Community Engagement for Vulnerable Communities: Flooding Impacts and Adaptation in East Riverdale-Beacon Heights

Leslie Delcid, Owen Flood, Emma Grier, Kathryn Hastings, Baindu Idriss, Hannah Imhoff, Haley Mullen, Skylar Petrik, Barbara Sikorski

Under the supervision of Professor Joanna Goger

ENSP400: Capstone in Environmental Science & Policy
The University of Maryland – College Park
Fall 2019

PALS - Partnership for Action Learning in Sustainability
An initiative of the National Center for Smart Growth

Gerrit Knaap, NCSG Executive Director
Kim Fisher, PALS Director

Contents

List of Figures

List of Tables

Executive Summary

Flood hazards and associated damage are expected to increase in intensity and frequency in the coming years due to increased development and progressing climate change. The severity of these impacts is directly related to the characteristics of drainage basins; severity increases as impervious surface area and development in urban areas increases (USGS, n.d.). Rain events are also set to increase in both intensity and severity as the climate changes in the northeastern United States, leading to an expected 45% increase in the size of the 100-year floodplain by the end of the century (Walsh et al., 2014; Hoegh-Guldberg et al., 2018; Denchak, 2019).

Many residents of East Riverdale-Beacon Heights currently live in floodplains; others will likely live in a one as floodplains increase in size. Additionally, the communities in East Riverdale-Beacon Heights are disproportionately vulnerable to the effects of flooding due to higher than average flooding exposure, and lower than average socioeconomic status and educational attainment. Due to these increased flood risks, this project first evaluated flood risks for the East Riverdale-Beacon Heights communities. GIS analysis revealed that 59 residential units are currently impacted by flooding, and demographic analysis revealed that these residents may be more vulnerable to the effects of flooding, given that a majority (57.2%) of them are Hispanic, more families live below the poverty line than the County average, and the percent of adults without a high school diploma is higher than the County average.

To address these findings, multiple flood mitigation strategies were researched and considered. Disregarding financial constraints and considering the vulnerability of the East Riverdale-Beacon Heights community, the best long-term strategy to mitigate flooding impacts was determined to be a buyout program and successful advertisement thereof, using communication strategies detailed in this report. However, if a buyout program is not possible, the most at-risk residents should be urged to either elevate or wet floodproof their homes. Additionally, we recommend that the County continue to acquire areas within the floodplain to use as open space and implement green infrastructure techniques to decrease the magnitude of floods. Green infrastructure recommendations in this report include permeable pavement, downspout disconnection, bioretention, blue roofs, green roofs, and urban tree canopy.

These mitigation solutions should not only be adopted by the County but also recommended to citizens in the East Riverdale-Beacon Heights area. The County should continue to use the websites and mailing systems they have in place and update the information to include the findings of this report. Moreover, this project has determined that the best way to communicate this information is through the consistent use of multiple social media platforms and, most importantly, public outreach meetings and events. Outreach events allow the County to make flooding information more accessible and explain more complex information through conversation.

In conclusion, Prince George's County can optimally decrease flood risk for the maximum number of residents, both inside and outside of East Riverdale-Beacon Heights, by implementing as many of these strategies as possible. Using strategies that decrease exposure, hazard, and vulnerability can cohesively and systematically increase flood resiliency for this human-environmental system.

1. Introduction to the Problem

Riverine flooding is a major problem across the United States and intersects with public health and safety, social equity, and environmental concerns. Riverine flooding is especially of concern in urban areas, where floods can happen quickly and without warning (USGS, n.d.). People and structures can be physically harmed in a short time period, which can result in injury, death, property damage, or displacement of individuals and families (George, 2011).

The severity of a flood is determined by the characteristics of the drainage basin where the stream lies. Flood intensity is most directly linked to the amount of impervious surface area in a drainage basin and is often a consequence of increased development. Impervious surfaces disrupt the hydrologic connectivity between streams and groundwater, prevent infiltration of precipitation into the soil, and increase the amount of runoff entering streams during storms, all of which increases stormflow and decreases the time it takes for a stream to flood, leading to more dangerous floods (USGS, n.d.). Additionally, flood frequency and intensity is expected to increase in the northeastern United States due to increased precipitation as a result of climate change (Walsh et al., 2014; Hoegh-Guldberg et al., 2018).

Certain groups are more at risk from the effects of flooding than others. Flood risk can be thought of in terms of hazard, exposure, and vulnerability (Kaźmierczak and Cavan, 2011). The hazard, in this case, is flood intensity and propensity for damage, determined by stream characteristics and its drainage basin, and made worse by climate change (USGS, n.d.).

Exposure is defined by whether or not a person or structure is physically exposed to floods. The most severe floods occur in the 100-year floodplain, an area surrounding the streams that has an annual 1% chance of an extremely severe and damaging flood event. Those who live in a floodplain are at a higher risk of property damage or physical injury. Housing also contributes to exposure, as some structures are more resistant to flooding than others depending on the "elevation of the lowest floor relative to the BFE [Base Flood Elevation], the type of building and foundation, the number of floors, and whether there is a basement or enclosure below an elevated building" (FEMA, 2015). Additionally, individual flood risk management efforts cannot be used for high-density housing and apartment buildings, so residents must rely on community flood protection measures (FEMA, 2015; Kaźmierczak and Cavan, 2011).

Vulnerability is determined by a person's access to information and their ability to prepare, respond, and recover from a flood event. Vulnerability can be influenced by income level, age, and access to community resources and social networks among other factors (Kaźmierczak & Cavan, 2011).

The East Riverdale-Beacon Heights community is mostly suburban, comprising mostly single and multifamily residential zones, with commercial development along Kenilworth Avenue and Riverdale Road (See Figure 1). As recorded in the East Riverdale-Beacon Heights Sector Plan, three main waterways run through the area and are at risk of flooding: Northeast Branch, a tributary of the Anacostia River; Brier’s Mill Run; and Captain John’s Branch, both tributaries of Northeast Branch (The Maryland-National Capital Park and Planning Commission Prince George's County Planning Department [M-NCPPC Prince George’s County Planning Department], 2017). Due to intense development and large areas of impervious surface upstream, all three streams are characterized by flashiness and high-volume stormflow (Anacostia Watershed Restoration Partnership, n.d.). Additionally, as part of the Anacostia River Flood Control and Navigation Project, Captain John’s Branch and portions of Brier’s Mill Run were directed into concrete stormwater channels in the 1950s. These factors have increased the flood risk of these streams. Further development in the sector plan area and in other areas of the watershed are likely to exacerbate these issues. As evidence of this, the “development floodplain,” designated by the Prince George’s County 1989 Floodplain Study of the Anacostia River and its tributaries, includes both existing conditions and projected future development that is likely to impact the watershed. This area is significantly larger area than FEMA 100-year floodplain. It covers 257 acres of the East Riverdale-Beacon Heights sector plan area, while the FEMA 100-year floodplain only covers 166 acres of the East Riverdale-Beacon Heights sector plan area (M-NCPPC Prince George’s County Planning Department, 2017).

Figure 1. Single-family homes and a commercial shopping center in East Riverdale Heights (M-NCPPC Prince George’s County Planning Department, 2017)

Comprehensive regulations to limit development within the floodplain were introduced in 1989 as part of the Floodplain Ordinance (Prince George’s County, Maryland, n.d.-a). The Floodplain Ordinance requires the lowest floor of any new building or significant addition to an existing building to be built one foot above the elevation of the 100-year floodplain (*Hazard Mitigation Plan*, 2010). However, many of the residences in the floodplain built before 1970 have been designated as “existing development” and are not required to comply with the 1989 ordinance, thus making them more vulnerable to flooding (M-NCPPC Prince George’s County Planning Department, 2017).

In addition to the physical flooding hazard these streams present, the minority and low-income residents of the East Riverdale-Beacon Heights communities are likely to be vulnerable to flooding impacts. Minority and low-income communities often face higher than average exposure to flooding risks because they are more likely to live in floodplains due to low housing prices. Additionally, these communities are often the least informed about flooding and have the least ability to prepare for floods due to a lack of financial resources (Kaźmierczak and Cavan, 2011). The East Riverdale-Beacon Heights sector plan area exceeds County averages for the number of families living in poverty and the number of families living below poverty with children (M-NCPPC Prince George's County Planning Department, 2017). It follows that these individuals are more exposed to hazardous floods and are also more vulnerable to flooding effects.

In summary, the East Riverdale-Beacon Heights communities face a heightened flood risk due to physical flood hazard, the community's potential vulnerability and exposure to floods, and the likelihood that flooding impacts will increase in the future due to further development and climate change. Given the significant risks and vulnerability this community faces and is likely to face in the future, the M-NCPPC Prince George's County Planning Department, working through the Partnership for Action Learning in Sustainability (PALS) program at the University of Maryland, asked our group to complete this report to determine the extent of flood risk in East Riverdale-Beacon Heights, and to determine appropriate flood mitigation strategies to be used by Prince George's County and the residents of East Riverdale-Beacon Heights.

2. Goals and Objectives

This project's goal was to determine those communities most exposed and vulnerable to floods, and to suggest appropriate flood mitigation strategies that Prince George's County and its residents can use to lessen their risk of flood exposure. While the County already has existing flood mitigation strategies in place, our team sought to review and expand on them in the context of the East Riverdale-Beacon Heights community.

The project's first objective was to determine which communities are most vulnerable to flooding by analyzing demographic, floodplain, housing, and flood infrastructure GIS data. The aim was to create maps that provide a spatial analysis of East Riverdale-Beacon Heights with illustrating the most effected demographic groups, the building types at risk, and the flood infrastructure currently available, to determine which residents are most exposed to floods and the most appropriate flood mitigation strategies.

A geographic analysis showed a range of flood risks across East Riverdale-Beacon Heights and yielded data on the specific areas that are the most vulnerable. This data was quantified to produce a list of affected building types for each current and projected flood zone. Those zones were created using two data sets, one from FEMA and one from Prince George's County. Current flood zones were created based on each data set, and the flood zone projection was created based on the Prince George's County data. This also provided a visual sense of the area's vulnerabilities, creating a product that can be used to communicate risks to the community and policymakers.

The project's second objective was to determine which flood risk mitigation strategies were most appropriate. The goal was to provide a range of solutions that could be implemented by both the County and residents. This was based on which strategies had the most potential for long-term flood risk reduction, while also being reasonably cost-effective. This list allows residents to mitigate and adapt to floods by playing an active role in creating a safer community. The spatial analysis from the first objective also provided insight into the best locations for the suggested infrastructure changes.

The project's third objective was to inform the County Planning Department of best practices for communicating flooding impacts and adaptation measures to East Riverdale-Beacon Heights residents. Analysis of the mitigation strategies researched in objective two led to the recommendations most appropriate for this community.

3. Methodology/Research Approach

3.1 Geographic Information Systems (GIS)

GIS data was collected from the GIS Data Catalog from the Planning Department of Prince George's County, Maryland's GIS Data Catalog from Maryland's Department of Information Technology, the Federal Emergency Management Agency, and from the County's 2019 East Riverdale-Beacon Heights Sector Plan Snapshot Report. Data sets from these sources contained land use categories, flood zones, flood infrastructure, and demographic and socioeconomic data, which were then analyzed through standard spatial analysis using ArcMap and Excel. Flood projection maps were developed by creating buffer zones around a map feature (in this case, floodplains) set to a specific distance. Buffers of 10 and 30 meters were created to reflect the possible expansion of the floodplain due to climate change.

3.2 Demographic and Socioeconomic Analysis

Data compiled from the County's 2019 East Riverdale-Beacon Heights Sector Plan Snapshot Report covers race, ethnicity, age, and homeownership for Beacon Heights, and compares income and education between East Riverdale-Beacon Heights and Prince George's County.

3.3 Flood Mitigation and Communication Strategies

To develop mitigation strategies that reduce exposure, hazard, and vulnerability, we conducted multiple literature reviews of both peer-reviewed articles and government sources. By analyzing multiple resources, we were able to determine which solutions were most effective at reducing flood risk, their benefits and limitations, and specific ways that Prince George's County and residents can execute these solutions. We also sought insight from experts and from community members to determine the residents' needs and the best way to communicate with them.

4. Findings: GIS Maps and Analysis

4.1 Land Use Types

Figure 2 was created using land use data from the Prince George's County Planning Department on property type, including commercial, institutional, and residential. The property information is color coded according to the standard land use color schemes designated by the American Planning Association. Table 1 summarizes the property information.

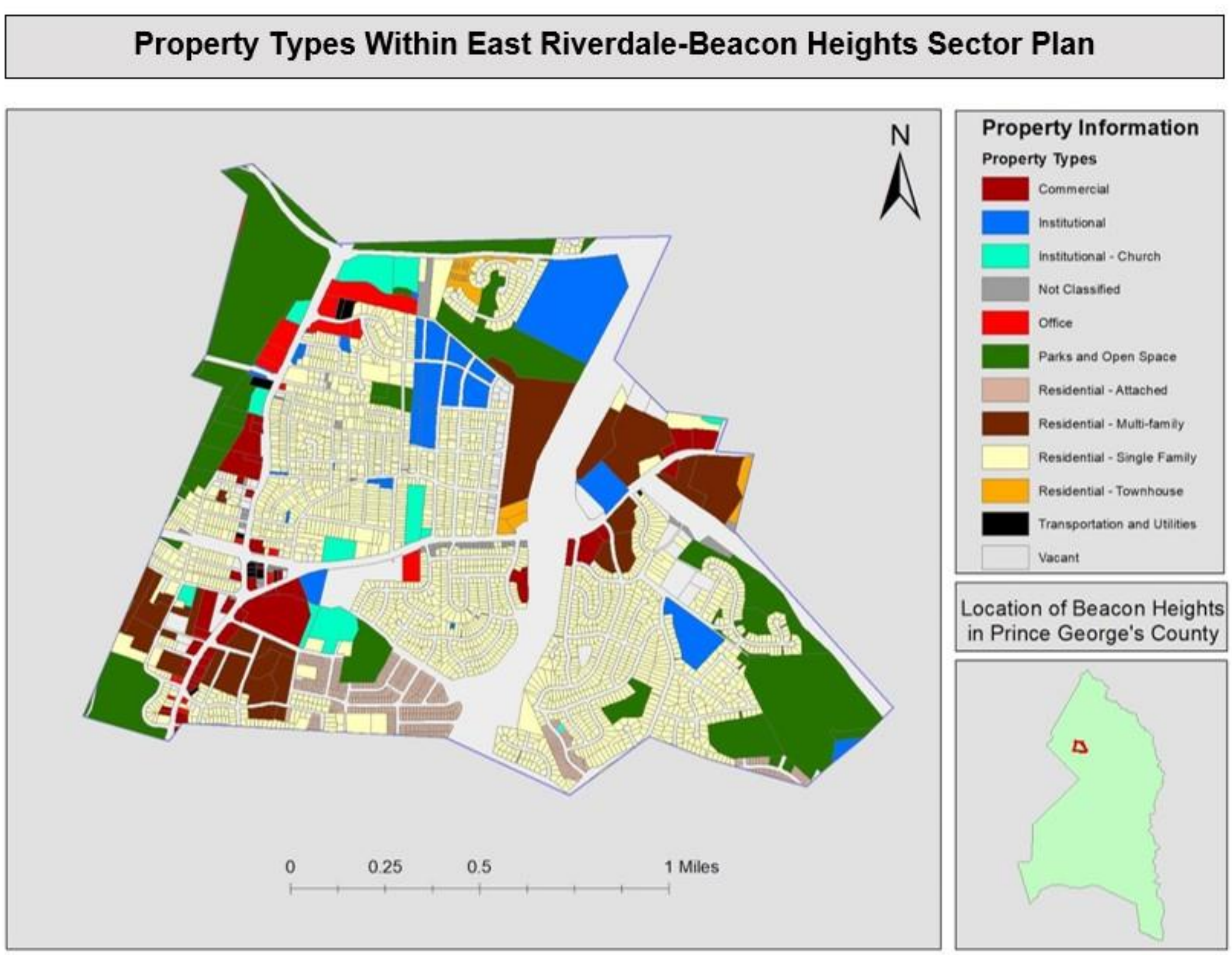

Figure 2. Property types in East Riverdale-Beacon Heights

As Figure 2 shows, most properties in East Riverdale-Beacon Heights are residential; 2,557 out of 2,639 total units, or 96%.

Table 1. Property Types in *East Riverdale-Beacon Heights Sector Plan*

Property type	Number of units in East Riverdale-Beacon Heights
Commercial	41
Institutional	41
Residential	2,557
Total	2,639

4.2 Flood Zones

Table 2. FEMA Flood Zone Definitions - High Risk Areas

Zone	Description
A	Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage; detailed analyses are not performed for such areas; no depth or base flood elevations are shown within these zones.
AE	Areas subject to inundation by a 1% annual chance of flooding determined by detailed methods; mandatory flood insurance purchase requirements and floodplain management standards apply.
AO	River or stream flood hazard areas; areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones.

Figure 3 is based on the FEMA flood zone categories described in Table 2. The 'A' zone indicates areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. The 'AE' zone is defined as areas subject to inundation by the 1% annual chance of flooding determined by detailed methods. The 'X' zone, not described in the table, is a "low risk area" covering areas of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floods.

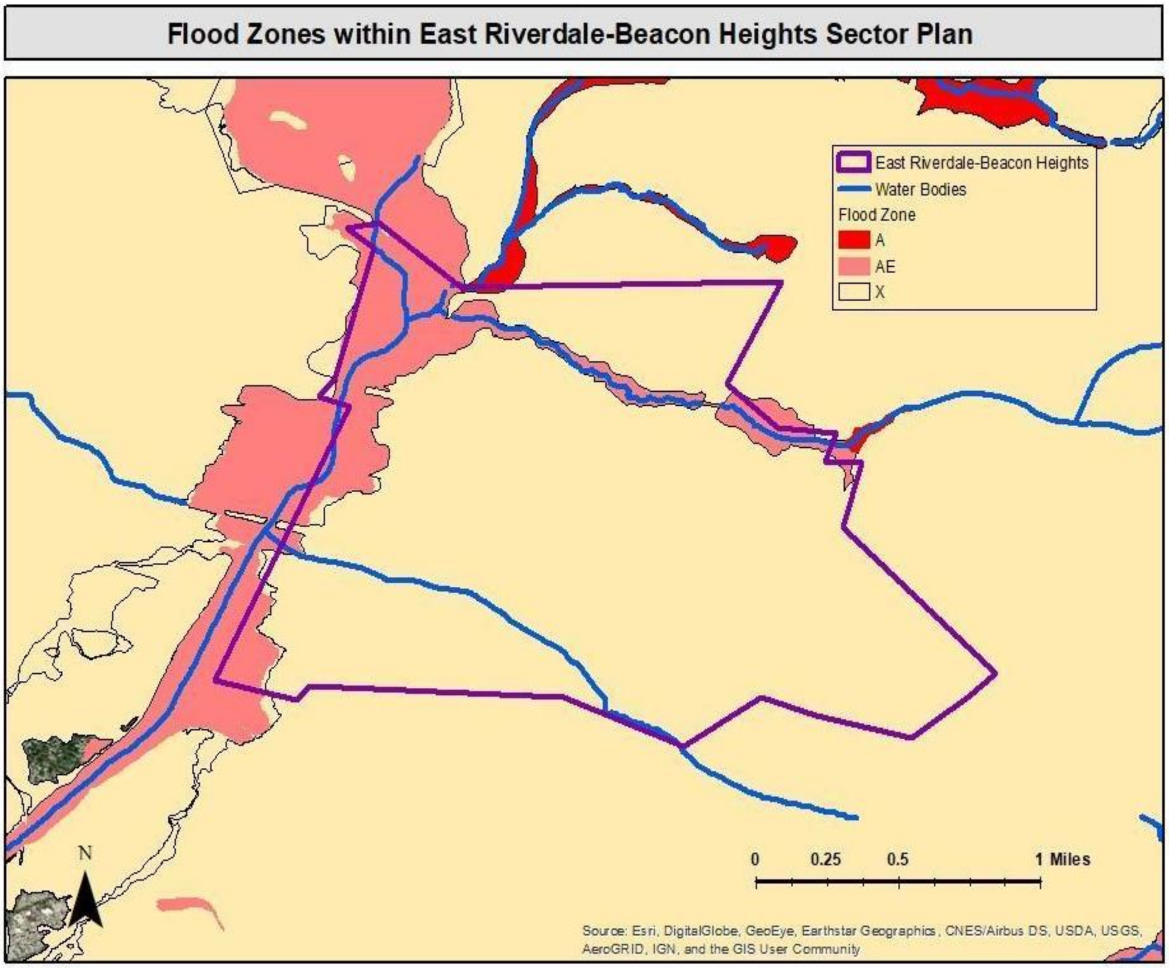

Figure 3. Flood zones in East Riverdale-Beacon Heights

As displayed above, the 'X' layer covers the largest portion of land in East Riverdale-Beacon Heights. However, because this zone is classified by FEMA as "low risk," our research is focused on the 'AE' zone, a "high risk area" that covers more land than the 'A' zone.

