

Flooding Hazard in Howard County: Causes and Green Infrastructure Solutions

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Contents

Environmental Variation in Howard County	2
Land Use	2
Plant Communities	4
Waterways and Watersheds	6
Howard County Water Quality	9
Flood Risk in Howard County	11
Flood Risks and Management	11
Hazards of Flooding	14
Predicted Climate Change in Howard County	16
Climate Change Projections.....	16
Green Infrastructure Solutions for Howard County	19
Green Roofs	19
Permeable Pavers	22
Bio-swales and Rain Gardens	24

Environmental Variation in Howard County

Land Use

Jonathan Kim

Different forms of land use have significant environmental impact. They fulfill different functions for the ecosystem services of the human population. These include provisions, regulations, habitats, and culture. The variation and distribution of land use in Howard County are diverse and have different implications for the area's environment, economy, and social elements. This essay examines these implications, as well as touching on the County's various land use forms.

Howard County's lands are used for diverse purposes, and the variation in land use is extensive. Overall, the county is roughly 161,000 acres. Within this area, land is used for different purposes depending on geographic location. In the east, the county's major cities of Columbia and Ellicott City are developed for residential and commercial purposes, which reflects the activity of its growing population density.¹ Agricultural land is also a primary land use resource, and is generally located further west in Howard County. According to the Maryland Department of Natural Resources, roughly 22,400 acres has also been allocated for agricultural, historic, and environmental easements with many acres dedicated to parkland and natural resource areas. Much of this land is located along the Patuxent and Patapsco Rivers, the two main tributaries that form the major watersheds of Howard County.²

In comparison with the range in the State, country, and the world, Howard County has a greater percentage of land dedicated to development, including for residential, commercial, and industrial purposes relative to its scale. It has less land dedicated to agriculture, forest, and other resources.

Howard County land can be broken down into specific distributions that make up the composition of land use. According to the Maryland Department of Planning, 50.6 percent of land, or 81,572 acres, in Howard County is developed, either for residential, commercial, industrial, or other purposes. 79,605 acres, or 49.3 percent of the land, comprises the total resource lands in the county, including land for agriculture, forests, wetlands, and barren land. The most prevalent categories are residential, with 63,596 acres making up the majority of the County, forestlands with 42,375 acres, and agricultural lands with 36,178 acres. The rarest are wetlands, which cover 30 acres of the County.³

¹ Engelberg, Daniel (2015). An Introduction to Howard County, Maryland. Retrieved from https://myelms.umd.edu/files/39667949/download?download_frd=1

² Department of Natural Resources (2000). Maryland Atlas of Greenways, Water Trails, and Green Infrastructure. Retrieved from <http://www.dnr.state.md.us/greenways/counties/howard.html>

³ Maryland Department of Planning (2010). Land Use/Land Cover. Retrieved from <http://www.mdp.state.md.us/OurWork/landuse.shtml>

Most of the county's developed land is near main roads that run to the major cities of Baltimore and Washington D.C. to the north and south, I-95, US 29, and Route 1, which are primarily located in the southeast section of the county. This area has a large concentration of medium and high-density residential lands, industrial lands, and commercial lands. The developing pressure of these communities can be attributed to the two expanding urban centers and the growing population, which is projected to increase by 16 percent by 2020.

Conversely, in the northwest areas of Howard County, there is more low-density residential and agricultural land. Forestlands are dispersed throughout the county and also generally border the Patuxent and Patapsco tributaries.

The relatively high-density population of Howard County concentrated in the southeast may have significant impacts on the environment. For starters, over half of the county's water sources are impaired as assessed by the Environmental Protection Agency in section 303(d) of the federal Clean Water Act. A specific example is the Middle Patuxent River, which is reported as impaired by zinc, sediments, nutrients, and impacts to biological communities.⁴ There is also potential for other forms of pollution, such as runoff and overconsumption of resources.⁵ This is detrimental to the overall ecosystem; however, the area's development reflects a relatively higher quality of life and economic opportunities.

Overall, Howard County represents a significant case study for land use. Determined by its location between two major urban centers, as well as between two tributaries, the implications for the potential in environmental and human impact are high. Its well-developed residential areas, which reflect a relatively high rate of growth and its current environmental conditions, point to a need for more review.

⁴ Maryland Department of the Environment (2008). Water Quality Analysis of Zinc in Middle Patuxent River, Howard County, Maryland. Retrieved from http://www.mde.state.md.us/assets/document/Middle%20Patuxent%20Metals%20Report_080808_final.pdf

⁵ Chesapeake Bay Foundation (2014). Howard County has a Big Problem: Polluted Runoff. Retrieved from <http://www.cbf.org/document.doc?id=2027>

Plant Communities

Katie Mullen

Although it is one of the State's smallest counties, Howard County, Maryland, is home to a wide variety of plant life. Located in central Maryland, between the Piedmont Plateau and the Coastal Plains, Howard County hosts multiple natural habitats including forests, meadows, wetlands, and more.⁶ This environmental range creates a diverse and fascinating collection of plant communities with many benefits and ecological services for surrounding areas.

There are many different plant species within Howard County but most can be sorted into one of two main categories: forest and aquatic. These groupings are determined by soil moisture since wetlands are a major part of Maryland's landscape. When looking at a map, one can see that the forests and wooded areas are mostly found in western Howard County but can also be seen around the edges of wetlands.⁷ Most of the plant communities in this area are shady trees or shrubs; the tree species require large amounts of sun while the shrubs and plants underneath are able to thrive without much sunlight escaping through the tree canopy. Since these forests are close to rivers and streams, the members of the community are accustomed to moist soil and can handle seasons of moderate flooding as well as drought. The forest populations of Howard County include plants such as the River Birch, Intermediate Wood fern, Scarlet Oak, Poison Ivy and many more.⁸

Along with offering food and shelter to the local wildlife, the woodland communities provide many helpful and necessary ecological services to the residents of Howard County. They improve air and water quality by absorbing pollutants and producing oxygen while also preventing excess water runoff and soil erosion. Trees also help reduce heating and cooling costs for homes and offices by offering shade.⁹ Without the forests and woodlands, Howard County would not have the high standard of living it currently enjoys.

The other major plant community in Howard County is composed of aquatic plants. This is caused by the county's location within the watersheds of the Chesapeake Bay and the Patuxent and Patapsco

⁶ (2001, September). Native Plants for Wildlife Habitat and Conservation Landscaping in Maryland. USFWS Bayscapes Conservation Landscaping Program. <http://www.nps.gov/plants/pubs/nativesMD/info.htm>

⁷ Google Earth. (2015). 39 12'13.58" N 76 51'39.74" W. Columbia, Maryland.

