Assessing Green Infrastructure Needs in Hampton Roads, Virginia and Identifying the Role of Virginia Cooperative Extension

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ABSTRACT

The Hampton Roads region of southeast Virginia is largely defined by its abundant water resources. These water resources are also a source of unique issues for the region. Specifically, water quality challenges related to the Chesapeake Bay and recurrent flooding are the major concerns. Green infrastructure (GI) has emerged in recent years as an alternative to traditional stormwater conveyance and detention focused systems. GI practices focus on integrating infiltration, evapotranspiration, and other components of the water cycle into more conventional stormwater management systems. These systems provide several positive benefits, including local water quality and quantity control, community revitalization, and various public health benefits. In addition, GI implementation has seen strong levels of support from the Cooperative Extension System, with Extension faculty and staff around the U.S. supporting local municipalities through GI research, promotion, and program development. Despite widespread interest, GI has been slow to be adopted due to various barriers to its implementation. This study sought to identify the major barriers to the implementation of GI practices in Hampton Roads by conducting a needs assessment. Municipal stormwater staff were invited to participate in an online survey aimed at identifying the most significant barriers in the region. At the same time, local staff with Virginia Cooperative Extension (VCE) were interviewed to explore their potential to become involved in promoting GI adoption in Hampton Roads. Survey respondents and interview participants found common ground in identifying costs, funding, and maintenance issues as the most significant

barriers to GI implementation in Hampton Roads. In addition, VCE staff were found to be well suited to support widespread GI adoption in the region, having familiarity with the GI concept and access to unique resources in the form of knowledgeable Master Gardener volunteers and connections to Virginia Tech. Recommendations for VCE involvement in promoting GI in Hampton Roads include conducting cost studies, developing and hosting maintenance training programs, and taking advantage of partnerships to identify and obtain funding from diverse sources. By focusing on these widely acknowledged challenges at the regional scale, VCE can support GI implementation throughout all of Hampton Roads.

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GENERAL AUDIENCE ABSTRACT

Hampton Roads is a region with a history and economy tied to its local waters. Today, the region is facing significant challenges related to these waters, including frequent flooding impacts on residents and pollution control needs for the nearby Chesapeake Bay. Green infrastructure (GI), a relatively new approach to managing water in cities, could help local governments address these challenges. Virginia Cooperative Extension (VCE), an organization formed through a partnership between federal and local governments and land grant universities in Virginia, seeks to meet community needs through community outreach and educational programs. As a community-centered organization with a history of advancing environmental education, VCE may also be an important partner for municipalities in Hampton Roads interested in adopting GI practices. To identify the barriers to GI in Hampton Roads and the potential role of VCE in addressing them, a needs assessment of municipalities in the region with stormwater permits was conducted. Based collected documents, surveys of municipal staff, and interviews with VCE personnel, three major barriers to GI adoption were identified. Permitted municipalities in Hampton Roads are uncertain of GI costs, have limited funds to support GI practices, and lack the knowledge and resources needed to maintain GI practices over time. VCE can help municipalities address these challenges using its many resources. Through its connection to Virginia Tech and Virginia State University, VCE can help in developing cost research studies for Hampton Roads. As an educational organization, VCE can also help municipalities win funding for GI projects that they would

otherwise not have access to. Finally, local Virginia Tech faculty at the Hampton Roads Agricultural Research and Extension Center and experienced Master Gardener volunteers can work to develop GI maintenance training resources for maintenance staff throughout the region. With its strong background, expert knowledge, and existing connections in the region, VCE can play an important role in addressing the GI adoption challenges in Hampton Roads.

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I would like to thank all the participants in this study. This project would not have been possible without the participation and thoughtful responses of the municipal personnel of the Hampton Roads region and Virginia Cooperative Extension personnel living and working in the area. My hope is that the results herein will make a positive impact in Hampton Roads, supporting and complimenting the work of these participants and the countless others who strive to make the region a better place for its residents.

Finally, I'd like to thank my family and friends, who constantly supported me over the last three years. Elyse, Candace, Mom, Dad, thank you all for rooting for me and cheering me on as I moved toward the finish line. Nyomi, it took some time but I think I finally taught you what I do for a living. I cannot thank you enough for your continued support and encouragement through these years.

DEDICATION

This thesis is dedicated to Ruth Anne Hanahan, who taught me that valuing service, education and stewardship is the core of an exciting and impactful engineering career.

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1.1 Cooperative Extension and Urban Stormwater

Cooperative Extension in the U.S. holds a unique role at the nexus of government, research, education, and public engagement. Created by the Smith-Lever Act of 1914, the Cooperative Extension System (CES) was developed to educate farmers and others in rural communities on the use of the latest agricultural research to improve their prosperity. The earlier work of George Washington Carver and Seaman A. Knapp inspired this effort, as both worked to systematically engage and inform farmers about university-based farming technologies and techniques through on-site demonstrations. The establishment of CES adapted this non-formal education model to a national scale, empowering land-grant universities throughout the U.S. to introduce the rural public to the latest scientific advancements (Gould *et al.*, 2014).

The focus of Extension grew beyond its agricultural roots over time, expanding into several areas related to community health (Gould *et al.*, 2014). Today, Extension programs mainly fall within of four major topical areas: family and consumer sciences, youth development, community development, or agriculture and natural resources (Franz and Townson, 2008). These expanded focus areas have evolved in response to new community needs. However, in meeting these needs, Cooperative Extension continues to follow its practice of disseminating university research to members of the community.

Thanks to this expansion of scope, Extension is now capable of addressing many needs in rural communities (Henning *et al.*, 2014). However, adequately addressing the concerns of urban residents remains an elusive target for Extension. One significant challenge is the differing needs of urban and rural areas. Historically, Cooperative Extension focused its attention on issues and problems related to rural communities. The resulting unfamiliarity with urban challenges makes adapting to urban populations difficult for Extension personnel unfamiliar with urban issues such as unemployment, poverty, and environmental degradation (Young and Vavrina, 2014). Another significant challenge for Extension is the nature of urban communities. Characteristics such as large population sizes and diverse cultural groups are commonly found in cities and have been noted as significant barriers to Extension programming success (Webster and Ingram, 2007).

Scholarly research in Extension has acknowledged these challenges and suggested various strategies to improve urban outreach efforts. These include expanding urban partnerships, boosting volunteer development, and engaging with university resources and departments outside of agriculture colleges (Henning *et al.*, 2014). The leadership and governing body of CES, known as the Extension Committee on Organization and Policy (ECOP), has recognized the common challenges and potential solutions for Extension entering urban areas. In 2014, ECOP established the National Urban Extension Leaders (NUEL) organization, whose purpose is "to advocate and advance the strategic importance and long-term value of urban Extension activities by being relevant locally, responsive statewide, and recognized nationally" (De Ciantis *et al.*, 2015).

Cities have struggled to address several important issues of their own, and environmental concerns are among the most pressing challenges facing urban areas today. Dense populations and high volumes of automotive vehicles on roads have raised concerns in cities related to air quality (Parrish *et al.*, 2011). Urban areas filled with hardscapes that absorb heat throughout the day contribute to the urban heat island effect (Susca *et al.*, 2011). Urban centers are also resource intensive, and consumption demands drive resource extraction needs. However, the extraction process often degrades the surrounding environment (Swilling *et al.*, 2013). These and other challenges impact urban residents and their immediate environment in significant ways. A key challenge facing urban areas is runoff from impervious surfaces in urban landscapes.

Figure 1.1 compares the runoff generated on undeveloped and developed land. Rain that falls on undeveloped land mainly infiltrates into the pervious soil layer, depending upon soil characteristics, slope, and antecedent moisture conditions. Infiltration recharges aquifers and provides base flow for streams and other water bodies. Infiltrated water is stored in soil, where it is accessible by plant life and soil-based organisms. Undeveloped land only produces overland flow, or runoff, when available void space in the soil is full. Natural runoff is generally slow moving due to roughness of the land surface, so it has limited erosive capacity to cause streambank or stream channel erosion. Runoff serves an important role in the environment, regulating water flow regimes and providing nutrients to aquatic organisms (U.S. EPA, 2003).

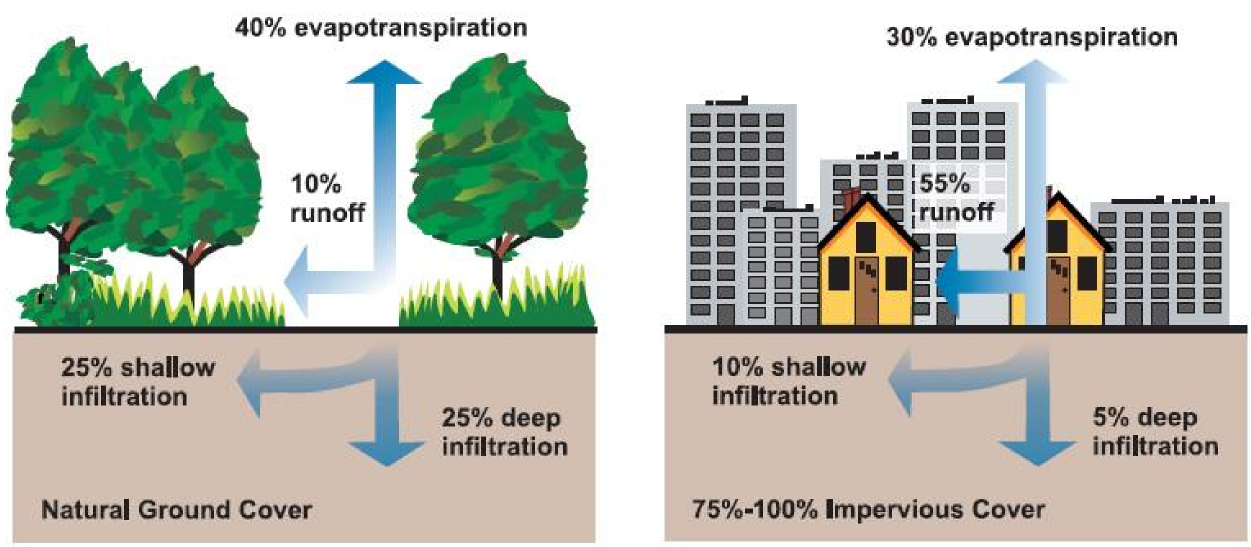


Figure 1.1: Runoff on Undeveloped and Developed Land (U.S. EPA, 2003)

Urbanization generally reduces the amount of exposed soil in an area. The buildings and pavements that replace porous soil surfaces are impervious, preventing infiltration. Thus, urban development results in a lower capacity for a site to infiltrate rainwater, greatly increasing the peak and total volume of runoff generated (Schueler, 1994; Schueler *et al.*, 2009). In addition, pavements and pipe conveyances typically increase runoff velocity. Therefore, runoff from urban development is more likely to erode downgradient stream banks and streambeds and disrupt natural flow regimes (Burns *et al.*, 2012). Increased peak runoff also heightens downstream flood risk. This is particularly important in cities with combined sewer systems, where heavy rains can overload wastewater treatment facilities and cause the mixture of untreated sewage and stormwater to inundate streets or backup into basements (Field *et al.*, 1999; Lucas and Sample, 2015).

The other major concern with increased urban runoff is water quality. Urban landscapes and streets can be a source of pet waste, toxic chemicals, sediment, and other pollutants. Curb and gutter, storm sewer pipes and other drainage system components convey these pollutants to local receiving waters through runoff. Degraded water quality significantly impacts the aquatic and terrestrial organisms that rely on these waters (Alberti *et al.*, 2007). Polluted waters also raise water management concerns for municipalities downstream that treat these waters for human uses (National Research Council, 2009).

Historically, the focus of stormwater system design has been water quantity, with the goal of maximizing flood protection by conveying excess drainage away from affected properties quickly. Scientific evidence of urban runoff pollution began to appear in the 1970s and 80s through the National Urban Runoff Program (NURP) (U.S. EPA, 1983), which is still used today as an important source of runoff water quality data for specific land uses The National Pollutant Discharge Elimination System (NPDES) was created in 1972 through 33 U.S.C. § 1251 et seq, Also known the Clean Water Act (CWA), this law already regulated the many point sources of pollution degrading water resources (U.S. EPA, 1990). In 1990, the NPDES program expanded to include municipalities with populations of over 100,000 residents. These large cities now obtain stormwater discharge permits and must satisfy conditions to address nutrients, sediments, and other pollutants found in urban discharge if designated as municipal separate storm sewer systems (MS4s). Smaller MS4s began to follow the same requirements starting in 2003 (Foster and Matlock, 2001).

To satisfy MS4 permit conditions, cities across the nation have established programs to address pollution attributed to urban runoff. Many Extension offices have recognized this need, partnering with land grant universities to initiate programs focused on stormwater management. One example is the University of Nebraska-Lincoln Extension, which formed its Stormwater and Greenspace Work Group as part of the Nebraska Water Center in 2006 in response to requests from municipalities across the state seeking educational resources (https://watercenter.unl.edu). In 2009, the program received a grant from the National Institute of Food and Agriculture to address local education needs through Extension programming. Specifically, the Extension group provided municipal leaders, green industry professionals, and Nebraska residents with hands-on experience and learning materials focused on stormwater management. The group also used their funding to conduct several research studies on rain gardens (Shelton *et al.*, 2015).

Another example is the Rutgers Cooperative Extension Water Resources Program, located in New Jersey (http://www.water.rutgers.edu). In 2010, the program began a contract with the City of Camden, NJ to address combined sewer overflows (CSOs). In cities with combined sewers, heavy rains can overload the capacity of the drainage system, flooding streets and property with raw sewage and stormwater. The Rutgers Cooperative Extension program worked with a range of partners, including non-profit organizations, civic organizations, and local and state governments, to address this problem through the application of green infrastructure (GI). GI techniques take advantage of processes in the hydrologic cycle like infiltration and evapotranspiration to reduce the generation of runoff. The program proved to be successful, installing 49 GI practices throughout the City while educating residents on the issues caused by CSOs. Similar GI programs have since launched in Newark, Trenton, and other nearby cities in New Jersey to address their stormwater challenges (Obropta, 2017).

Extension researchers and personnel across the U.S. are tackling urban runoff concerns. The North Carolina State Extension Stormwater Engineering Group, headed by Bill Hunt, Ph. D, conducts research on GI practices while also educating local communities on stormwater issues (https://stormwater.bae.ncsu.edu). A particularly robust part of the North Carolina State Extension program is its continuing education workshops. The University of Minnesota Extension's Stormwater Education Program provides local customized workshops for community members and stormwater professionals focused on meeting MS4 permit requirements throughout the state (http://www.extension.umn.edu/environment/water/stormwater/index.html). The Washington Stormwater Center, a partnership between Washington State University and the University of Washington, provides stormwater education resources for Washington municipalities and businesses. It also conducts research studies and evaluations on emerging stormwater technologies (http://www.wastormwatercenter.org).

These and other examples demonstrate the advantages of Cooperative Extension addressing urban stormwater management challenges. Extension offices link cities to colleges and land grant universities that are engaged in water resources research, providing access to experts in the field. This connection with academia reinforces the reputation of Cooperative Extension, making the organization ideal for partnerships on challenging topics. In addition, Cooperative Extension specializes in public engagement and is mission bound to educating communities. MS4 permits require that cities engage with their citizens on runoff management issues, making Cooperative Extension an attractive partner for addressing challenges through public engagement as a component of stormwater management.

Hampton Roads is a region defined by its abundant water resources, with local industries and economies that are strongly connected to the Chesapeake Bay and the Atlantic Ocean. Thus, pollution of the Chesapeake Bay and potential sea level rise present major challenges for residents and public officials in the region. GI is a potential solution to runoff quality and quantity challenges. Its support from the U.S. EPA has led to widespread implementation programs in New York (Bloomberg and Holloway, 2010), Philadelphia (Philadelphia Water Department, 2011), and other major metropolitan areas. Yet, even with the current momentum and federal-level enthusiasm for GI, local implementation of these practices is slow due to various obstacles (Copeland, 2014).

Several studies have identified different barriers to GI, but these vary from MS4 to MS4. While the known benefits of widespread GI implementation, particularly local water quantity and quality control, may address some of the water-related challenges Hampton Roads is facing, it is important to understand which impediments to GI are of greatest concern within the region. It is also important to understand that the specific impediments may vary not only by MS4, but also by region, by local perspective, and by agency (i.e. municipal government and Cooperative Extension).