Figure 4 shows the flood zone in East Riverdale-Beacon Heights as defined by Prince George's County. The number and types of buildings affected by this floodplain are described in Table 3.

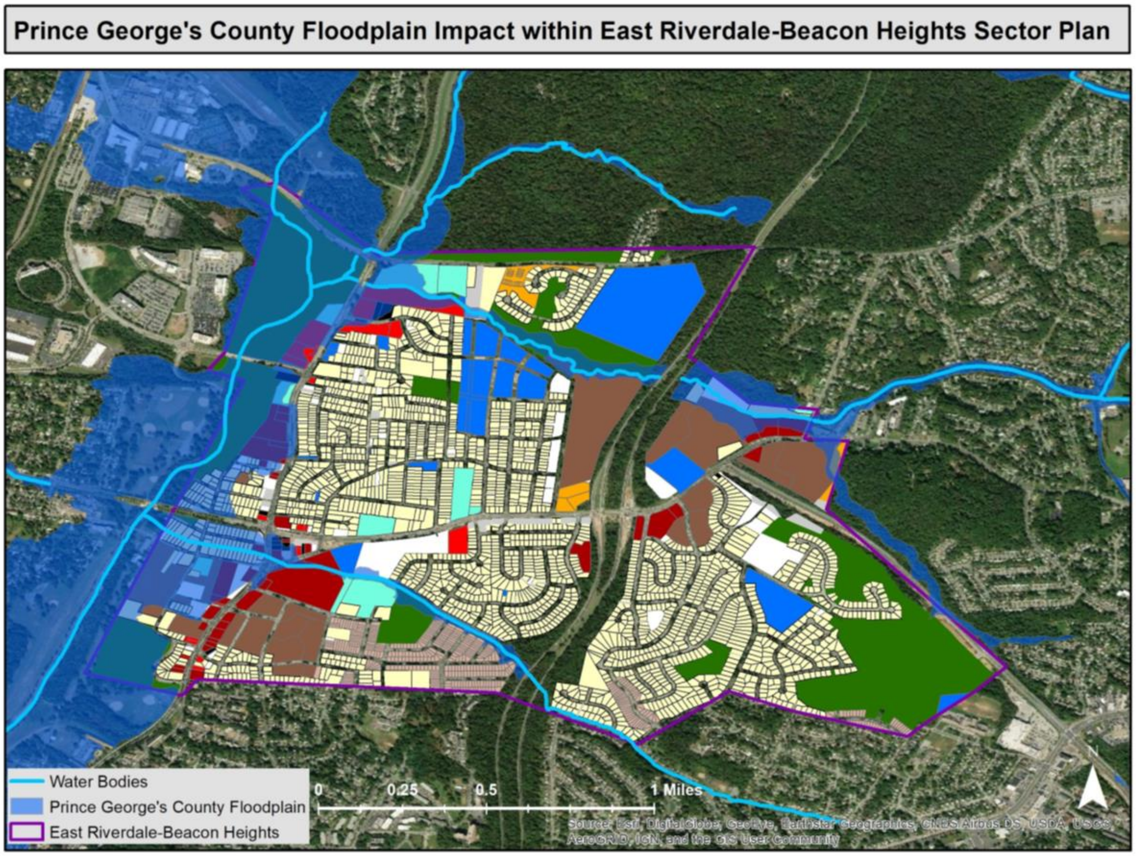

Figure 4. Prince George's County floodplain in East Riverdale-Beacon Heights

Table 3. Units impacted by Prince George's County floodplain in East-Riverdale-Beacon Heights

Property type	Number of units impacted by County flood zone
Commercial	31
Institutional	15
Residential	156
Total	202

Figure 5 compares Prince George's County's floodplain with the FEMA AE flood zone in the *East Riverdale-Beacon Heights Sector Plan* area. As demonstrated, the County's floodplain is considerably larger than the FEMA AE flood zone. The County floodplain data is updated to reflect current conditions.

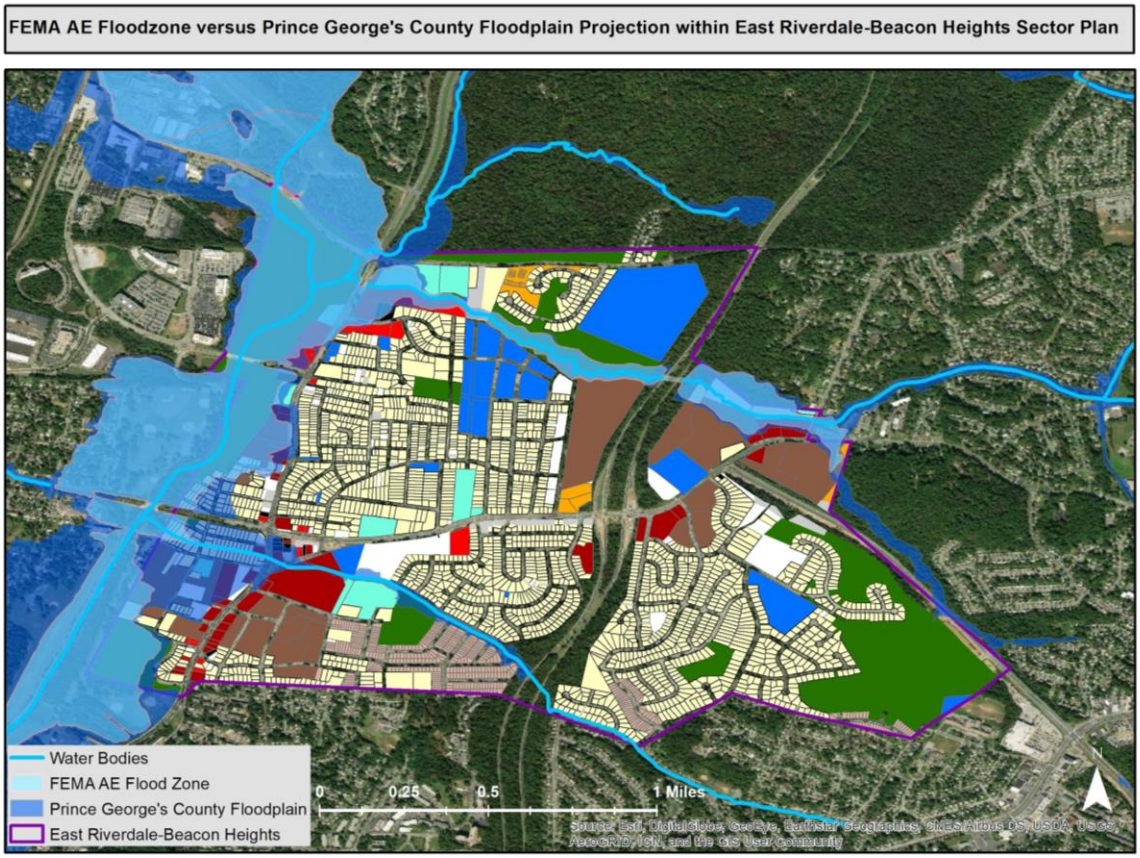

Figure 5. Comparison between FEMA AE flood zone and the Prince George's County floodplain in East Riverdale-Beacon Heights

Based on these findings, residential units represent the largest portion of property types in East Riverdale-Beacon Heights and are also the most at risk of flood damage. The current AE (1% annual chance of flooding) impacts 82 units.

Table 4. Property types impacted by FEMA AE flood zone in East Riverdale-Beacon Heights

Property type	Number of units impacted by AE flood zone
Commercial	14
Institutional	8
Residential	60
Total	82

4.3 Flood Projections

Current literature that uses GIS to create climate change projections for floodplains typically uses geoprocessing techniques, including buffer analysis. Some studies use buffers of up to a half-mile for small scale mapping, while larger scale projections may use buffers of up to several miles. For example, a 2002 study conducted at the City University of New York used half-mile buffers to predict impacts from "large-scale" zoning changes in areas spanning from four blocks to more than ten blocks (Maantay, 2002). Further, a study performed at Saint Mary's University used a 300-foot buffer around streams to predict flooding impact (Carlin, 2009). Based on studies such as these, we determined that a relatively small buffer would be most appropriate to model flooding projections in Beacon Heights, an area that covers a little over one square mile. Thus, we chose to create buffers of 10 and 30 meters, which each predict rough estimates of what the extension of the floodplain could look like due to increased flooding from climate change.

For figure 6, a 10-meter buffer was created around the Prince George's County flood layer using the geoprocessing "buffer" tool in ArcMap.

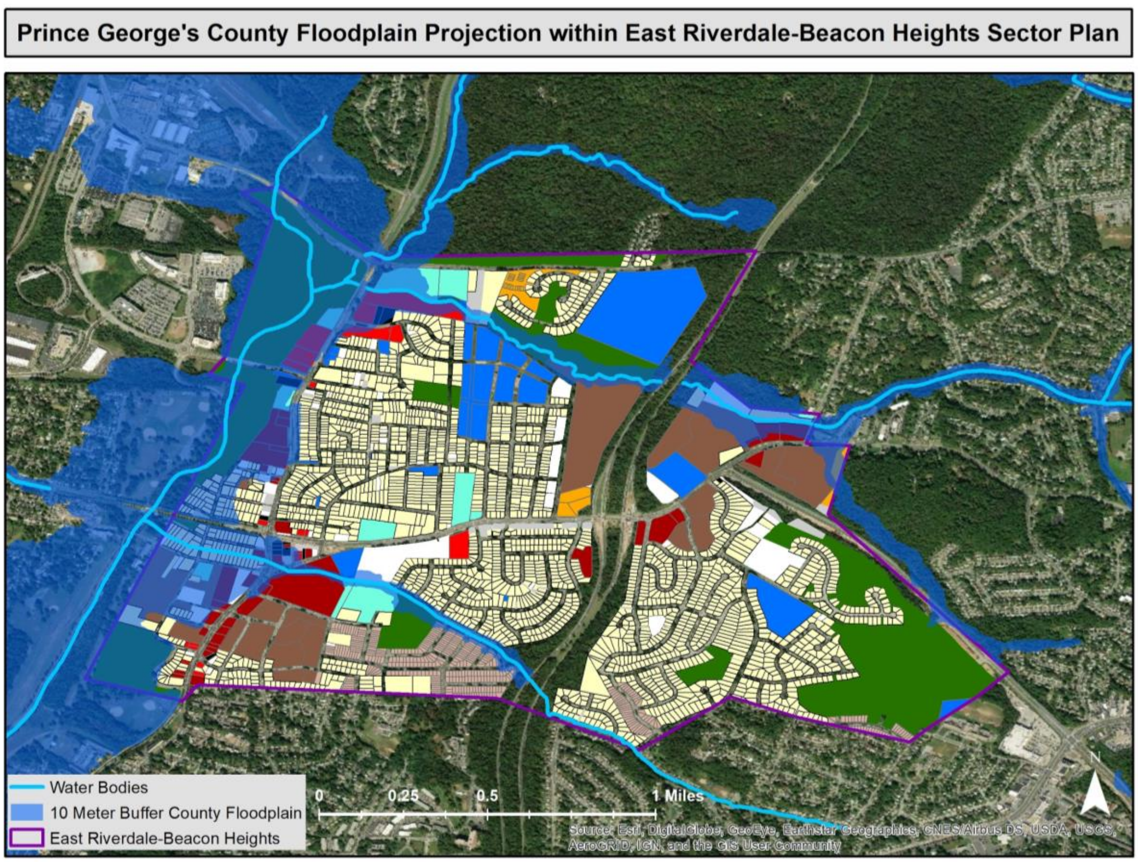

Figure 6. 10-meter Prince George's County floodplain projection within East Riverdale-Beacon Heights

Figure 6 shows a 10-meter buffer around the Prince George's County's floodplain layer in the *East Riverdale-Beacon Heights Sector Plan* area. The 10-meter buffer was selected based on existing GIS literature. Table 5 shows how many residential, commercial, and institutional units are impacted by the buffer.

Table 5. Property types impacted by the 10-meter Prince George's County floodplain projection

Property type	Number of units impacted by 10-meter buffer
Commercial	35
Institutional	20
Residential	207
Total	262

Figure 7 depicts a 30-meter buffer around the Prince George's County flood layer using the geoprocessing "buffer" tool in ArcMap.

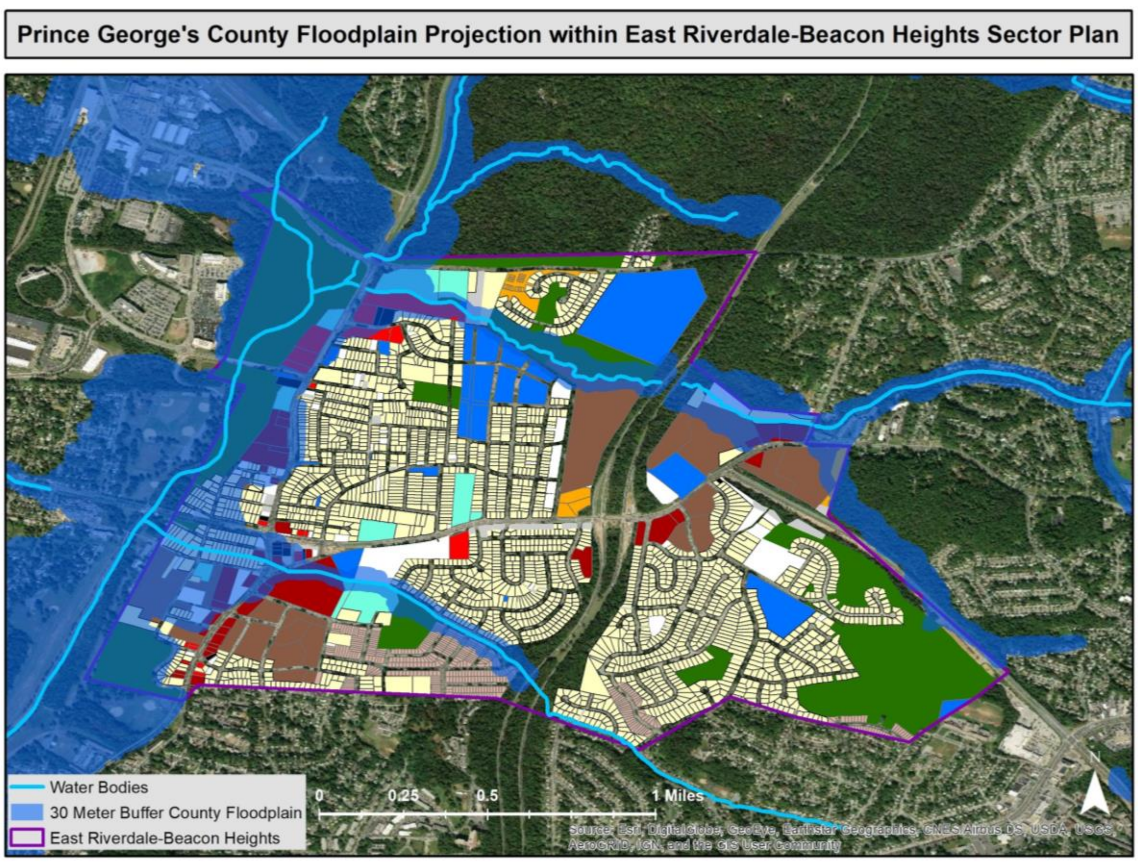

Figure 7. 30-meter Prince George's County floodplain projection in the *East Riverdale-Beacon Heights Sector Plan*

Figure 7 shows a 30-meter buffer around Prince George's County's floodplain layer in the *East Riverdale-Beacon Heights Sector Plan*. Table 6 shows how many residential, commercial, and institutional units are impacted by the buffer.

Table 6. Units impacted by the 30-meter Prince George's County floodplain projection

Property type	Number of units impacted by 30-meter buffer
Commercial	36
Institutional	22
Residential	270
Total	328

4.4 Flood Infrastructure

Figure 8 shows various levels of physical and policy infrastructure to address flooding beginning with environmental easements in East Riverdale-Beacon Heights and land designated as Clean Water Partnership areas with the National Resource Inventory, based on information layers in the GIS Open Data Portal of the County Planning Department. This first layer contains data about the environmental easement areas, which are areas designated for conservation, and land designated as part of the Clean Water Partnership. Plans for these areas are created to fulfill Clean Water Act requirements and reviewed by the Maryland-National Capital Park and Planning Commission's Environmental Protection Section. These areas are important to flooding as a place for watershed protection and restoration.

A layer of impervious surface areas was added to compare East Riverdale-Beacon Heights to Prince George's County. Data showing current stormwater infrastructure in East Riverdale-Beacon Heights operated by the State Highway Administration (SHA) and that has National Pollution Discharge Elimination System (NPDES) permits filed with the Maryland Department of the Environment (MDE) was also collected from Maryland's GIS Data Catalog (Maryland.gov).

These layers were clipped to the County level, to the sector plan boundary, and to the urban area within Prince George's County as defined by the 2010 Census of Urbanized Areas and Clusters within ESRI. Each of those clipped layers was then compared to analyze the differences in flood infrastructure within East Riverdale-Beacon Heights compared to the County as well as to the urban areas within the County.

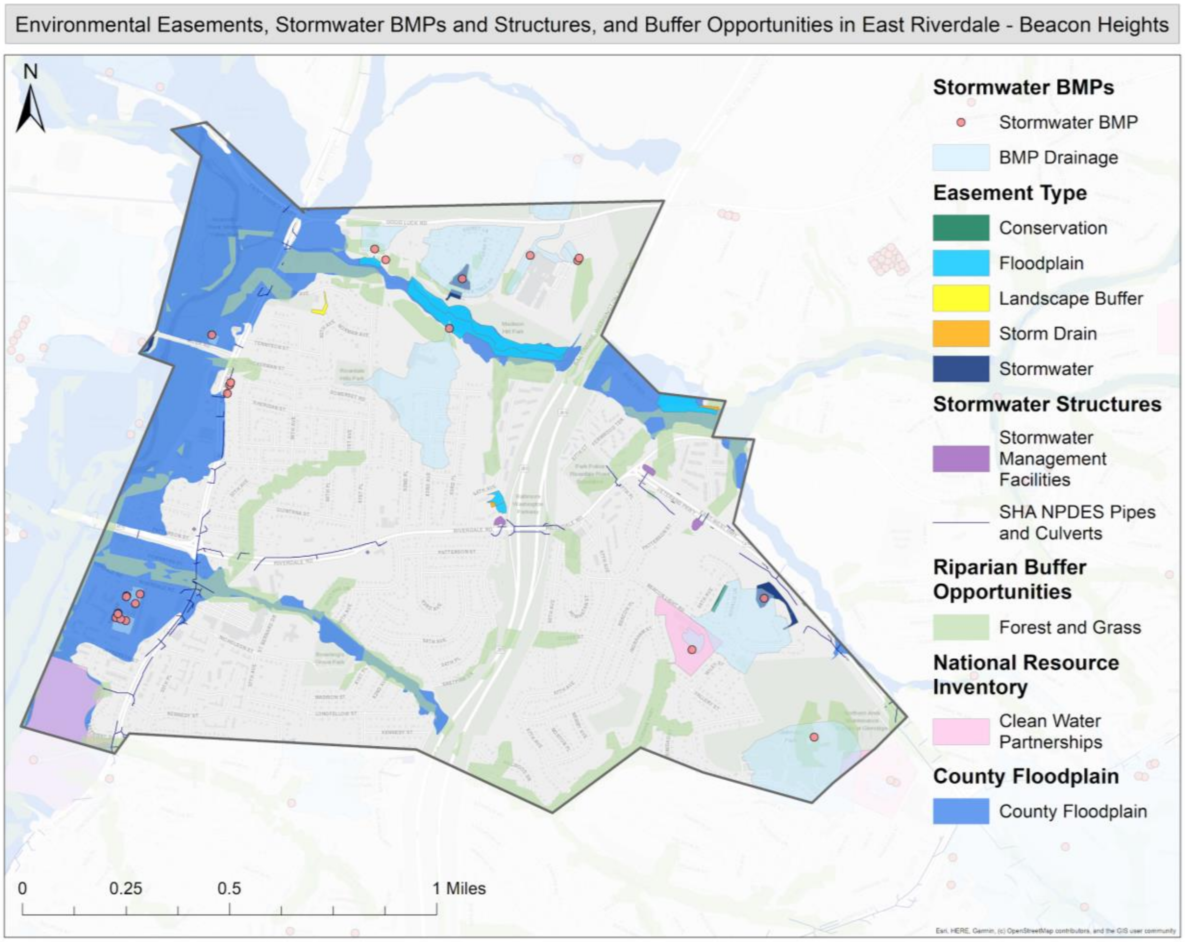

Figure 8. Environmental easements, stormwater best management practices and structures, and buffer opportunities in East Riverdale-Beacon Heights

Figure 8 shows the current environmental easements within East Riverdale-Beacon Heights, which are areas designated for conservation by the County Code of Prince George's County (GIS Open Data 2019). The map also shows areas designated as part of the Natural Resource Inventory Clean Water Partnership (NRI-CWP) project. Through an analysis of these GIS layers as well as additional spatial analysis within ArcMap, it has been determined that 1.672% of the East Riverdale-Beacon Heights area is designated as environmental easements, which includes land designated for conservation, stormwater management, and floodplain restoration and management. By comparison, 3.556% of Prince George's County land is designated as environmental easements, and in the County's urban areas, 3.953% of land is designated as environmental easements.