⁸ Johnson, Kirsten. (2014, June). Patapsco Valley State Park (Mckeldin Area), Howard County, MD. Maryland Native Plant Society Plant List. <http://mdflora.org/Resources/FieldTripPlantLists/PatapscoStatePark06072014.pdf>

Yacovissi, Ginny. (2012, January). Middle Patuxent Environmental Area, Howard County, MD. Maryland Native Plant Society Plant List. <http://mdflora.org/Resources/FieldTripPlantLists/MiddlePatuxentEnvirArea10012011.pdf>

⁹ (2014). Tree Canopy Program. Howard County Maryland Parks and Recreation. <http://countyofhowardmd.us/treecanopy.htm>

rivers.¹⁰ Whether they are found submerged or lining the streams and rivers within the county, there is a huge variation of aquatic plant life, including Cattails, Pickerel Weed, Water Fern, algae, etc. These plants are able to withstand completely soaked soil and, depending on their proximity to the Chesapeake Bay, can tolerate high degrees of salinity.¹¹

Wetlands play a major role in improving Howard County's environmental health. According to the county's Parks and Recreation Department, plant species that live on the edge of riverbanks help stabilize shorelines and prevent erosion. Species that live within the streams and rivers help oxygenate and filter the water.¹² Most of the wildlife in Howard County depends on aquatic plants for their food and shelter. Without the aquatic plant community, the County's environmental health would suffer and most of the biodiversity would be lost.

Unfortunately, this could become a reality. Many of the County's natural plant communities are under threat from human interaction and invasive species. According to the Maryland Department of Natural Resources, many local species have become endangered or extinct since the county has been established; this pattern may continue with the further development of land for Howard County residents. Some of the endangered or extinct species include the Small-headed Sunflower, Blunt-leaved Giardia, Gray Birch and many others.¹³

Another threat the plant communities face is the invasive species, Purple Loosestrife. This perennial weed was introduced into Maryland wetlands for medicinal purposes but soon began degrading the environment by outcompeting the natural vegetation and leaving local wildlife without suitable habitats.¹⁴ Without conservation actions regarding the effects of both land development and invasive species, Howard County could face severe loss in the biodiversity of its plant communities.

Due to its location, Howard County finds itself in a regional collision resulting in a plethora of plant species. Although they can be divided into either forest or aquatic communities, all the natural plant populations provide beneficial environmental services and create healthy habitats for people and wildlife. Despite the potential threats of human development and invasive species, the vast range of Howard County's plant communities is notable and beautiful.¹⁵

¹⁰ (2013). Watersheds, Rivers & Streams. Live Green Howard County. <http://livegreenhoward.com/green/water-resources/watersheds-rivers-streams/>

¹¹ (2014). Common Aquatic Plants of Howard County. Howard County Maryland Parks and Recreation. <http://www.howardcountymd.gov/Departments.aspx?id=2392>

¹² (2014). Common Aquatic Plants of Howard County. Howard County Maryland Parks and Recreation. <http://www.howardcountymd.gov/Departments.aspx?id=2392>

¹³ (2010, April). Current and Historical Rare, Threatened and Endangered Species of Howard County, Maryland. Maryland Department of Natural Resources Wildlife and Heritage Service. <http://dnr2.maryland.gov/wildlife/RTE%20Plants%20%20Animals/rtehowa.pdf>

¹⁴ (2014). Purple Loosestrife Alert. Howard County Maryland Parks and Recreation. <http://www.howardcountymd.gov/DisplayPrimary.aspx?id=2399>

Waterways and Watersheds

Molly Crothers

Howard County borders are defined by water, recreation services, and cities. The Patapsco River runs along the north and north-eastern border, while the Patuxent River flows lengthways as the southern border. There are 10 watersheds of which seven feed into the Patuxent River; the other three flow into the Patapsco River.¹⁶ Due to these watersheds, the County's water resources are abundant and varied. Their use ranges from recreational to agricultural and industrial. Agriculture and industrial water run-off causes many environmental issues for Howard County's waters. Water is an essential part of life that provides many services, therefore, measures to protect these watersheds must start at the local, county level.

Howard County receives its water resources from lakes, rivers, reservoirs, streams, and the largest estuary in the United States, the Chesapeake Bay.¹⁷ The Chesapeake Bay is an estuary that leads into the Susquehanna River then into the Atlantic Ocean and provides many habitats for across the county and State. These include "shallow waters, open waters, marshes and wetlands, sandy beaches, mud flats, and oyster reefs".¹⁸ Howard County is a good representation of Maryland's various water sources because, according to the Environmental Protection Agency, "we all live in a watershed." Not only does Howard County consist of 10 watersheds, but it has four lakes and two reservoirs, as well. This is proportional to the nation's number of lakes and reservoirs because "lakes and reservoirs cover 40 million acres of the United States".¹⁹ Having different types of water resources provides Howard County and the United States with a wide range of habitats and uses.

Howard County uses its waters in a variety of ways including fishing, swimming, agriculture, and industry. For example, five of the County's six parks have streams and/or a lake as a main attraction.²⁰ The Patuxent River provides a 7,000-acre park area.²¹ The Patapsco River Valley State Park follows the Patapsco River for 32 miles, which creates more than 16,000 acres of public trails

¹⁶ Engelberg, Daniel. (2015) Introduction to Howard County. *Partnership in Action Learning in Sustainability*.

¹⁷ Environmental Protection Agency. (2013b, October). Streams. Retrieved from <http://water.epa.gov/type/rsl/streams.cfm>

¹⁸ Chesapeake Bay Program. (2015). The Estuary System. Retrieved from <http://www.chesapeakebay.net/discover/bayecosystem/estuarystem>

¹⁹ Environmental Protection Agency. (2013b, October). Streams. Retrieved from <http://water.epa.gov/type/rsl/streams.cfm>

²⁰ Howard County Maryland. (2015). Interactive Map. Retrieved from <https://data.howardcountymd.gov/InteractiveMapV3.html#tab10>

²¹ Prince George's County Department of Parks and Recreation. (2015). Patuxent River Park. Retrieved from http://www.pgparcs.com/Things_To_Do/Nature/Patuxent_River_Park.htm

and recreational opportunities.²² The services provided by these water bodies are common throughout Maryland due to the Chesapeake Bay and the Susquehanna River as the main estuaries in Maryland.

The county's land use is split evenly between agricultural and commercial/industrial use, therefore, the majority of the water distribution is used for these practices.²³ According to the USDA, agriculture accounts for 80 percent of water use in the United States. It can even reach up to 90 percent in some Western states due to agriculture as their main means of profit.²⁴ The distribution of water usage is disproportional not only in Howard County, but throughout the United States.

The land use distribution is a reflection of where water is used. In western Howard County, where agriculture is the main way of living, agriculture usage is highest. Within more populated areas, industrial water use is common. The more populated areas, like Columbia and Ellicott City, are created around streams to provide water services to the residents of those cities. But water also serves mining, power plants, etc., which is why the cities were established here. Most major U.S. cities are located on a river or a large body of water because the locations allowed factories and industries to grow, as well as provided for the transportation of goods and services. Therefore, cities have high industrial water usage. Agriculture water use is seen mostly in the Western States with their vast open lands of corn, wheat, and soy. In California, which produces most of our fruits, the drought is causing many residents to limit their water use. However, agriculture accounts for 90 percent of the usage. The amount of water used for agriculture must be balanced with providing the country with goods and preserving some for residential use in Howard County and across the U.S.