1.2 Hampton Roads and Water

The Hampton Roads region is located on the southeastern corner of Virginia along the Atlantic coastline and is largely characterized by the nearby Chesapeake Bay and its many tributaries. European settlement began in the early 1600s, making Hampton Roads one of the oldest settled areas in America. Early colonizers recognized the waters of Hampton Roads and the Chesapeake Bay as offering an excellent harbor. The plentiful wood on the surrounding land gave rise to ship building as one of the first industries in the region (Whichard, 1959a).

The area now known as Hampton Roads was originally made up of three independent counties: Elizabeth City, Warwick River, and Warrosquyoack. The region has since established several municipal bodies that have changed continually over time. In Virginia, the legislative body favored the growth of cities and encouraged their expansion through annexation, allowing cities to claim land from nearby counties through judicial proceedings. Counties in Hampton Roads consolidated their borders in response to the successful annexations of their neighbors, becoming cities themselves (Whichard, 1959a, b; Eyre, 1969). This effectively protected their lands from annexation, as cities cannot annex portions of other cities. The cities that resulted from these annexation and consolidation processes remain today and include Virginia Beach, Norfolk, Suffolk, Newport News, Portsmouth, Hampton, and Chesapeake. Together, these are known colloquially known as the Seven Cities. Other jurisdictions in the region include the Town of Smithfield, the Cities of Williamsburg, Franklin, and Poquoson, and the Counties of James City, York, Isle of Wight, Gloucester, Surry, and Southampton. These jurisdictions are all members of the Hampton Roads Planning District Commission (HRPDC). Figure 1.2a displays Hampton Roads in relation to the state of Virginia. Figure 1.2b shows the counties of the Hampton Roads region.

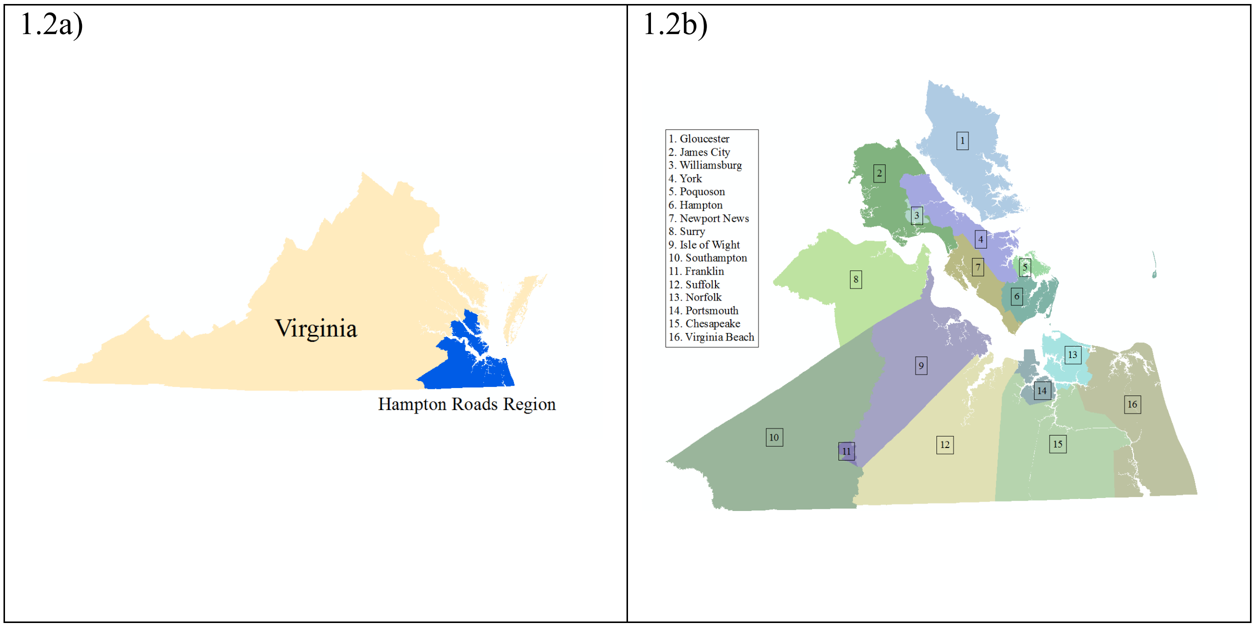


Figure 1.2: Hampton Roads and its County Boundaries

Today, Hamptons Roads is a major contributor to Virginia's overall economy. Home to approximately 1.7 million residents, the region is among the largest metropolitan areas in the U.S. While each municipality is unique in culture, they share several common characteristics. Perhaps the most important of these is a strong connection to local water resources. This connection is responsible for much of the local economy. Three industries in the region provide much of the regional economic growth and exemplify the importance of water to Hampton Roads. These include defense, global trade, and tourism (Koch, 2012).

The Chesapeake Bay is valued for its role as a natural harbor by the U.S. Department of Defense and local industry. Several U.S. military facilities are located in Hampton Roads, including the largest naval base in this country, Naval Station Norfolk. Department of Defense spending directly and indirectly supports nearly 40% of all economic activity in Hampton Roads. Military employment is also an important factor in the economy, supporting more than 86,000 residents (Center for Economic Policy Analysis, 2015). These and other assets make Hampton Roads a critical point of concern for the U.S. military and local leaders.

Business interests also value the Chesapeake Bay as a harbor. The Port of Virginia, located in Norfolk, is a vital hub for international trade in the state. The industries supported by the Port are responsible for up to 7% of the economic value of Hampton Roads (Center for Economic Policy Analysis, 2016). The resulting economic activity is further facilitated by rail and highway transportation availability, making Hampton Roads an important destination for domestic goods. As world trade increases, so too will the economy of the Hampton Roads region.

Tourism, the final of the three major economic pillars of Hampton Roads, also shares a strong connection to local waters. In addition to the numerous well known historic sites found in the region, Hampton Roads is home to popular beaches and numerous waterways and natural features that attract visitors (Koch, 2012), primarily from late spring to late fall. While the Great Recession negatively impacted this industry in recent years (Center for Economic Policy Analysis, 2016), tourism is still considered a primary source of external capital brought into Hampton Roads (Clary and Grootendorst, 2016).

To summarize, water resources play an important role in the Hampton Roads economy. Protecting these valuable assets is a significant concern for residents, businesses, and local governments. Among the most pressing water resource issues in the area is the health of the Chesapeake Bay.

1.3 The Chesapeake Bay

The Chesapeake Bay, shown in Figure 1.3, is the largest estuary in the U.S., draining 64,000 square miles of watershed area that occupies portions of six states and the District of

Columbia (D.C.) (Matuszeski, 1995). Over 100,000 streams and tributaries feed the waters of the Bay, making land use and activities in the watershed significant contributors to Bay health (Jones, 2013). About two thirds of Virginia drains to the Bay, including most of Hampton Roads. The Chesapeake Bay has also been among the most productive estuaries in the U.S. Its relatively shallow depths have allowed it to support thousands of species, which in turn has supported various commercially viable fisheries.

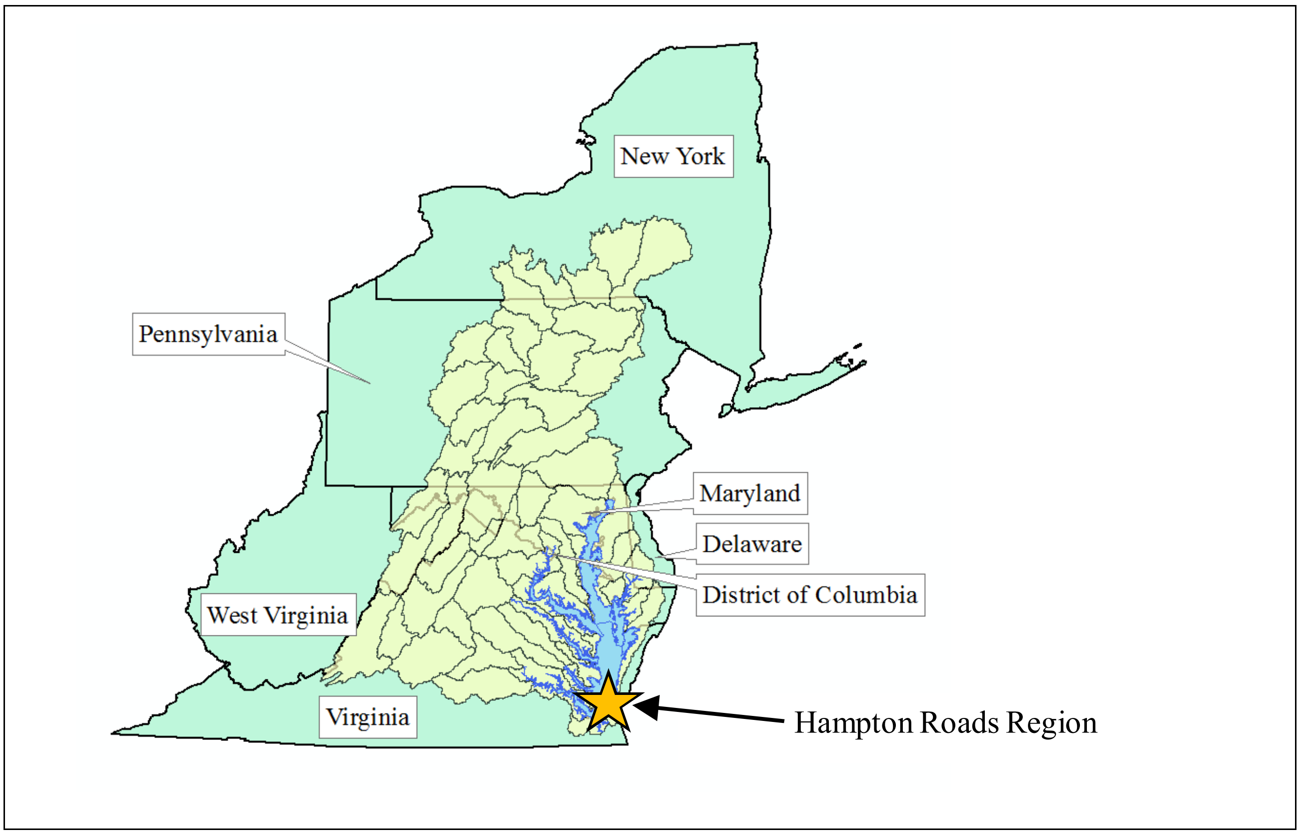


Figure 1.3: The Chesapeake Bay Watershed

This productivity has decreased over time due to the declining health of the Bay. Researchers now recognize that nutrient loadings to estuaries worldwide have grown due to the growth of human populations and agriculture in contributing watersheds (Kennish, 2002). This trend is particularly evident in the Chesapeake Bay watershed. Nutrient loadings increased due to a variety of human activities, including excessive fertilizer use in agriculture and urban landscapes, increased population and associated wastewater discharges and septic system return flows, and increased runoff from impervious areas. This anthropogenic pollution resulted in eutrophication-induced hypoxia and anoxia in the Chesapeake Bay (Kemp *et al.*, 2005), similar to oxygen-degraded conditions found in other estuaries worldwide.

1.3.1 The Chesapeake Bay TMDL

Water pollution has continued to plague the health of the Chesapeake Bay in recent history, despite the implementation of several federal laws to address this challenge. Excess nitrogen and phosphorus has polluted the estuary since at least the 1950s, causing sharp increases algal growth (Kemp *et al.*, 2005). Microorganisms deplete dissolved oxygen to decompose the overgrown algae it uses up the available nutrients and dies. This process, known as eutrophication, leads to hypoxic areas in the Chesapeake Bay where nothing can live, also called dead zones (U.S. EPA, 2015). In addition, upstream erosion causes sediment plumes to form in the Bay, preventing photosynthesis in underwater vegetation and further contributing to the production of dead zones (Langland and Cronin, 2003).

The Chesapeake Bay Partnership signed in 1983 was the first of several cooperative efforts to improve the health of this ecosystem (Jones, 2013). A significant outcome from these attempts includes the development of the Chesapeake Bay Model (CBM). The 5.3 version of this complex water quality model is composed of three components: the Chesapeake Bay Watershed Model, based upon Hydrologic Simulation Program-FORTRAN (HSPF) (Bicknell *et al.*, 1997), an airshed model (Chesapeake Bay Program, 2018a), and a land cover model (Hopkins *et al.*, 2000). The CBM continues to evolve, with version 6.0 now being released (Chesapeake Bay Program, 2018b).

Improvements to the CBM will continue to positively influence restoration efforts in the Chesapeake Bay (Linker *et al.*, 2013).

Despite modeling and other advancements to improve the health of the Bay, voluntary programs did not achieve the rapid restoration results desired, and it was eventually recognized that a strong federal involvement in cleaning the Chesapeake Bay would be necessary (Hall, 2011). Work to develop a Total Maximum Daily Load (TMDL) for the Chesapeake Bay began in 2005. TMDLs begin with a modeling study which determines the pollutant load the impaired water body can receive. This is followed by an allocation of allowed point and nonpoint source loadings, normally including a margin of safety. Finally, an implementation plan is developed, specifically describing how the load reductions will be achieved (U.S. EPA, 2010).

The large drainage basin for the estuary requires cooperation between the U.S. EPA, six state governments, Washington D.C., and the multitude of local, state, and federal jurisdictions that contribute pollutant loads to the Bay. In addition, the Chesapeake Bay TMDL is comprised of individual pollution control goals for 92 distinct segments in the watershed, each of which must show improvement to influence the overall health of the Bay. (U.S. EPA, 2010). This expansive reach makes the Chesapeake Bay TMDL the largest and most complex program of its kind in the U.S.

The creation of the Chesapeake Bay TMDL highlights the importance of federal involvement in addressing the Bay's degradation. The Obama Administration emphasized this point by enacting Executive Order 13508 in 2009. This Order developed a federal strategy for restoring and protecting the Bay waters and designated the U.S. EPA to play a central role in improving water quality measures in the estuary. The plan also directs other federal agencies to work toward improving the Bay through direct habitat recovery, wildlife protection, and land conservation efforts. These agencies currently engage in indirect strategies to improve water quality in the Bay. These include improving citizen involvement and scientific knowledge of the Chesapeake Bay (Exec. Order No.13508, 2009).

The Chesapeake Bay TMDL focuses on impairments due to nitrogen, phosphorus, and sediment. As previously described, an excess of nutrients in waterbodies causes a significant depletion in dissolved oxygen. Excessive sediment reduces water clarity, reducing the availability of sunlight to aquatic plant life. Other pollutants also attach to sediment, causing additional environmental health concerns. While the Chesapeake Bay TMDL does not address these and other pollutants, state and local jurisdiction are encouraged to create separate TMDLs where necessary (U.S. EPA, 2010).

Scientists used models extensively in calculating the load allocations necessary to improve water quality in the Bay. They first sought to understand the effects of various pollutant loadings in the Bay on water quality. Researchers used this data to identify management solutions that could achieve water quality requirements. Three models generated recommendations for nitrogen, phosphorus, and sediment load reductions across the Chesapeake Bay. The airshed model calculates atmospheric deposition of N, while the watershed model calculates nutrient and sediment load responses in the receiving estuary from inputs. The hydrodynamic/water quality estuarine model predicts water quality responses resulting from the watershed and airshed models within the Chesapeake Bay estuary (Linker *et al.*, 2013).

Implementation of management activities needed to meet the goals of the Chesapeake Bay TMDL occurs at the local level. To ensure progress toward reducing pollutant levels in the Bay, the U.S. EPA required that each jurisdiction develop a Watershed Implementation Plan (WIP). These WIPs act as roadmaps, guiding state and local governments on how to achieve the allocation targets set for them by the models. The U.S. EPA split WIPs into three separate phases. The Phase I WIPs informed the pollutant allocations stated in the final Bay TMDL (Commonwealth of Virginia, 2010), while Phase II WIPs subdivided these allocations amongst local governments and other stakeholders (Commonwealth of Virginia, 2012). The final Phase III WIPs, planned for finalization in 2017, details actions required for Bay jurisdictions to reach the 2025 goal of implementing all pollution control measures. States and municipalities track progress toward accomplishing the goals of the Bay TMDL through 2-year milestones reviewed by the U.S. EPA, with increased federal oversight and enforcement actions promised where progress has stalled (U.S. EPA, 2010).