Land designated as part of the Clean Water Partnerships was also compared between East Riverdale-Beacon Heights and Prince George's County, and showed that 0.440% of County land is designated, compared to 0.671% of land in the County's urban areas and 2.071% of land in East Riverdale-Beacon Heights (GIS Open Data 2019).

The amount of impervious area impacts peak discharge times and is an integral aspect of flood mitigation. As shown in Table 7, 16.44% of Prince George's County is impervious, 24.42% of the County's urban areas are impervious, and i48.24% of East Riverdale-Beacon Heights is impervious (GIS Open Data 2019).

Table 7. Impervious area in East Riverdale-Beacon Heights and Prince George's County

	East Riverdale-Beacon Heights	Prince George's County	Prince George's County Urban Areas
Impervious area	48.24%	16.44%	24.42%

Figure 8 also shows the SHA's stormwater infrastructure in East Riverdale-Beacon Heights that have NPDES permits filed with the Maryland Department of the Environment. These include stormwater management facilities, storm drain structures, pipes, and culverts. The structures follow the two main highways operated by the SHA, and a majority of the stormwater management facilities are located on the eastern half of the *East Riverdale-Beacon Heights Sector Plan* area.

This map also shows areas that have been identified by the State as potential opportunities for planting riparian grass and forest buffers, based on land use type and hydrological characteristics. Riparian buffers, in conjunction with the naturalization of streams, can filter pollutants and reduce the flooding effects. An analysis of stormwater best management practices (BMPs) shows that East Riverdale-Beacon Heights has 11.12 BMPs per square mile, while Prince George's County has 10.82 BMPs per square mile. Although East Riverdale-Beacon Heights has a higher concentration compared to the County, it falls behind the County's urban areas at 16.5 BMPs per square mile (Maryland's GIS Data Catalog, 2019).

4.5 Demographic and Socioeconomic Analysis

Table 8. Race and ethnicity in East Riverdale-Beacon Heights

Race	Total Population	Percent of total population
White	10,565	54.3
Black	7,128	36.6
Native American	563	2.9
Asian	616	3.2
Pacific Islander	46	.2
2 or more	540	2.8

Ethnicity	Total Population	Percent of total population
Not Hispanic	8,334	42.8
Hispanic	11,123	57.2

The majority of the area's population is Hispanic, which may indicate potential language barriers when communicating flood risk and mitigation strategy recommendations.

Table 9. Age in East Riverdale-Beacon Heights

Age	Total Population	Percent of total population
Below 19	5,720	29.4
20-64	12,036	61.9
65+	1,701	8.7
Median	33	---

Table 10. Homeownership in East Riverdale-Beacon Heights

Homeownership	Number of units	Percent of total units
Owner-occupied units	2,748	49.8
Renter-occupied units	2,598	47
Total	5,522	---

Table 11. Median income in East Riverdale-Beacon Heights and Prince George's County

Median Income	
East Riverdale-Beacon Heights	$63,856
Prince George's County	$84,008

The area's median income is about $20,000 less than in Prince George's County. This implies that some community members may not have the funds necessary to respond to and successfully recover from large flood events.

Table 12. Education in East Riverdale-Beacon Heights and Prince George's County

Education	Beacon Heights (%)	Prince George's County (%)
No HS diploma	37.7	13.8
HS diploma	25.4	25.9
Some college	22.8	28.3
Bachelor's degree	9	18.4
Advanced degree	5.1	13.6

The community's education level is also significantly lower compared to the County. The percent of people holding a bachelor's degree in East Riverdale-Beacon Heights is half that of the County. The portion of the community that has not obtained a high school diploma is 37.7% compared to the County, at 13.8%. The lower levels of obtained education could make it more difficult for people to receive the information necessary to make informed decisions about flooding risks.

5. Findings: Flood Mitigation Strategies

As urban development and the effects of climate change continue to increase, flood risk is also expected to increase. However, the amount of increase is uncertain. As a result, improving the resiliency of a system has the potential to accrue greater long-term benefits than prioritizing stability. Resiliency refers to a systems ability to recover from a disturbance and return to a stable regime.

In practice, this will mean shifting away from preventing floods and moving toward building a community that lives with floods. This can be accomplished by minimizing the damage caused by floods and increasing community preparedness and adaptability. Resiliency can be increased by decreasing all aspects of risk: exposure, hazard, and vulnerability. Although addressing just one of these aspects will decrease risk and increase resiliency, all three aspects must be addressed. Including redundancy in risk mitigation actions accounts for unexpected disturbances, which, without redundancy, would put people at greater risk (Liao, 2012).

Although Prince George's County as a whole has a high risk of flooding (*Hazard Mitigation Plan*, 2010), there are comprehensive regulations in place that help decrease this risk. This section outlines the benefits and limitations of the County's flood mitigation measures currently in place, suggests necessary improvements, and proposes additional strategies and their limitations.

5.1 Reducing Exposure

Exposure is most directly tied to a structure's location in relation to the 100-year floodplain. As stated previously, buildings within the 100-year floodplain are exposed to frequent minor floods, as well as a 1% chance annually of a major flood that has the potential to destroy property and put individuals at risk. Additionally, as development progresses and climate change worsens, a growing number of residents will be exposed to floods.

Prince George's County has made efforts to reduce exposure to floods. The County's Floodplain Ordinance limits further development in the floodplain and outlines guidelines for new development to avoid flood exposure (*Hazard Mitigation Plan*, 2010). However, homes and structures built before the 1970s when the ordinance was put in place, are likely to be unequipped to withstand flooding (M-NCPPC Prince George's County Planning Department, 2017). To deal with this, the County "encourages property owners to retrofit flood-prone buildings," and has funded measures to protect flood-prone homes, primarily using site grading and floodwalls around entrances. The County, with the support of State and federal funds, has also previously acquired flood-prone homes and has dedicated that land as open space (*Hazard Mitigation Plan*, 2010).

To decrease exposure, Prince George's County should provide residents with information about how to flood-proof their homes, and financially support the acquisition of flood-prone homes whenever possible.

5.1.1 Flood-Proof Housing

5.1.1.A Single-family Homes

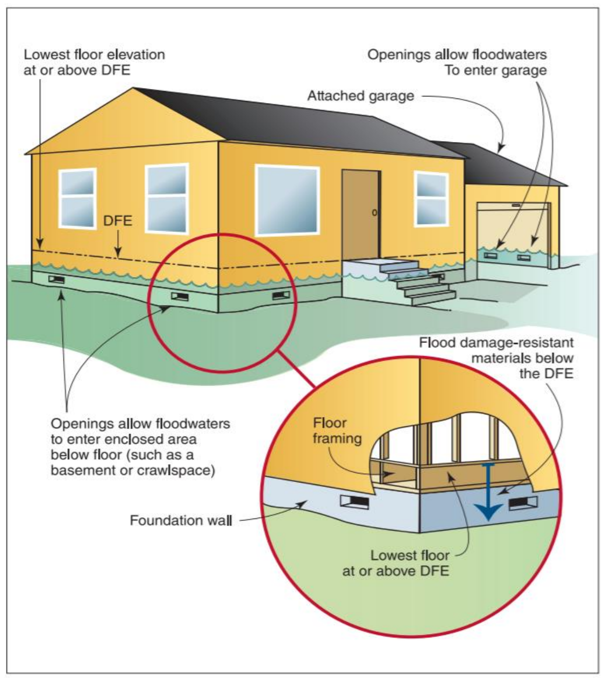

Figure 9. Typical wet floodproofing (FEMA, 2014)

Many of the single-family homes in the East Riverdale-Beacon Heights floodplain area are frame houses built on basement foundations. Excluding the basement levels, most of these homes are already elevated at least one foot or more above the ground, which is above the base flood level of 1 to 3 feet. To further prevent flood damage, these homeowners should wet floodproof their basements. Wet floodproofing involves allowing floodwaters to enter the lowest floor of the building in such a way that it will not cause structural damage. This is accomplished by installing small openings in exterior walls of enclosed areas exposed to flooding; these openings allow floodwater to enter so that the home is not damaged by the pressure of floodwater on the outside of the house (see Figure 9). These areas exposed to floods, as well as the building exterior, are replaced by flood-damage resistant materials. For example, carpet should be replaced with vinyl or tile, flood-resistant insulation should be installed, and exterior walls can be covered in waterproof veneer. Finally, all utilities, heating and cooling systems, other building equipment systems, and any valuables currently below the base flood elevation are either protected or moved to an elevation above the base flood elevation (FEMA, 2014).

Although wet floodproofing is less expensive than elevating the entire home, it has limitations. First, it may not be a viable option for some households, as some basement walls are not able to be wet-floodproofed. Furthermore, relocating utilities and other building equipment systems is sometimes at the discretion of the utility provider, who may require that utility meters remain below the base flood elevation. Additionally, animals may be able to enter the home through vents in the exterior walls, because floodwaters must be able to enter the home automatically, which vent covers prevent (FEMA, 2014).

For homes that are not or are only minimally raised above base flood elevation, elevation of homes should be considered. Elevation is more costly than wet floodproofing but is more effective at preventing flood damage and can lower flood insurance premiums.

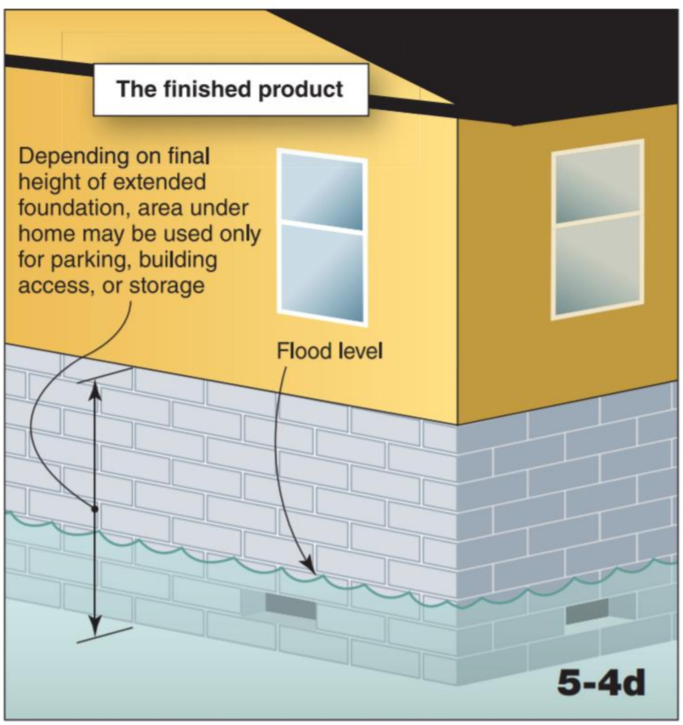

Figure 10. Elevation of a basement home on extended foundation walls (FEMA, 2014)

Elevation requires separating the home from its foundation, raising it, and then extending the foundation to the desired height, so that the living area is not exposed to floods (FEMA, 2014) (see Figure 10). As part of the Floodplain Ordinance, this would be considered a substantial improvement, and would require raising the house at least one foot above the 100-year floodplain elevation. However, raising the home's lowest floor to at least three feet above the base flood elevation is considered the safest elevation in the 100-year floodplain (*Hazard Mitigation Plan*, 2010). After the elevation is completed only a crawlspace below the first floor, which was previously the basement, is exposed to flooding, and can be used only for parking, building access, or storage of non-valuables (FEMA, 2014).

While elevation is the best option to protect single-family homes, it is not always economically feasible for many families; elevation can cost upwards of $100,000 (Hurley, 2017). The cost depends on the type of home and the desired elevation height. Generally, frame homes on basement foundations are the easiest to elevate, as the basement walls can simply be extended to the desired height. Elevating masonry homes or homes built on slab-on-grade foundations is more costly. In addition to the expense, elevation can restrict access for those who use wheelchairs and other mobility aids. Ramps or elevators can be purchased; however, they add to the overall cost (FEMA, 2014).

Elevation costs can sometimes be covered as part of FEMA's Flood Mitigation Assistance grant program (FMA) (FEMA, 2014). Individual homeowners, whose homes are insured under the National Flood Insurance Program (NFIP), can apply for an FMA grant through eligible sub-applicants, including local governments, such as Prince George's County. The County can sponsor applications to the State of Maryland on behalf of the homeowner. Applications must then be submitted to FEMA by the State of Maryland (FEMA, n.d.-a). In fact, with FMA assistance, elevation can sometimes be cheaper than wet-floodproofing, which is not eligible for FMA grants (FEMA, 2014).

5.1.1.B Multifamily Homes and Apartment Complexes

For multifamily buildings and single-family homes that cannot be elevated, other measures must be taken to prevent flood damage. These include basement infill, abandoning or elevating the lowest floor, or dry floodproofing. These options all work by moving living areas, utilities, and service equipment to higher elevations, and then wet floodproofing the lowest floor. These options work well for single-family homes that can't be elevated but they are of limited use for apartment complexes. Abandoning the lowest floor is not an option if dwelling units are located on the lowest floor (Figure 12). Elevating the lowest floor is also complicated because it involves lowering the height of all floors so that the lowest livable floor can be elevated within the frame of the building (Figure 11). Basement infill is the most appropriate option, as it involves abandoning the basement, filling it, and then wet floodproofing the lowest floor (Figure 13). However, this option is still not ideal for many residents, who would not like their homes to be filled with exterior vents that cannot be closed. Despite its limitations, however, wet-floodproofing is the least expensive option (FEMA, 2015).

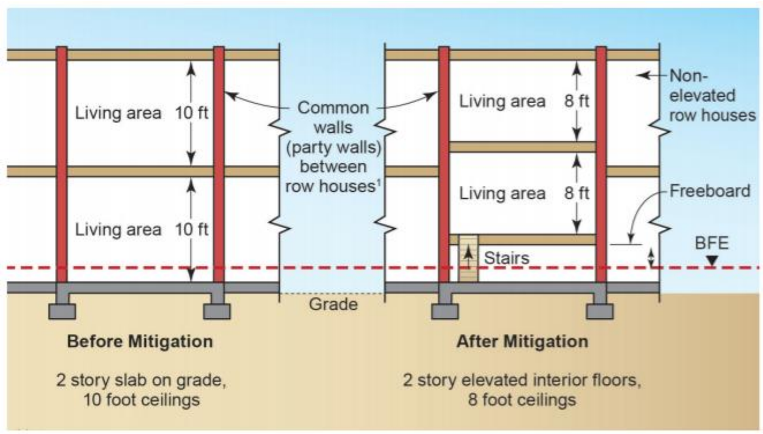

Figure 11. Elevating the lowest floor involves lowering the height of all rooms (FEMA, 2015)

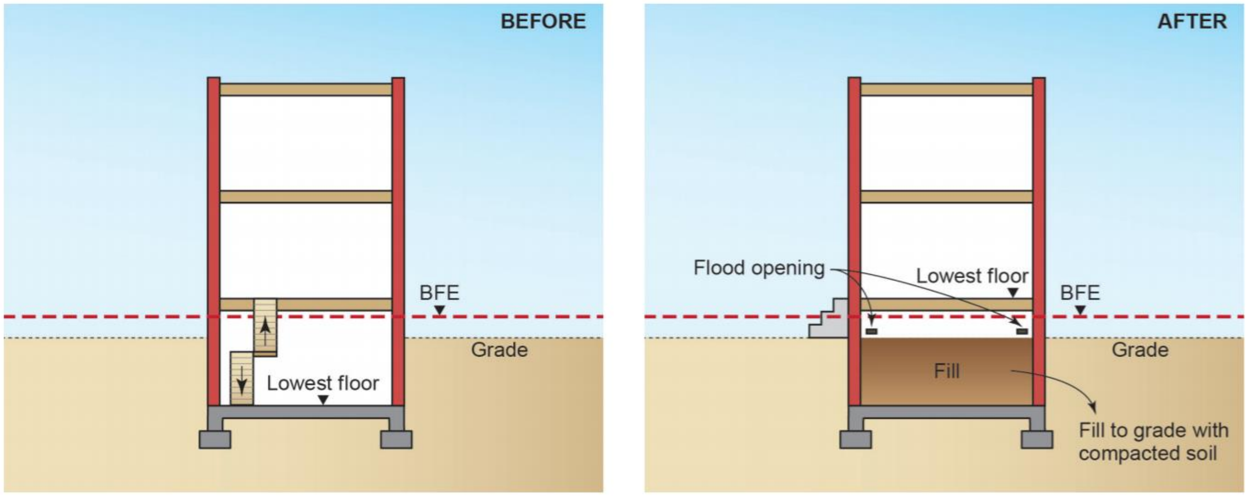

Figure 12. Abandoning the basement floor using fill (FEMA, 2015)

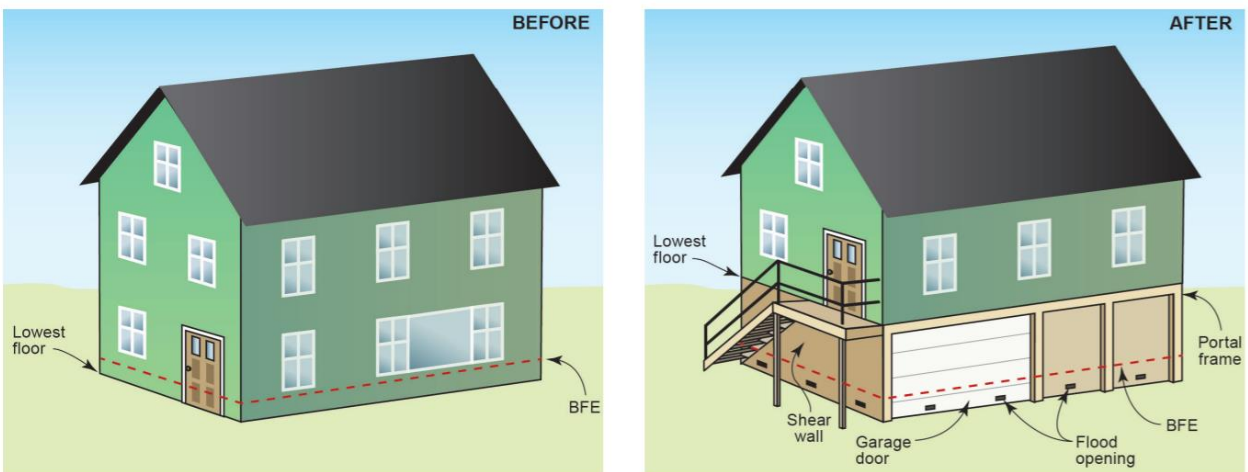

Figure 13. Abandoning the lowest floor and wet-floodproofing (FEMA, 2015)

Alternatively, if the building doesn't have a basement, dry floodproofing can be used. This option is likely to be the most ideal option for an apartment complex; it doesn't involve changes to the inside of the building, and no residents will lose their homes. Dry floodproofing involves coating or covering the exterior walls with a water-resistant material to at least three feet above ground level, or ideally, at least one foot above the base flood elevation. Dry floodproofing can also be used on buildings with basements if the basements are first abandoned and filled. While dry floodproofing is effective at preventing water damage, it can put additional pressure from floodwaters on foundations, exterior walls, and floors. The building's structural components may need to be reinforced to make dry floodproofing a viable option. Additionally, dry-floodproofing is the highest cost option (FEMA, 2015), although it is eligible to be covered by FMA grants (FEMA, 1998).

Ultimately, individual homeowners and apartment complex owners must decide if they want to flood-proof and which floodproofing method they want to use. FMA grants can be used for elevation projects, but funding for other types of floodproofing must be provided by the property owner. However, Prince George's county should encourage homeowners to retrofit their homes whenever possible and provide them the necessary information and assistance to do so.