Even though water is one of Howard County's major environmental resources, the waters are mistreated and mostly impaired. The Maryland Department of Environment (MDE) sets standards to protect a body of water depending on its designated use, ranging for example, from recreational uses to wildlife protection. The MDE uses these designations to determine water quality thresholds that will support that system. About fifty percent of the watersheds are not up to standard according to the EPA Watershed Assessment of Maryland. No watersheds meet the State's ion pollution standards. Howard's Centennial Lake, Rocky Gorge, and the Triadelphia Reservoirs have phosphorus levels that exceed MDE's thresholds.²⁵

This is not a localized problem, it is a State-wide problem with 40 percent of waters reported as good and 60 percent reported as impaired. In Maryland, 13,000 miles of water are threatened or impaired

²² Department of Natural Resources. (2015). Patapsco Valley State Park. Retrieved from <http://dnr2.maryland.gov/publiclands/Pages/central/patapsco.aspx>

²³ Google Earth. 2015.

²⁴ United States Department of Agriculture. (2013, June). Irrigation and Water Use. Retrieved from <http://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use.aspx>

²⁵ Engelberg, Daniel. (2015) Introduction to Howard County. *Partnership in Action Learning in Sustainability*.

due to agriculture or urban run-off. The quality of life of animals, marine life, and even humans are at risk if nothing is done about the lack of care to the water.²⁶

With its many streams, lakes and reservoirs, Howard County is very similar to the country's water variety and distribution. It provides many services that keep the county happy and thriving in the cities and in the agricultural industry. The county's 10 watersheds provide thriving ecosystems that allow the quality of life to continue the way it is. However, if the water is poorly cared for due to the lack of regulations on agricultural and urban run-off, the today's livable and healthy environment will be threatened.

²⁶ Environmental Protection Agency. (2013a, September). My Waters Mapper. Retrieved from http://watersgeo.epa.gov/mwm/?layer=LEGACY_WBD&feature=02060003&extraLayer

Water is a precious resource that must be maintained and guarded. It is used for many purposes, such as drinking water, hygiene, and agriculture. To ensure that the water supply is sufficient to sustain society, it has to be monitored and, if necessary, repaired. In Howard County, the local government, as well as other organizations, such as the Chesapeake Bay Foundation, take this responsibility. Their reports show that the county's waterways and watersheds exhibit a degree of variation, although a not unexpected one.

According to Live Green Howard County, there are nine major watersheds in the county.²⁷ These watersheds, which are areas of land draining into the same waterway, are all individually assessed by the Howard County Public Works Department. The biological assessments checked two things: the benthic population, and the habitat environment. The benthic population are the organisms living at the very bottom of the bodies of water, sometimes even below the ground. According to the Public Works Department, these organisms are a good indicator of water quality and health. The habitat environment is given one of three ratings: non-supporting, partially supporting, or supporting.

The assessment reports received by the Department are startling. Almost all of the watersheds received a benthic population rating of "poor" and a habitat environment rating of "non-supporting." The Upper Brighton Dam received the best assessment, with a benthic population rating of "fair" and a habitat environment rating of "partially supporting." On the other hand, the Little Patuxent watershed received a benthic population rating of "poor" and a habitat environment rating of "non-supporting".²⁸ Unfortunately, these poor water quality ratings seem to be the case throughout the nation, according to Environment California's Research and Policy Center's "Wasting our Waterways" report, which in turn quoted the Environmental Protection Agency (EPA), saying that more than 17,000 miles of waterways are being polluted by industry.²⁹

According to Google Earth's EPA WATERS dataset, the majority of the "non-supporting" or "impaired" waterways are present near Howard County's larger cities, such as Columbia. This makes sense for several reasons. One of the obvious reasons is that larger, more urban environments will produce more waste than smaller, rural ones. Another important reason, however, is more subtle. According to the Chesapeake Bay Foundation, a major reason for the impairment of Howard County watersheds and waterways is the mere presence of pavement. The pavement is an "impervious" or "hard" surface, and such surfaces prevent the water from infiltrating the ground; waters instead

²⁷ Watersheds, Rivers & Streams. (n.d.). Retrieved September 22, 2015, from <http://livegreenhoward.com/green/water-resources/watersheds-rivers-streams/>

²⁸ Howard County - Watershed Surveys. (n.d.). Retrieved September 22, 2015, from <http://www.howardcountymd.gov/DisplayPrimary.aspx?id=359>

²⁹ Wasting our Waterways. (2014, June 19). Retrieved September 22, 2015, from <http://www.environmentcalifornia.org/reports/cae/wasting-our-waterways-0>

gather speed, volume and temperature, as well as pollutants, and becomes runoff. According to the paper, the water quality in areas with just 10 percent impervious surface suffer significantly. For example, the sub-watershed that includes Ellicott City is about 25 percent covered by impervious surfaces. The water run-off, which travels along impervious surfaces such as sidewalk and roofs gathers motor oil, grease, pesticides, and other garbage, makes its way to the waterways, and starts to destroy the usability of that water.³⁰ In light of this knowledge, it isn't surprising that the waterways and watersheds in the vicinity of the larger cities seem to be in worse condition than those in the more rural parts of the county, since the cities are filled with paved roads, sidewalks, residential housing, and businesses, while the rural areas have farms and woods.

Although not particularly surprising, since water quality has been declining for a while, the implications of the situation are still sobering. Especially in larger cities and in areas with heightened levels of industry, people must either try to solve their water quality issues, or accept a lower standard of living. Even that is unsustainable, however, because people need water for nearly everything. Unless something changes in the way people use and maintain their water, many water sources will become unusable. Fortunately, most local governments are aware of these issues (as well as national and state governments) and are implementing several methods to curb pollution and promote healthy, sustainable water usage. As stated by the Chesapeake Bay Foundation, the benefits to communities far outweigh the potential costs, primarily the possibility that businesses will relocate to areas with less restrictive water policies—although that would be difficult to do, given the widespread awareness and concern for water quality.

In conclusion, water is a precious resource that must be maintained. Although Howard County's waterways and watersheds seem to be "impaired" for the most part, the government is definitely taking protective steps in the direction of sustainability.

³⁰ Polluted Runoff In Howard County. (n.d.). Retrieved September 22, 2015, from file:///Users/EthanPro/Downloads/5_Polluted_Runoff_in_Howard_Co.pdf

Flood Risk in Howard County

Flood Risks and Management

Johanna McAlister

The risk of floods in Howard County is high and they occur often, and thus managing this risk is a high priority. Different aspects of this risk, such as the factors that affect flooding, the impacts on local people and properties, current risk management, and historic flooding events all can be assessed to determine how well this issue is managed and the toll of flood impacts on the local people.