1.3.2 Hampton Roads and the Chesapeake Bay

Of the 92 tributaries of the Chesapeake Bay requiring a TMDL due to their impairment, 40 are at least partially located in Virginia. These segments are in the Potomac, Rappahannock, York, James and Eastern Shore river basins. Localities must manage various sources of nutrient pollutants to effectively reduce loadings, including wastewater facilities, agricultural lands, stormwater runoff, on-site septic systems, forest lands, and resource extraction sites. The Commonwealth of Virginia engaged its local governments through regional planning districts throughout the state to determine feasible strategies and actions needed for pollutant reduction. Local partners provided technical and financial resources to develop and implement compliance strategies, and shared these solutions with state officials once the consultation was completed (Commonwealth of Virginia, 2010, 2012)

Hampton Roads MS4s are largely contained within the York, Lower James, Hampton Roads, and Lynnhaven-Poquoson sub-basin hydrologic units, which drain to the Chesapeake Bay (Katchmark and Smith, 2017). Hydrologic units refer to delineated watersheds recognized as part of a hierarchical drainage system by national agencies and local jurisdictions. Other hydrologic units in the region, such as Albemarle, drain directly to the Atlantic Ocean (Katchmark and Smith, 2017).

The Hampton Roads Planning District Commission (HRPDC) engaged with its member governments to determine how the region should address its nutrient reduction requirements for the Chesapeake Bay TMDL. Regional governmental bodies recognized numerous pollution control strategies and practices that the Bay models did not include. In addition, municipalities identified model revisions, lack of supportive policy, and lack of funding as three key challenges for implementation of the Bay TMDL. A series of recommendations were given to address these challenges and ensure the attainment of load reduction goals (HRPDC, 2012).

Improving water quality in the Chesapeake Bay and its tributaries is critical for Hampton Roads, since the area relies heavily on the ecosystem services the Bay and tributaries provides. An example of the positive result the Bay TMDL could bring to the region is the Lynnhaven River in Virginia Beach. A former source of local pride and revenue as a center for oyster populations, water quality in the river began to decline due to bacterial inputs from surrounding developments. Oyster numbers in the Lynnhaven declined as urban development in the river's watershed increased. The resulting decrease in water quality led to the establishment of a TMDL for bacterial impairment in 2004. The combination of federal enforcement actions and local engagement through the local nonprofit organization Lynnhaven River Now led to significant improvements in the waterbody. By 2012, oysters had returned to the river, and much of the river was considered safe for shellfish consumption. As a result, businesses began growing and harvesting them locally (Jones, 2013). This model example illustrates the potential for the Chesapeake Bay TMDL to improve the Hampton Roads region environmentally and economically, while also strengthening the local community. However, achieving these benefits will require significant efforts from local, state, and national stakeholders.

1.4 Flooding in Hampton Roads

Flooding is another water-related challenge facing Hampton Roads. Globally, floods are caused by various local characteristics, including precipitation patterns, land and soil properties, and the presence of nearby waterbodies. Surface runoff that exceeds the capacity of existing channels causes riverine floods. Similarly, precipitation intensity that exceeds the capacity of the soil to infiltrate water causes pluvial flooding (Jha *et al.*, 2012). Hurricanes, tropical storms, and nor'easters in coastal regions cause water to pile against the coastline, resulting in storm surge flooding. In addition, extreme high tide events can lead to coastal flooding in low-lying areas, even on sunny days. Hampton Roads experiences each of these flooding types repeatedly throughout the year, cumulatively referred to as recurrent flooding (Mitchell *et al.*, 2013).

Change in climate is also thought to play an important role in flood risk, though this relationship is not yet fully understood. Hypotheses have linked storm frequency and warming trends (Huntington, 2006), and climate change is anticipated to increase precipitation quantity and intensity in the Chesapeake Bay watershed (Najjar *et al.*, 2010). These expectations are now building evidentiary support, with recent studies successfully linking increased precipitation persistence and intensity in the northeastern United States to global circulation changes (Guilbert *et al.*, 2015). Thus, flood risk in Hampton Roads is likely to increase as a result of changing local and global climate patterns.

1.4.1 The Role of Sea Level Rise

Climate impacts also influence coastal flooding through sea level rise. Global sea level rise comprises two major components. The first component is thermal expansion, which refers to the expansion of water as its temperature increases due to the resulting decrease in water density. The second component of sea level rise is an increase in the volume of ocean water due to melting ice in Polar Regions. As water levels in the oceans rise, storm surge and tidal flooding are expected to increase in all coastal communities (Pachauri *et al.*, 2014). In Hampton Roads, land subsidence exacerbates localized flooding impacts. Excessive groundwater pumping has led to the compaction of the Potomac aquifer, subsequently causing the land to sink. The combination of sinking land surface and rising sea level is termed relative sea level rise, and it further increases flood risk in the region (Eggleston and Pope, 2013).

Climate models indicate that precipitation, storm frequency, and sea level rise will increase the severity and frequency of flooding in coastal Virginia. Several studies have sought to understand the impacts of future flooding on the region, with many focusing on increased risks due to sea level rise. Regional economic assets, such as military installations (Spanger-Siegfried *et al.*, 2016), roadway networks (Belfield, 2016), and residential properties (Van Houtven *et al.*, 2016), are already vulnerable to the flooding that occurs in the present day. As sea levels continue to rise, the roadway and land area inundated during flood events will increase. These increasing impacts will in turn influence the regional economy. Van Houtven *et al.* (2016) compared the financial impacts of no sea level rise with two sea level rise scenarios during a 100-year flood event. Study results indicate that a rise of 2.5-ft (0.75 m) will increase household income losses and tax revenue losses due to historic flooding by 3.5 and 11 times, respectively.

The financial impacts of flooding in Hampton Roads extend to local resident vulnerability. Kleinosky *et al.* (2007) found that areas in the region most likely to experience storm surge flooding were areas with high levels of poverty, high numbers of immigrants, and high densities of the elderly and the disabled. Populations at the highest risk of flooding were also the populations least able to adapt themselves. Liu *et al.* (2016) identified differences in population vulnerability in the region. Physical landscape characteristics and household socioeconomic conditions strongly influenced vulnerability to storm surge flooding in urban areas, while limited access to critical infrastructure like hospitals and shelters influenced the vulnerability of residents in rural areas. In addition, these studies predicted sea level rise to increase the vulnerability of residents to flooding in Hampton Roads.

1.4.2 Addressing Flooding Challenges

There are three major adaptation strategies to address the flooding concerns of the Hampton Roads region. Management and retreat strategies focus on limiting development in areas with high flood risks, and reclaiming, restoring and preserving flood prone lands. Accommodation strategies improve the management of flood events in populated areas and are implemented throughout Hampton Roads. They include establishing emergency management plans for flood evacuation and retrofitting existing roadway and stormwater infrastructure. Protection strategies generally call for engineering design and include hard structures like levees and storm surge barriers. Other engineered solutions designed to protect land from flood damage include shoreline enhancement, wetland or marsh creation, and green infrastructure installation (Mitchell *et al.*, 2013).

Unfortunately, flooding and the role of sea level rise in Hampton Roads has become a politically divisive issue at the state level (Yusuf *et al.*, 2014; Yusuf *et al.*, 2016), leading to limited policy support to address flooding challenges in the region. Effective planning to address sea level rise and flooding will be complex, requiring a wide range of actors at multiple levels of government and in multiple industries and civic sectors. Recognizing the need for cross-sectoral and cross governmental collaboration, Old Dominion University initiated the Hampton Roads Sea Level Rise Preparedness and Resilience Intergovernmental Pilot Project, also known as the IPP. The IPP aimed to develop a framework to coordinate sea level rise preparedness and resiliency planning. The "whole of government and community" approach adopted by the project sought to involve stakeholders across all the Hampton Roads municipalities at the local, state, and federal levels of government, and to engage those in private and public sectors (Steinhilber *et al.*, 2015).

Leaders throughout the region were fully engaged in the framework development process through their voluntary participation in working groups and advisory committees. Working groups focused on one topic selected for its importance for sea level rise planning, including infrastructure vulnerability, public health impacts, citizen engagement, and related legal issues. Advisory committees worked to support working group activities and engage new audiences on sea level rise issues and impacts, providing several recommendations on how Hampton Roads should move forward to address the challenge of sea level rise. The IPP ended in 2016, resulting in the drafting of a resolution to address the short term realities and long term goals in preparing for sea level rise (Steinhilber *et al.*, 2016). This activity and others with similar goals demonstrate Hampton Road's commitment to mitigating sea level rise impacts.

1.5 Green Infrastructure

Traditionally, urban water managers have largely relied on ditches, pipes, and hardscapes to drain cities efficiently. This gray infrastructure conveys large volumes of stormwater to streams and other water bodies. Negative results of excessive stormwater volumes produced by this method include channel degradation, habitat loss, and flooding. In addition, gray infrastructure does little to treat runoff leaving urban areas, leading to increased pollutant loads (Field *et al.*, 1999). These shortcomings of urban runoff management eventually led to a paradigm shift in the field that emphasizes on-site stormwater management. This new approach, referred to as low impact development (LID), was initially developed in Maryland in response to pollution control needs for the Chesapeake Bay. LID allows sites to mimic their predevelopment hydrology by capturing and infiltrating stormwater (Prince George's County, 2000). In addition to capturing and infiltration, LID practices reduce pollution loads by treating the water they capture through various processes. Green infrastructure (GI) is the name given to structural practices used to achieve the goals of LID in the U.S. Recently, the National Research Council (2009) formalized this paradigm shift in management of urban runoff, in effect making GI implementation a national goal.

GI practices generally use vegetation in their design to improve local hydrologic function. The implementation of GI does not eliminate the need for traditional gray infrastructure solutions in urban areas. However, GI practices are designed to capture runoff and reduce the stormwater volume that reaches the storm sewer system. GI therefore extends the lifecycle of traditional gray infrastructure and reduces the high costs associated with repairs, replacement and maintenance (Copeland, 2014). In addition, plant roots and soil systems are capable of various forms of pollutant removal. These include nutrient uptake of nitrogen and phosphorus, filtration of suspended solids, and adsorption of dissolved particulates (Erickson *et al.*, 2013).

Common vegetated GI practices include bioretention, swales, green roofs, and constructed wetlands. Planter boxes, street trees, floating treatment wetlands, and various other designs can also be implemented. This diversity of practices allows for sites with different characteristics to benefit from the application of GI. Site characteristics such as soil types, slope, elevation, land use, and groundwater table all determine which GI practices will be effective. Other criteria considered in GI selection for a site include available space, site layout, and overall project goals (Water Environment Federation, 2014).

There are also non-vegetated GI practices. Permeable pavements can replace the asphalt or concrete in parking lots, walkways, and other hard surfaces. They promote infiltration by allowing runoff to flow through them for capture and treatment. Rainwater harvesting uses cisterns or rain barrels to collect and temporarily store water on-site. Captured stormwater can be used later as a resource or slowly released for infiltration (Water Environment Federation, 2014).

1.5.1 Benefits of Green Infrastructure

Since the development of LID, various communities across the U.S. have adopted GI practices to address stormwater management needs. The emphasis on GI adoption by the U.S. EPA indicates its support at the federal level, which declared the practices as "…an environmentally preferable approach to reduce stormwater and other excess flows entering combined or separate sewer systems…" (U.S. EPA, 2007). Various partner organizations and federal agencies collaborate with the U.S. EPA to advance the adoption of GI through capacity building activities (U.S. EPA, 2014b, a). This widespread support for GI is in part attributed to the many benefits these practices confer on the sites and communities in which they are installed.

There are two primary benefits of GI. The first benefit is that GI practices manage stormwater pollutant levels on site. Pollutant reduction is a primary concern for the Chesapeake Bay Program, which developed a peer-review process to define consistent pollutant removal rates for GI and other stormwater control measures installed in the region based on the runoff reduction approach to pollutant accounting (Comstock *et al.*, 2012). The results from this process were synthesized by Simpson and Weammert (2009) and adopted by the Chesapeake Bay Program. In general, stormwater wet ponds and detention ponds did not perform as well as infiltrative stormwater practices generally associated with GI. Removal rates adopted by the Chesapeake Bay Program are shown in Table 1.1.

Table 1.1: Chesapeake Bay Program Approved Pollutant Removal Rates (Comstock *et al.*, 2012)

Stormwater Management Practices	**Mass Load Reduction (%)**		
Traditional Practices	**Total Nitrogen**	**Total Phosphorus**	**Total Suspended Solids**
Wet Ponds/Constructed Wetlands	20	45	60
Dry Detention Ponds	5	10	10
Dry Extended Detention Ponds	20	20	60
Green Infrastructure Practices			
Infiltration	80	85	95
Filtering Practices	40	60	80
Dry Swale	70	75	80
Bioretention[1]	80	85	90
Permeable Pavement[1]	80	80	85
Grass Channels[1]	45	45	70

[1]Load reduction assumes A/B soils with no underdrain included in design

It is important to note that the values in Table 1.1 were determined through consultation with an expert panel recommending nutrient and sediment reduction estimates to be included in Phase 5 of the Chesapeake Bay Program Watershed Model. This panel reviewed literature from various sources, including peer-reviewed studies and gray literature not subjected to the peer review process, to approximate pollutant removal efficiencies of traditional stormwater management practices and GI practices (Simpson and Weammert, 2009). Soil type and design components were noted by the expert panel to significantly impact the anticipated pollutant removal performance of GI practices. Additional factors, including maintenance, operational scale, and lag time for a practice to reach optimal efficiency were also considered, and best professional judgement was often applied by the panel in making final performance recommendations for stormwater management practices (Simpson and Weammert, 2009).

Other reviews of stormwater practice performance studies do not necessarily conclude that GI is more effective than traditional treatment practices. The Virginia Runoff Reduction Method assigns credits to stormwater practices based on the 50th and 75th percentile removal rates derived from the literature. The authors acknowledge that assigned pollutant credits are based on a limited number of studies and are expected to change as more data becomes available over time (Battiata *et al.*, 2010). The current literature on stormwater pollutant removal efficiency shows wide variations in performance when comparing the same practice in different studies. In addition, studies on practice performance are generally short term and do not consider changes in efficiency over time. Additional data must be collected to better understand GI pollutant removal, the factors that impact its effectiveness, and how to maintain high levels of performance over long periods of time (Liu *et al.*, 2017).

The second major use of GI is to effectively manage water quantity. Dietz (2007) and Ahiablame *et al.* (2012) conducted literature reviews of LID effectiveness studies, with results showing that GI practices applied to developed sites were capable of managing flow regimes and restoring predevelopment hydrology conditions (Burns *et al.*, 2012). The potential environmental benefits of this restoration include reversing the impacts of urban stream syndrome (Askarizadeh *et al.*, 2015) and protecting ecologically sensitive areas (Wella-Hewage *et al.*, 2016).

GI is also noted to be multifunctional, capable of providing various additional benefits to their surroundings (Hansen and Pauleit, 2014). The ecosystem services produced by GI, like urban heat island effect reduction and air pollution removal, have physical and psychological health benefits (Tzoulas *et al.*, 2007). Rain gardens, which are used to collect and infiltrate runoff on smaller sites, can produce vegetable yields similar to those of conventional gardens and support local food systems (Richards *et al.*, 2015; Richards *et al.*, 2017). GI can also have important social benefits when implemented equitably (Heckert and Rosan, 2016), addressing issues associated with poverty and other needs in distressed communities (Dunn, 2010). In one example, green infrastructure installed in an economically strained neighborhood in Baltimore, MD contributed to an urban revitalization effort. The combination of green infrastructure and educational initiatives in the community improved indicators of water quality in runoff and quality of life for local residents (Hager *et al.*, 2013).

1.5.2 Factors in Green Infrastructure Adoption

Implementation of GI across the U.S. has been slowed by various obstacles (Copeland, 2014). These barriers derive from the various factors that influence the adoption of GI. One important factor is the state of existing stormwater institutions (Brown and Farrelly, 2009). Stormwater governance policies initially addressed only flood control needs. Solutions developed to address water quantity challenges generally encouraged centralization in stormwater management (Porse, 2013).

Today, stormwater institutions are responsible for addressing flooding concerns, while also adopting newer practices for water quality improvement and environmental protection. Some authors have argued the paradigm shift toward distributed GI practices to manage these new goals is incompatible with the centralized system already in place (Van de Meene *et al.*, 2011; Dhakal and Chevalier, 2016). Others recognize the shortcomings of existing urban water management institutions and advocate for their transition to more sustainable practices through experimental governance and policy (Farrelly and Brown, 2011; Bos and Brown, 2012; Chini *et al.*, 2017). For Porse (2013), the integration of green infrastructure into existing stormwater management systems will require stormwater institutions to at least consider adapting existing governance structures to continue to be successful.

Centralized stormwater governance structures also influence the support mechanisms for GI adoption. GI is a novel approach to stormwater management that requires input and expertise from disciplines outside of the engineering discipline to satisfy needs and minimize ecosystem impacts (Fekete and Bogárdi, 2015). Integrating stakeholders with varied backgrounds into water management is a new and complex task for many existing stormwater institutions (Ruiz *et al.*, 2015). Stormwater managers will need to adopt new frameworks and practices that encourage collaboration to maximize the potential of GI within their MS4 (Fryd *et al.*, 2012).