5.1.2 Buyouts

For homes that cannot be floodproofed, or for those who cannot afford to flood-proof their homes, floodplain buyouts are an option. Floodplain buyouts are the voluntary acquisition of flood-prone property by a government entity, which eliminates the risk of flooding for the homeowner, protects their property and assets (Environmental Law Institute [ELI], 2017), and permanently removes development pressure in the floodplain (Wright, 2007).

Buyouts can have large environmental benefits. If structures on the acquired property are demolished and the land is restored and preserved as open space, it can restore the stream's hydrologic connection and provide permeable surface area that increases infiltration and reduces runoff. This reduces the likelihood that a flood will occur as well as the intensity of future floods (Opperman et al, 2009; Wright 2007). In other words, buyouts combined with restoration efforts and maintenance of open space may have a positive impact for homeowners—who give up their property and remove potential financial and physical flood risks—and for those who live downstream of the floodplain. In addition, restoring the natural floodplain also benefits the stream's biodiversity (Opperman et al, 2009) and can provide recreational opportunities and benefits to nearby communities (ELI, 2017).

The two primary methods of floodplain land acquisition are fee simple and less-than-fee simple. Fee simple acquisition is the most common method and often the most desirable. By this method, the County acquires the full title to and control of the property, and the property owners receive fair market value as compensation.

Less-than-fee simple acquisition is used when property owners don't want to give up the land title and is accomplished using leases and easements. The property owner may lease their land to the County, while still retaining title. Leases are often less expensive than purchasing the full title. The County may also obtain an easement—the right to use the land for a specific purpose over a specific period of time—which allows the landowner to maintain rights to use the land for all uses that don't interfere with the rights specified in the easement.

In East Riverdale-Beacon Heights, the primary land use in the 100-year floodplain is residential development, which would conflict with the desired easement use of undeveloped space. A lease approach also would not grant property owners the full market value of a fee simple approach, likely limiting their ability to relocate. Therefore, fee simple acquisition is probably the most desirable approach in this community.

Several programs fund floodplain buyouts. FEMA administers two grant programs, the Pre-Disaster Mitigation grant program (PDM) and the Flood Mitigation Assistance grant program (FMA), that the County could use to assist with acquiring homes in the floodplain. Both grant programs provide 75% of the cost of acquisition, while the state or local agency that applies for the grant on behalf of the homeowner must cover the other 25%. To be eligible to apply, the state or local agency must have a FEMA-approved flood risk mitigation plan in place.

The PDM grant assists municipalities seeking to implement pre-disaster hazard mitigation projects, which can include property acquisition and relocation of flood prone structures. The FMA grant program includes planning grants which may be used to implement measures, including property acquisition and relocation, to reduce or prevent flood loss to NFIP-insured properties. Eligible properties are located in areas at risk of flooding, including the 100-year floodplain (ELI, 2017).

In addition to federal funding, other state and local grant programs can subsidize floodplain buyouts. The State's Comprehensive Flood Management grant program (CFMGP) assists communities in funding flood mitigation actions, such as property acquisition. The program funds 50% of the remaining cost of acquisition not funded by federal programs, or 12.5% of the total cost. In cases when federal funding is not available, CFMGP will fund up to 75% of the total costs (Maryland Department of the Environment, 2019).

Buyouts can be a cost-effective option for flood mitigation. After the initial cost of acquisition and restoration, removing structures exposed to flooding reduces future disaster-related costs, including costs associated with emergency response, evacuation and sheltering, and debris removal. However, these savings may be outweighed by the loss of property taxes from former residents, and the cost of maintaining the new open space. Additionally, if the buyout program is not subsidized with grants, they can be expensive.

Buyouts are a voluntary process; it is up to the individual homeowner to decide if they would like their home to be acquired (Salvesen, BenDor, Kamrath, & Ganser, 2018). Residents of established communities, such as East Riverdale-Beacon Heights, are likely to resist relocation, which could mean a loss of their social support networks, communities, and income sources. Residents are also more likely to resist or be uninterested in acquisition if they are unaware of the potential impacts of floods (ELI, 2017). Condemnation can be used when property owners don't want to sell, when a fair market price can't be agreed on, or when the property title is unclear (Wright, 2007). Prince George's County has the legal power to condemn private property when the land is acquired for public use (Jonathan, 2007). However, condemnation is often viewed as undesirable by landowners and community members (Wright, 2007).

The acquisition of flood-prone properties is one of the most effective ways to reduce flooding and improve the quality and function of natural stream hydrology. Buyout programs both completely remove flood risks for those who live in the floodplain and decrease flood risks for those who live downstream. However, there are significant costs, including the costs of purchasing the homes and potentially high maintenance costs of maintaining noncontiguous land parcels.

Despite these drawbacks, Prince George's County should prioritize a buyout program as one of the main strategies to minimize flood risk for the residents of the *East Riverdale-Beacon Heights Sector Plan* area, because the potential benefits are extremely high.

To ensure that buyouts are a cost-effective option, local governments should acquire properties in the same area, thus forming contiguous parcels that can be maintained as a single unit. This can be accomplished by effectively advertising the buyout program to residents (Salvesen, BenDor, Kamrath, & Ganser, 2018). We recommend that the County advertises the buyout program specifically to residents between Northwest Branch and Kenilworth Avenue, who are located within the Prince George's County Floodplain Study area, and within the projected floodplain area (Figure 4).

Advertisement methods often include informational materials, public announcements, and public meetings (FEMA, 1998), and are discussed in section 5.3.3. Acquiring the homes closest to the Northwest Branch should be prioritized, as the resulting land can be maintained as part of the stream valley park that borders the Northwest Branch northwest of these homes (M-NCPPC Prince George's County Planning Department, 2017). Additionally, if possible, entrusting a third party, such as a conservation organization, to maintain the open space can reduce maintenance costs (Salvesen, BenDor, Kamrath, & Ganser, 2018).

The County should apply for funding through the PDM, FMA, and CFM grant programs to assist with acquiring properties using a fee simple approach. It is recommended that the County only exercises the power of eminent domain to avoid piecemeal land acquisition, such as in cases where only a few landowners are resisting relocation, and other properties have already been acquired (Wright, 2007).

5.2 Reducing Hazards

Hazard, in this case, refers to the intensity and frequency of floods. Flood hazard is determined by both the volume of water entering a stream during a storm, and the ability of the stream to store that volume of water. In the Northeast Branch and Brier's Mill Run watersheds, stormflow is artificially high, due to increased amounts of runoff and low amounts of infiltration caused by high impervious surface area (M-NCPPC Prince George's County Planning Department, 2017). Reducing hazards can be accomplished by decreasing runoff and by increasing the floodwater storage capacity in the Northeast Branch and Brier's Mill Run drainage basins.

5.2.1 Maintaining Space in the Floodplain

The County currently preserves over 13,400 acres of floodplain as open land in the form of stream valley parks. Additionally, under its Green Infrastructure Plan, the County plans to work with the State to buy land when it becomes available, to limit further development in areas important for flood control. Long term plans for these lands are the "protection of sensitive habitats, conservation, and where appropriate, development of recreational facilities that include trails, athletic fields, and buildings" (*Hazard Mitigation Plan*, 2010). This is perhaps the most effective method that the County is using to decrease flood hazards. Maximizing the natural abilities of the floodplain and natural wetlands to store floodwaters by preserving open space in key areas reduces stream discharge and minimizes flood damage. In fact, while impervious surface area is correlated with flood hazard, impervious surface area in the floodplain and in natural wetlands has a much higher effect on flood risk (Brody et al., 2007). Therefore, the County should prioritize the reduction of impervious surface area in natural wetlands and floodplains.

The County should continue its practice of preserving land as publicly owned stream valley parks, buying land to preserve as open space, and using that space for "protection of sensitive habitats, conservation, and where appropriate, development of recreational facilities that include trails, athletic fields, and buildings" (Liao, 2012). The County can purchase undeveloped land to prevent future development in the floodplain and implement a buyout program to convert developed land in the floodplain to open space, discussed in section 5.1.2 (Wright, 2007).

To minimize the land acquisition costs while maximizing flood-damage reduction potential, the County should prioritize buying parcels that offer the largest amount of land for the lowest price—a "bang for the buck" approach. A Wisconsin study on the effectiveness of floodplain land acquisition at minimizing flood damage in a highly developed watershed found that this method can be effective at preserving a large amount of floodplain acreage for the lowest possible cost (Kousky, Olmstead, Walls and Macauley, 2013). We also recommend that any necessary structures within these floodplains be built to be flood-proof and maintained so that the area is allowed to flood, which will maximize flood resiliency (Liao, 2012).

In addition to preserving open space in the floodplain, the County can also increase the area of floodable land. Floodable land refers to the amount of land within a watershed that is able to be flooded due to its underlying geology, soil type, lack of chemical contaminants, and, lack of development. Floodable land does not necessarily refer to the 100-year floodplain, or any other floodplain based on the statistical probability of flooding, but rather an entire valley floor between valley walls in a drainage basin. Maximizing floodable land is directly linked with decreased flood hazard and increased resiliency (Liao, 2012).

5.2.2 Stream Restoration and Floodplain Reconnection

As mentioned previously, sections of the Northwest Branch, Brier's Mill Run, and Captain John's Branch have all been channelized (M-NCPPC Prince George's County Planning Department, 2017). Levees along the Northwest Branch also exist to channel stormwater flow. These stormwater controls have been effective in the past; no major floods have occurred along the Northwest Branch in at least 30 years (*Hazard Mitigation Plan*, 2010).

However, grey infrastructure, such as stormwater controls and levees, have significant limitations. Grey infrastructure reduces the hydrologic connectivity of streams, which then prohibits floodwater storage in the ground. This means that when stormflow exceeds the capacity of flood control structures, flood damage is worse than it would have been without flood control structures (Brody et al., 2007). In fact, the County's *Hazard Mitigation Plan* has outlined areas next to Northwest Branch that would be damaged if the levees were to overtop. In addition, flood control structures are expensive to maintain, and they harm natural ecosystems (Brody et al., 2007). While stormwater controls can be effective in the short term, in the face of increasing flood risk and uncertainty, they are unsustainable and non-resilient strategies in the long term.

The current channelization of these streams and the presence of levees presents an opportunity to restore them to natural conditions. Stream restoration is defined as the “reestablishment of the structure and function of ecosystems and floodplains to return the ecosystem as closely as possible to its natural conditions and functions prior to being developed” (FEMA, n.d.-b). In this context, stream restoration should include removing the concrete channels and levees to restore hydrologic connectivity, stabilizing banks with erosion control structures, and planting native riparian vegetation (Figure 14). These techniques decrease flood risk by both decreasing the amount of damage caused by flood events, and by maximizing the natural floodwater storage capacity of these streams and floodplains (Brody et al., 2007; Opperman et al., 2009). In addition to flood hazard mitigation and ecosystem benefits, stream restoration can have the added benefits of increasing a stream’s natural beauty, increasing recreational opportunities, and creating educational opportunities (European Centre for River Restoration [ECRR], 2014; Opperman et al., 2009).

Figure 14. Stream restoration where hydrologic connectivity is restored (Maeder, 2019)

While there are many benefits associated with stream restoration, there are also limitations. Removing stormwater controls will likely increase the area that is flooded during flood events that would have previously been controlled by the stormwater control infrastructure, and, over time, the stream will likely meander from its current path. This may be of particular concern for residents along Northwest Branch, south of East-West Highway (Figure 3). That area is deemed part of zone X, rather than AE, because it is protected by the Bladensburg levee system (NFIP, 2016). This likely implies that restoring Northwest Branch will requires acquiring properties in East Riverdale-Beacon Heights bounded by Northwest Branch, East-West Highway, and Kenilworth Avenue, and potentially others in the floodplain as well (FEMA, n.d.-b). A major stream restoration project usually costs from $200 to $300 per linear foot but can exceed $1,000 per linear foot. These costs include consulting, administration, construction, and input materials costs (McGill, 2014; Templeton, Dumas, and Sessions, 2008; Texas Water Development Board, 2013). However, despite the costs, implementing both floodplain property acquisition and stream restoration greatly increases flood resilience and could be an important long-term solution (ECRR, 2014).

More research and analysis should be done on the geomorphology of Northwest Branch, Brier's Mill Run, and Captain John's Branch, to determine if levee removal and stream restoration is a viable option for these streams, particularly its potential to increase or decrease flood risk and the associated costs. However, if removing stormwater controls and complete restoration is not feasible for the County, we recommend, at a minimum, reforesting and planting riparian borders, which can be an effective mechanism to reduce flood risk (ECRR, 2014).

5.2.3 Green Infrastructure

In addition to floodplain reconnection, green infrastructure can be used to decrease flood hazard, primarily by reducing runoff. Using a combination of techniques, green infrastructure increases the amount of stormwater that is intercepted, transpired, or infiltrated, before it can enter a stream as runoff (Figure 22). Green infrastructure techniques often use plants, because water is more easily retained in soils and plant bodies compared to cement, asphalt, or other hard surfaces. Although green infrastructure techniques are not often used for the express purpose of flood mitigation, they can still help reduce flood intensity, especially in combination with the techniques discussed in section 5.2.1 and 5.2.2 (EPA, 2015).

Different green infrastructure techniques can be applied on a range of scales and have a wide range of costs; they can be implemented by the County, residents, or both. In general, the broader the scale of implementation, the larger the benefit. To generate the greatest decrease of runoff into the Northwest Branch and Briers Mill Run, and the greatest decrease in flood hazard, these green infrastructure techniques should be implemented throughout the Northwest Branch and Briers Mill Run watersheds.

5.2.3.A Permeable Pavement

Urban areas with impermeable pavement allow larger volumes of water to travel above ground (Kushal & Belt, 2012). By contract, permeable pavements allow water to accumulate vertically, running into the ground rather than accumulating as surface runoff (Figure 15). According to the U.S. Environmental Protection Agency, permeable pavements help "infiltrate, treat, and/or store rainwater where it falls." Water seeps through the pavement into the soil and rocks beneath, which helps mitigate the amount of water accumulation, as well as filtering the water and therefore reducing the amount of pollutants that pose health risks. (EPA, 2018). Accumulating water in urban areas increases the risk of spreading pollutants, such as "carbon, contaminants…and nutrients" (Kushal & Belt, 2012). Permeable pavements can decrease both the physical damages and the health risks posed by flooding.

Figure 15. Permeable concrete (left) and permeable pavers (right) (NOAA, 2015)

The University of California, Davis (UC Davis) conducted a cost-benefit analysis of permeable versus impermeable pavements on its campus. Various permeable pavements were tested for runoff absorption and compared to conventional asphalt. All forms of permeable pavements absorbed around 98% of runoff, while asphalt absorbed about 32% of runoff. Permeable pavements can drastically reduce runoff levels by assimilating nearly all water runoff from flood events and allowing it to percolate into the earth below (Terhell et. al., 2015). It is this quality that enables permeable pavement to reduce flooding, "allow the recharge of underground water storage…[and remove] pollutants" (Terhell et. al., 2015). By reducing the amount of runoff at its source, permeable pavement also reduces the need for other green infrastructure and stormwater management techniques (Selbig and Buer, 2018)

While permeable pavements are nearly 300% more effective than traditional asphalt in water absorption, they pose an initial cost barrier that may make them difficult to implement in East Riverdale-Beacon Heights. The three types of permeable pavements tested at UC Davis were porous asphalt, pervious concrete, and concrete pavers costing $1.11 per square foot, $6.66 per square foot, and $11.10 per square foot, respectively (Terhell et. al., 2015). However, these three options have long lifespans and low upkeep costs; porous asphalt lasts 17.5 years; pervious concrete, 25 years; and concrete pavers from 25 to 30 years (Terhell et. al., 2015). These lifespans are comparable to asphalt, but they are all less prone to cracking. Once maintenance costs are included, permeable pavements cost $14.08 per square foot, whereas asphalt costs $17.05 per square foot, making asphalt much more expensive in the long run (Terhell et. al., 2015).

East Riverdale-Beacon Heights contains various types of commercial, office, and residential development, as well as mixed-use zones (Figure 2). The Northwest Branch and Briers Mill Run watersheds are also highly developed (M-NCPPC Prince George's County Planning Department, 2017). While development has increased the volume of water entering these streams as runoff during storm events, it also indicates a high potential for implementing permeable pavement, an extremely effective way to minimize runoff that the County should fully consider.

5.2.3.B Downspout Disconnection

Located on existing infrastructure, downspouts are pipes meant to drain surface water off roofs and into sewer systems (Sandink, 2015). A majority of these downspouts are connected to underground sewer systems where runoff from other sources combines with roof runoff, increasing the amount of stormwater in the sewer system (Sandink, 2015). Disconnecting these downspouts allows roof runoff to drain onto pervious surfaces, like grassy areas or gardens (Figures 16 and 17). This decreases the total amount of water flowing into sewer systems and nearby water sources, thus reducing flooding. Without disconnecting these downspouts, roof runoff will combine with runoff from other surfaces, increasing the volume of water that can enter a waterway and contribute to flood volumes.

According to Foster et al. (2011), one study concluded that if 80% of the studied neighborhood had disconnected their downspouts, there would have been a 30% reduction in runoff in that community. If residents within the same neighborhood installed a rain garden, there would have been an additional 4%-7% reduction in stormwater (Foster et al, 2011).

A professional downspout disconnection can cost around $2,000, making it an expensive residential project. As an example, Portland, Oregon invested $8 million in green infrastructure that saved $250 million in hard infrastructure costs (Foster et al, 2011) ofr physical structures, such as roads, bridges, and rails (Portugal-Perez & Wilson, 2010). Essentially, Portland replaced these hard structures that negatively impact the environment with green infrastructure that takes works with the environment. Portland's Green Street projects have managed 8 billion gallons of water, equating to 40% of Portland's annual runoff (Foster et al, 2011). Furthermore, if buildings and homes in the Portland region participated in downspout disconnection, combined storm and sewer overflow volume would be reduced by 20% (Foster et al, 2011). It is clear that downspout disconnection can greatly reduce the amount of water from storms and sewer systems in suburban and urban areas, which, in turn, reduces the vulnerability and exposure for residents in a floodplain, such as those in East Riverdale-Beacon Heights.

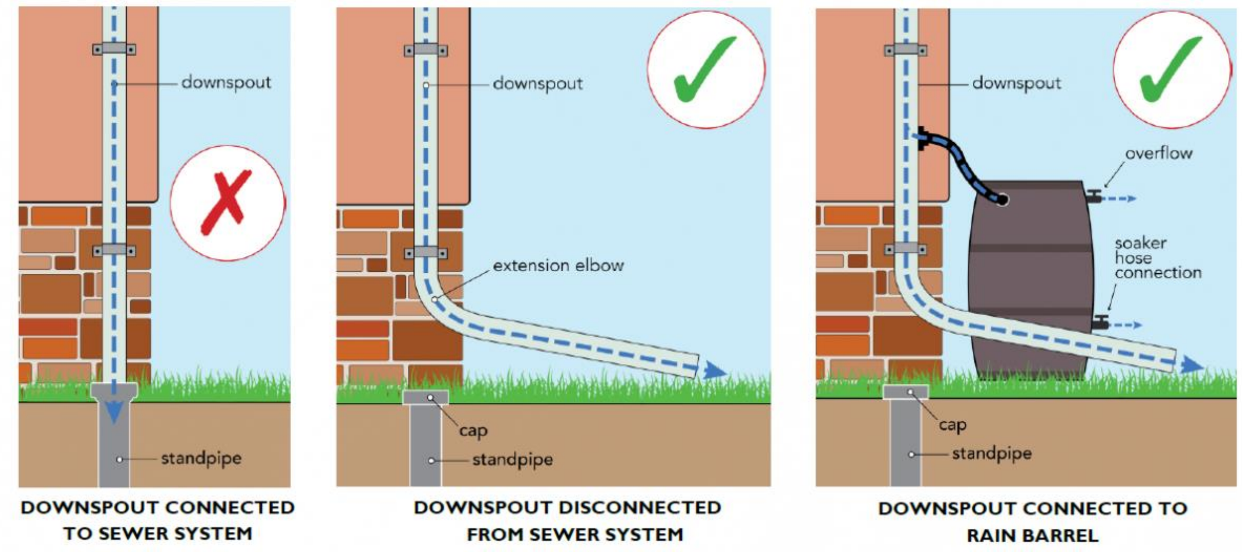

Figure 16. Downspout connected to sewer system (left), downspout disconnected (center), and downspout connected to a rain barrel (right) (DC Water, 2017)

Figure 17. Disconnected downspout (Brown, 2019)

Overall, downspout disconnect is effective in decreasing the amount of runoff, but homeowners need incentives to agree to make these green infrastructure changes. Most county-level environmental efforts in residential installation of green infrastructure offer incentives to encourage residents to install them. In 2009, Brian C. Fletcher from Portland State University conducted a study to identify what incentives "would help persuade [residents] to disconnect their downspouts." Fletcher sent out 500 surveys to residents in a high suitability zone asking what incentives would encourage them to disconnect the downspouts on their homes. Only 94 residents sent the survey back (19% of the survey population), and the top three incentives were "1) a $2.32 per month stormwater utility fee discount (35%), 2) free materials (20%) and 3) a how-to guide (18%)" (Fletcher 2009). Furthermore, 88 of the 94 residents that returned the survey answered whether they were willing to disconnect their downspouts (Fletcher 2009). Out of 88, 31% of residents said they were not willing to, 28% were willing, and 10% had already disconnected their downspouts (Fletcher 2009). The article did not state why residents were unwilling to disconnect.