Beyond heavy rainfall, Howard County is unique in its topographical factors that affect flooding. Most floods result from large and small-scale weather systems, such as tropical storms, nor'easters, hurricanes, thunderstorms, and short lived rainstorms that quickly fill up the county's surrounding and integrating rivers and streams. The flooding of these streams and channels originates from the flooding of the Patuxent and Patapsco river tributaries.³¹ Waters from the streams rise to at or above road level, which in result, floods county streets. Because Howard County consists mostly of hills that lie on watersheds with the roads near channels and waterways, these roads end up conveying flood waters throughout the county, flooding both private and public properties, as well as causing other issues.³²

According to the Hazard Risk Matrix presented by the county's Office of Emergency Management, flooding is the county's highest risk disaster, where the likelihood is a four out of a 0-4 scale and the consequence is approximately a 2.8 out of a 0-4 scale. Even with a small amount of rainfall, Howard County is at high risk for flooding and the impacts can be detrimental depending on the proximity to waterways and flood preparation.

Flood impacts include road closures, power loss, flooded basements, utility damage, water seepage, mud slides, and overall damage to private homes and public infrastructure. Additionally, there are major safety issues such as sewage, chemical contamination, and electricity running through flooded roadways that can be extremely harmful, as well as the mental toll, stress, and physical exhaustion associated with flood cleanup and repairs, and loss of property.³³ When personal property gets

³¹ Howard County Department of Public Works. (2015). HC Government's FEMA FIRM Information Service.

Retrieved from <http://www.howardcountymd.gov/dfirm.htm>

³² Howard County Office of Emergency Management. (2012). Case Study: Valley Mede- Ellicott City Tropical Storm Lee Flood Event. Retrieved from

<https://myelms.umd.edu/courses/1156778/files/folder/PALS%2520resources?preview=40196763>

³³ Howard County Department of Public Works and Flood Mitigation Plan Steering Committee. (2010). Flood Mitigation Plan: Howard County, Maryland. Retrieved from

<https://myelms.umd.edu/courses/1156778/files/folder/PALS%2520resources?preview=40197238>

damaged, people with flood insurance, such as from the National Flood Insurance Program or the Federal Emergency Management Agency, get protected financially, and depending upon the program and damage level, the amount of money the resident pays varies.³⁴

Residents of Howard County are prepared for these impacts with the help from the county. Its Office of Emergency Management notes the county is more interested in planning for and mitigating frequent flooding more than the less common 20- and 100-year floods. Their approach to flood mitigation is to take small steps in specific areas of the county rather than county-wide projects. The Howard County Management Plan's goal is to increase community flood resistance so residents and businesses are less susceptible to future flooding, resulting in fewer losses and damages.

The Management Plan includes regulations designed to mitigate the flooding, primarily through infrastructure regulation, including zoning regulations on where to build, avoiding flood sensitive areas like the floodplain, improved building codes for infrastructure built on a floodplain or other sensitive areas, flood-proofing homes, such as with higher foundations and backup electrical and sewage components, as well as stormwater management infrastructure to help guide where the water goes.

Other flood preparations to keep the county better prepared include making the public aware of flood predictions, improved flood warnings, and information on how to deal with a flood. The county has made huge efforts in management, such as improving emergency systems and maintaining, monitoring, and strengthening roads and flood management systems.

Specific examples of flooding and their effects on the Howard County include tropical storm Lee and Hurricane Agnes. In 2011, tropical storm Lee's heavy rains resulted in major flooding, mainly in Valley Mede and Ellicott City. As expected, roadways acted as water conveyances from the floodplain and channels, and depending upon a resident's proximity to the channel, flood impacts varied from 12- to 18-inch deep flooded roads, fallen trees and foot bridges, and property damages such as water seepage through walls and the basement. Lee also caused one roof collapse, damage to utilities, and the loss of water, electricity, and gas for several days.³⁵

Similarly, in 1972, Hurricane Agnes delivered many of the same impacts, however that storm was much more severe, including damages such as mangled railroad tracks, roadway sections pulled out,

³⁴ Howard County Department of Public Works. (2015). HC Government's FEMA FIRM Information Service. Retrieved from <http://www.howardcountymd.gov/dfirm.htm>

³⁵ Howard County Department of Public Works and Flood Mitigation Plan Steering Committee. (2010). Flood Mitigation Plan: Howard County, Maryland. Retrieved from <https://myelms.umd.edu/courses/1156778/files/folder/PALS%2520resources?preview=40197238>

lock jams of cars, infrastructure wiped away, resulting in the loss of seven lives and over \$20 million in damages.³⁶

The impacts of floods can be extremely severe in the Howard County area, and with the area's high likelihood of flooding due to frequent storms and hilly topography, it is important that management plans and precautions are implemented and monitored.

³⁶ Hotzberg, Janene *The Baltimore Sun*. (2012). 40 years later, Howard looks back at Tropical Storm Agnes. Retrieved from http://articles.baltimoresun.com/2012-04-15/news/bs-ho-hurricane-agnes-40th-0415-20120415_1_enalee-bounds-ellicott-s-country-store-tropical-storm-agnes

Hazards of Flooding

Caitlin Banez

Located in central Maryland, Howard County, like any other area of the United States, is susceptible to a variety of natural disasters such as flooding, severe winter storms, wildfires, and hurricanes, among others. However, the most frequent hazard in the county is flooding, which occurs when a large accumulation of water exceeds its confines and leads to an inundation of a normally dry area of land. Flooding is a common natural disaster that occurs worldwide, during all months of the year and its aftermath can be taxing and costly for a community. Furthermore, the flooding hazards in Howard County include varied risks such as economic and social distress for residents and their property.

According to NOAA, the accumulation of rainfall over a period of time, especially from a storm, is the most common cause of flooding, which will overflow from a stream or river onto usually dry lands.³⁷ Generally, there are two main types of flooding, triggered by either a prolonged period or a shorter period of rain. Prolonged rainfall can drive bodies of water to inundate, however flooding can also be a result of a flash flood, when a large amount of precipitation occurs in a very short period of time. USGS states, “Natural processes, such as hurricanes, weather systems, and snowmelt, can cause floods. Failure of levees and dams and inadequate drainage in urban areas can also result in flooding”.³⁸ Despite constant regulation, dam failures can be unpredictable. Maryland’s Department of the Environment monitors dams and classifies their risk factors into three categories—low, medium, and high-level hazards—to better understand the possibility of a flood caused by a dam break.

Howard County’s location in nine watersheds, streams, and rivers greatly enhances its susceptibility to flooding. In addition, many structures in the county, especially residential areas, are built on floodplains. These lowlands near a river have an increased exposure to flooding.³⁹ In addition to natural topography and weather events, human actions, such as urbanization caused by deforestation, can cause flooding by blocking water soaking into the land and leading to surface runoff into the river.⁴⁰ In the event inundation is triggered and leads to flooding spread across floodplains, serious effects can negatively impact the residential area.