Another important factor influencing GI adoption is perception. In her dissertation, Carlet (2014) explored the perceptions of stormwater management personnel about GI and their impact on its adoption. Perceptions of GI as beneficial, compatible with the needs and values of communities, and testable through trial experiments all led to a positive disposition toward adopting the practices. Perception of technical and financial resource availability also influenced whether municipal practitioners showed favor toward adopting GI. Finally, the association of GI with high levels of risk negatively influenced attitudes toward green infrastructure adoption.

Public perception of GI also plays an important role in its adoption. Unlike traditional gray infrastructure that is commonly underground and unseen, GI is visible and subject to public scrutiny. Therefore, positive citizen reception is essential for its adoption. Communities that are knowledgeable of stormwater challenges are more receptive to GI (Baptiste *et al.*, 2015), while those that lack awareness are less willing to adopt these practices (Keeley *et al.*, 2013). In addition to awareness, perceptions of GI also depend on a sense of ownership over its implementation. This requires the meaningful engagement of residents in GI adoption and throughout the lifecycle of the practice (Everett and Lamond, 2016).

Finally, local context is an important consideration in decisions involving GI implementation. Young *et al.* (2014) sought to develop a typology to identify the stage of GI development in different governing units. They found the local social system as one of the major factors motivating GI implementation. Important social components include local political climate, existing governance structures, and the local labor market and configuration. The other major factor considered in the progress of GI development was the surrounding ecological system. Climate setting, recent weather events, and existing amenities were all influential in GI development.

Flynn and Davidson (2016) used a socio-ecological framework to identify the significant variables that influenced GI adoption. Social factors like economic and social contexts, existing systems of governance, local politics, and actors in the community were all important for GI implementation. Ecological factors determined to be important for GI include local ecosystems and available resources. Interactions between these various factors also influenced GI adoption, highlighting the complexity of decision-making involving GI.

Every municipal body has unique social, political, and economic contexts that have important implications for GI adoption. An example is cities with challenges of blight and negative population growth that identify a unique role for GI in redevelopment and beautification (Keeley *et al.*, 2013). In addition, different municipalities have varying ecological, physical, biological, and climatic characteristics. These environmental attributes also influence GI, like coastal areas and role of GI in addressing sea level rise (Azevedo de Almeida and Mostafavi, 2016). The complex interactions between these ecological and social factors create the unique context that determines the implementation of GI practices in any MS4. Methods of improving GI adoption must be place-based, taking into consideration the individual context of the surrounding community and its environment.

1.5.3 Green Infrastructure in Hampton Roads

Challenges to GI implementation are present throughout the U.S., and these barriers may interact with each other in unique ways to reinforce resistance to change in the status quo of stormwater management (Winz *et al.*, 2014). The factors of stormwater institutions, perceptions, and local context combine with locally relevant barriers to make the pursuit of GI unique to each MS4. In Virginia, the runoff reduction method (RRM) informs stormwater management design. Established in 2008 by the Center for Watershed Protection and the Chesapeake Stormwater Network, the RRM is a compliance tool designed to minimize runoff volumes from sites of development (Battiata *et al.*, 2010). The use of stormwater control measures (SCMs), many of which are GI practices, accomplishes the goals of runoff reduction and are required for nearly all development projects.

The RRM has become a regulatory tool in the Virginia, used to encourage the use of SCMs to control stormwater and reduce pollutants throughout the state. However, poor soil quality, flat terrain, and high groundwater table impede the application of many SCMs in the Coastal Plain of Virginia. A recent study evaluated the applicability of stormwater SCMs in the City of Virginia Beach. Johnson and Sample (2017) developed a software tool to analyze geospatial data and determine which locations allowed SCM implementation based on physical site characteristics and SCM design criteria. Practices that did not rely on infiltration were most widely applicable, while those that depended on infiltration were among the least applicable. Conversely, while implementing GI in the Coastal Plain may be difficult due to physical constraints, the tool identifies those areas for which GI may be uniquely suited, and thus should help facilitate adoption in those areas.

The Hampton Roads region is at the nexus of a variety of water concerns. Land subsidence, sea level rise, climate change, and ongoing development make the region prone to flooding impacts. The Chesapeake Bay TMDL requires water quality treatment from municipalities responsible for stormwater discharges. In addition, local waters influence much of the economy in the region. This combination of characteristics benefits Hampton Roads, and at the same time causes it to be at the mercy of its water resources. GI holds promise in providing some relief to these challenges. The Hampton Roads Planning District Commission (HRPDC) has recognized the potential role for GI in the region, releasing its regional plan for the implementation of GI practices in 2010 (Kidd *et al.*, 2010). Today, it is vital to understand which barriers to GI adoption are most significant in Hampton Roads, and to understand how to overcome these challenges and allow the benefits of GI to positively impact the region.

This research project has three goals. The first is to assess the current application of and support for GI in Hampton Roads municipalities. The second goal is to identify specific barriers to GI adoption in Hampton Roads. The final goal is to identify how local Extension offices could potentially work in support of GI implementation in Hampton Roads.

The mission of Cooperative Extension is to serve the needs of the local community through university-based education and applied programming. Identifying these needs is one of Extension's core functions, and characterizing local needs is necessary to serve members of the community. My hope is that this manuscript facilitates the expansion of the role of Cooperative Extension in the Hampton Roads region through strengthened partnerships at the municipal and regional level, in stormwater management and in other environmental areas of public concern.

Through these enhanced connections, local agents, researchers, and personnel can help to improve the adoption of GI in Hampton Roads through education and knowledge, continuing Extension's long history of meaningful engagement on environmental issues with the communities it serves.

Chapter 2. Methodology

2.1 Study Setting

This study focuses on municipalities in Hampton Roads permitted as MS4s from 2011 to 2016. Virginia released Isle of Wight County from MS4 permit regulations in May of 2016, so that municipality is not included in this analysis. Extension offices located in the corresponding municipalities were also examined. In total, the study assessed 11 municipalities and 9 Extension offices. Table 2.1 lists the MS4s included in this study.

Table 2.1: MS4s in Hampton Roads

Name	Location	Phase
Chesapeake	Southside	Phase I
Hampton	Peninsula	Phase I
James City	Peninsula	Phase II
Newport News	Peninsula	Phase I
Norfolk	Southside	Phase I
Poquoson	Peninsula	Phase II
Portsmouth	Southside	Phase I
Suffolk	Southside	Phase II
Virginia Beach	Southside	Phase I
Williamsburg	Peninsula	Phase II
York	Peninsula	Phase II

2.2 Methodological Basis

The procedures for this study follow established Cooperative Extension procedures for needs assessments, which identify and prioritize needs to inform problem solving decisions. There are three phases in needs assessments. The first phase, pre-assessment, focuses on understanding the status of a need. The assessment is the second phase and focuses on collecting new data on the need examined. The final phase, post assessment, identifies appropriate responses to needs examined based on the information gathered throughout the assessment (Mertens and Wilson, 2012).

2.3 Data Collection

During the pre-assessment phase of the study, a document review of available information on stormwater programs in the Hampton Roads region was conducted. Document reviews examine existing information to collect independently verifiable data on a topic (Watkins *et al.*, 2012). The documents selected for review were MS4 Annual Reports and municipal budget documents, which are publicly available from municipal websites. Municipalities are required to submit annual reports to the Virginia Department of Environmental Quality (VDEQ) to maintain permit compliance. These reports describe the events and programs conducted throughout the year to meet permit goals. They also report metrics on stormwater-related activities conducted by the division in charge of stormwater management. Municipal budget documents are completed and submitted annually. One key aspect of the budget documents is the description of anticipated future municipal spending. Capital improvement budgets focus on major infrastructure investments and describe water infrastructure spending, including stormwater and drainage infrastructure A listing of all the municipal documents examined during the pre-assessment can be found in Table 2.2. Please note that fiscal years for the Municipal Budgets and MS4 Annual Reports run from July to June. For this study, only documents with reporting periods within the calendar years 2011-2016 were considered for examination. Therefore, only reports for FY12-FY16 were eligible for review.

Table 2.2: Municipal Documents Reviewed

Name	MS4 Annual Reports	Municipal Budgets
Chesapeake	n/a	FY13, FY14, FY15, FY16
Hampton	FY13, FY14, FY15, FY16	FY13, FY14, FY15, FY16
James City	FY13, FY14, FY15, FY16	FY12, FY13, FY14, FY15, FY16
Newport News	FY12, FY13, FY14, FY15	FY12, FY13, FY14, FY15, FY16
Norfolk	n/a	FY12, FY13, FY14, FY15, FY16
Poquoson	FY13, FY14, FY15, FY16	FY12, FY13, FY15, FY16
Portsmouth	n/a	FY12, FY13, FY14, FY15, FY16
Suffolk	FY13, FY14, FY15, FY16	FY12, FY13, FY14, FY15, FY16
Virginia Beach	n/a	FY12, FY13, FY14, FY15, FY16
Williamsburg	FY12, FY13, FY14, FY16	FY12, FY13, FY14, FY15, FY16
York	FY12, FY13, FY14, FY15, FY16	FY12, FY13, FY14, FY15, FY16

Extension Situation Analysis Reports and the Virginia Cooperative Extension (VCE) Strategic Plan were also reviewed to understand the current role of Extension in GI. Situation Analysis reports describe the unique conditions of the areas Extension offices serve. They also identify major focuses for local Extension personnel. The Strategic Plan provides an overview of the major programs of VCE throughout the state. These documents provide insight into the role of VCE offices in Hampton Roads in promoting GI adoption. A listing of the VCE documents examined during the pre-assessment phase can be found in Table 2.3.

Table 2.3: VCE Documents Reviewed

Document Name	Citation
VCE Strategic Plan	(Virginia Cooperative Extension, 2010)
Chesapeake Situation Analysis Report	(Virginia Cooperative Extension, 2015a)
Hampton Situation Analysis Report	(Virginia Cooperative Extension, 2015b)
Newport News Situation Analysis Report	(Virginia Cooperative Extension, 2015c)
Norfolk Situation Analysis Report	(Virginia Cooperative Extension, 2015d)
Portsmouth Situation Analysis Report	(Virginia Cooperative Extension, 2015e)
Suffolk Situation Analysis Report	(Virginia Cooperative Extension, 2015f)
Virginia Beach Situation Analysis Report	(Virginia Cooperative Extension, 2015g)

The assessment phase followed two separate procedures. The survey portion targeted municipal leaders and managers in municipalities in Hampton Roads permitted to produce stormwater discharges. Those in leadership positions were considered best equipped to answer questions related to barriers to GI implementation, making them ideal survey candidates. Research subjects were selected with guidance from the HRPDC, who provided insights on municipal stormwater personnel who act as local leaders. In total, 70 subjects throughout Hampton Roads met candidate criteria and received invitations via email to participate in the survey. The survey was available for 5 weeks, from April 17th to May 19th. Three reminder messages were sent to study candidates throughout the survey who were invited and had not yet completed the survey.

The interview portion of the assessment targeted Cooperative Extension personnel focused on natural resource issues. Study researchers were interested in recent actions and attitudes in Extension toward GI. Ten subjects were contacted via email to participate in the in-person, one-on-one semi-structured interview. All interviews were audio recorded and transcribed. Research subjects in both assessment portions who agreed to participate gave consent for the use of the data they provided. Subjects in the assessment phase were guaranteed anonymity for their participation.

2.4 Survey Development and Format

The municipal surveys were developed with two distinct goals in mind. The first was to identify the most important barriers preventing the spread of GI in Hampton Roads. To achieve this goal, studies of barriers to GI in various contexts were reviewed and compared. Common themes were identified in order to compile a list of representative challenges to commonly encountered in GI implementation. The studies used to create this list are shown in Table 2.4. HRPDC staff reviewed this list and provided comments to make it relevant to the local context in Hampton Roads. A final list was developed in response to this feedback. The barriers on this final list include laws and regulations, public education, training and data, costs and funding, management and coordination, maintenance, residential implementation, and climate and land features.

Table 2.4: List of Green Infrastructure Barrier Studies

Article Title	Author(s)	Citation
Analysis of Barriers to Low Impact Development in the North Coast Redwood Region, California	Abbey Stockwell	(Stockwell, 2009)
Barriers and Gateways to Green Infrastructure	Kristyn Abhold Lorraine Loken Ben Grumbles	(Abhold *et al.*, 2011)
Barriers and Opportunities for Low Impact Development: Case Studies from Three Oregon Communities	Derek Godwin Betsy Parry Frank Burris Sam Chan	(Godwin *et al.*, 2008)
Breaking Down the Barriers to Low Impact Development in Colorado	Andrew Earles Derek Rapp Jane Clary Janice Lopitz	(Earles *et al.*, 2009)
Understanding and Overcoming Legal and Administrative Barriers to LID: A Florida Case Study	Thomas Rupert Mark Clark	(Ruppert and Clark, 2008)
Risk: A Fundamental Barrier to the Implementation of Low Impact Design Infrastructure for Urban Stormwater Control	Joshua Olorunkiya Elizabeth Fassman Suzanne Wilkinson	(Olorunkiya *et al.*, 2012)
Understanding Barrier Interactions to Support the Implementation of Sustainable Urban Water Management	Ines Winz Sam Trowsdale Gary Brierley	(Winz *et al.*, 2014)

Laws and regulations refer to legal restrictions on GI, or concerns with the legal ramifications of implementing these practices. Training and data challenges refer to issues regarding a lack of knowledgeable professionals specializing GI design, maintenance, or management and to a lack of information on GI performance and benefits. Management and coordination challenges for GI refer to issues centered on responsibilities and conflicts within and between municipalities regarding GI practices. Cost and funding challenges refer to challenges paying for GI practices both initially and throughout their lifecycle. Climate and land feature challenges refer to both the physical limitations of the surrounding landscape on GI implementation and concerns regarding the compatibility of GI with the local climate. Maintenance challenges refer to issues in preserving the functionality and performance of GI practices over time. Public education and engagement challenges were those related to public familiarity with GI. Residential implementation challenges refer to issues with homeowners adopting GI practices on their property.

The second goal of the survey was to understand how the most important challenges impact GI in practice. The final list of GI barriers represented broad categories that contained more specific challenges, so it was important to understand which of these aspects of the broader barriers were important. There was also a need to characterize the impact of these challenges. Details regarding how long the barrier had existed, if and how it had been previously addressed, and the way it disrupts GI adoption were included to provide deeper insights into the needs of MS4s to address these challenges. The final survey was reviewed and approved by graduate advisors and HRPDC staff.

The survey begins with an introductory section to gather general identification information of the respondent. Questions in this section include identifying which MS4 permit applies to the respondent's municipality, number of years in their current position, and number of years in the stormwater field. MS4 permits target large cities under Phase I agreements and smaller cities under Phase II. Since large and small cities have their own unique challenges, this question was included to account for potential differences in perspective based on size of the municipality. Similarly, differences in perspective based on level of experience could potentially affect survey answers, providing another source of comparison. The final question in the introductory section asked participants about their familiarity with VCE. This was included to understand how or if municipal personnel engage with VCE offices in stormwater management.

Following this introductory section, survey participants ranked challenges in order of significance for GI implementation within their municipality. Once participants ranked the barriers to GI implementation, they were asked to characterize the challenge they identified by selecting the significance of the given barrier components. Other questions in this section include how long these challenges had been a barrier, how these challenges impacted GI implementation, how progress had been or would be made toward addressing the challenge, and activities that would be most useful in addressing the challenge. The final section of the survey asked participants to identify any additional challenges to GI not discussed in the survey.

2.5 Interview Development and Format

Interviews were also developed to achieve two goals. The first was to gather information regarding Cooperative Extension's water related programming. Cooperative Extension personnel were asked to provide their perceptions regarding water management issues within their municipality. This was important since VCE offices have multiple responsibilities to their communities which may or may not include water management. The participants identified local water management priorities, estimated the amount of time devoted to water programs, identified the strengths and weaknesses of their Extension office regarding its support for these programs, and noted primary partners on water issues within the municipality.

The second goal of the interviews was to determine how VCE offices had previously and were currently engaged in stormwater and GI. Participants were asked to identify which municipal office was responsible for stormwater management and provided a definition of GI in their own words. They were also asked to comment on their history with programs supporting GI, identify which barriers to GI were most significant within their municipality, note time and resources devoted to the top three challenges identified, and identify additional challenges to GI implementation. VCE interview questions were reviewed and approved by graduate advisors before interviews were conducted.