Residents of the East Riverdale-Beacon Heights area will likely seek financial or other incentives to make some of these changes because area household income is low. In addition, residents need to be educated about some of the advantages of downspout disconnection, such as the ability to harvest rainwater.

5.2.3.B.1 Rainwater Harvesting

Rainwater harvesting, as defined by Boers (1997), is "inducing, collecting, storing, and conserving runoff from various sources for various purposes." The practice occurs in "small-scale operations in terms of catchment area, the volume of storage and capital investment" (Boers, 1997). Individual homes and smaller buildings are able to harvest rainwater, but a county, per se, cannot collect all of the rainwater that falls in its area into one container that the rest of the county can use.

Rainwater harvesting can provide many economic benefits. As stated by Rahmen et al (2012), rainwater harvesting has "great water saving potential" that can decrease the amount of water consumed per household. There is also a feeling of high reliability of having a water supply on hand (Rahmen et al., 2012). Water captured in rain barrels can be used for watering lawns and plants, and, most relevant to this project, can decrease the amount of water that contributes to flooding. Collecting rainwater decreases the amount of water going into sewer systems, which lowers the risk of flooding. Rainwater harvesting eventually pays for itself, but the time range over which this occurs varies with the type of installation. Imteaz et al (2011) conclude that the total cost of construction for installed tanks can be earned back "within 15 to 25 years depending on the size of the tank, as well as climatic conditions and future water price increase rates." It is feasible for homeowners to install structures that would collect rain and allow them to use it.

Figure 18. A garbage can used as a rain barrel ("Great DIY Rain Barrel", 2011)

The cost of rain barrels varies depending on the type of rain barrel and where the customer is buying it. Rain barrels can cost anywhere from $33.99 to $2,000, depending on their quality, size, and durability. A 50-gallon rain barrel can be purchased from Amazon.com for $33.99, while a higher quality, more professional rain barrel that holds 5,000 gallons from National Tank Outlet will cost approximately $2.000. Homeowners can also create a rain barrel themselves, an affordable option that will work just as well. For example, an industrial garbage can, shown in Figure 18, can cost up to $62 dollars depending on how many gallons it can contain ("Uline Trash Can - 55 Gallon, Gray," n.d.). Other materials needed would be a spigot, two hoses (one for regular use and one to function as an overflow drain), a utensil or drill to cut holes, a curved end-piece of the downspout, brackets, and other materials. In this instance, this rain barrel is used to water the property's gardens and landscaping. The total cost depends on what the rain barrel would be used for, such as drinking water or a greywater system. Residents of East Riverdale-Beacon Heights have many options for installing rain barrels and rainwater harvesting systems. Some can be affordable, while other options are more expensive. In both cases, a rain barrel can be an effective way to mitigate flooding in the community.

5.2.3.C Bioretention

Bioretention is a stormwater management practice that reduces runoff and removes pollutants by creating spaces where stormwater can be redirected, filtered, or absorbed to limit water quantity and improve water quality (Scott, 2013). The efficacy of a bioretention practice ranges with size, structure, and placement, but can lead to anywhere from 40-80% reduced runoff, 56-69% removal of total nitrogen, 66-80% removal of total phosphorus, and 71-86% of total suspended solids (Scott, 2013).

All bioretention areas use vegetation as a part of their filtration, as plants are able to take up stormwater and different types of pollutants (Scott, 2013). When planting in any type of bioretention structure, the vegetation can be optimized to decrease overall cost and the structure's longevity. For example, if mulch is used, it can be costly to replace every year after it's washed out or decomposing, but a "careful selection of a diverse plant palette that includes herbaceous material such as ground covers in lieu of widely spaced woody species can result in a reduction in maintenance costs" (Scott, 2013). Additionally, a planting plan should consider the dynamic nature of plants and how conditions may change over time instead of planting to meet only current requirements. Plant evaluations in specified time increments (e.g., every couple of years) can evaluate plant condition to confirm they are still appropriate (Scott, 2013).

Since bioretention facilities vary in vegetation and structure, their installation and maintenance costs also vary, with the capital cost ranging from "$7 to $60 per cubic foot of storage provided depending on the type of bioretention" (Center for Neighborhood Technology, 2018). Most of the cost is related to construction and initial maintenance, but given their design and purpose, they have lower maintenance requirements and costs moving forward. The County should consider recommending and implementing bioswales and rain gardens, due to their efficiency and costs.

5.2.3.C.1 Bioswales

Bioswales are "vegetated, mulched, or xeriscaped channels that provide stormwater treatment and retention" (Environmental Protection Agency, 2018). Bioswals are beneficial in areas of impervious pavement, such as parking lots or alongside streets and sidewalks. They are similar to gardens, but they don't require an outside source of water (such as a sprinkler) to survive. The water runoff filters through layers of plants and soils, it accumulates in a pipe in the gravel underneath the bioswale and eventually returns to the storm drain system (Crapps et. al., 2014).

While bioswales are "the most effective type of green infrastructure facility in slowing runoff velocity and cleansing the water," they are a mitigation solution that would be difficult for residents to implement on their own properties, making them more appropriate as a County project (Social Ink, 2016). Everett et al (2015) surveyed bioswale awareness and opinions among residents in Portland, Oregon. The survey measured the percentage of residents aware of bioswales, their advantages, and their disadvantages. Further findings showed whether residents mentioned the characteristics of bioswales or their specific advantages and disadvantages. About 45% of residents interviewed were aware of bioswales and less than 10% of residents could mention the specific advantages or disadvantages (Everett et. al., 2015). The study noted patterns in low acceptance of bioswales based on "environmental attitudes, awareness and understanding of purpose and function, plant choice and maintenance, and mess and littering," which reflects the public education that was provided to Portland residents.

There are numerous benefits associated with bioswales, including "water quality and flood benefits," air-quality improvement, and improvement in "biodiversity, aesthetics, which in turn have been argued to improve mental wellbeing" (Everett et. al., 2015). If these benefits were highlighted, along with their flood mitigation, East Riverdale-Beacon Heights could create an engaged community to facilitate positive attitudes toward more intensive or expensive flood mitigation strategies.

Implementing bioswales in East Riverdale-Beacon Heights will require upfront costs for building and for hiring engineers who can construct the bioswales, as well as additional costs to maintain the bioswales. According to Crapps, Bolanos, and Folchi in their Santa Clara University thesis, one bioswale can cost up to $17,500 excluding labor costs, depending on size, location, and resources (Crapps et al, 2014). However, implementation and maintenance costs can be partially supported by tax revenue. This would be similar to Portland, where "the residents' sewer and water fees are used to install and maintain bioswales, opening up debate" among residents about how their tax money should be spent (Everett et. al., 2015). If bioswales are a successful mitigation strategy for East Riverdale-Beacon Heights, there would need to be extensive education and awareness, so residents have the background needed to make educated decisions on whether they support bioswales or not.

5.2.3.C.2 Rain gardens.

Rain gardens are another bioretention method for managing stormwater runoff. While bioswales are designed to filter and redirect stormwater, rain gardens are designed to absorb stormwater to reduce runoff (US EPA, 2015). They serve as basins that help filter out pollutants as stormwater percolates through the soil (Scott, 2013). Most rain gardens are structured to create a bowl shape, which allows water to temporarily pond on the surface and then sink through the "filter bed" (or media layer) where it is collected by an underdrain (a perforated pipe beneath the filter bed) and conveyed to the storm sewer system (Scott, 2013). Figure 19 shows an example of a rain garden between two parking lots and illustrates the bowl shape with a drain at the center. Not all rain gardens require an underdrain, especially in areas where soils have good infiltration capacity (Scott, 2013). In many cases, amended soils or gravel beds can be used for drainage. In any case, the soil's infiltration capacity should be tested.

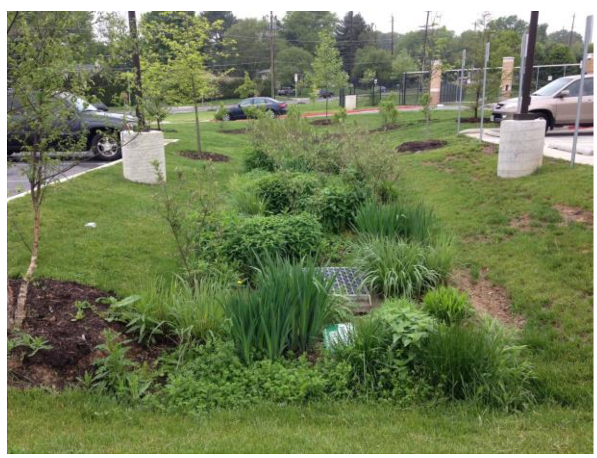

Figure 19. A rain garden (Montgomery County Government, 2019)

Rain gardens are most effective at smaller scales that receive "runoff from an area of no more than one to two acres to avoid high volume flows that would erode plant materials" (Naturally Resilient Communities, n.d.), making them a viable option for individuals to implement on their own properties. While rain gardens of any size are beneficial, they generally should be “10 and 20 percent of the square footage of the area of impervious surface (driveway, sidewalks, etc.) that they are receiving runoff from” (Naturally Resilient Communities, n.d.). On average a rain garden’s installation costs are between $5.15 and $16.05 per square foot, 31 to 61 cents per square foot for maintenance, and can last 25 to 50 years (Center for Neighborhood Technology, 2018). Smaller and less expensive rain gardens are an accessible and effective option for both individual citizens and the County.

5.2.3.D Green Roofs

Figure 20. A rural green roof (Moore Farm, 2019)

According to the United States Environmental Protection Agency, a green roof is defined as one "covered with growing media and vegetation," which "enable rainfall infiltration and evapotranspiration of stored water" (Environmental Protection Agency, 2018). This natural form of modern urban and suburban infrastructure slows the movement of water and helps with absorption and purification, in addition to preventing water from accumulating as runoff (Figure 20). Green roofs decrease flood intensity because they slow the storm peak entering the drainage system, which reduces the amount of runoff, in addition to "purifying the air pollutants as well as runoff quality" (Li & Yeung, 2014).

However, green roofs are currently used more often in urban rather than suburban settings and they are also very expensive. These aspects may reduce the incentive for residents in the East Riverdale-Beacon Heights area to invest in green roofs. Additionally, there are many factors to consider when determining which plants to use in a green roof. Green roofs are generally composed of "drought tolerant, solar radiation tolerant, and cooling ability plants," but the plants must also be able to survive in the climate they're placed in (Li & Yeung, 2014).

A general cost-benefit analysis performed in Belgium showed that the lifespan of a green roof is "significantly longer than standard roof covering;" they also provide greater protection against harsh weather and better heat insulation (Claus & Rousseau, 2012). According to Li & Yeung, cost depends on the "growing medium, quantity of plants, and drainage system." Prices also vary depending on whether the green roof is extensive or intensive, with the source of materials, and the maintenance costs. Simple or extensive green roofs can cost as little as $10 per square foot, which converts to about $100.76 per square meter. Complex, or intensive green roofs, can cost up to $270 per square meter. Maintenance costs range between $8 to $11 per square meter. Costs increase dramatically based on the source of the materials; materials imported from outside the country of construction can cause green roofs to cost anywhere from $90 to $130 per square meter with maintenance costs between $1 to $6 per square meter. In contrast, green roofs that rely on local materials, can cost between $50 to $80 per square meter with maintenance costs from $0.1 to $0.3 per square meter (Li & Yeung, 2014). The cost of green roofs can be very high however, with local construction and maintenance, they have the potential to reduce the impacts of flooding in East Riverdale-Beacon Heights.

Green roofs are most likely not practical for East Riverdale-Beacon Heights residents, due to the high costs. However, this solution could be implemented by the County, with roof replacement on municipal buildings with larger and flatter roofs that can support green roofs (Claus & Rousseau, 2012). Additionally, subsidies could be used to encourage green roof construction on commercial buildings and to encourage residents to consider green roofs to mitigate flood risk in their community.

5.2.3.E Blue Roofs

Blue roofs are similar to green roofs in that they are designed to store water and reduce peak flow and runoff volume, however, they are not vegetated (Figure 21). On average blue roofs are designed to hold “up to eight inches of precipitation either on its surface or in engineered trays” (Eastern Research Group, Inc., 2014). Blue roofs decrease runoff by storing water prior to discharge and allowing some of that water to evaporate (Eastern Research Group, Inc., 2014). While they are effective at storing water and reducing runoff, they lack “the additional pollutant removal-benefits of green roofs”(Eastern Research Group, Inc., 2014). Precipitation discharge is released slowly and controlled by “a flow restriction device around a roof drain”(Eastern Research Group, Inc., 2014). The water is either released to a storm sewer system, cistern, bioretention area, or other green infrastructure practice (Eastern Research Group, Inc., 2014).

Figure 21. A blue roof (NOAA, 2015)

Like green roofs, blue roofs “require flat or gently sloping roofs that are structurally engineered to withstand the necessary weight for these systems” (NOAA Office for Coastal Management, 2015). Roofs with slopes greater than 2% may have limited storage capacity and are not well suited for blue roof infrastructure (Philadelphia Water Department, 2019). Blue roofs are more versatile and less costly than green roofs, and usually only add an additional $1 - $5 to the cost of a traditional roof per cubic foot (Eastern Research Group, Inc., 2014). Capital costs for blue roofs range from $2 to $10 per cubic foot of storage provided, and $1 to $5 per square foot with a 6-inch depth (NOAA Office for Coastal Management, 2015).

Blue roofs can be effective under certain conditions. Some sites may receive limited benefits if the roof is only a small portion of the total impervious area (Philadelphia Water Department, 2019), and they may limit opportunities to retrofit structures. Additionally, they don’t provide the benefits that come with green roof vegetation such as improved aesthetics, habitat creation, and improved air quality (Philadelphia Water Department, 2019). It is also crucial to consider any other structures installed on the roof or conditions that may affect the roof ponding such as mechanical systems, roof furniture, and overhead trees (Philadelphia Water Department, 2019). Depending on the individual building, blue roofs may be more accessible than green roofs for the larger and flatter roofs in the East Riverdale-Beacon Heights area, as they are less costly and require less maintenance. However, many other factors must be considered first.

5.2.3.F Urban Tree Canopy

As previous strategies have shown, nature-based flood mitigation techniques can be very effective. Urban tree canopies are another such technique that can be used to “reduce and slow stormwater by intercepting precipitation in their leaves and branches” (Environmental Protection Agency, 2018). This is a simple flood mitigation strategy that both residents and the County can use.

There are numerous reasons trees are beneficial for flood mitigation, including their ability to intercept precipitation and perform transpiration, infiltration, and pollutant removal (Figure 22). Interception is defined as the absorption of precipitation that falls on plants’ leaves, branches, or trunks. Interception slows the water and prevents it from reaching the ground and becoming runoff.

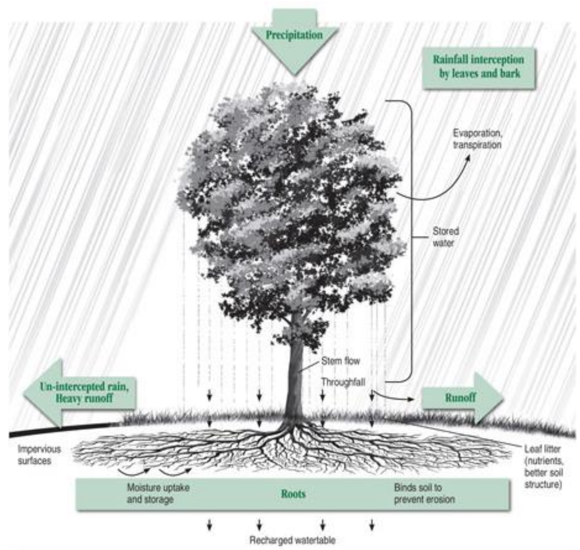

Figure 22. Interception, transpiration, and infiltration ("Tree Canopy BMP", n.d.)

Transpiration, the process by which trees uptake water from the soil and release it as water vapor is another benefit provided by trees to prevent flooding (Stone Environmental, 2014). Transpiration allows trees to hold water and emit it back into the atmosphere; it serves as a form of water storage other than surface and groundwater.

Finally, plant roots also create soil conditions that promote infiltration. Infiltration decreases flood risk by “reducing both the rate and volume of stormwater runoff” (Stone Environmental, 2014).

Planting trees is a mitigation strategy that can be implemented by both residents and the County. Residents can plant trees in their yards, and the County can do the same on public land, varying the scale and number of trees planted. Tree planting also has a low initial cost barrier. According to Vogt et. al. (2015), only 14% of tree planting costs are associated with planting, while the majority of the costs are maintenance. However, trees require a lot of care in their early stages, making them difficult to see into maturity. There are numerous incentive programs in Maryland, such as the Environmental Quality Incentive Program (EQIP), and the Woodland Incentive Program (WIP); however, these two programs mainly focus on providing timber or reforesting large-scale areas that have been deforested (Maryland Department of Natural Resources, n.d.). It would be difficult to find State or federal programs that accommodate small scale planting to reduce floods. Prince George’s County could start their own incentive program or raise awareness for residents to plant their own trees.

5.2.3.G Economic Incentives

Encouraging residents to apply green infrastructure techniques can be difficult, since they ask residents to pay for something they don't immediately or directly benefit from. However, residents can be encouraged residents to apply these techniques.

As mentioned previously, citizens may be more willing to disconnect their downspouts if they were given a stormwater utility fee discount, free materials, or a "how-to" guide (Fletcher 2009). Similarly, residents of Milwaukee, Wisconsin were given free rain barrels, which led to their increased use (Great Lakes Coalition, 2010). Providing rain barrels would be a low-cost way for the County to encourage both downspout disconnection and rainwater harvesting. Even if the County can only supply rain barrels for a some of residents, it can lead to greater use overall. Residents are typically more inclined to take action if they see their neighbors disconnecting their downspouts, using rain barrels, and installing rain gardens (Kousky and Shabman, 2015).

Additional funding can be provided by the Rain Check Rebate Program, a Chesapeake Bay Trust and Prince George's County partnership. This program offers homeowners and businesses incentives to install stormwater management systems that will reduce runoff ("Prince George's County Rain Check Rebate," n.d.). If a homeowner or business purchases a rain barrel or any other installation that reduces environmental impacts of stormwater and flooding, the County will reimburse them for costs covered by the program ("Prince George's County Rain Check Rebate," n.d.). Seven practices are eligible for reimbursement: rain barrels ($2/gallon stored), cisterns ($2/gallon stored), urban tree canopies ($150/tree), rain gardens ($10/square foot), pavement removal ($6/square foot), permeable pavement installation ($12/square foot), and green roofs ($10/square foot) ("Prince George's County Rain Check Rebate," n.d.). Property owners who reduce the quantity or improve the quality of stormwater leaving their property using green infrastructure practices (termed best management practice by Prince George's County) are also eligible for a Clean Water Act Fee reduction credit (Prince George's County, Maryland, n.d.-c).

5.2.4 Funding Options

Multiple options are available to fund the flood hazard mitigation actions recommended above—fees, taxes, grant programs, and loans. Currently, Prince George's County residents are charged a Clean Water Act Fee, which includes an Administrative fee of $20.58, and an Impervious Area fee rate of $20.90 per 2,465 square feet of impervious area, which is termed an Equivalent Service Unit (Clean Water Act Fee Regulation of 2013). Fees like this, are an equitable way to consistently raise money each year (via the Adminstrative Fee) and charging people for their contribution to runoff (via the Impervious Area fee) (Clean Water Act Fee Regulation of 2013).

The County could also raise taxes to raise money for flood mitigation actions. However, though taxes provide a consistent annual funding source, they aren't an equitable way to charge people for their contribution to stormwater runoff (EPA, 2008).