The social affects of flooding on a community can be detrimental, leading to 140 deaths nationwide annually.⁴¹ According to FEMA, floods are the number one natural disaster in the United States.⁴²

³⁷ National Oceanic and Atmospheric Association. (2015). Retrieved from: <http://www.floodsafety.noaa.gov>

³⁸ United States Geological Survey. (2015). Retrieved from: <http://pubs.usgs.gov/fs/2006/3026/2006-3026.pdf>

³⁹ Howard County, Maryland Government. (2015). Retrieved from: http://www.howardcountymd.gov/flood_protection.htm

⁴⁰ Jackson, Alexander. (2015) Retrieved from: <https://geographyas.info/rivers/flooding/>

⁴¹ United States Geological Survey. (2015). Retrieved from: <http://pubs.usgs.gov/fs/2006/3026/2006-3026.pdf>

⁴² National Flood Insurance Program, Federal Emergency Management Agency (2015). Retrieved from: https://www.floodsmart.gov/floodsmart/pages/flooding_flood_risks/what_causes_flooding.jsp

Floodwaters contain raw sewage and debris, which contaminates not only the floodwater, but the drinking water as well, and infected flood water is costly and difficult to clean from houses.⁴³ Furthermore, Howard County's Chief of the Stormwater Management Division, Mark Richmond, explained that new county residents are strongly encouraged to attain flooding insurance due to the high possibility of flooding.⁴⁴ In another effort toward risk management, Howard County's Emergency Operations Center constantly informs new and current residents of flood risks. In fact, the EOC distributes language-appropriate comprehensive brochures to the growing Hispanic and Korean communities so that they can also take preemptive measures toward flooding, including flood insurance, properly elevating furniture, and securing appliances. In addition, Richmond stated that 85 percent of the county's drinking water comes from a single reservoir in Baltimore.⁴⁵ Thus, if floodwater pollution were to affect that neighboring county a basic amenity—clean water—would be unusable, posing an extremely negative situation for the county, and putting people within the community at risk.

In addition to the social distress caused by floodwater in residents' homes, the destruction of other properties contributes to the economic effects of flooding. Water damages not only immediately effect infrastructure by damaging power lines, roads, and pipes, but also over time, that infrastructure will deteriorate and compromise safety. The USGS states that flooding "damages infrastructure, causing indirect losses due to disruption of economic activity".⁴⁶ An example of the costly outcome of such destruction is the effects of Tropical Storm Lee. According to Michael Hinson of the Howard County Office of Emergency Management, Lee damaged many county-owned properties, though FEMA covered seventy-five percent of their repair costs through a cost-share program.⁴⁷ Howard County also contains many historic sites and buildings, which are at a greater risk.

Furthermore, flooding poses great social, economic, and safety risks on Howard County residents, and the historical land area. Inundation causes great damage to the infrastructure and properties. However, the county's risk management solutions are beneficial to the residents, despite the distressing affects.

⁴³ Jackson, Alexander. (2015) Retrieved from: <https://geographyas.info/rivers/flooding/>

⁴⁴ Howard County, Maryland Government. (2015). Retrieved from: http://www.howardcountymd.gov/flood_protection.htm

⁴⁵ Richmond, M. (2015, October 10). Personal Interview.

⁴⁶ United States Geological Survey. (2015). Retrieved from: <http://pubs.usgs.gov/fs/2006/3026/2006-3026.pdf>

⁴⁷ Hinson, M. (2015, October 10). Personal Interview.

Predicted Climate Change in Howard County

Climate Change Projections

Johanna McAlister

Within the century, the effects of climate change in Howard County will include increasing temperatures and extreme precipitation patterns due to the increase in greenhouse gas emissions over the past few decades and major changes in land use. The magnitude and likelihood of these future impacts vary depending on projected greenhouse gas emissions, but follow an overall pattern, with temperature predictions being more certain than precipitation predictions. Implications for the livelihoods and environment in Howard County are useful in planning what to do now and in the future.

The main climate variables predicted to change in the Howard County region are seasonal temperatures, precipitation, and general climate event extremes, with projections based on different emission level models. Both winter and summer temperatures are projected to increase as the century progresses. The temperatures in January, approximately mid-winter, will rise from an average of -0.62°C in 2020-2029, to 0.03°C in 2040-2049, to 0.25°C by 2060-2069. The Nature Conservancy predicts the average winter temperature by the 2050s will be around 40°F , and by the 2080s, the average winter temperature will be in the 50s. Mean temperatures in August, approximately mid-summer, will increase from 22.17°C in 2020-2029, to 22.79°C in 2040-2049, to 23.88°C in 2060-2069.⁴⁸ The Nature Conservancy predicts summer temperatures by the 2050s to be in the 80s, and by the 2080s, will be in the high 80s.

Average precipitation amounts and patterns in the Howard County region are predicted to increase in winters and slightly decrease during the summers, with extreme precipitation events playing a large role. These extreme weather events include more floods, increases in the chance of heavy precipitation sporadically with long, dry periods in-between them.⁴⁹ Additionally, in places that are already typically wet, such as Howard County, there will be an overall increase in the amount of precipitation, especially in the colder months. The average amounts of annual precipitation vary from 2.89 mm/day in 2020-2029, to 3.04 mm/day in 2040-2049, to 2.82 mm/day in 2060-2069.⁵⁰ There is no clear pattern of increasing or decreasing because you will see an increase during the winter, a decrease during the summer, and more heavy sporadic rains followed by dry periods,

⁴⁸ USGS. (2015). Regional Climate Change Viewer. Retrieved from:

<http://regclim.coas.oregonstate.edu/visualization/rccv/index.html>

⁴⁹ IPCC. (2015). 5th Assessment Report. Retrieved from: <http://www.ipcc.ch/report/ar5/index.shtml>

⁵⁰ USGS. (2015). Regional Climate Change Viewer. Retrieved from:

<http://regclim.coas.oregonstate.edu/visualization/rccv/index.html>

which skews the annual average. The accuracy of these projections depends on local and national greenhouse gas emissions and land use changes.

Depending upon the emission model, different projections exist. The change in January temperature by 2020-2029, in comparison with the 1980-1999 baseline averages, is predicted to be 0.12°C and by 2060-2069, temperature will increase from the baseline by 2.29°C. The temperature will increase slightly more in the summer by an average of 0.36°C by 2020-2029, and by 2.72°C by 2060-2069 (USGS, 2015). The Nature Conservancy's comparison models, which have a slightly earlier and larger baseline period of 1961-1990, project an increase of 4-6°F during the summers and winters by 2050 and 2080 respectively. Average precipitation in the winter could increase by 20 percent by 2050, while in the summer, could increase by less than 5 percent.⁵¹

Howard County in the coming years will experience more intense periods of rain, both the length and amount of precipitation, increased flooding, and more intense and lengthy storms.⁵² This poses a serious threat to the already flood prone area, which will be discussed more in detail later.