2.6 Methods of Analysis

Qualitative and quantitative techniques were used to analyze the data collected throughout this study. For the document review, the analysis was largely qualitative. MS4 Annual Reports, VCE Situation Analysis reports, and the VCE Strategic Plan were read through, and all mentions of GI and related concepts were noted. In Municipal Budget reports, funding amounts for stormwater and drainage infrastructure projects were extracted. Data organization varied by document type, as not every municipality included in the study supplied documentation for the study period selected. When feasible, comparisons were drawn between Phase I and Phase II MS4s and between Peninsula and Southside municipalities to identify possible program scale and geographic differences. Otherwise, documentation data were grouped and presented as a regional representation.

To analyze the survey responses, collected data was categorized based on the respondent MS4 i.e., Phase I or Phase II. MS4 location was also used to categorize responses as either Peninsula or Southside. Questions in the survey were defined as nominal or ordinal. Nominal questions were analyzed using the chi-square test (Reynolds, 1984). Ordinal questions were analyzed using the Mann-Whitney-U test (Gibbons, 1993). P-values obtained from tests were used to determine if survey questions were answered differently based on MS4 Phase or location. P-values less than 0.05 indicated significant differences between groups.

It is important to note that respondents did not answer every question available in the survey. Instead, respondents only expanded on individual barriers for their top three highest ranked challenges. Therefore, analyses for each barrier featured a different number of observations. In some cases, very few respondents in a category listed a challenge in their top three. In cases where less than three respondents in either group being compared were represented, statistical analyses were not performed due to the small sample size. Statistical analysis was also not performed when only one group was represented.

Interview responses were coded for each question to identify major themes for comparison between Phase I and Phase II municipalities and Peninsula and Southside. Grouping survey responses by program type and location allowed for comparisons with survey responses that would inform the post assessment. James City County was the only municipality where two interviews were conducted because it was the only municipality in the study without a full-time Extension Agent for Agriculture and Natural Resources.

In the final phase of the assessment, data gathered from the document reviews, surveys, and interviews were compiled to draw conclusions. Information gained from the document review was used to define the current state of GI implementation in Hampton Roads. Data collected from interviews was used to determine the current role of VCE in GI implementation and the level of interest in expand that role. Rankings of GI barriers collected from municipal and VCE personnel were compared to determine similarities and differences between them in their understandings of local GI challenges. Municipal personnel responses regarding the top GI barriers selected were aggregated to identify common themes in how problems for GI manifest in Hampton Roads. Finally, actions to address the top two ranked GI barriers were matched to the strengths and resources identified in VCE interviews to determine how VCE can facilitate GI implementation in Hampton Roads.

Chapter 3. Results

3.1 Document Review

In total, four document types were selected for review: MS4 Annual Reports, municipal budget reports, the VCE Strategic Plan, and the VCE Situation Analysis Reports. MS4s submit yearly reports regarding the outcomes of their stormwater management programs to comply with the terms of their stormwater discharge permit. Not all municipalities provided MS4 reports publicly. In addition, several MS4s with reports available online did not provide one or multiple years of reporting during the interest period, making this data source challenging to use in this study.

Municipal budget reports detailed how municipalities allocated funding, and included information regarding stormwater and drainage spending for capital improvement projects. While these reports included both allocated and projected spending for capital improvements, this review only considered allocated funding. Budget reports also possessed information on stormwater utility fees for those municipalities that charge them. Internet searches helped supplement the stormwater utility fee information and fee credit availability. Wide availability and standardization across the municipalities of Hampton Roads made budget documents a valuable resource in this study. However, many of the drainage project descriptions lacked specificity in whether GI would be used, making this set of documents less relevant to the question of GI implementation.

The final two documents focused on VCE. The Strategic Plan (Virginia Cooperative Extension, 2010) detailed the goals of the VCE organization from 2011 to 2016. The Situation Analysis Reports, conducted by VCE offices in 2013, discussed the primary objectives for each VCE office in the Hampton Roads region. While both documents mentioned issues related to stormwater management, neither was focused solely on the topic. Documents reviewed from Virginia Cooperative Extension are listed in Table 2.2. Please note that while Situation Analysis Reports were produced in 2013, they were all published in 2015.

3.1.1 MS4 Documents

MS4 Annual Reports were examined to understand how Hampton Roads municipalities worked to support GI adoption over the interest period. Of the eleven municipalities permitted for MS4 discharges in Hampton Roads, Norfolk, Portsmouth, Virginia Beach, and Chesapeake did not have MS4 Annual reports available to the public online. This analysis considers the remaining municipalities as a single group to identify commonalities between the municipalities in Hampton Roads for which reporting was available.

Reviews of the MS4 Annual Reports during the period of interest revealed two categories of GI support in the region. Activities refer to programs, events, and projects that support GI adoption through educational or participatory methods. One activity commonly held throughout the region was rain barrel workshops. These events focused on educating the public on the importance, usage, and installation of rain barrels on residential property. Other activities noted in the region include rain garden installation projects, educational presentations and training related to GI, and the homeowner participation program Bay Star Homes. This program is administered by the Hampton Roads Planning District Commission (HRPDC) through askHRgreen (http://askhrgreen.org/programs/bay-star-homes/) and is part of a regional effort to restore the Chesapeake Bay by promoting residential action. Participants are encouraged to engage in various activities at their homes, including the installation of rain barrels and rain gardens in their yards.

In some reports, MS4s also noted the type and number of stormwater management practices installed during that fiscal year. The total numbers of GI practices installed were generally smaller than the numbers for more traditional stormwater management practices, particularly detention and retention ponds. In addition, GI installations generally treated smaller areas than pond practices, meaning their overall impact on improved water quality and quantity in the region was smaller compared to traditional practices.

One example of this is James City County, which recorded all the stormwater management practices that were installed from FY13 to FY16. During these four years, 50 traditional stormwater management practices were installed throughout the MS4, treating 878.26 acres. Over the same period, 70 GI practices were installed, treating only 135.08 acres. Treatment areas varied widely based on the individual practices installed. Based on these numbers, traditional practices treated 9.1 times more area than GI practices. Figure 3.1 shows the comparison between traditional and GI practices installed in James City County.

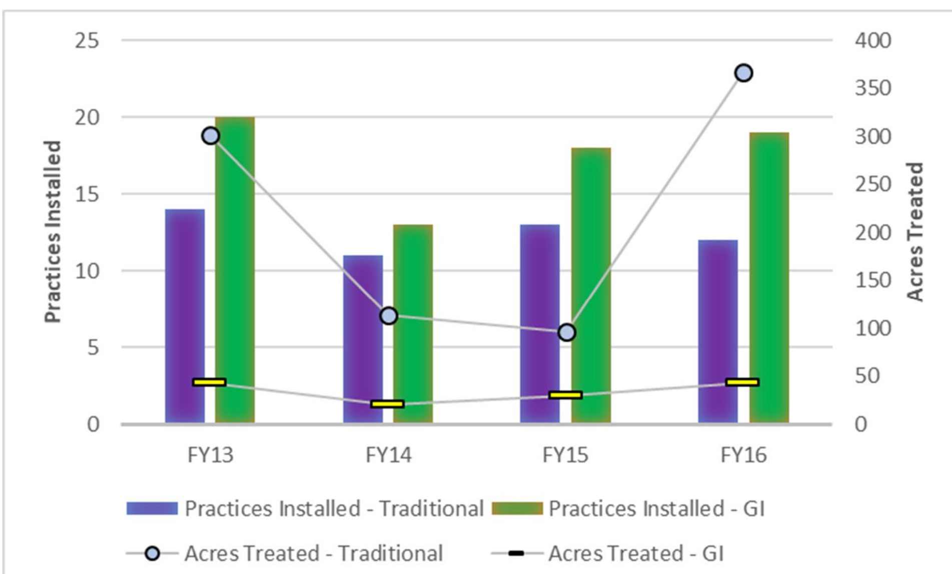


Figure 3.1: GI and Traditional Stormwater Practices in James City County

Municipal budget documents were used to determine the amount of funding Hampton Roads municipalities contributed to GI implementation in the region through major infrastructure projects between 2011 and 2016. Capital Improvement Project (CIP) and municipal budgetary documents were reviewed from FY12 to FY16, focusing on projects primarily concerned with stormwater, waterways, or drainage. Other projects that would impact local water quality and quantity, such as those related to land use changes or transportation improvements, were not considered in this review. In addition, this review only considered funding approved for the fiscal year of the report being reviewed. This was necessary to eliminate either double counting or speculative spending values and focus exclusively on actual spending during the period of interest. Finally, it should be noted that only projects primarily focused on drainage and stormwater were included in this analysis. Transportation projects and other capital improvement expenditures that include land disturbance that would require the implementation or drainage or stormwater controls were not examined.

Budget documentation for all Hampton Roads municipalities was available to the public online. However, spending information was not available for every year of interest. Specifically, CIP information from Hampton and Chesapeake was not publicly available for FY12, and CIP information for Poquoson was not available for FY14. Project descriptions and titles provided in the documentation were used to categorize them based on their support for GI implementation. Projects that included the use or mention of GI practices were identified as GI supportive. Those that specified gray infrastructure, ponds, and other traditional methods of drainage and stormwater management were labeled as GI unsupportive. Many project descriptions did not specify engineering methods to achieve drainage goals. These could not be clearly classified as supportive or unsupportive of GI practices and were therefore labeled as unspecified stormwater spending.

In total, over $238 million was spent on stormwater capital improvement projects in Hampton Roads over the last five years. Nearly $7 million of this amount was marked as supportive of GI practices. This amounts to 2.86% of the budget dedicated to stormwater infrastructure likely implementing GI practices in Hampton Roads from 2011 to 2016. Over $170 million, or 71.57%, of the total stormwater CIP spending from 2011 to 2016 was unspecified. Figure 3.2 displays the total stormwater CIP spending in Hampton Roads.

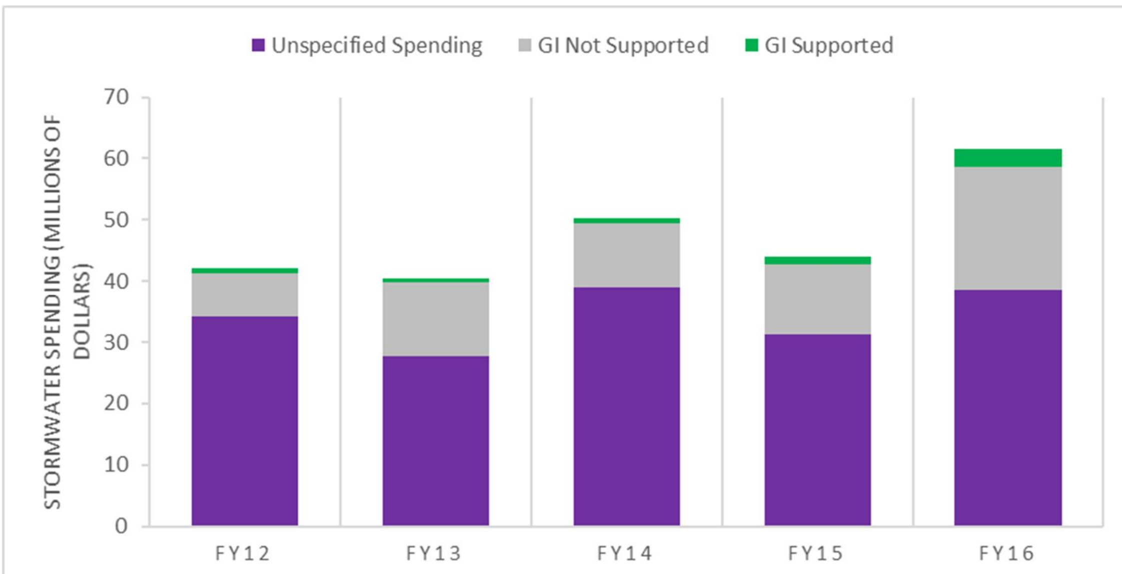
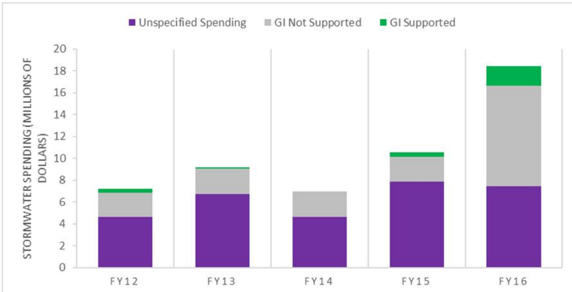
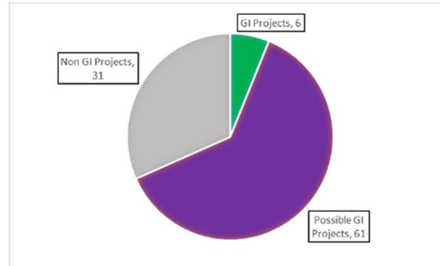


Figure 3.2: Total CIP Spending for Stormwater Projects

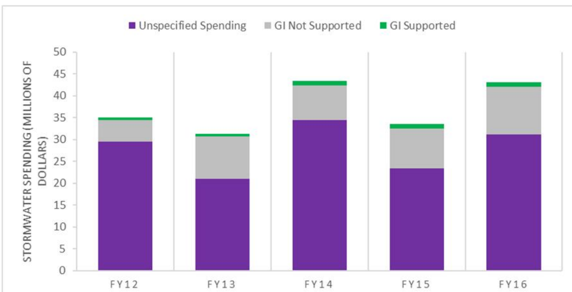
These values differ somewhat when comparing subgroups within the region. Peninsula municipalities used 5.31% for GI, with 59.81% unspecified. Southside municipalities contributed 2.17% to GI, with 74.88% unspecified. Phase I municipalities contributed 2.74% of their budget to GI over the period of interest, while 71.54% was unspecified. Meanwhile, Phase II municipalities utilized 4.34% of CIP budget to improve GI adoption, with 71.93% unspecified. Figure 3.3 shows the total CIP stormwater spending and the number of stormwater projects funded during the period of interest in each Hampton Roads subgroup.

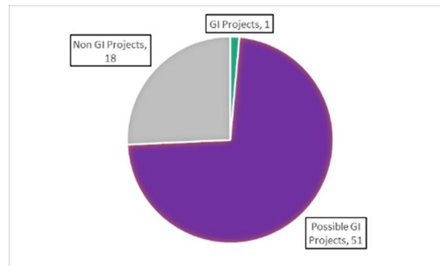
3.3a) Peninsula



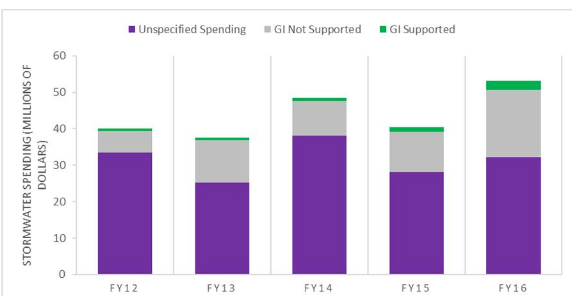


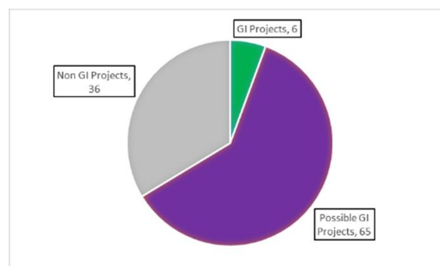
3.3b) Southside



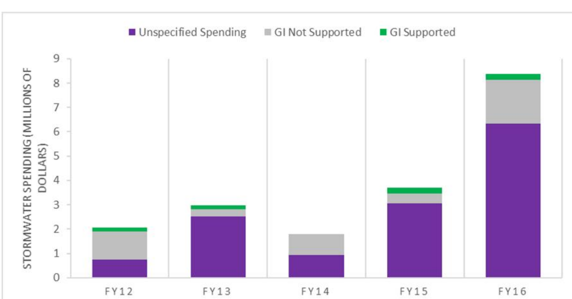


3.3c) Phase I





3.3d) Phase II



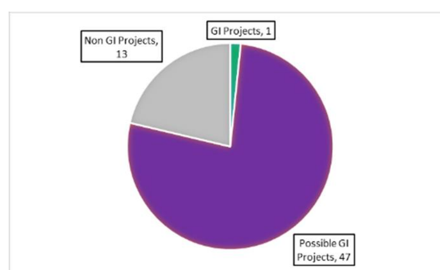


Figure 3.3: CIP Allocation and Number of Stormwater Projects in Hampton Roads

The number of stormwater and drainage projects across Hampton Roads was also compared. Of the 168 projects that received funding in the region over the last 5 years, seven described the use of GI in their budgetary descriptions. Six of those seven were in Phase I municipalities, with only one in a Phase II MS4. Six of the seven projects were also located in the Peninsula and one in Southside. 112 of the funded projects did not specify if GI was implemented to meet stormwater management goals. 65 of these projects are in Phase I MS4s, and 47 are in Phase II. 51 projects with unspecified funding are in the Southside region, compared to 61 in the Peninsula.