The County can also seek external sources of funding in the form of grants and loans, such as the Prince George's County Stormwater Stewardship Grant, funded by the Chesapeake Bay Trust. The Chesapeake Bay Trust provides grant funding to "non-profit organizations, municipalities, watershed organizations, education institutions, community associations, faith-based organizations, civic groups, and more" for the installation of "bioretention cells, bioswales, rain gardens, and other Environmentally Sensitive Design (ESD) stormwater techniques" (Chesapeake Bay Trust, 2019b). Up to $200,000 of funding is available depending on the project size. The Trust's grant program also offers up to $150,000 for tree-planting projects, as long as 80% of trees are planted on residential properties. East Riverdale is a designated priority zone for urban tree canopy, meaning that funding for a project in East Riverdale-Beacon Heights is likely to be approved (Chesapeake Bay Trust, 2019b).

The Chesapeake Bay Trust also manages the Green Streets, Green Jobs, Green Towns (G3) Grant Program, which is funded by the EPA. Any municipalities "interested in integrating green stormwater infrastructure as a matter of standard practice in current or future strategies" are eligible. Green streets are those that incorporate green infrastructure techniques to reduce runoff, reduce the urban heat island effect through the use of urban tree canopy, and improve the walkability, bikeability, and aesthetic appeal of the street. Up to $15,000 is available for conceptual green street plans, up to $30,000 for a complete engineered design, and up to $100,000 for the construction and implementation of a green streets project (Chesapeake Bay Trust, 2019a).

Another grant opportunity is the Outreach and Restoration Grant Program, also managed by the Chesapeake Bay Trust. This grant program funds projects that improve the quality of natural resources, including water quality, and that engage and inform community members about environmental resources. Up to $50,000 is available for restoration-only projects accomplished through techniques such as planting tree, creating riparian forest buffers, and implementing green stormwater infrastructure, including "bioretention cells, bioswales, rain gardens, rain barrels, and other low impact development techniques" (Chesapeake Bay Trust, 2019c). Up to $75,000 is available for projects that restore water quality and natural habitats and "measurably build knowledge within the community served" (Chesapeake Bay Trust, 2019c). In Prince George's County, a restoration program that increases recreational opportunities around the Northwest Branch and provides educational opportunities, as current stream valley parks do, would be eligible for funding under the Outreach and Restoration Grant Program. Including residents in planning and design also increases the funding priority of the project (Chesapeake Bay Trust, 2019c), and increases the likelihood of project success (ECRR, 2014).

The Five Star and Urban Waters Restoration Grant Program, managed by the National Fish and Wildlife Foundation (NFWF) and the Wildlife Habitat Council (WHC), also provides grant funding for wetland or riparian habitat restoration, urban tree canopy enhancement, and green infrastructure practices. Funding priority goes to projects that decrease environmental hazards and engage communities, especially underserved communities, in project design and implementation. Emphasis is placed on engaging youth. Projects must also have a diverse group of five community partners, including the applicant. While Prince George's County is eligible to apply, it is not located in a geographic priority area (National Fish and Wildlife Foundation, n.d.).

The Clean Water State Revolving Fund (CWSRF), a loan program managed by the EPA, can also be used to fund green infrastructure projects. Eligible projects include the green infrastructure techniques mentioned above, as well as stream restoration and land acquisition. Loans are paid back over the course of 30 years or the life expectancy of the project, whichever is less. Interest rates range from 0% to market rates, at an average of 30% below market rate. Loans are capitalized 80% by the EPA and 20% by the State of Maryland. The CWSRF will fund the capital costs of green infrastructure projects and other projects that reduce pollutants entering waterways. Land acquisition can also be covered, if the land is used for stormwater control purposes. Since the infiltration of stormwater into soil is a method to reduce runoff and associated pollutant discharge, land acquisition for the purpose of green infrastructure projects can be eligible for loans. CWSRF loans will not cover maintenance projects. The State of Maryland can also charge an additional fee on CWSRF loans to pay for insurance that covers green infrastructure projects in case they fail (EPA, 2016).

5.2.5 Implementation of Holistic Flood Mitigation Plans

Many municipalities have greatly reduced their flood risks by using a combination of techniques. For example, in 2011 New York City implemented an extensive and multifaceted flood mitigation plan (NYC DEP, 2013). The City's goal was to implement green infrastructure. After forming the Green Infrastructure Task Force in 2012, it began constructing structures including blue roofs and bioswales (NYC DEP, 2013). The City also implemented a grant program "to strengthen public-private partnerships and public engagement in regard to the design, construction and maintenance of green infrastructure," that provided private entities with funding to implement green infrastructure in critical areas (NYC DEP, 2013). The City monitored these efforts and observed varied results due to the particulars of each structure but found "a reduction in the volumetric runoff coefficients for areas where practices were constructed." The City concluded that green infrastructure was a "valuable tool in managing stormwater runoff" (NYC DEP, 2014).

Kansas City also undertook a successful flood mitigation program using green infrastructure. The project was extensive, applied to an area of approximately 100 acres (KC Water Services, 2013). The project included developing 135 vegetated structures and 27,490 square feet of non-vegetated solutions, including "rain gardens, bioretention, curb extension rain gardens, permeable paver sidewalk, and porous sidewalk" (KC Water Services, 2013). Monitoring of the infrastructure installments found an overall decrease in runoff at each site (KC Water Services, 2013). One particular site collected 292,000 gallons of stormwater and reduced the peak runoff flow by 76% (KC Water Services, 2013). Additionally, this project increased community investment by residents. Researchers noted a surge in community pride after the project's completion and that a previously less active neighborhood group now meets "monthly and continues to actively seek projects and support from the City to improve their neighborhood, with much success" (KC Water Services, 2013).

Milwaukee was also able to reduce the risk associated with flooding of the Kinnickinnic River using some of the aforementioned techniques. Similar to Northwest Branch, the Kinnickinnic River was channelized in the 1960s, which put adjacent homes at a greater flood risk. To reduce this risk, the river was re-naturalized, and the adjacent 56 homes were bought and converted into open space, allowing more flood waters to be stored in the floodplain. Additionally, after the community was educated on ways to reduce their own flood risk, residents began using green infrastructure techniques to reduce runoff. At least 40 residents installed rain gardens on their property, and many more have started using rain barrels donated by the Milwaukee Metropolitan Sewerage District. These changes have reduced flood risk for the Milwaukee residents (Great Lakes Coalition, n.d.).

5.3 Reducing Vulnerability

In addition to the physical aspects of flooding, hazard and exposure, the characteristics of an individual or a group can make that person or group more vulnerable to the effects of flooding. Vulnerability can be defined as “the state of susceptibility to harm from exposure to stresses associated with environmental and social change and from the absence of capacity to adapt” (Adger, W. Neil, 2006). In the context of floods, it refers to a person’s ability to prepare for, respond to, and recover from a flood. Vulnerability is influenced by age, race, socioeconomic status, and other social characteristics (Kaźmierczak and Cavan, 2011). It can be reduced in multiple ways, however strategies must be created to address the specific needs and perspectives of individuals. While strategies that address vulnerability are varied, the key to each solution is providing every member of the community the tools they need to adapt and change. By addressing vulnerabilities within a community, the County gives each individual access to safety and information, while also strengthening the community as a whole.

5.3.1 Flood Insurance

The ability to prepare and recover from a flood event can be increased with the purchase of flood insurance. Residents in a 100-year floodplain are required to purchase federal flood insurance. However, low-income communities not in a floodplain are less likely to purchase flood insurance due to premium cost; this puts them at greater risk and leaves them less likely to recover if a flood event occurs (Prince George’s County, Maryland, n.d.-a).

The County participates in the NFIP Community Rating System (CRS) program, which provides flood insurance discounts to participating communities that take actions to decrease flood risk. The CRS program awards credits in various amounts for each approved and documented action a community takes to decrease flood risk. The number of credits corresponds to a class rating scale, ranging from 1 to 9, with Class 1 corresponding to the highest number of credits, which generates a flood insurance price reduction. Class 9 corresponds to the least number of credits and limited flood insurance price reduction (FEMA, 2017). Prince Georges County is rated as class 5, which grants County residents who live in the 100-year floodplain, termed a Special Flood Hazard Area (SFHA), a 10% price reduction on flood insurance. Residents not in the 100-year floodplain merit a SFHA 25% price reduction (*Hazard Mitigation Plan*, 2010).

There are actions the County could take to earn a better rating, which could lower flood insurance premiums even further. The CRS programs awards credits for flood mitigation actions in four categories: public information, mapping and regulations, flood damage reduction, and warning and responses (FEMA, 2017). Following the suggestions to reduce flood risk discussed above, as well as the communication strategies discussed below, FEMA would be likely to award the County additional CRS credits, which may be enough to move it to a Class 4 rating. This would grant residents who do not live in a SFHA a 30% reduction in flood insurance costs (FEMA, 2018), increasing the likelihood that residents will be able to purchase flood insurance, and decreasing their vulnerability.

5.3.2 Prioritizing Census Participation

An important strategy that can combat vulnerability is communicating the importance of the US Census. While many may view the census simply as a way for the government to gain insight into an area's demographics, the information gathered shapes the way the government allocates money and resources in their budgeting process (USCB, 2018). In a recent study, the United States Census Bureau found that many US citizens see no point in the Census, with 40% of participants stating that they did "not feel it matters whether they are personally counted in the 2020 Census" (Walejko, 2019) and that "young people ages 18 to 34 were the least likely to believe it matters if they are counted" (Walejko, 2019). The study also revealed that many distrust the government and Census participation, with about 25% of respondents being concerned with the confidentiality of their answers to and 25% of respondents fearing "that their answers to the 2020 Census will be used against them" (Walejko, 2019).

The 2010 Census miscounted Prince Georges' County by a staggering 19,900 people, which resulted in more than a quarter billion dollars of funding being denied to the County (Valerio, 2019). According to online guidance provided by the Census Bureau, "single mothers, and parents in low-income areas, are less likely to take time to fully complete the forms (Valerio, 2019)." Census officials have mapped the lowest levels of census participation in the Count; areas with lower-incomes closest to Washington D.C rank among the highest in levels of non-participation (M-NCPPC, 2019).

It is particularly dangerous for residents in flood zones not to participate in the census. Regional emergency managers use Census data to "track population growth, identify vulnerable communities, analyze how commutes impact evacuation routes, and study characteristics and growth in housing units" (Khashan, 2018). Along with other flood risk communication, it is important that the County convey that "census participation is important and desirable" especially among young people (Walejko, 2019). Additionally, the County "will need to assure and reassure people that participation is safe" and that "they will not be asked for information that would compromise their privacy or safety" (Walejko, 2019). Census data is not shared with any other government agencies, especially law enforcement, and it won't be used against participants (Walejko, 2019).

5.3.3 Access to Information and Communication Strategies

In the past, risk communication has usually been carried out by government officials, scientists, and nonprofit organizations that disperse information about flooding in a top-down manner. This includes "guidelines, information brochures, media campaigns, and internet websites, which individuals may or may not [comprehend]" (Aerts et al., 2014). Usually, these efforts assume that the risk involved is objectively understood and that the public simply needs more information to bridge a gap in knowledge (O'Sullivan et al., 2012). Given this assumption, "most emergency management practices and related communication campaigns are still dominated by… one-way learning and systems approaches" (Mitchell et al., 2008). Risks are also usually explained for a general audience and do not take into account special interests or needs. Assessment of risk can be affected by a variety of situational, social, cultural and psychological factors, and is additionally influenced by the socio-cultural context and perception of risk by the community as a whole (O'Sullivan et al., 2012). Moving forward, authorities need to assess how different groups of people take in and respond to new information by researching within the community itself. Additionally, the County should adopt community-centered communication focuses on specific needs as opposed to a one-size-fits-all plan to effectively reduce risk.

In addition to the gap in traditional communication systems, many people do not understand their relationship to flood risk. When assessing a variety of environmental hazards, people often find risks to be remote, abstract or too fantastic and catastrophic to be taken seriously (Sheppard, 2012). The average person residing in an urban environment such as East Riverdale-Beacon Heights cannot accurately envision how flooding will affect their lives because they are living in a controlled environment surrounded by infrastructure (Sheppard, 2012). Environmental disaster is usually depicted as melting ice caps and famine in remote villages, which contributes to the disconnect between perceived and actual environmental risks. Global examples don't feel applicable, leaving many people with no real understanding of how projections will impact flooding in their community. Using global or large-scale examples can also be frightening, and research has shown that the public feels "overwhelmed and powerless to act" (Sheppard, 2012) when presented with this type of information.

Dense charts and figures that are hard to interpret also contribute to a lack of understanding (Sheppard, 2012). In *Climate Change and Storytelling,* Anika Arnold perfectly describes the perception dilemma when she states that "complex scientific issues such as climate change and related topics pose challenges to 'classic' communication strategies, that cannot be met by simply steering the public debate in a scientific direction" (Arnold, 2018). Since flood risk is often incorrectly perceived, it is important to prioritize the accurate conveyance of severity.

Community engagement efforts should combat the disconnect in perception between flooding and each citizen's role in mitigation. It is important to emphasize that flooding is a real risk, likely to impact a growing number of residents in the East Riverdale-Beacon Heights area. It is also crucial for citizens to know the actions they can take to prevent flood damage to themselves and their property, and the mitigation efforts that can be enacted on an individual level. The next section explores communication strategies that can be used to encourage immediate action in East Riverdale-Beacon Heights.

5.3.3.A Current Strategies

The County uses several methods to inform residents about flood risks. Public libraries contain elevation certificates, flood insurance rate maps, floodplain studies, and other information about flood damage and risk. Additionally, the State of Maryland requires disclosure of flood risk in real estate transactions, and disclosure of flood risk is also required for zoning and permitting in Prince George's County.

Public outreach is a major part of the County's flood risk reduction strategies. The County conducts an annual outreach to floodplain residents, mailing "letters about flood hazards and mitigation measures to about 3,700 owners of properties that are impacted by mapped flood hazard areas and brochures about the NFIP to about 300 insurance agents, mortgage lenders, and real estate agents that do business in the County." The County has also declared June "Flood Awareness Month," providing flood information booths at various fairs, and having a dedicated telephone number for citizens to use for questions about flooding and stormwater concerns (*Hazard Mitigation Plan*, 2010). However, the most accessible way that Prince George's County residents can find information about flood risks is on the County's website. The website provides access to the Flood Protection Program, Flood Protection Library, Flood Warning Program, Flood Assistance Program, Flood Protection Assistance Program, Maintenance of Stormwater Management Facilities and the Development Review Activities (Prince George's County, Maryland, n.d.-b).

Though these resources are informative, there is room for improvement in how they can help the East Riverdale-Beacon Heights community. At present, these resources don't prioritize East Riverdale-Beacon Heights residents' access to information; they are provided for the County as a whole and are not specifically targeted to the East Riverdale-Beacon Heights community. Nor does the material adequately convey the urgency of the problem. Also, most of these strategies use a top-down approach, where the County serves as a source of information. To effectively convey this information to the community, there is a need for more localized outreach that describes residents' relationship to flood risk by personalizing the issue and considering their unique perspectives.

5.3.3.B Localization

As previously stated, many members of the public don't accurately perceive the risks of flooding and other natural disasters. The risks are either minimized or not dealt with because of the uncertainty of their occurrence, or because they are projected far into the future. A National Weather Service study of its Flood Forecast and Warning Tools found that "people differ in how they react to uncertainty; for some, not having a concrete example of what a risk means can make them uncertain of what the actual impacts might entail, and thereby impede their decision on whether to take action" (Hogan Carr, 2015). The study found that even in situations where people would have plenty of time and warning, they might "fail to respond to warnings and often suffer substantial damages and loss of property" (Hogan Carr, 2015). This study analyzed a test group who experienced flooding in the Susquehanna River Basin by exposing them to different types of flood warning materials (Hogan Carr, 2015); it found that the most effective risk communication occurred when the context was localized for a target audience.

When projections included community reference points, such as maps that mark specific regions and towns, citizens were more likely to respond and act. Additionally, the design and word choice of messaging was crucial to the response (Hogan Carr, 2015). The map's and warning system's fonts and colors affected how easily the audience was able to understand the information, and viewers responded to a color scheme that "clearly delineate[s] areas likely to have damaging river flooding" (Hogan Carr, 2015). Audiences also responded more readily to wording such as "damaging river flooding impacts" rather than "significant;"

they were unclear on what significant meant and were left to interpret the meaning on their own (Hogan Carr, 2015).

By specific, easy-to-understand graphs and maps, the National Weather Service localized the issue for Susquehanna River Basin residents. Similarly, the GIS maps in this report can be used to communicate the flood risk specifically within East Riverdale-Beacon Heights. These maps show areas lacking mitigation solutions and areas likely to be affected by future flooding due to climate change. Community outreach directors should use these maps to help residents grasp the immediacy of the issue and visualizing where flooding issues will occur.

Similar communities have been receptive to GIS materials. A study of a South Carolina community impacted by environmental hazards found that residents "have expressed interest in obtaining training in GIS to increase environmental awareness and build community capacity to address local environmental health issues (Wilson, Murray, Jiang, Dalemarre, Naney, Rahim, 2015). Specific maps are not only a desirable resource to specify flooding risk, they also improve on County resources.

Other strategies can be used to localize flooding issues for East Riverdale-Beacon Heights. Before and after photos and virtual reality can effectively convey urgency and the potential of mitigation and adaptation strategies. Sheppard asserts that "visual evidence, pictorial examples, and new media approaches will stimulate community-level dialogue and action plans" (Sheppard, 2012). Imagery showing an area as it will appear during a flooding event creates a sense of urgency to take mitigation and adaptation action. Any use of visuals such as "site design, signs, photography, maps, film, and science-based visualizations of the future" will further improve residents' perceptions of the issue and prompt them to take action. Conveying the risk of flooding through visual presentations and processes helps engage the community by making it tangible.

Visuals can be built into mitigation strategies using eco-revelatory design. This tactic aims to frame or explain the environmental impact through visualization to increase public awareness, promote sustainable behavior, and reveal ecological processes (Sheppard, 2012). Eco-revelatory design allows citizens to visualize the direct effect of their actions on their surroundings, which in turn connects them to the solutions enacted. Designs can range from practices that emphasize the potential of flooding by capturing rainwater in rain gardens or commemorating a stream lost to infrastructure by painting the stream's original location (Sheppard, 2012). The University of Maryland has used eco-revelatory design to spread campus awareness of air pollution. The McKeldin Library biowall contains 1,000 plants in eight varieties that filter the air and absorb air pollution. The wall, near the entrance, creates a beautiful setting and encourages student engagement. This strategy communicates the ecological benefits of a garden and provides students with an example of plant species they can incorporate into their own living spaces. Similar effects can be achieved in East Riverdale-Beacon Heights if mitigation strategies are implemented with design in mind, or with additional signs as supplementary educational material.

5.3.3.C Personalization

The perception of flooding and mitigation can also be altered by personalizing flooding risk. The National Weather Service study on flood communication in the Susquehanna River Basin also found that a key component of successful communication was the involvement of peers and neighbors. Participants placed great value on the actions and opinions of peers in their vicinity, and that "seeking out and reflecting upon information with family, friends, and neighbors is a critical step in motivating preparedness" (Hogan Carr, 2015). By communicating with others in their immediate circle they were able to watch "others prepare and discuss plans with trusted sources" (Hogan Carr, 2015).

Peer influence and risk personalization were deemed directly connected, which suggests that strategies using group communication or the involvement of influential community members would be effective. Overall the study found that the most effective strategies use a "balanced approach that draws on both the emotional and analytical processing systems" (Hogan Carr, 2015) to localize and personalize flooding and its effects. By appropriately introducing the issue and their relationship to it, citizens are much more likely to participate in risk reduction.

In addition to using peers and community members to personalize flooding issues, outreach directors can use narratives—stories—to communicate risk. While facts and figures are a crucial part of risk communication, narratives are easy to remember and easy to share, making it possible for a communicator to reach more individuals (Arnold, 2018). Narratives break through the communication barriers that may arise using only facts. When communicating with a story, messages should be tailored to the medium and audience, and use carefully researched metaphors and examples to show personal relevance (Arnold, 2018). One way using narratives would be to compare the risk that East Riverdale-Beacon Heights faces with the experiences of a community facing similar risks. For example, East Boston and Everett, two minority communities in Boston with demographics similar to East Riverdale-Beacon Heights, have experienced similar levels of flooding and flooding effects (Douglas et al, 2011). Communicating the stories and mitigation strategies of communities with similar flooding experiences, such as East Boston and Everett, can help residents envision themselves undertaking those same mitigation strategies. This will decrease the perception block that makes flooding mitigation and adaptation seem difficult to employ.