The certainty in these projections varies by model. But across all models—the IUCN, the Nature Conservancy, the EPA, and the USGS—temperature increases throughout the century are highly certain, with a 95-100 percent significant level by the USGS and a highly likely estimate given by the IPCC. However, projections for precipitation increasing and becoming more intense and sporadic are much less certain than for temperature. It is much more difficult to predict the climate impacts that come with the increasing temperature; the USGS giving the precipitation predictions a much lower significance and the IPCC labeling the predictions as a medium-high confidence. Since it is more likely than not that these projections are accurate, it is absolutely necessary to take action to mitigate and adapt to the climate changes, particularly if the current course of action of high fossil fuel emissions continues.

The effects of these climate change predictions in Howard County will be detrimental to the cities, livelihoods, and environment if the County does not prepare adequately or fails to do their part in mitigating climate change. The highest potential risk for Howard County, floods, will only get more intense and frequent with time as predicted in the models, due to extreme precipitation events, storms, and water-level rise. However, as a relatively high-income county, Howard has a better chance of adapting and preparing for the changes brought by climate change, such as negatively impacting drinking water availability, growing crops, and increased flooding, since it is predicted that poorer regions will have a more difficult time adapting⁵³. Additionally, the environment and local

⁵¹ The Nature Conservancy. (2007). Climate Wizard. Retrieved from: <http://www.climatewizard.org/>

⁵² United States Environmental Protection Agency. (2014). Future Climate Change. Retrieved from: <http://www3.epa.gov/climatechange/science/future.html#Temperature>

⁵³ United States Environmental Protection Agency. (2014). Future Climate Change. Retrieved from: <http://www3.epa.gov/climatechange/science/future.html#Temperature>

ecosystem could see negative effects on wildlife and plants with the extreme weather changes, expanding the impacts.

It is extremely important that Howard County and the rest of the world take action to reduce fossil fuel emissions and adapt to the increasing temperature and sporadic, intense precipitation events. Regardless, these climate changes are already happening and will only worsen, so adaption and mitigation are absolutely essential.

Green Infrastructure Solutions for Howard County

Green Roofs

Jordan Arndt

Fostering a sustainable environment in which future generations will prosper is a growing concern for policymakers and community leaders. Green infrastructure, particularly green roofs, has become more prevalent in urban areas throughout the United States. Defined as a “network of interconnected waterways, wetlands, forest, meadows, and other natural areas,” green infrastructure has a significant role to play in stormwater management.⁵⁴

Green roofs, one element of green infrastructure, provide an alternative to less sustainable “gray infrastructure” practices. A layer of plants acting as a sponge, green roofs retain rainwater more effectively than their traditional gray infrastructure counterparts.⁵⁵ In comparison, human engineered gray infrastructure is more costly, less sustainable, and less aesthetically pleasing. Green roofs provide numerous benefits aside from stormwater management, which include energy conservation, the reduction of the urban heat island effect, and improved air quality. The traditional gray infrastructure alternatives are composed of “steel-colored networks of cement and metal pipes, valves, pumps, and energy-hungry treatment plants”.⁵⁶ Bill Mahoney, Howard County’s Sustainability Project Manager, is not alone in concluding that green roofs provide the best solution for the triple bottom line.

Before diving into the numerous benefits that accompany green roofs, it is of paramount importance to understand their purpose. The development of green roofs “involves the creation of “contained” green space on top of a human-made structure”.⁵⁷ At their core, green roofs alleviate the rainwater runoff that traditional gray infrastructure solutions, steel roofs and storm drains for example, effectively fail to do. According to the European Federation of Green Roofs Association, green roofs retain 70-80 percent of summer rainfall.⁵⁸ As a result, the sewage systems that exist near buildings with green roofs are less stressed at peak flow times, as less water runoff occurs.⁵⁹ While they

⁵⁴ “Green Infrastructure Network.” *Live Green Howard*. Howard County, MD, n.d. Web. 22 Nov. 2015.

<http://livegreenhoward.com/green/land/green-infrastructure/>

⁵⁵ “Green Roofs.” *EPA*. EPA, 24 Sept. 2015. Web. 22 Nov. 2015. <http://www2.epa.gov/soakuptherain/green-roofs>

⁵⁶ Zimmerman, Leda. “Greening Gray Infrastructure.” *MIT Spectrum RSS*. MIT, n.d. Web. 22 Nov. 2015.

<http://spectrum.mit.edu/articles/greening-gray-infrastructure/>

⁵⁷ “About Green Roofs.” *Green Roofs for Healthy Cities*. Green Roofs for Healthy Cities, 2014. Web. 22 Nov. 2015.

www.greenroofs.org/index.php/about/aboutgreenroofs

⁵⁸ “Environmental Advantages.” *European Federation of Green Roofs Association*. European Federation of Green Roofs Association, n.d. Web. 22 Nov. 2015. http://www.efb-greenroof.eu/verband/fachbei/fa01_englisch.html

⁵⁹ “Green Roof Benefits.” *Green Roofs for Healthy Cities*. Green Roofs for Healthy Cities, 2014. Web. 22 Nov. 2015.

<http://www.greenroofs.org/index.php/about/greenroofbenefits>

present many advantages for stormwater management, green roofs also provide additional benefits that must be carefully examined.

Along with improving stormwater management, green roofs conserve energy, reduce the urban heat island effect, and improve air quality. Research has shown that green roofs serve as an effective means of building insulation; in a study published by the National Research Council of Canada, the daily demand for air conditioning fell by over 75 percent in buildings that contained green roofs.⁶⁰ Green roofs also help insulate heat during the winter; according to one study by Ontario's Trent University, the average temperature under a green roof was measured at 4.7°C. This is in stark contrast to the average temperature of 0.2°C measured under traditional "gray roofs".⁶¹

Equally as important, the urban heat island effect is reduced as a result of green roofs. Being composed of plants, green roofs first absorb heat and later release it through evapotranspiration. It is by this process that green roofs effectively reduce the urban heat island effect. Another study conducted by Trent University revealed that on a day with an average temperature of 18.4°C, a traditional roof recorded an average temperature of 32°C; by comparison, green roofs measured a mean temperature of only 15°C.⁶² The mitigation of the urban heat island effect is directly related to the improved air quality of communities in which green roofs are present. Green roofs can effectively improve air quality by "reducing temperatures and capturing air pollutants" which include ozone and particulate matter. Through improvements in air quality, resulting from the plants that make up green roofs, human health and standard of living are ultimately enhanced as well.⁶³ As the aforementioned benefits of green roofs indicate, their effect on the triple bottom line of people, planet, and profit is significantly greater and more advantageous than that of "gray infrastructure" alternatives.

