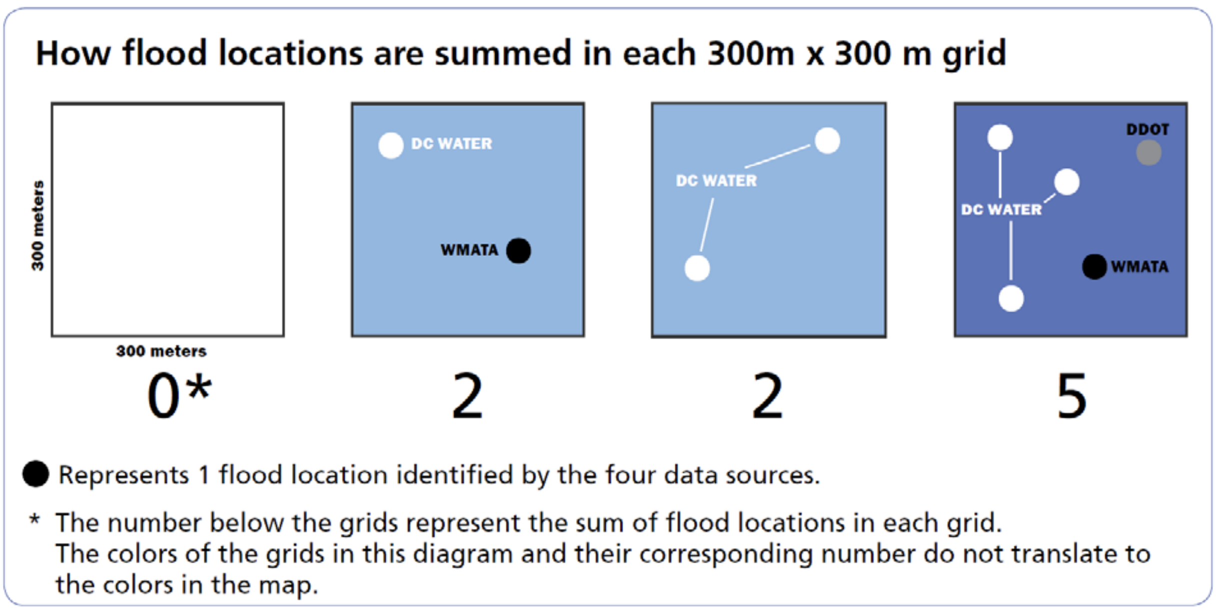

Figure 3: How flood locations are summed in each 300m x 300m grid.

Notes When Using the Map

Please be careful when using this map. Do not draw conclusions that are not supported by the data. Below are a few notes on the data which may be helpful in understanding the data's limitations.

1. Datasets used in the map are at different time scales. They have not been standardized; one data set may reflect a major flood event that occurred before another dataset began recording. Older data may not be as relevant as recent data.
2. Datasets have different definitions of flooding, and data points from each dataset represent different impacts of flooding. DC Water data, for example, represent calls for service, while NFIP data represent flood insurance claims.
3. Since DC Water's data is driven by complaint calls, if there is an area of the city that is relatively unpopulated, it would stand to reason that there would be less service calls, even though flooding may actually occur more often.

Next Steps and Recommendations

The Interior Flooding Task Group of the DC Silver Jackets developed the following recommendations on how to improve the accuracy of future maps and better understand the interior flooding problem.

The primary recommendation of this group is to create a citywide integrated flood model. The model will combine coastal, riverine, and interior flooding models and incorporate comprehensive data, including climate change projections for sea level rise and precipitations. Specifically, this model would include locations and connections of storm-sewer inlets and pipes, as well as detailed topography data that allow accurate prediction of where interior flooding would occur given a certain amount of rainfall. This model would not only allow for identification of flood-prone areas, but would also be used to identify the efficacy of proposed flood mitigation solutions.

In lieu of a city-wide interior flood model, the Interior Flooding Task Group recommends the following to improve upon the initial mapping effort outlined in this report.

1. Find additional existing data sources to include on the map – District of Columbia agencies, federal agencies and other entities may have additional flood data that has not yet been accessed.
2. Locate data on flood damages at locations of interior flooding to better quantify consequences.
3. Conduct small scale hydraulic modeling studies on areas with suspected interior flooding, as identified in this and future maps.
4. Further standardize the data that is already being collected by various agencies.
5. Develop improved systems to collect interior flooding data so that a similar map created 10 years from now would be more accurate. This might involve a concerted agency effort to start collecting new data, such as adding a new "interior flooding" category for complaint calls, or publishing reports on relevant data at regular monthly or quarterly intervals.
6. Create additional mapping overlays (such as proposed development zones, critical infrastructure locations, or population density).
7. Utilize depth-damage curves (an analysis that estimates damage to facilities based on the depth of flood water) to estimate impacts of flooding from modeled results. Combining probability with consequences will give better picture of interior flood risk.
8. Improve coordination amongst stakeholders on data collection and sharing that will help enhance interior flooding modeling and mapping.

Interior Flooding in Washington, DC

The DC Silver Jackets produced this map from an accumulation of data from four sources: DC Water, the District Department of Transportation (DDOT), the Washington Metropolitan Area Transit Authority (WMATA), and the National Flood Insurance Program (NFIP). The map depicts areas where interior flooding occurs within Washington, DC's boundaries, and does not reference the 100-year or 500-year floodplains. This is not a regulatory map. Please see the associated report for more information on the data sources and how this map was created.