5.3.3.D Community-based Research

To effectively change a group's perception of an issue and move them to act, it is necessary to understand each person's perspective. Reaching community members requires stakeholders to step beyond simply providing accurate and accessible flooding information (National Research Council, 1989). The effect of community outreach depends on the messages that individuals receive and how they are interpreted (National Research Council, 1989). Assumptions can be made about a group, but the most effective way to encourage change is to learn the community's needs and to its members in the process. An engaged community can merge expert findings with the uniqueness of a specific community to yield the best results (Burwell-Naney, 2018). Community-based participatory research (CBPR) is a strategy that blends quantitative research and community input. It breaks from the traditional top-down approach of "community-based research" to a partnership approach that prioritizes equal participation from the community (Burwell-Naney, 2018). Specific CBPR principles include:

> "1) acknowledging the community as a unit of identity, 2) building upon community strengths and resources, 3) promoting mutual learning among partners, 4) achieving a balance between research and action that benefits science and community needs, 5) emphasizing the value in community-defined problems, 6) promoting a cyclical and iterative process to develop sustainable partnerships, 7) disseminating results to all partners, and 8) a long-term commitment from all partners (Burwell-Naney, 2018). "

These principles can help develop trust between the community and the stakeholders/policymakers, allowing community members to be more open to adopting mitigation strategies and using suggestions. Once initial CBPR is conducted, officials can proceed to communicate their findings. CBPR gives researchers the information they need about the community, and also requires proper communication of the information they wish to disperse.

Another form of bottom-up research is collaborative learning. Dr. Michael Paolisso, a UMD anthropology researcher, describes the collaborative learning research approach in which researchers don't enter a community and enforce their findings as the ultimate solution to an environmental hazard (Paolisso, 2019). Rather, researchers enter a community and establish an understanding of the environmental hazards among residents, stakeholders, and researchers (Paolisso, 2019). Once the hazard is defined, researchers and the community work together to combine the learned and experiential knowledge on mitigation and adaptation strategies (Paolisso, 2019). Collaborative learning is particularly useful because the process builds rapport between stakeholders and residents, which ultimately increases trust (Paolisso, 2019). Paolisso states that collaborative learning "does not impose knowledge but [works] to learn about each other's knowledge about the problem. We are all involved in the process" (Paolisso, 2019). In terms of communication and public outreach, a collaborative learning strategy engages the public from the beginning. This is carried out through community conversations and workshops (Paolisso, 2019).

Risk communication should always be based on credible scientific findings, but this does not always translate to the automatic trust of a community, which is imperative to community engagement. To gain the community's trust, Prince George's County must turn to local public officials who have established an ethos in the community. For instance, Prince George's County Council Member Dannielle M. Glaros is a public official who has gained the trust of District 3 through her "foot on the ground" approach to public policy. The residents of Beacon Heights-East Riverdale respect her as a public official who is credible, consistent, and persistent. Another public official, District 3's Chief of Staff, Aimee Olivo. Regarding education and engaging with the youth, Sandra Sheppard on the Prince George's County School Board and works with the Latin American Youth Center, is an individual with great community rapport. Lastly, David Smith Sr. with Prince George's County Office of Community Relations is a vital actor in general community engagement (Blackwell, personal communication, November 13, 2019).

This project is a step in the right direction. The Prince George's County Planning Department has expressed the intention to address the flooding issues in East Riverdale-Beacon Heights because there is already an awareness of the community's vulnerability. The County should employ these research techniques in the future, as well as using our recommendations.

5.3.3.E Consideration of Vulnerable Demographics

As noted above, to communicate risk most effectively to a particular group it's important to consider each person's perspective and experience, to reach the most people possible and ensure that mitigation strategies are adopted. To best serve East Riverdale-Beacon Heights, the following demographics should be considered when engaging with the community.

One demographic often overlooked in risk preparedness and prevention is children. In our society, it is generally accepted that guardians make decisions about their child's care, including their relation to risk. It is assumed that parents are responsible for and able to pass on information related to risk; this communication is left to the guardians' discretion (Mitchell et al. 2008). While guardians are responsible, leaving children out of the loop ignores their individual rights and "the value or utility of the child as an agent able to assimilate and manage information and to convey rational risk management choices among their families and wider networks" (Mitchell et al. 2008). To consider how to best communicate with youth, analysis must be done on the amount of trust placed in different communication sources, how people receive, verify, and act on risk communication, and the cultural and individual meaning of the risk communication (Mitchell et al. 2008).

Children are often more willing to trust new information sources, and more open and able to absorb new information. Since children are permanent members within a family and community, their relationship gives them a threshold of trust and continuous communication with other community members that outsiders may not be able to access (Mitchell et al. 2008). By including children in the intended audience for risk communication, Prince George's County can reach a necessary audience while reinforcing communication with adults. To ensure flooding risk materials are reaching children, the County should establish flooding curriculum in schools and recreation centers. The County can also create kid-friendly flooding education materials available with the resources already online.

Socioeconomic influences are also important to consider when preparing community flood mitigation strategies. Individuals with low incomes are likely less able to expend additional time and resources on flood risk; it is important to ensure tht adopted strategies serve their needs while also serving the community. Communication strategies should consider income levels and any negative economic consequences of participation. While social media is an integral part of modern society, group meetings and workshops can reach those without regular internet access and the County's online resources.

Gloria Aparicio Blackwell, University of Maryland Community Outreach Director, emphasizes the importance of community meetings in bridging "the digital divide." The digital divide is defined as patterns of inequity in access to information technology based on income, race, ethnicity, gender, age and geography. There is also a skill divide, with many citizens lacking the technical competency to operate hardware and software on a digital device, including a disparities in the ability to find and apply online information (Mossberger. Tolbert, Stansbury, 2003).

5.3.3.F Outreach and Education

Once the County has assessed community and considered multiple demographics and perspectives, it can more effectively relay flood risk and mitigation information. As previously mentioned, public meetings are a great communication strategy especially in low-income areas. In FEMA's "Flood Risk Toolkit" developed by FEMA, emphasis is placed on the importance of inviting "residents to participate in discussions about how to protect the people and things they value most" (FEMA, 2019). FEMA prioritizes public meetings as one of the most effective tools that can be used to communicate flood risk within a community (FEMA, 2019). This strategy has been successful in other flood-prone areas. For example, in 2013, New York City's Department of Environmental Protection (DEP) created a BioswaleCare Program, which provided "free workshops and materials to participants interested in learning about environmental stewardship" (NYC DEP, 2013). The workshops were held in three neighborhood demonstration areas, and one was coordinated with multiple Brooklyn churches. Participants received hands-on training in caring for bioswales and green streets, and were able to sign up to adopt or care for a green infrastructure feature in their community (NYC DEP, 2013). The program successfully generated community interest and drew 77 participants (NYC DEP, 2013).

Careful planning of outreach events is important as "scheduling the date, time, and location of meetings can be a critical barrier to community engagement" (Toor, 2014). Events should not be scheduled during traditional work hours or during community social or municipal events. Events should not be scheduled during traditional mealtimes "to ensure minimal interference" with the routines and health of individuals (Toor, 2014). If a meeting is scheduled during mealtime, organizers should consider providing attendees with a healthy meal, which may serve as an additional incentive (Toor, 2014). Event location is also crucial; it should be "accessible by multiple modes of transportation, and in the neighborhood or region where the project is taking place" so that there is little or no travel cost (Toor, 2014). Effective engagement "meets the community where they are" (Blackwell, personal communication, November 13, 2019). Restaurants, bars, grocery stores and schools are excellent locations for meetings and events that can help build a sense of familiarity between residents and the County. For example, the Beacon Heights community hosts a Wednesday morning town hall meeting at Jason's Deli in College Park, which could be an excellent location that builds on the aspects of familiarity and community. Other possible locations include libraries and community centers in the East Riverdale-Beacon Heights area: the Maryland Cultural Youth Center, Center for Educational Partnership, International Rescue Committee, Fairmount Heights Branch Library, Beacon Heights Library, and New Carrollton Branch Library. If available, transportation reimbursement or shuttle services should be considered to maximize attendance. The cost of childcare should also be considered and can either be provided or made unnecessary by encouraging children's participation (Toor, 2014). By optimizing outreach conditions, more people can be involved, especially those who need it most.

As well, the information presented can be personalized by using social media as a means of connection. As mentioned, not everyone has regular access to the internet and social media platforms, however social media can be used as part of a larger education scheme and is often more engaging than using only a website or static source. Education via social media is one of the two strategies suggested in FEMA's Flood Risk Toolkit, as it allows for consistent connection (FEMA, 2019). FEMA also recommends using social media in multiple ways, especially to maintain an engaging communication channel between officials and residents (FEMA, 2019).

Social media networking sites can be used as an instrument for conveying flood risk information more frequently, as social media is now a staple of American life. The term social networking refers to internet-based applications that encourage information sharing from a variety of parties on computers and cell phones. Social media applications facilitate messaging, chatrooms, dialog discussions, and image sharing. Popular sites include Twitter, Facebook, YouTube and Instagram. The sources have seen increased use by international, national, state, and local associations. In addition to the standard social media sites, there are more localized sites, which can help distribute location-based information. Nextdoor is a social media application that enables conversations that "empower neighbors to build stronger and safer communities" (Nextdoor, 2019), and attracts an older demographic, which can extend accessibility.

Government agencies in particular have increased their use of social media, viewing it as a compelling vehicle for sharing formal and casual data sources with different users, creating a vehicle for powerful two-way correspondence between residents and governments (Haer et al, 2016). For example, to distribute flooding information, the city officials of Kansas City, Missouri used a multi-platform strategy with technologies aside from popular social media platforms, including a specific website dedicated to providing flood education, a regularly updated blog, and an e-newsletter distributed by email (Water Environment Research Foundation, 2009).

In their Flood Risk Toolkit, FEMA recommends consistent use of using multiple platforms, especially during flooding season. The Toolkit includes a template of sample posts as well as a posting schedule. The regular use of social media helps personalize flooding education, bringing it into the everyday realm of community life. By dispersing flooding education materials on social media platforms, the County would enable citizens to share and respond to the information, which increases overall engagement with the material and allows citizens to see how their peers are reacting. The County has a wealth of information on its website but might consider an additional social media presence to ensure materials reach the community.

Social media can be a great tool if used properly. It is important to eliminate top-down style communication to increase the residents' comprehension of the message (Paolisso, 2019). Using social media should be viewed as process of communication rather than solely a means to distribute information. Conversations will host an inflow and outflow of knowledge between all parties involved (Paolisso, 2019). Gloria Aparicio Blackwell, University of Maryland's Community Outreach Director, recommends a combined approach, so that engagement facilitators can meet residents in environments that merge technology and conversation. This includes providing access to spaces such as communal computer labs, libraries and community recreation centers. Providing real-life sessions can expand accessible communication by teaching residents how to navigate online resources such as flood zone maps, pamphlets and informative websites, while thoroughly explaining how to apply the information to their lives. This can decrease the digital divide, skill divide, and information poverty.

Additionally, community engagement professionals should seek alternative communication resources, like radio, to combat the digital divide (Blackwell, personal communication, November 13, 2019). According to the National Center for Media Engagement, the primary motives for community engagement through radio is continually "convening, connecting and collaborating to discover, understand, and address community needs and aspirations (National Center for Media Engagement, 2013)." Local radio stations increasingly convey and fulfill their commitment to serve local communities by engaging with community leaders, stakeholders, and residents on local concerns (National Center for Media Engagement, 2013). Prince George's County should take the opportunity to work with the radio stations that reflect the diversity of the Beacon Heights-East Riverdale community, as a means of spreading key flood adaptation strategies, particularly drawing on the concept of narratives. This approach can raise awareness, change attitudes, and catalyze community action.

5.3.3.G Action in Communication

Flooding information can be confusing, and as stated, many individuals have skewed perceptions about flood risk. It is important to present this information as choices rather than conditions in communicating to East Riverdale-Beacon Heights residents. If the County only focuses efforts on communicating flood risk to citizens, "individuals may never engage in a detailed analysis" (Kousky and Shabman, 2015). The County should help guide citizens "toward particular choices, rather than simply providing data and information to inform choices" (Kousky and Shabman, 2015). Including mitigation strategies as a part of communication is crucial to citizen understanding of the issues (Kousky and Shabman, 2015). Providing actionable solutions, allows "individuals retain freedom to make choices," and encourages action rather than complacency (Kousky and Shabman, 2015). A directed "nudge" can lead to outcomes that best serve at-risk individuals and can help them successfully interpret flood risk and mitigation information.

6. Conclusion and Recommendations

This report offers strategies for addressing flooding issues in East Riverdale-Beacon Heights. In this section, we provide our recommendations for the best course of action for Prince George's County. To decrease flood risk and damage for East Riverdale-Beacon Heights residents and increase resilience in general, the County should work toward decreasing all aspects of flood risk: exposure, hazard, and vulnerability. However, the County's immediate priority of should be to decrease exposure and vulnerability of those in the development floodplain determined by the 1989 Floodplain Study (*Hazard Mitigation Plan*, 2010).

The best way to decrease exposure for those potentially affected is a buyout program. Although buyout programs are expensive and optional, they are the most effective and permanent solution to increase long-term, large-scale resilience. Acquiring flood-prone structures completely removes the risk for those in the floodplain and decreases flood intensity for those living downstream. We recommend that as many properties be acquired as possible, but that those closest to Northwest Branch between Northwest Branch and Kenilworth Avenue should be prioritized (Figure 4).

We also recommend that to minimize management costs and costs associated with flood damage, that the acquired properties be managed as part of the closest stream valley park, include only floodproofed structures, and be used only for recreational purposes.

If a buyout program is not possible, or if residents don't opt into the program, the County should directly contact residents in the development floodplain and urge them to flood-proof their homes. Elevation is the best possible solution, but wet-floodproofing and dry-floodproofing can be used as less expensive options. We recommend that the County advise and sponsor property owners in applying for funding through the FMA grant program.

The County should also ensure that residents are aware of flood risks and of their options for preventing flood damage. The County should use varied communication methods to effectively reach residents with diverse backgrounds and perspectives. The County should recontextualize flood risk so that flooding is taken seriously, and mitigation strategies can be implemented. Flood risk should be personalized by sharing this report's GIS maps, using designs and visuals within the community, and sharing outreach materials to show residents their direct relationship to flooding. Flood risk should be further personalized by sharing examples and narratives of similar communities and by adopting communication strategies that involve peers and community leaders.

To communicate flood risks and mitigation the County should schedule public meetings and encourage the use of flood curriculums in schools and recreation centers, to bridge accessibility gaps for the community's more vulnerable populations. Face-to-face encounters recommended; this form of communication is centered around conversation, is accessible to multiple income levels, and is already an established form of community engagement within the East Riverdale-Beacon Heights area. Multi-platform social media communication should also be used, extending the internet presence beyond the County website. A combined approach is recommended, to reach the most people. The County should establish more methods and points for communication moving forward to continue educating the citizens, and to allow the community to express needs and concerns.

To increase long-term flood resilience, the floodplain's natural capacity for storage should be increased long with reducing the volume of water that enters streams during storm events (Brody et al., 2007). The recommended buyout program would reduce the number of structures in the floodplain, thereby dramatically increasing the floodplain's storage capacity and decreasing the flooding intensity.

Restoring Northwest Branch and Briers Mill Run would also increase the streams' water storage and would decrease flood intensity. However, additional studies should be done on the hydrology of these streams to determine feasibility.

Finally, to reduce runoff, the County should install bioswales, bioretention structures, and permeable pavement. While these are costly strategies, they are the most effective solutions to reduce runoff, and are inaccessible to individual citizens. The County should also use blue roofs and green roofs, on any government buildings in the area with flat to slightly-sloped roofs. The County should also employ small-scale, inexpensive green infrastructure solutions, such as downspout disconnection and rain gardens, on public lands and County buildings wherever possible. County residents, particularly those in the Northwest Branch and Briers Mill Run watersheds, should be encouraged to implement small-scale cost-effective green infrastructure techniques, including downspout disconnection, rainwater harvesting, and rain gardens. The County should offer incentives—free materials, how-to guides, or reimbursement.

To fund these mitigation strategies, the County should continue its Clean Water Act Fee, apply for grant funding through the various Chesapeake Bay Trust grant programs, the Five Star and Urban Waters Restoration Grant Program, and apply for loans through the EPA's Clean Water State Revolving Fund.

7. Limitations and Future Studies

Limitations encountered while creating the GIS maps included difficulties obtaining the correct data and discrepancies over which data and boundaries to use. The boundary for the *East Riverdale-Beacon Heights Sector Plan* had to be manually digitized and is not fully accurate. The GIS maps were also limited by difficulties accessing stormwater data. Some data was only available from Prince George's County and other data was available at the State level, so combining data sets occasionally revealed missing data or data that applied only to part of the Sector Plan area.

The main limitation of the flood mitigation suggestions is the lack of specific cost estimates to implement these solutions. In some cases, we were able to estimate which strategies cost more or less than others, but we were not always able to give specific dollar amounts. When we were, it was usually in dollars per area and not an estimate of the total implementation cost. Estimates are difficult because these costs vary widely and there was a lack of specific information about where solutions would be implemented and the extent of implementation. To address this, future studies should conduct specific cost-benefit analyses of these strategies.

Additionally, while we had information about demographics, residences located in the floodplain, and various storm control structures, we lacked information about the specific residents in the development floodplain, and their concerns. Future studies can address this by surveying these residents to determine their concerns and values. Surveys can also help determine the flood mitigation strategies residents would be willing to implement. In addition, if the County can provide incentives that encourage residents to adopt these mitigation strategies, surveys can help determine the most effective incentives. Alternatively, if the County prefers to implement large-scale solutions, surveys can be help determine if and what residents would pay to have the County implement flood risk reduction strategies that decrease the flood risks of everyone in the East Riverdale-Beacon Heights area or the entire County.

While researching communication strategies, we also had difficulty narrowing the research scope to appropriately serve East Riverdale-Beacon Heights given the project's short timeline. After focusing our research, the main issue was establishing communication within the community. Most of the contacted community leaders did not respond. Moving forward with this project, establishing more avenues of communication is key. Contacting more people within the community will allow the County to implement the proposed strategies and will also allow the County to gain more information and further tailor its plans.

Works Cited

Adger, W. Neil. (2006). *Vulnerability*. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK. from https://www.sciencedirect.com/science/article/pii/S0959378006000422?via%3Dihub#!

Anacostia Watershed Restoration Partnership. (n.d.). Anacostia Watershed Characterization. Retrieved from https://www.arcgis.com/apps/MapJournal/index.html?appid=ae231c75bf314329a26d7ab17d83ab74#

Arnold, A. (2019). *Climate change and storytelling: narratives and cultural meaning in environmental communication*. Basingstoke, Hampshire: Palgrave Macmillan.

Boers, T.M. (1997). *Rainwater harvesting in arid and semi-arid zones.* Wageningen, The Netherlands: International Institute for Land Reclamation and Improvement.

Brody, S. D., Zahran, S., Maghelal, P., Grover, H., & Highfield, W. E. (2007). The rising costs of floods: Examining the impact of planning and development decisions on property damage in Florida. *Journal of the American Planning Association*, *73*(3), 330-345.

Brown, J. (2019, April 23). 55 Budget-Friendly Ways To Instantly Boost Your Home's Curb Appeal. Retrieved November 15, 2019, from https://homehacks.co/55-budget-friendly-ways-instantly-boost-curb-appeal/.