Green roofs have been shown to ameliorate the lives of people, foster sustainability on the planet in which we live, and have beneficial economic outcomes. First, through the implementation of green roofs, people are not only provided with a more aesthetically pleasing alternative to "gray roofs," but reap the benefits of better air quality as well. The urban heat island effect is diminished, making summers more pleasurable for city residents especially; buildings remain warmer and more insulated during cold winter months. Second, these insulating factors help buildings conserve energy and, as a result, the use of nonrenewable and unsustainable resources, oil for instance, decreases in

⁶⁰ "Green Roof Benefits." *Green Roofs for Healthy Cities*. Green Roofs for Healthy Cities, 2014. Web. 22 Nov. 2015. <http://www.greenroofs.org/index.php/about/greenroofbenefits>

⁶¹ "Environmental Advantages." *European Federation of Green Roofs Association*. European Federation of Green Roofs Association, n.d. Web. 22 Nov. 2015. http://www.efb-greenroof.eu/verband/fachbei/fa01_englisch.html

⁶² "Environmental Advantages." *European Federation of Green Roofs Association*. European Federation of Green Roofs Association, n.d. Web. 22 Nov. 2015. http://www.efb-greenroof.eu/verband/fachbei/fa01_englisch.html

⁶³ Garrison, Noah, Cara Horowitz, and Chris Ann Lunghino. "Looking Up: How Green Roofs and Cool Roofs Can Reduce Energy Use, Address Climate Change, and Protect Water Resources in Southern California." *Natural Resources Defense Council* (n.d.): n. pag. Emmett Center on Climate Change and the Environment, UCLA School of Law, 2012. Web. 23 Nov. 2015. <http://www.nrdc.org/water/pollution/files/greenroofsreport.pdf>

the presence of green roofs. Finally, there are economic advantages to green roofs over traditional “gray roofs.” As buildings with green roofs use less air conditioning and heating throughout the year, money is saved on lower energy costs.

The many benefits of green roofs represent legitimate arguments from which the sustainable urban planners of the future should begin their work. When comparing green roofs to the traditional “gray roofs,” there is substantive evidence that corroborates the notion that the sustainable, energy efficient, and cost effective option of the future is green roofing. The support of Bill Mahoney and other champions of urban sustainability projects will aid in expanding green roofs from commercial and residential buildings in the cities to those in more rural areas of the country. In fostering a more sustainable environment for future generations, green roofs undoubtedly provide the best alternative for a more advantageous and fruitful triple bottom line.

Permeable Pavers
Michael Fangmeyer

Stormwater management is a practice that, when executed the right way, can provide many community benefits. Normally, stormwater runoff is handled by gray infrastructure that handles rainfall in urban areas by streaming the water somewhere else through the use of gutters, sewers, and other means of water collection and transportation. According to the Environmental Protection Agency, “Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts”⁶⁴.

Permeable pavers are a form a green infrastructure that treats and stores rainwater in the location that it falls. Permeable pavement can be created using pervious concrete or asphalt or through the use of permeable interlocking pavers. These permeable pavers will eliminate the heavy flow of water and runoff, and will greatly reduce the amount of pollutants that end up in nearby bodies of water. These pavers can also be very effective in reducing flooding and property damage as well as reducing the effects of icing in the winter.

There are three main designs for permeable pavers: mulches, grass pavers, or permeable/interlocking pavers. Mulches are the easiest to install as they are simple mixes of ground-up wood or gravel that allows water to flow in the cracks between the solid pieces of stone or wood. Grass pavers are installed with gaps in their structure where soil and vegetation can be planted which will absorb water rather than transfer it and pollutants somewhere nearby. Permeable/interlocking pavers are designed in grids and have holes in the surface that can be filled with gravel or other porous materials that allow for the rainwater to seep into the soils below the surface.

These permeable surfaces have been proven to be cost-effective in installation and can be widely applied throughout society, particularly in urban areas where concrete surfaces are most common. Installation of permeable pavers requires proper site preparation before the actual pavers are laid. First the designated area must be excavated and a layer of gravel is placed on the excavated area. Next, a Geotextile fabric is laid over the surface and poured with a layer of sand. Finally, the pavers are installed by hand or by using machinery and the gaps in the surface are filled with gravel, soil, or a porous pavement based on the paver design chosen.

One of the main benefits of using permeable pavement is the potential it has to be used in numerous places without causing a large negative economic or geographical impact. Not only does the integration of permeable pavers reduce the power and quantity of rainwater runoff, it reduces pollution to local areas, as well as preventing water damage such as erosion. Also, reducing the infrequent and sometimes heavy water flow provides a more stable ecosystem for local wildlife and plant life.

⁶⁴ EPA. (2015, November 2). Retrieved November 24, 2015, from <http://www2.epa.gov/green-infrastructure/what-green-infrastructure>

Gray infrastructure is effective at controlling the flow of rainfall and runoff and dispersing it to a location where it can't cause flooding or damage. However, it still has flaws. The continued dumping of pollutants can cause serious environmental harm if no action is taken to remedy the situation. Gray infrastructure in urban areas results in high amounts of pollution in the runoff as the rain lands on the buildings and other urban surfaces covered in dirt and bacteria. However, permeable pavers would significantly reduce the effects of the pollution by in-taking the water and other substances and dispersing them in the soil.⁶⁵

People who occupy areas with high flood risks could greatly benefit from the installation of permeable pavement in their communities. "Porous pavement provides groundwater recharge and reduces stormwater runoff volume. Depending on design, paving material, soil type, and rainfall, permeable paving can infiltrate as much as 70% to 80% of annual rainfall".⁶⁶ Reducing the flood risk and frequency will also result in lower amounts of property damage caused to residential homes and local businesses. Despite the more expensive construction costs for permeable pavers than regular asphalt, the cost of installing permeable pavement will outweigh the costs that will continue to surface because of flooding and other byproducts resulting from the runoff in the long run. The environment will be the beneficiary of green infrastructure installation like permeable pavers. The reduction of pollutants being spread as well as a more stable flow of water will promote a more healthy and prosperous ecosystem.

⁶⁵ Permeable Pavement Fact Sheet. (2011, August 13). Retrieved November 24, 2015, from [https://extension.umd.edu/sites/default/files/docs/programs/master-](https://extension.umd.edu/sites/default/files/docs/programs/master-gardeners/Howardcounty/Baywise/PermeablePavingHowardCountyMasterGardeners10_5_11_Final.pdf)

[gardeners/Howardcounty/Baywise/PermeablePavingHowardCountyMasterGardeners10_5_11_Final.pdf](https://extension.umd.edu/sites/default/files/docs/programs/master-gardeners/Howardcounty/Baywise/PermeablePavingHowardCountyMasterGardeners10_5_11_Final.pdf)

⁶⁶ Fact Sheet: Permeable Paving. (2010, February 5). Retrieved November 24, 2015, from <http://www.mapc.org/resources/low-impact-dev-toolkit/permeable-paving>

Bio-swales and Rain Gardens

Shaun Moore

Currently, water pollution and erosion are the predominant environmental challenges that Howard County is trying to overcome. Whether these issues are due to runoff containing excess amounts of inorganic fertilizers, stormwater, or industrial waste spills that contaminate local streams and lake habitats, green infrastructure aims to combat these problems.