Seven municipalities charge residents and property owners stormwater utility fees. Utility rates have increased over the interest period for all municipalities in the region except for the City of Chesapeake. Online searches were used to determine if stormwater utility rates could be reduced through GI implementation on site. Fee reduction programs were available in five municipalities. However, only Norfolk offered this program to residential properties. Other municipalities only offered fee reductions for non-residential or commercial properties. Table 3.1 lists the utility fees in every Hampton Roads municipality with a stormwater fee.

Table 3.1: Utility Fees in Hampton Roads Municipalities

Name	**FY12**	**FY13**	**FY14**	**FY15**	**FY16**
Chesapeake	$ -	$ 7.85	$ 7.85	$ 7.35	$ 7.35
Hampton	$ 4.60	$ 6.41	$ 6.99	$ 6.99	$ 7.83
Newport News	$ 5.45	$ 7.45	$ 8.00	$ 9.75	$ 10.75
Norfolk	$ 8.70	$ 9.96	$ 10.24	$ 10.52	$ 11.80
Portsmouth	$ 8.25	$ 9.25	$ 9.25	$ 9.25	$ 9.25
Virginia Beach	$ 9.48	$ 10.98	$ 12.48	$ 12.99	$ 12.99
Suffolk	$ 5.24	$ 5.24	$ 6.00	$ 6.00	$ 6.00

3.1.2 VCE Strategic Plan and Situation Analysis Reports

VCE developed its strategic plan in 2009 in response to a comprehensive review of its programs conducted by citizens and officials. Specific community issues were selected for VCE to focus its efforts on. VCE then identified goals related to each of these issues.

Focus Area II of the plan, titled Sustaining Virginia's Natural Resources and Environment, has the greatest implications for the impact of VCE on GI adoption. Per Goal 4 under this focus area, VCE is to "Provide education to conserve and protect Virginia's surface and groundwater resources, including the Chesapeake Bay". VCE is to educate residents on various pollutants and their impacts on Virginia waterways and groundwater resources. VCE is to also educate homeowners, landowners, producers, and youth on practices and behaviors that influence water quality and water resource conservation. GI is not specifically mentioned regarding the water resources education responsibilities of VCE.

In the VCE Situation Analysis Reports, nearly every municipality identified the need for public education for water-related concerns, particularly pollution reduction for water quality improvement. Several offices also noted the need to protect existing natural resources, particularly wetlands. Master Gardeners were identified by several offices as an important component of addressing public education needs in their local area. However, only one Situation Analysis Report identified a specific GI practice, rain barrels, to be promoted in local communities through educational programs.

3.2 Green Infrastructure Survey

The Hampton Roads GI Survey was offered in two rounds. In the first round, 69 potential subjects were selected from the permitted municipalities in Hampton Roads. One additional participant was recommended for inclusion in the survey by another participant. In total 70 stormwater professionals were initially invited to participate. The survey was open for a period of 5 weeks, from April 17 to May 19, 2017. 25 professionals responded to the survey, yielding a 35.7% response rate. 19 participants completed the survey, yielding a 76% completion rate for those who responded.

Following the conclusion of the initial survey, a second round was offered to those who had not completed the survey during the first round, and to participants who did not respond to the initial invitation. This second round was open for one week, from July 30 to August 5, 2017. There were no participants in the second round. The second round did not include any additional participants who were not invited during the first round. Those who had started but not completed the survey in the first round may have felt that there was no further need to engage in the study beyond their initial contribution of time.

While only 19 participants completed the survey, each survey question was treated individually to maximize the number of responses reported. Therefore, the results from all 25 survey participants are reported in this results section.

3.2.1 Survey Introduction

In the first part of the survey, participants answered introductory questions regarding their municipality and level of experience. Fourteen of the survey participants worked in a Phase I municipality, while eleven worked in a Phase II. Thirteen of the participants were relatively new to their current positions, having only started them within the last 3 years. Four participants were in their current positions for the last 4-6 years, and another eight were in their positions for longer than 7 years. Six participants were new to the stormwater field, having only started in the field within the last 6 years. Another nine worked in stormwater for between 6 and 14 years. Ten participants had 15 or more years of experience in the field.

As this study focused on the potential for partnership between Hampton Roads municipalities and VCE offices in the region, an important consideration was the current relationship between these entities. Nine participants had working relationships with Cooperative Extension personnel. Thirteen knew of VCE programs and activities held within their municipality, and six knew of VCE programs and activities in other municipalities. Only three participants were completely unfamiliar with VCE.

3.2.2 Green Infrastructure Barrier Assessment

The second part of the survey had participants rank the barriers to GI according to significance within their municipality. A ranking of "1" represented the most significant challenge, and the ranking of "8" represented the least significant. As previously described, the barriers were chosen from a range of research articles. Barriers to GI implementation selected included laws and regulations, training and data, management and coordination, costs and funding, climate and land features, maintenance, public education and engagement, and residential implementation.

After ranking each barrier by its significance, participants were directed to specific questions regarding their three highest ranked challenges. These follow up questions were designed to allow participants to further characterize the most important barriers to GI implementation within their municipalities. The first follow up question asked participants to indicate which aspects of their chosen barrier are significant in their municipality. The second question asked how long the challenge has been significant in their municipality. The third question was intended to determine at what stage of implementation this barrier manifests as a challenge. The fourth question and it's follow up ask about progress within the municipality toward addressing this challenge. The final question asks participants about actions to take toward addressing the challenges associated with this barrier.

Participant rankings assigned a numeric value between 1 and 8 to each challenge. Overall challenge rankings were determined by calculating the average ranking of each GI barrier. Lower averages indicated a higher overall ranking, since participants were instructed to rank their greatest challenge as "1". Conversely, higher averages indicated lower ranked challenges. Figure 3.4 shows the ranking and distribution of the green infrastructure challenges from the survey. Table 3.2 shows the ordered rankings for the entire region and for the chosen subdivisions examined in this study.

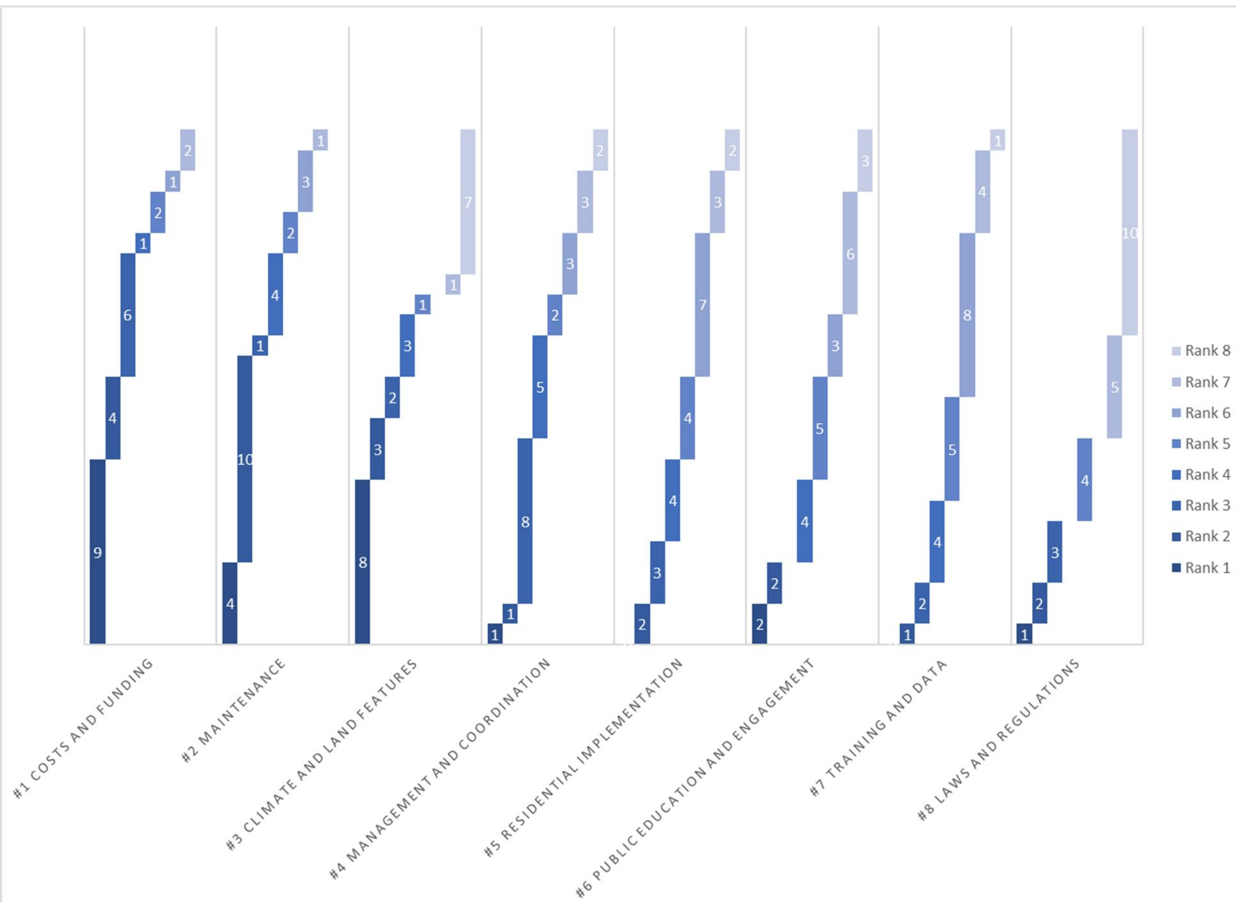


Figure 3.4: Overall Green Infrastructure Barrier Ranking Distribution

Table 3.2: GI Barrier Rankings for Hampton Roads

Rank	Overall	Peninsula	Southside	Phase I	Phase II
1	Costs and Funding	Costs and Funding	Climate and Land Features	Costs and Funding	Costs and Funding
2	Maintenance	Maintenance	Costs and Funding[1] (2)	Maintenance	Maintenance
3	Climate and Land Features	Management and Coordination	Maintenance[1] (2)	Climate and Land Features	Management and Coordination
4	Management and Coordination	Public Education and Engagement	Management and Coordination	Management and Coordination	Training and Data[1] (4)
5	Residential Implementation	Residential Implementation	Laws and Regulations	Residential Implementation	Public Education and Engagement[1] (4)
6	Public Education and Engagement	Training and Data	Residential Implementation	Public Education and Engagement	Residential Implementation[1] (4)
7	Training and Data	Climate and Land Features	Training and Data	Training and Data	Climate and Land Features
8	Laws and Regulations	Laws and Regulations	Public Education and Engagement	Laws and Regulations	Laws and Regulations

1. Ranking calculations which resulted in a tie are indicated with their associated rank

3.2.2.1 Barrier 1: Costs and Funding

The most significant challenge to GI implementation in Hampton Roads was costs and funding, with 19 of the 25 respondents listing it as one of their top three. In total, 16 respondents answered additional questions related to this challenge. Six respondents were from the Peninsula, while 10 were from Southside. Eleven survey respondents were from Phase I MS4s, while five were from Phase II MS4s. Costs and funding was also the number 1 ranked challenge for GI for survey respondents from Phase I, Phase II, and Peninsula MS4s. Survey respondents from Southside MS4s ranked this challenge as number 2. Table 3.3 shows all the calculated p-values associated with costs and funding.

Table 3.3: Cost and Funding p-values

Question Subject	Response Choices	p-value	
		Location	Phase
Barrier Components	Limited Funding	0.6643	0.7949
	Costs Unknown	0.0002	0.4071
Longevity		1.0000	1.0000
Impacts	Prevents Consideration/Approval	1.0000	0.5089
	Hinders Design	0.6066	0.0357
	Delays Construction	0.2335	1.0000
	Challenges Inspection	0.5879	1.0000
Progress Made		0.6084	1.0000
Progress Methods - If Yes	Internal Communication Improvement	X	1.0000
	External Communication Improvement	X	1.0000
	Hired Consultant	X	1.0000
	Developed Action Plan	X	0.1964
Desired Progress Methods - If No	Internal Communication Improvement	1.0000	X
	External Communication Improvement	1.0000	X
	Hire Consultant	0.4286	X
	Develop Action Plan	1.0000	X
Actions	Identify New Funding Sources	0.6044	0.5467
	Generate New GI Revenue	1.0000	0.5467
	Conduct Lifecycle Cost Analyses	0.6044	1.0000
	Conduct Comparative Analyses	0.6044	1.0000

Two major aspects of cost and funding challenges were identified from the literature. The first, limited or unavailable funding for GI implementation, was significant or highly significant for 12 of the 16 survey respondents. Eleven of the 16 total survey respondents found unfamiliarity with cost information to be highly or very highly significant. Survey respondents from Phase I MS4s strongly agreed that limited funding was highly or very highly significant, while respondents from all Phase II MS4s identified lack of cost information as highly or very highly significant. Statistically significant differences were observed based on participant location regarding GI implementation costs, with a p-value of 0.0002. All six Survey respondents from Peninsula MS4s agreed that this challenge was highly significant, while respondents from Southside MS4s varied from low to high significance.

There was strong agreement among all survey respondents that costs and funding was a longstanding challenge for GI adoption in Hampton Roads; being a major concern for over five years. Similarly, there was strong agreement that issues with costs and funding prevented GI from being considered or approved. Statistically significant differences were observed based on MS4 program scope regarding cost and funding issues hindering the design process of GI, with a p-value of 0.0357 observed. Nine of the 11 survey respondents from Phase I MS4s noted this challenge, compared to only one of the five respondents from a Phase II MS4. Figure 3.5 displays the challenge component, longevity, and impact of costs and funding challenges for GI.

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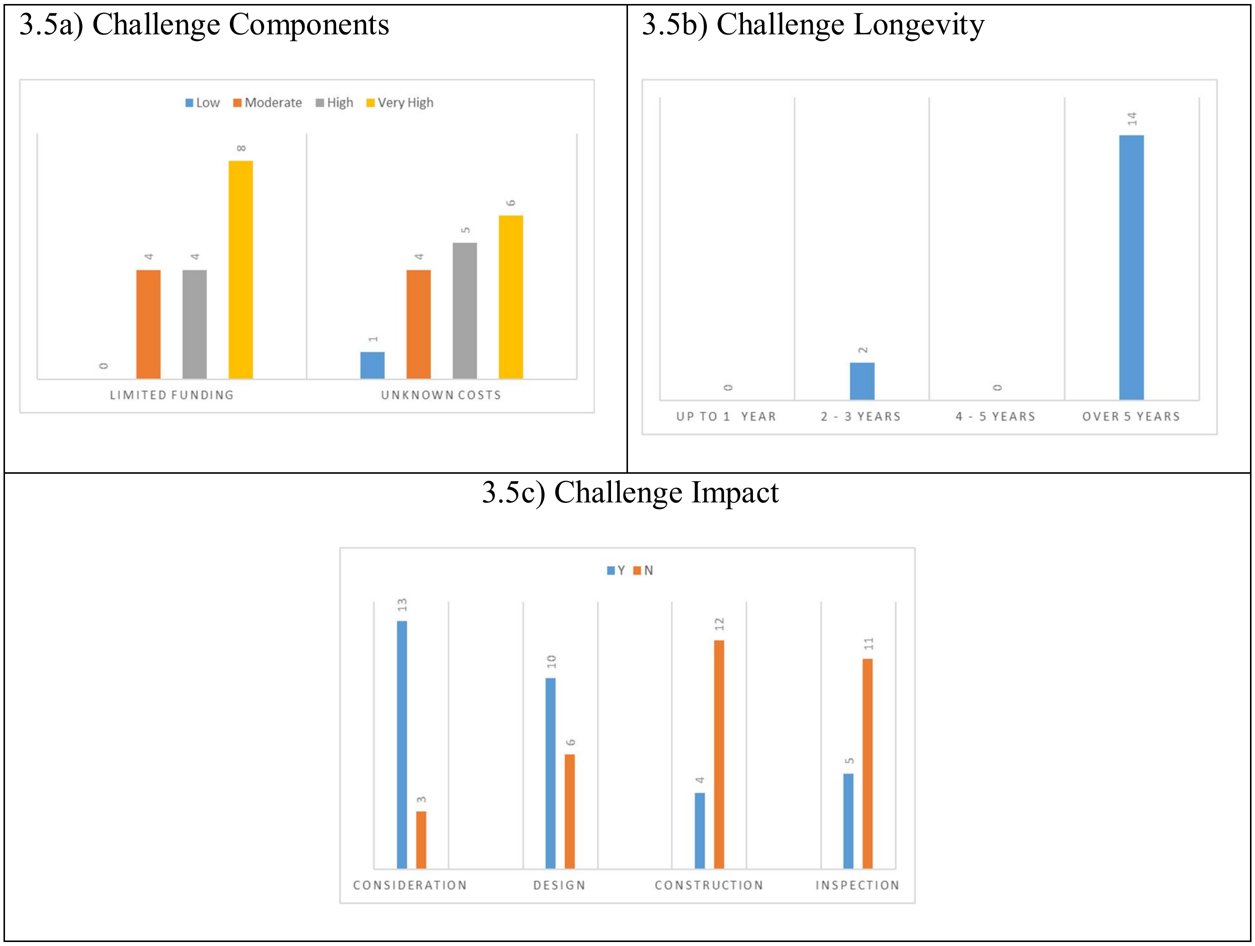


Figure 3.5: Costs and Funding Challenge

Progress toward addressing challenges with costs and funding were split, with half of survey respondents saying positive improvements were made. Of those who did see progress, increased communication with relevant personnel within the MS4 was identified as an important contributing factor to their success. Similarly, those who did not see progress believed that improving communications internal to each MS4 would likely lead to improvement in the future. Figure 3.6 if and how progress was made to address this challenge.