Burwell-Naney, K., Wilson, S. M., He, X., Sapkota, A., & Puett, R. (2017). Development of a Cumulative Stressors and Resiliency Index to Examine Environmental Health Risk: A South Carolina Assessment. *Environmental Justice*, *11*(4), 165–175. doi: 10.1089/env.2018.0002

Center for Neighborhood Technology. (2018) *Green Values National Stormwater Management Calculator*. (n.d.). Retrieved November 7, 2019, from http://greenvalues.cnt.org/national/cost_detail.php

Cheng, J. (2007). Prince George's County v. Collington Crossroads, Inc.: The Legitimacy and (Un)Fairness of Public Land Banking, The Unarticulated Issues of Eminent Domain. *Legal History Publications*, 8. https://digitalcommons.law.umaryland.edu/mlh_pubs/8

Chesapeake Bay Trust. (2019a). *Green Streets, Green Jobs, Green Towns Grant Program.* Retrieved from https://cbtrust.org/wp-content/uploads/Green-Streets-RFP-2019-FINALv2.pdf

Chesapeake Bay Trust. (2019b). *Prince George's County Stormwater Stewardship Grant Program Application Package*. Retrieved from https://cbtrust.org/wp-content/uploads/CBT-Prince-Georges-Co-Stormwater-Stewardship-RFP_FY20_final_090519.pdf

Chesapeake Bay Trust. (2019c). *2020 Outreach and Restoration Grant Program.* Retrieved from https://cbtrust.org/wp-content/uploads/Outreach-and-Restoration_RFP_FY20_Final.pdf

Claus, K., Rousseau, S. (2012). Public versus private incentives to invest in green roofs: A cost-benefit analysis for Flanders. *Urban Forestry & Urban Greening*. 11, 417-425. https://doi.org/10.1016/j.ufug.2012.07.003

Crapps, M., Bolanos, J., Folchi, A. (2014). Rainwater Catchment System A Walden West Outdoor Science School. *Santa Clara University Senior Theses*

DC Water. (2017). Downspout Disconnection Program. Retrieved from https://www.dcwater.com/projects/downspout-disconnection-program

Douglas, E. M., Kirshen, P. H., Paolisso, M., Watson, C., Wiggin, J., Enrici, A., & Ruth, M. (2011). Coastal flooding, climate change and environmental justice: identifying obstacles and incentives for adaptation in two metropolitan Boston Massachusetts communities. *Mitigation and Adaptation Strategies for Global Change*, *17*(5), 537–562. doi: 10.1007/s11027-011-9340-8

Eastern Research Group, Inc. (2014). *Economic Assessment of Green Infrastructure Strategies for Climate Change Adaptation: Pilot Studies in The Great Lakes Region*. NOAA Coastal Services Center. from https://coast.noaa.gov/data/digitalcoast/pdf/climate-change-adaptation-pilot.pdf

Environmental Law Institute. (2017). *Floodplain Buyouts: An Action Guide for Local Governments on How to Maximize Community Benefits, Habitat Connectivity, and Resilience*. Retrieved from https://www.eli.org/sites/default/files/eli-pubs/actionguide-web.pdf

European Centre for River Restoration. (2014). How does river restoration reduce flood risk. Retrieved from http://www.ecrr.org/RiverRestoration/Floodriskmanagement/tabid/2615/Default.aspx

Everett, G., Lamond, J. E., Morzillo, A. T., Matsler, A. M., Chan, F. K. S. (2015). Delivering green streets: an exploration of changing perceptions and behaviors over time around bioswales in Portland, Oregon. *Journal of Flood Risk Mitigation*. 11(S2), S973-S085. https://doi.org/10.1111/jfr3.12225

FEMA. (n.d.-a). Flood Mitigation Assistance Grant Program. Retrieved from https://www.fema.gov/flood-mitigation-assistance-grant-program.

FEMA. (n.d.-b). *Floodplain and Stream Restoration Fact Sheet*.

FEMA. (1998). Property Acquisition Handbook For Local Communities: A Summary for States. PROPERTY ACQUISITION HANDBOOK FOR LOCAL COMMUNITIES: A Summary for States. Retrieved from https://www.fema.gov/pdf/government/grant/resources/hbfullpak.pdf

FEMA. (2014). *Homeowner's Guide to Retrofitting 3rd Edition*. *Homeowner's Guide to Retrofitting 3rd Edition*. Retrieved from https://www.fema.gov/media-library/assets/documents/480

FEMA. (2015). *Reducing Flood Risk to Residential Buildings That Cannot Be Elevated*. Retrieved from https://www.fema.gov/media-library-data/1443014398612-a4dfc0f86711bc72434b82c4b100a677/revFEMA_HMA_Grants_4pg_2015_508.pdf

FEMA. (2017). *Community Rating System Fact Sheet*. Retrieved from https://www.fema.gov/media-library-data/1507029324530-082938e6607d4d9eba4004890dbad39c/NFIP_CRS_Fact_Sheet_2017_508OK.pdf

FEMA. (2018). *National Flood Insurance Program Community Rating System*. Retrieved from https://www.fema.gov/media-library-data/1562876385763-262f88e35f4dde1484be9093b099e670/2018_NFIP_CRS_Brochure_June_2018_508OK_corrected.pdf

5000 Gallon Bushman Black Rainwater Collections Storage Tank. (n.d.). Retrieved November 13, 2019, from https://www.ntotank.com/5000gallon-bushman-black-rainwater-tank-x6173512?gclid=EAIaIQobChMI46ja0Lfq5QIVipyzCh2jlQDWEAQYASABEgLc9vD_BwE

Fletcher, B. (2009). Downspout Disconnection Suitability and Incentives Analysis. *Master of Environmental Management Project Reports.* doi: 10.15760/mem.27

Foster, J., Lowe, A., Winkelman, S. (2011). The Value of Green Infrastructure for Urban Climate Adaptation. *Center for Clean Air Policy*, 1-51. Retrieved from http://savetherain.us/wp-content/uploads/2011/10/Green_Infrastructure_Urban_Climate_Adaptation.pdf

George, P. (2011). Health Impacts of Floods. *Prehospital and Disaster Medicine*, *26*(2), 137–137. doi: 10.1017/s1049023x11000148

GIS Open Data Portal. (2019). Planning Department of Prince George’s County, Maryland. Retrieved from https://gisdata.pgplanning.org/opendata.

Great DIY Rain Barrel For Those Who Want To Go Green. (2011, November 1). Retrieved November 15, 2019, from https://www.shelterness.com/great-diy-rain-barrel-for-those-who-want-to-go-green/.

Great Lakes Coalition. (2010). Kinnickinnic River Naturalization. Retrieved from https://healthylakes.org/success_stories/kinnickinnic-river-naturalization/.

Haer, T., Botzen, W. W., & Aerts, J. C. (2016). The effectiveness of flood risk communication strategies and the influence of social networks—Insights from an agent-based model. *Environmental Science & Policy*, *60*, 44–52. doi: 10.1016/j.envsci.2016.03.006

Hoegh-Guldberg, O., Jacob, D., Taylor, M., Bindi, M., Brown, S., Camilloni, I., ... & Guiot, K. (2018). Impacts of 1.5 ºC global warming on natural and human systems.

Hurley, A. K. (2017). The House of the Future Is Elevated. Retrieved from https://www.citylab.com/design/2017/12/the-house-of-the-future-is-elevated/540327/

Imteaz, M. A., Shanableh, A., Rahman, A. (2011). Optimisation of rainwater tank design from large roofs: A case study in Melbourne, Australia. *Resources, Conservation and Recycling*, *55*(11), 1022-1029. doi: 10.1016/j.resconrec.2011.05.013

Kaźmierczak, A., & Cavan, G. (2011). Surface water flooding risk to urban communities: Analysis of vulnerability, hazard and exposure. *Landscape and Urban Planning*, *103*(2), 185–197. doi: 10.1016/j.landurbplan.2011.07.008

Kaushal, S.S. & Belt, K.T. (2012). The Urban Watershed Continuum: Spatial and Temporal Dimensions 15: 409. https://doi.org/10.1007/s11252-012-0226-7

KC Water Services. (2013). *Kansas City's Overflow Control Program*. https://www.burnsmcd.com/~/media/files/documents/finalreportkansascityoverflowcontrolprogrammiddleblueriverbasingreensolutionspilotproject201311.pdf

Khashan, N. (2019, May 23). Area Vulnerable to Flooding Uses Census Data For Emergency Planning. Retrieved from https://www.census.gov/library/stories/2018/02/hampton-roads.html.

Kousky, C., Olmstead, S. M., Walls, M. A., & Macauley, M. (2013). Strategically Placing Green Infrastructure: Cost-Effective Land Conservation in the Floodplain. *Environmental Science & Technology*, *47*(8), 3563–3570. doi: 10.1021/es303938c

Kousky, C., & Shabman, L. (2015). *Understanding Flood Risk Decision Making*. *Understanding Flood Risk Decision Making*.

Li, W. C., Yeung, K. K. A. (2014). A comprehensive study of green roof performance from environmental perspective. *International Journal of Sustainable Built Environment. 3(1) 127-134. https://doi.org/10.1016/j.ijsbe.2014.05.001*

Liao, K. H. (2012). A theory on urban resilience to floods—a basis for alternative planning practices. *Ecology and Society*, *17*(4).

LIVINGPAL 50 Gallon Foldable Rain Barrel, Collapsible Tank Water Storage Container Water Collector with Spigot Filter. (n.d.). Retrieved November 14, 2019, from https://www.amazon.com/LIVINGPAL-Foldable-Collapsible-Container-Collector/dp/B07TYVQK5P/ref=asc_df_B07TYVQK5P/?tag=hyprod-20&linkCode=df0&hvadid=385169514948&hvpos=1o1&hvnetw=g&hvrand=11558044952482013608&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9060031&hvtargid=pla-827178608360&psc=1&tag=&ref=&adgrpid=80078690138&hvpone=&hvptwo=&hvadid=385169514948&hvpos=1o1&hvnetw=g&hvrand=11558044952482013608&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9060031&hvtargid=pla-827178608360

National Fish and Wildlife Foundation. (n.d.). Five Star and Urban Waters Restoration Grant Program 2020 Request for Proposals. Retrieved from https://www.nfwf.org/fivestar/Pages/fivestar2020rfp.aspx.

National Flood Insurance Program (Cartographer). (2016). Flood Insurance Rate Map Prince George's County Maryland and Unincorporated Areas [Map]. Map Number 24033C0133E. Retrieved from https://www.princegeorgescountymd.gov/DocumentCenter/View/17465/24033C0133E?bidId=

National Oceanic and Atmospheric Administration. (2015). *Green Infrastructure Options to Reduce Flooding*. *Green Infrastructure Options to Reduce Flooding*. Retrieved from https://coast.noaa.gov/data/docs/digitalcoast/gi-econ.pdfNational Research Council (U.S.). Committee on Risk Perception and Communication. 1989. *Improving Risk Communication*. Washington, D.C.: National Academy Press.

Maeder, C. (2019). Stream Restoration & Channel Stabilization Modeling using HEC-RAS. Retrieved from https://www.civilgeo.com/knowledge-base/stream-restoration-channel-stabilization-modeling-using-hec-ras/.

Maryland Department of the Environment. (2019). Comprehensive Flood Management Grant Program. Retrieved from https://mde.maryland.gov/programs/Water/FloodHazardMitigation/Pages/floodmgmt.aspx

Maryland Department of Natural Resources (n.d). Cost Share Programs. *Forest Service.* Retrieved from https://dnr.maryland.gov/forests/Pages/programapps/costshareprograms.aspx#wip

Maryland's GIS Open Data Portal. (2019). Department of Information Technology. Retrieved from https://data.imap.maryland.gov

McGill, S. (2014, April 25). The Four Horsemen of Stream Restoration Sustainability. Retrieved from https://www.cwp.org/the-four-horsemen-of-stream-restoration-sustainability/

Montgomery County Government. (n.d.). Rain Gardens and Stormwater Ponds. Retrieved from https://www.montgomerycountymd.gov/DGS-OES/RGSWM.html.

Moore Farms. (2019). Green Roof. *Moore Farm Botanical Garden*. Retrieved from https://moorefarmsbg.org/the-garden/garden-guide/garden-wall/

New York City Department of Environmental Protection. (2013). *NYC Green Infrastructure 2013 Annual Report*. Retrieved from http://www.nyc.gov/html/dep/pdf/green_infrastructure/gi_annual_report_2014.pdf

New York City Department of Environmental Protection. (2014). REPORT FOR POST-CONSTRUCTION MONITORING GREEN INFRASTRUCTURE NEIGHBORHOOD DEMONSTRATION AREAS. Retrieved from https://www1.nyc.gov/assets/dep/downloads/pdf/water/stormwater/green-infrastructure/post-construction-monitoring-report-gi-neighborhood-demonstration-areas.pdf

Opperman, J. J., Galloway, G. E., Fargione, J., Mount, J. F., Richter, B. D., & Secchi, S. (2009). Sustainable Floodplains Through Large-Scale Reconnection to Rivers. *Science*, *326*(5959), 1487–1488. doi: 10.1126/science.1178256

National Research Council (U.S.). Committee on Risk Perception and Communication. 1989. *Improving Risk Communication*. Washington, D.C.: National Academy Press.

Naturally Resilient Communities. (n.d.). *Rain Gardens*. Retrieved November 7, 2019, from http://nrcsolutions.org/rain-gardens/.

NOAA Office for Coastal Management. (2015) Green Infrastructure Options to Reduce Flooding. National Oceanic and Atmospheric Administration. https://coast.noaa.gov/data/docs/digitalcoast/gi-econ.pdf

Philadelphia Water Department. (2019). *4.6 Blue Roofs*. Philadelphia Water. Retrieved from https://www.pwdplanreview.org/manual/chapter-4/4.6-blue-roofs#

Portugal-Perez, A., Wilson, J. (2012). Export Performance and Trade Facilitation Reform: Hard and Soft Infrastructure. *Policy Research Working Papers*, *40*(7), 1295-1307. doi: 10.1596/1813-9450-5261

Prince George's County Census 2020 Outreach. (n.d.). Prince George's County Census 2020 Outreach. Retrieved from http://mncppc.maps.arcgis.com/apps/Minimalist/index.html?appid=034309f2c21f471cb5615c2d19fb14f1#

Prince George’s County and The City of Laurel Maryland *Hazard Mitigation Plan*. (2010). *Prince George’s County and The City of Laurel Maryland Hazard Mitigation Plan*. Retrieved from https://www.princegeorgescountymd.gov/DocumentCenter/View/460/Prince-Georges-County-Hazard-Mitigation-Plan-PDF?bidId=

Prince George’s County Rain Check Rebate. (n.d.). Retrieved November 14, 2009, from https://cbtrust.org/grants/prince-georges-sounty-rain-check-rebate/.

Prince George's County, MD. (n.d.-a). Flood Insurance Rate Maps & Flood Insurance. Retrieved from https://www.princegeorgescountymd.gov/369/Flood-Insurance-Rate-Maps-Flood-Insuranc

Prince George's County, Maryland. (n.d.-b). Lowering Your Fee. Retrieved from https://www.princegeorgescountymd.gov/363/Flood-Management.

Prince George's County, Maryland. (n.d.-c). Flood Management. Retrieved from https://www.princegeorgescountymd.gov/280/Lowering-Your-Fee.

Prince George’s County, Maryland. Floodplain Ordinance, Subtitle 4 Building, Division 2 (1989).

Prince George’s County, Maryland. Clean Water Act Fee Regulation, Subtitle 10 Finance and Taxation, Division 20 § 10-304. (2013 & Supp. 2016).

Rahman, A., Keane, J., & Imteaz, M. A. (2012). Rainwater harvesting in Greater Sydney: Water savings, reliability and economic benefits. *Resources, Conservation and Recycling*, *61*, 16-21. doi: 10.1016/j.resconrec.2011.12.002

Salvesen, D., BenDor, T. K., Kamrath, C., & Ganser, B. (2018). *Are Floodplain Buyouts a Smart Investment for Local Governments? Are Floodplain Buyouts a Smart Investment for Local Governments?*

Sandink, D. (2015). Urban flooding and ground-related homes in Canada: an overview. *Journal of Flood Risk Management*, *9*(3), 208-223. doi: 10.1111/jfr3.12168

Selbig, W. R., & Buer, N. (2018). *Hydraulic, water-quality, and temperature performance of three types of permeable pavement under high sediment loading conditions*.

Sheppard, S. R. J. (2012). *Visualizing climate change: a guide to visual communication of climate change and developing local solutions*. London: Earthscan.

Social Ink (2016, October 5). Bioswales. *Urban Street Design Guide.* Retrieved October 28, 2019, from https://nacto.org/publication/urban-street-design-guide/street-design-elements/stormwater-management/bioswales/.

Stone Environmental, Inc. (2014). Stormwater Management Benefits of Trees.

Templeton, S. R., Dumas, C. F., & Sessions, W. T. (2008). *Estimation and Analysis of Expenses of Design-Bid-Build Projects for Stream Mitigation in North Carolina*. Clemson University.

Terhell, S., Cai, K., Chiu, D., Murphy, J. (2015). Cost and Benefit Analysis of Permeable Pavements in Water Sustainability. ESM 121.

Texas Water Development Board. (2013). *Evaluation of Natural Channel Design versus Traditional Stormwater Infrastructure in Texas*. Retrieved from http://www.twdb.texas.gov/publications/reports/contracted_reports/doc/1148321308_channeldesign.pdf.

The Maryland-National Capital Park and Planning Commission Prince George's County Planning Department . (2017). *The Preliminary East Riverdale-Beacon Heights Sector Plan*. *The Preliminary East Riverdale-Beacon Heights Sector Plan*. Upper Marlboro, MD: The Maryland-National Capital Park and Planning Commission.

Toor, P., & Cox, J. (2014). *A Guidebook to Community Engagement: Involving Urban and Low-Income Populations in an Environmental Planning Process*. Planning & Zoning Center at Michigan State University. PDF. from

https://www.canr.msu.edu/uploads/375/65790/GuidebooktoCommunityEngagement_FINAL_Sept2014.pdf.
Tree Canopy BMP (n.d.) Stormwater Benefits of Trees. Retrieved from http://treecanopybmp.org/tree-canopy-bmps/stormwater-benefits-of-trees
Uline Trash Can - 55 Gallon, Gray. (n.d.). Retrieved November 15, 2019, from https://www.uline.com/Product/Detail/H-3689GR/Trash-Cans/Uline-Trash-Can-55-Gallon-Gray?pricode=WA9597&gadtype=pla&id=H-3689GR&gclid=EAIaIQobChMIuOPnzq7t5QIVA2yGCh2ypghyEAQYAiABEgIuzPD_BwE&gclsrc=aw.ds.
United States Census Bureau (2018). *Why a Census?*. U.S. Department of Commerce. Retrieved from https://www.census.gov/programs-surveys/decennial-census/2020-census/about/why.html.
U.S. Environmental Protection Agency. (2008). *Green Infrastructure Approaches to Managing Wet Weather with Clean Water State Revolving Funds* . *Green Infrastructure Approaches to Managing Wet Weather with Clean Water State Revolving Funds* . Retrieved from https://www.epa.gov/sites/production/files/2015-10/documents/gi_in_cwsrf.pdf
U.S. Environmental Protection Agency. (2015). *Flood Loss Avoidance Benefits of Green Infrastructure for Stormwater Management*. *Flood Loss Avoidance Benefits of Green Infrastructure for Stormwater Management*. Retrieved from https://www.epa.gov/sites/production/files/2016-05/documents/flood-avoidance-green-infrastructure-12-14-2015.pdf.
U.S. Environmental Protection Agency, R. 01. (2015, August 19). Soak Up the Rain: Rain Gardens [Collections and Lists]. Retrieved October 31, 2019, from US EPA website: https://www.epa.gov/soakuptherain/soak-rain-rain-gardens.
U.S. Environmental Protection Agency, 903-K-18-001. (2018, March). Storm Smart Cities: Integrating Green Infrastructure into Local Hazard Mitigation Plans. Retrieved November 12, 2019, from US EPA website: https://www.epa.gov/G3/storm-smart-cities-integrating-green-infrastructure-local-hazard-mitigation-plans.
USGS. (n.d.). Impervious Surfaces and Flooding. Retrieved from https://www.usgs.gov/special-topic/water-science-school/science/impervious-surfaces-and-flooding?qt-science_center_objects=0#qt-science_center_objects.
Valerio, M. (2019, October 23). Kids and babies were under-counted in Prince George's County census. Retrieved from https://www.wusa9.com/article/news/local/census-under-counting-prince-georges-county/65-ee27c03a-2492-4bea-8c72-750d1b3c78e9.
Vogt, J., Hauer, R. J., Fischer, B. C., (2015) The Costs of Maintaining and Not Maintaining the Urban Forest: A Review of the Urban Forestry and Arboriculture Literature. *Arboriculture & Urban Forestry*. 41(6): 293-323
Walsh, J., Wuebbles, D., Hayhoe, K., Kossin, J., Kunkel, K., Stephens, G., Thorne, P., Vose, R., Wehner, M., Willis, J., Anderson, D., Doney, S., Feely, R., Hennon, P., Kharin, V., Knutson, T., Landerer, F., Lenton, T., Kennedy, J., & R. Somerville, R. (2014): Ch. 2: Our Changing Climate. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 19-67. doi:10.7930/J0KW5CXT.
Water Environment Research Foundation (2009). *Sharing Stormwater Management Responsibility with the Community*. Retrieved November 12, 2019, from https://www.werf.org/liveablecommunities/studies_kc_mo.htm
Walejko O, G., Vines, M., (2019, May 17) *Survey Finds Only 45 Percent Know That Census Data Guide Community Funding Decisions*. United States Census Bureau. U.S. Department of Commerce.

Wright, James P. (2007). *Chapter 15 Commonly Applied Floodplain Management Measures*. Knoxville, TN. https://training.fema.gov/hiedu/docs/fmc/chapter 15 - commonly applied floodplain mgmt measures.pdf.