Green infrastructure utilizes vegetation, soils, and natural processes to manage water and create healthier environments.⁶⁷ Scaled down, neighborhoods use green infrastructure to regulate stormwater management systems that mimic nature by soaking up and storing water through a variety of structures such as riparian buffers, green roofs, permeable pavers, bio-swales and rain gardens. This paper focuses on the construction of bio-swales and rain gardens, their role in environmental management, their traditional infrastructure counterpart, and how this solution is better for the triple bottom line (people, planet, and profit).

Bio-swales and rain gardens essentially play the same role in the filtration of runoff due to stormwater. Bio-swales come in three forms: wet swales, dry swales, and grassed channels.⁶⁸ While there are three types, the one that is the least costly and provides maximum filtration within residential settings, such as Howard County, would be a dry swale. A dry swale is a vegetated, mulched, or xeriscaped channel that allows for the treatment and retention of stormwater as it moves from its source to other areas, usually due to gravity. The swales' vegetation slows, infiltrates, and filters stormwater flow, prevents the runoff from causing erosion to local streams, and filters excess amounts of inorganic molecules found in fertilizers such as nitrogen and phosphorous.⁶⁹

Dry swales incorporate a deep fabricated soil bed into the bottom of the channel, which use sand and soil mixtures, usually mulch and wood chips, to replace existing soils that meet permeability requirements. The runoff that is filtered through this permeable mixture is then directed to an under drain system placed directly under the soil bed, usually consisting of several layers of gravel that encases a perforated pipe that leads to a watershed or to further water treatment facilities. In addition, natural plant life that helps retain of pollutants caused by fertilizers is implemented. These plants use their stems, leaves and stolons to slow the flow and thereby encourage settlement of the pollutants along with their uptake.⁷⁰ This structure is best situated next to highways or residential

⁶⁷ "What Is Green Infrastructure?" *EPA*. United States Environmental Protective Agency, 13 June 2014. Web. 23 Nov. 2015. http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm

⁶⁸ "Bioswales." *Capital Regional District*. N.p., n.d. Web. 23 Nov. 2015. <https://www.crd.bc.ca/education/low-impact-development/bioswales>

⁶⁹ "What Is Green Infrastructure?" *EPA*. United States Environmental Protective Agency, 13 June 2014. Web. 23 Nov. 2015. http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm

⁷⁰ "Bioswales." *Capital Regional District*. N.p., n.d. Web. 23 Nov. 2015. <https://www.crd.bc.ca/education/low-impact-development/bioswales>

roads that are impervious surfaces because they are designed linearly, thus allowing for stormwater runoff by sheet flow to be directed and filtered effectively.

Rain gardens on the other hand are shallow, vegetated basins that collect and absorb runoff from rooftops, sidewalks, and streets.⁷¹ They mimic natural hydrology in that they infiltrate and use evapotranspiration from the surface and plant transpiration. This structure's secondary purpose is to concentrate nutrients from fertilizers, particularly nitrogen and phosphorous, found in stormwater runoff that the natural plants uptake.

Designed to look like an aesthetic garden on the surface, potentially supporting habitats for birds and butterflies, what makes it a rain garden function is how it is designed below to handle the runoff. Beneath the garden's surface, soils are selected in order to mimic hydrologic actions of a healthy forest. The layers beneath the garden tend to be ordered in an ascending order starting with drought tolerant vegetation (typically natural foliage found in the region), growing media, filter fabric, a drainage layer, root barrier, and a waterproof membrane. There are two main types of rain gardens: an under-drained system and a self-contained system.⁷² Due to Howard County's excessive amount of stormwater and flooding, the under-drain system is preferred due to its conventional storm sewer pipe system below the filtered garden. The versatility of rain gardens in where they can be installed are their primary benefit. They can be installed in any unpaved space such as the front lawn of a house, typically close to drainage pipes that irrigate runoff from rooftops.⁷³

In Howard County, stormwater management is the primary solution to environmental and infrastructure damage from excess runoff, but bio-swales and rain gardens have additional benefits such as aesthetics and enhanced wildlife habitats. Though aesthetics may seem minimally important, the enhancement of natural wildlife habitats allows for the regeneration of species that could have been previously endangered due to either construction or pollution. As previously mentioned, these structures can host a variety of natural foliage that might have been previously displaced due to runoff. These structures allow for the accumulation of nutrients found in fertilizers from runoff and reincorporates them into natural cycles through plant root absorption and leaf transpiration, aiding the planet in the bottom line. Since these structures filter out pollutants caused by inorganic fertilizers, the runoff that eventually makes its way to watersheds such as lakes and streams is less likely to increase the pollution of those environments, thus allowing for natural inhabitants of those locations such as fish to repopulate.⁷⁴

⁷¹ "What Is Green Infrastructure?" *EPA*. United States Environmental Protective Agency, 13 June 2014. Web. 23 Nov. 2015. http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm

⁷² "What Is a Rain Garden?" *Rain Garden Design Templates*. N.p., n.d. Web. 23 Nov. 2015. http://www.lowimpactdevelopment.org/raingarden_design/whatisaraingarden.htm

⁷³ "What Is Green Infrastructure?" *EPA*. United States Environmental Protective Agency, 13 June 2014. Web. 23 Nov. 2015. http://water.epa.gov/infrastructure/greeninfrastructure/gi_what.cfm

⁷⁴ Shapiro, Leo. "Plant Root Assimilation." *Biological Sciences 207: Organismal Biology*. University of Maryland, College Park, MD. Fall 2015. Lecture.

The “gray” or traditional infrastructure that serves a similar purpose, but is not as sustainable, is storm drains. Stormwater runoff, which is directed initially through drains and gutters, requires extensive system of piping and drainage ditches that can be costly. These systems are usually found on roads that are sloped for runoff management and that filter runoff toward watersheds such as the Patuxent River. This management system presents various environmental hazards, such as pollutants being carried into waterways that can affect wildlife, water quality, and erosion due to excess volume of stormwater within stream banks. The main factor that causes pollutants to be an issue in this system is the lack of filtration or uptake of excess nutrients from fertilizers that eventually end up in watersheds. Similarly, the primary reason why this system can cause erosion is the fact that it does not reduce the flow rate of the runoff like other green infrastructures.⁷⁵

In conclusion, bio-swales and rain gardens are both forms of green infrastructure that allow for runoff flow rates to be regulated and decreased, and include a filtration system for inorganic nutrients from fertilizers that updates traditional infrastructure. These solutions are better for the triple bottom line in a variety of ways. For people, these solutions are aesthetically installed into residential communities, either on residential property or next to roads. The environmental benefits include the filtration of hazardous buildup of inorganic nutrients that pollute local streams and lakes. This solution is economically feasible because minimal construction is needed, and, compared to traditional infrastructure, both bio-swales and rain gardens use natural material found within the region such as soil minerals and natural vegetation.

⁷⁵ "Residential Storm Water Management." *NDS*. 2015. Web. 24 Nov. 2015. <http://www.ndspro.com/about-us/what-we-do/residential-stormwater-management>