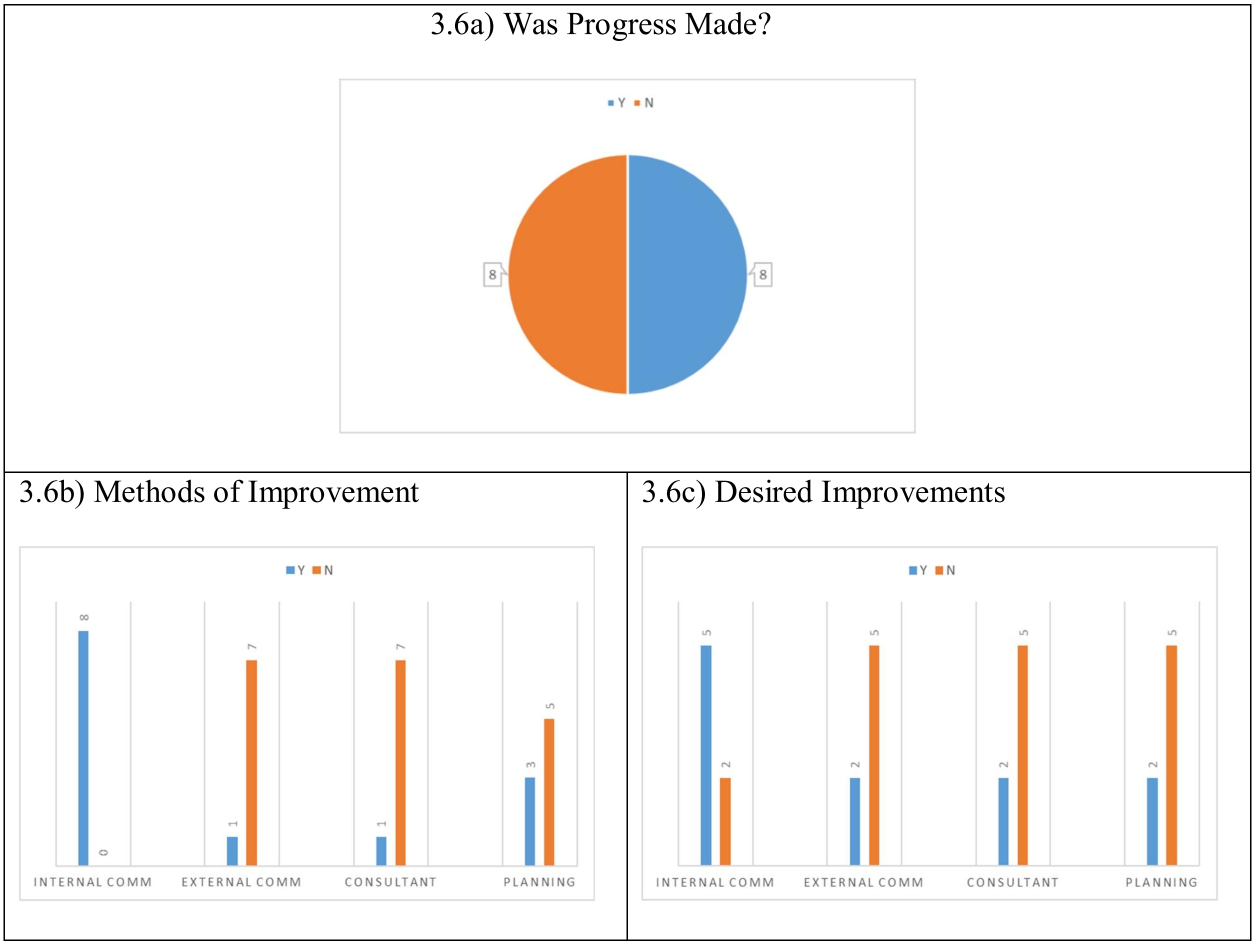


Figure 3.6: Costs and Funding Progress

Finally, respondents identified three activities to support potential solutions to address the challenges of costs and funding. These solutions were: identifying new funding sources for GI, conducting lifecycle cost analyses for GI practices, and conducting an economic analysis comparing GI practices to traditional gray infrastructure approaches. Survey respondents from Phase I MS4s seemed to favor finding new funding sources, while respondents from Phase II MS4s emphasized the lifecycle and comparative economic analyses. Figure 3.7 shows which actions would help address this challenge.

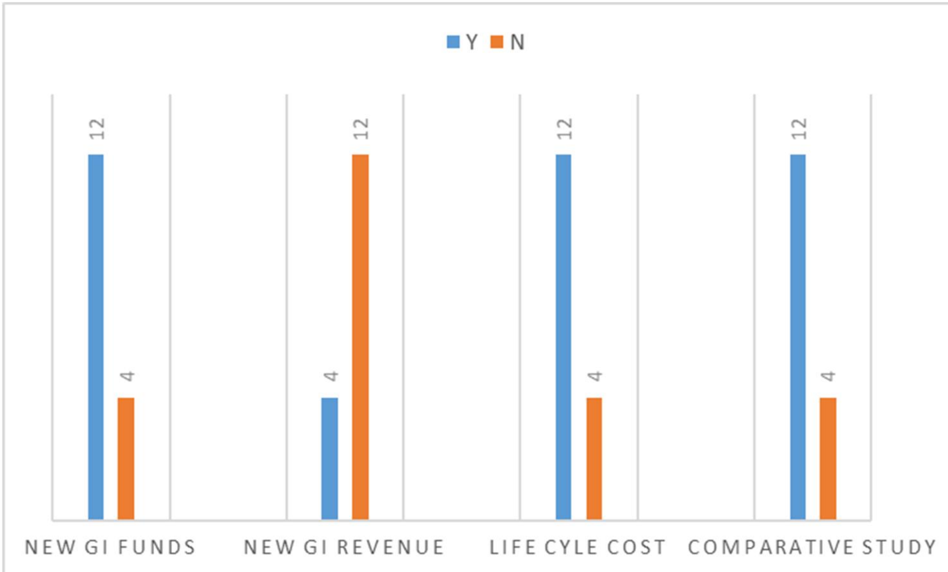


Figure 3.7: Actions to Improve Cost and Funding Challenges

3.2.2.2 Barrier 2: Maintenance

The second most significant challenge to GI implementation was identified as maintenance, with 15 respondents identifying it among their top three. Fourteen of the survey respondents answered additional questions related to GI maintenance issues. Five of the survey respondents worked in the Peninsula portion of Hampton Roads, while the remaining nine worked in the Southside portion. Nine survey respondents were from Phase I MS4s, and five were from Phase II MS4s. Maintenance was the number two ranked challenge for GI for survey respondents from Phase I, Phase II, and Peninsula MS4s. Survey respondents from Southside Ms4s ranked this challenge as number 3. Table 3.4 shows all the calculated p-values associated with maintenance.

Table 3.4: Maintenance p-values

Question Subject	Response Choices	p-value	
		Location	Phase
Barrier Components	Maintenance Costs are Unfamiliar	1.0000	1.0000
	Resources for Maintenance are Limited	0.5055	0.5055
Longevity		0.1099	0.6044
Impacts	Prevents Consideration/Approval	1.0000	1.0000
	Hinders Design	1.0000	1.0000
	Delays Construction	1.0000	1.0000
	Challenges Inspection	0.3007	0.0310
Progress Made		0.5055	0.5055
Progress Methods - If Yes	Internal Communication Improvement	0.1091	0.1091
	External Communication Improvement	1.0000	0.5455
	Hired Consultant	1.0000	0.4909
	Developed Action Plan	1.0000	0.1939
Desired Progress Methods - If No	Internal Communication Improvement	X	X
	External Communication Improvement	X	X
	Hire Consultant	X	X
	Develop Action Plan	X	X
Actions	Create GI Maintenance Training Programs	0.0070	0.2168
	Conduct Lifecycle Maintenance Costs Study	1.0000	1.0000
	Include Stakeholders in GI Maintenance	0.2657	0.2657
	Identify New GI Maintenance Funding Sources	1.0000	1.0000

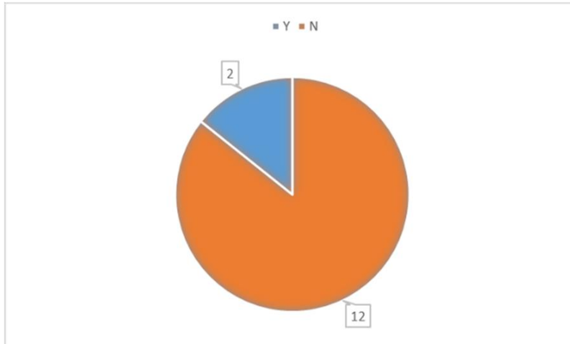
Two major components of maintenance challenges for GI were identified in the literature. The first is that the costs associated with GI maintenance were not well known. Eleven of the 14 respondents found this challenge to be highly or very highly significant, showing strong agreement regardless of location or phase. The second challenge, limited resources to support GI maintenance activities, was also recognized by all respondents as highly or very highly significant.

Agreement among all participants continued when discussing how long maintenance had been a challenge for GI in Hampton Roads. Twelve survey respondents indicated that this issue began over five years ago. In addition, 12 survey respondents noted that maintenance challenges likely prevent GI from being considered. There were also statistically significant differences between responses from Phase I and Phase II MS4s regarding maintenance challenges for GI inspections, with a p-value of 0.031. Six of the nine survey respondents from Phase I MS4s noted GI inspection concerns with maintenance, while none of the respondents from Phase II MS4s noted this concern. Figure 3.8 displays the challenge component, longevity, and impact of maintenance challenges for GI.

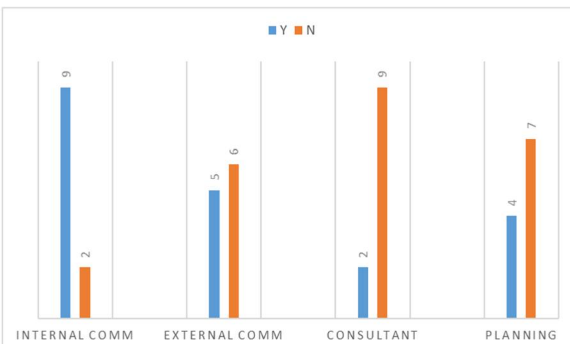
Figure 3.8: Maintenance Challenge

Despite concerns associated with GI maintenance, 12 survey respondents indicated that they had made positive progress in addressing these challenges. 9 of these 12 respondents stated that improved communication with relevant personnel within their MS4 helped to address maintenance issues. Figure 3.9 shows if and how progress was made to address this challenge.

3.9a) Was Progress Made?



3.9b) Methods of Improvement



3.9c) Desired Improvements

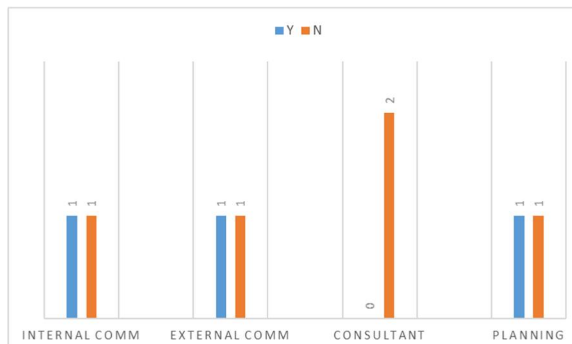


Figure 3.9: Maintenance Progress

Multiple actions to better address the challenges of GI maintenance were selected by respondents. The most popular activity overall was to conduct a study on lifecycle maintenance costs relevant to the local area. Statistically significant differences between survey respondents from Southside and Peninsula MS4s were observed regarding development of training programs focused on improving GI maintenance knowledge, with a p-value of 0.007. Eight of the nine survey respondents from Southside MS4s identified this preferred solution, while none of the respondents from Peninsula MS4s expressed this interest. Survey respondents from Southside and Phase I MS4s also expressed some interest in both involving local stakeholders in GI maintenance tasks and identifying new sources of funding for maintaining GI practices. Figure 3.10 shows which actions would help address this challenge.

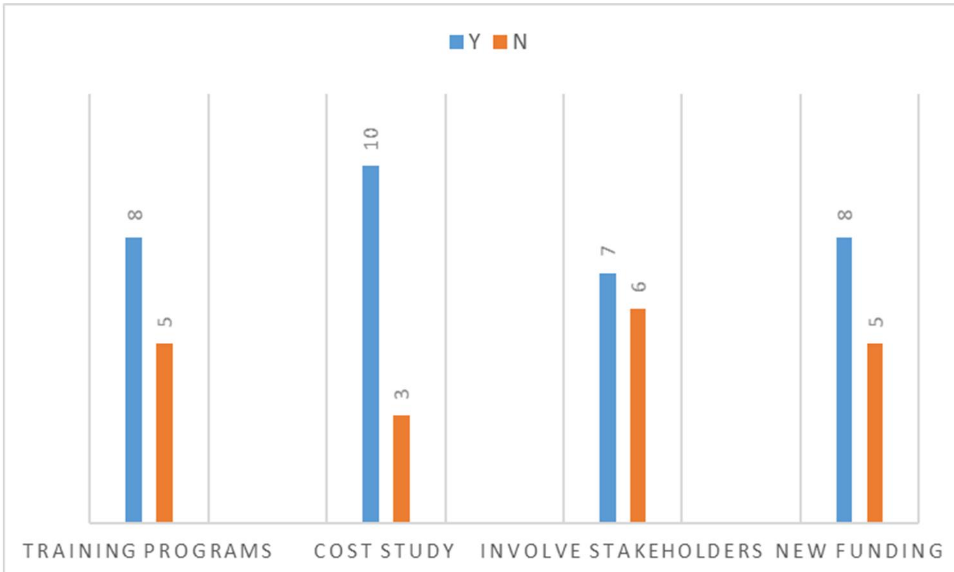


Figure 3.10: Actions to Improve Maintenance Challenges

3.2.2.3 Barrier 3: Climate and Land Features

Third on the list of most significant GI challenges was climate and land features. Thirteen respondents identified this challenge among their top three, and 12 respondents chose to answer additional questions related to climate and land feature issues. Ten of these 12 survey respondents worked in Southside Hampton Roads. Eight worked for Phase I MS4s, and four worked for Phase II MS4s. Despite its rank as the third most significant barrier to GI adoption overall, this challenge held different levels of importance throughout Hampton Roads. Survey respondents from Southside MS4s considered climate and land features to be their number 1 challenge to GI, while respondents from Peninsula MS4s ranked it as seventh out of eight. Similarly, survey respondents from Phase I MS4s ranked climate and land features third most significant, compared with respondents from Phase II MS4s that ranked this challenge as seventh. Table 3.5 shows all the calculated p-values associated with climate and land features.

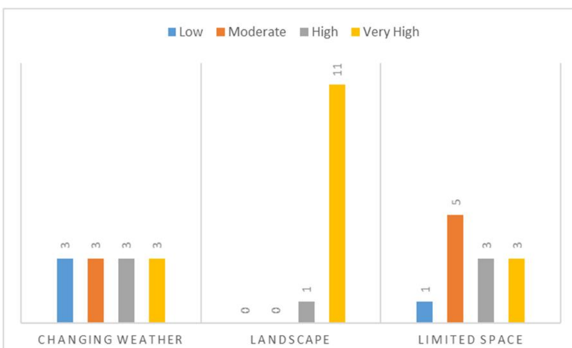
Table 3.5: Climate and Land Features p-values

Question Subject	Response Choices	p-value	
		Location	**Phase**
Barrier Components	Changing Weather Concerns	X	0.8364
	Physical Landscape Limitations	X	0.3333
	Space Limitations	X	0.5455
Longevity		X	1.0000
Impacts	Prevents Consideration/Approval	X	1.0000
	Hinders Design	X	1.0000
	Delays Construction	X	1.0000
	Challenges Inspection	X	0.5152
Progress Made		X	1.0000
Progress Methods - If Yes	Internal Communication Improvement	X	0.1429
	External Communication Improvement	X	0.3750
	Hired Consultant	X	0.4643
	Developed Action Plan	X	1.0000
Desired Progress Methods - If No	Internal Communication Improvement	X	X
	External Communication Improvement	X	X
	Hire Consultant	X	X
	Develop Action Plan	X	X
Actions	Study Weather Impact on GI Effectiveness	X	0.4909
	Determine GI Placement with Modeling Tools	X	0.2081
	Develop Strategies for GI in Difficult Spaces	X	1.0000
	Develop New GI Practices for the HR Region	X	1.0000

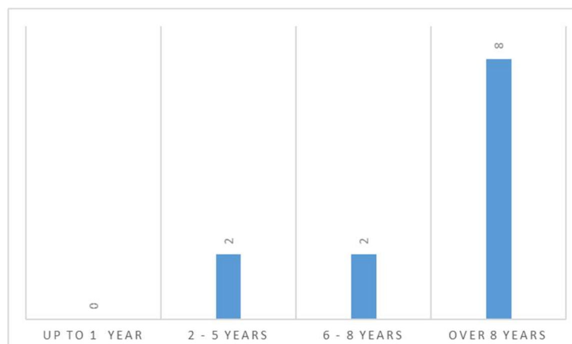
Three components of climate and land feature challenges were identified from the literature and were included in the survey. Of these, only the physical landscape component was deemed to be significant or highly significant by all survey respondents. The other components, concerns with changing weather patterns and challenges with limited space, were both seen as less important concerns for GI implementation.

Most respondents recognized climate and land features as a longstanding challenge. Eight survey respondents noted that this has been a barrier for GI adoption for over 8 years. In addition, 10 of the 12 survey respondents overall noted that this challenge prevents GI practices from being considered for implementation. Seven of the 10 survey respondents from Southside MS4s and three of the four survey respondents from Phase II MS4s also recognized that climate and land feature issues hinder the design of GI practices. Figure 3.11 displays the challenge component, longevity, and impact of climate and land feature challenges for GI.

3.11a) Challenge Components



3.11b) Challenge Longevity



3.11c) Challenge Impact

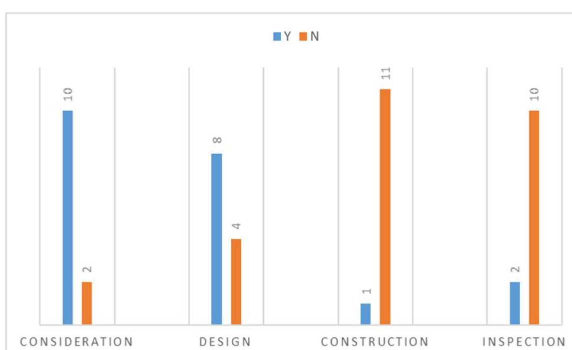


Figure 3.11: Climate and Land Features Challenge

Eight survey respondents noted that positive progress had been made in addressing this challenge. Seven of these eight respondents credited their success to increasing communication with personnel outside of their MS4. In addition, four of the five survey respondents from Phase I MS4s saw increased communication as an important factor of their improvement. Figure 3.12 shows if and how progress was made to address this challenge.

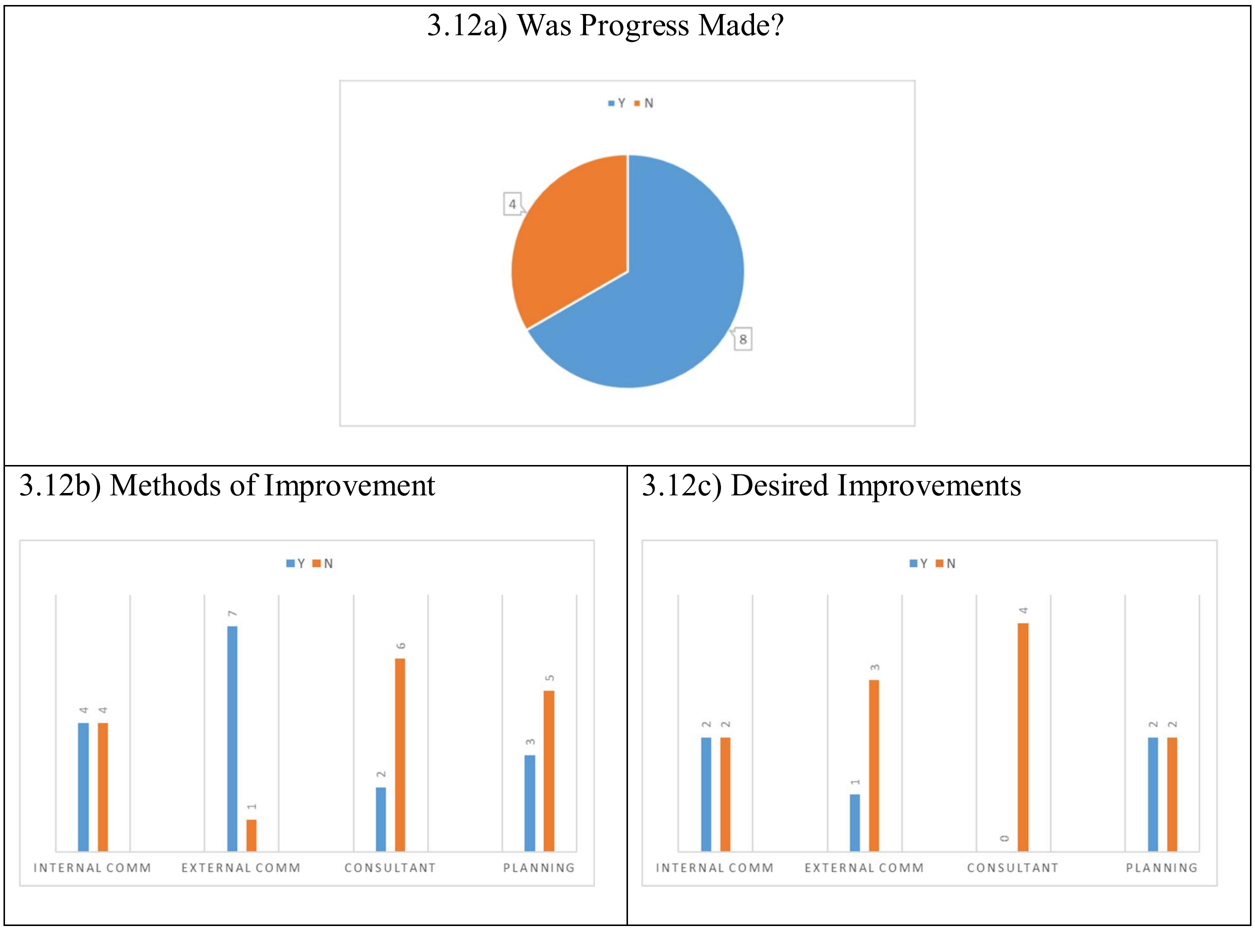


Figure 3.12: Climate and Land Features Progress

Survey respondents strongly favored developing new GI practices as a solution to challenges related to climate and land features. Novel designs would help address the water management concerns unique to Hampton Roads. In addition, seven out of 10 survey respondents from Southside MS4s and three out of four respondents from Phase II MS4s favored developing new strategies to implement current GI designs in difficult spaces. Figure 3.13 shows which actions would help address this challenge.

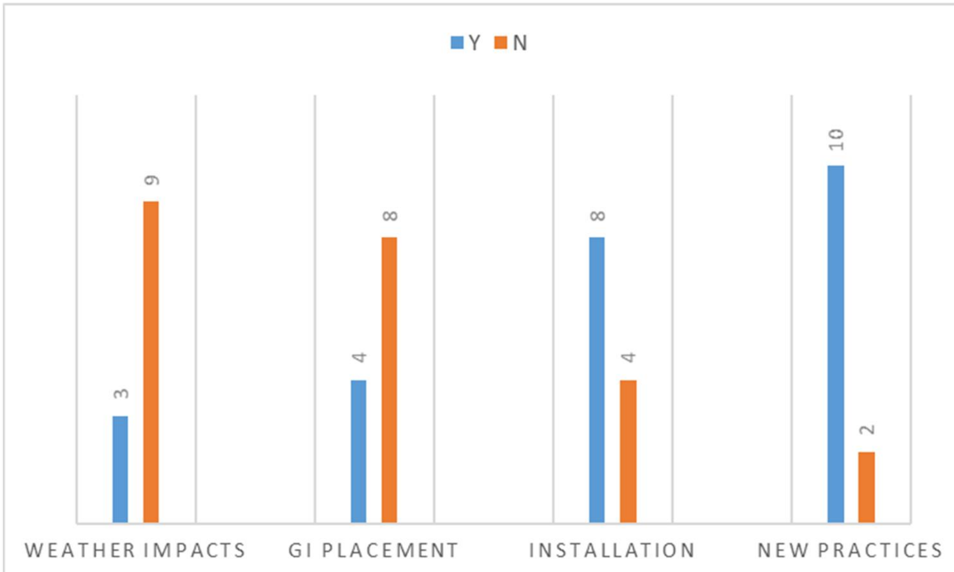


Figure 3.13: Actions to Improve Climate and Land Features

3.2.2.4 Barrier 4: Management and Coordination

Fourth on the list of significant challenges for GI implementation was management and coordination. Ten survey respondents identified this challenge in their top three. Of these, seven chose to answer additional questions related to management and coordination challenges. Three respondents worked forMS4s in the Peninsula portion of Hampton Roads, and the remaining four worked for MS4s in the Southside part of the region. Four respondents worked for Phase I MS4s, and three worked for Phase II MS4s. Management and coordination ranked as third most significant for survey respondents from Peninsula MS4s and fourth for respondents from Southside MS4s. Similarly, survey respondents from Phase I MS4s ranked this challenge fourth, while respondents from Phase II MS4s ranked it third. Table 3.6 shows all the calculated p-values associated with management and coordination.

Table 3.6: Management and Coordination p-values

Question Subject	Response Choices	p-value	
		Location	**Phase**
Barrier Components	Limited Inclusion of Stakeholders	0.4000	X
	Limited Cooperation Across Municipal Borders	0.4000	X
	Limited Coordination Between Municipal Offices	0.1000	X
Longevity		1.0000	1.0000
Impacts	Prevents Consideration/Approval	1.0000	1.0000
	Hinders Design	0.4857	1.0000
	Delays Construction	1.0000	1.0000
	Challenges Inspection	1.0000	1.0000
Progress Made		0.1429	1.0000
Progress Methods - If Yes	Internal Communication Improvement	X	X
	External Communication Improvement	X	X
	Hired Consultant	X	X
	Developed Action Plan	X	X
Desired Progress Methods - If No	Internal Communication Improvement	X	X
	External Communication Improvement	X	X
	Hire Consultant	X	X
	Develop Action Plan	X	X
Actions	Engage with Interested Stakeholders	0.4286	1.0000
	Integrate Stakeholders into GI Planning/Implementation	0.4857	0.4857
	Resolve Barriers to Cooperation Across Municipal Boundaries	1.0000	0.0286
	Identify Challenges to Coordination Between Municipal Departments	1.0000	0.4286

Three challenges for GI implementation were identified from the literature as related to management and coordination. These included limited inclusion of local stakeholders, lack of adequate cooperation across municipal boundaries, and little coordination between municipal offices involved in GI. Five survey respondents recognized community stakeholder involvement as a significant or highly significant concern. In addition, all three survey respondents from Peninsula MS4s noted municipal office coordination as a significant or highly significant concern.

Management and coordination challenges have also been longstanding. Five survey respondents noted that these issues have affected GI adoption for at least the last five years. In addition, management and coordination issues have a notable impact on GI implementation. Six of the seven survey respondents stated that management and coordination challenges often prevented GI from being considered or approved. Figure 3.14 displays the challenge component, longevity, and impact of management and coordination challenges for GI.

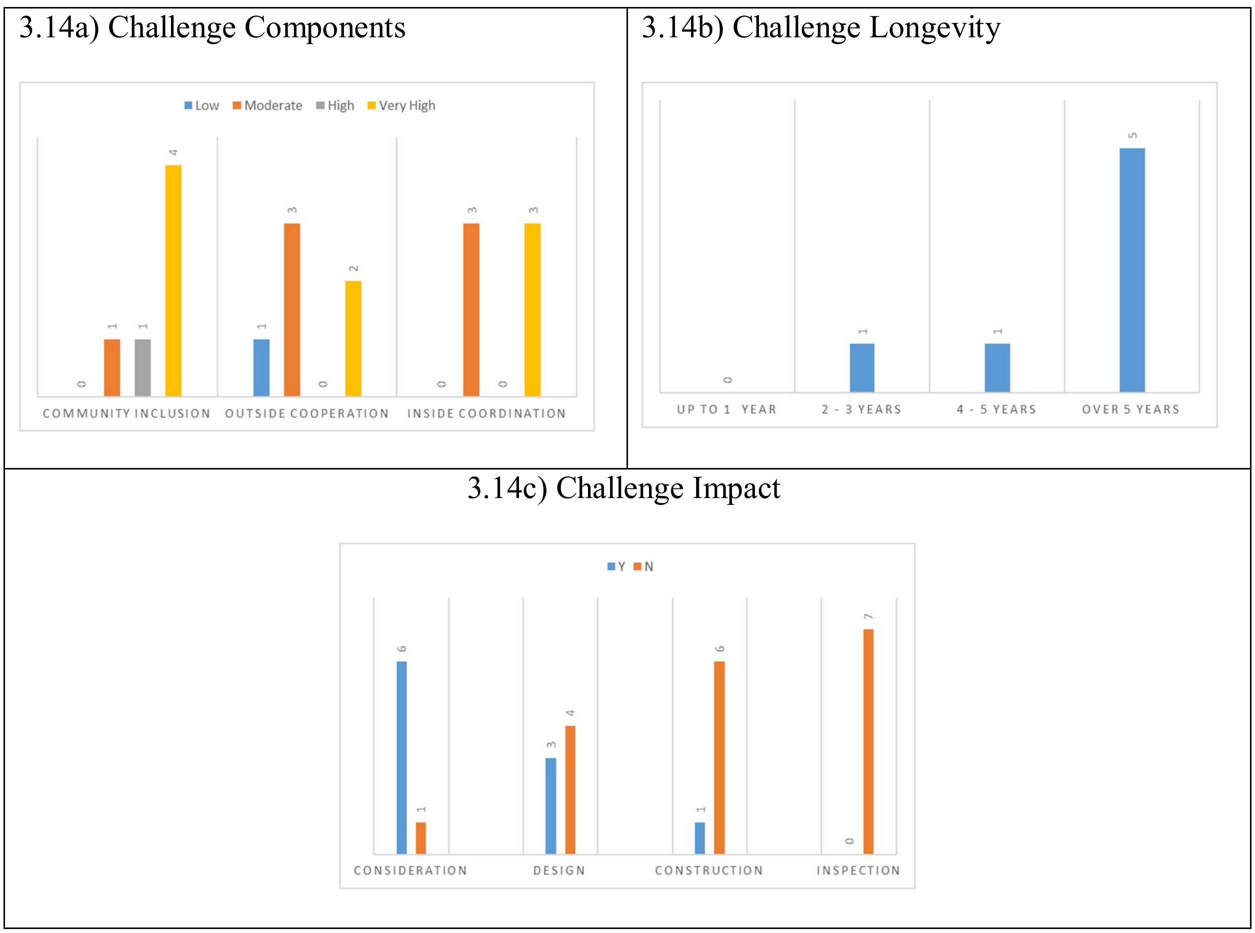


Figure 3.14: Management and Coordination Challenge

Progress toward addressing management and coordination challenges was mixed. The three survey respondents who did see positive improvement are all from the Southside, but their methods of improvement were varied. The three who did not see progress all believed that increasing communication within their MS4 would help to address local GI management and coordination challenges. Figure 3.15 shows if and how progress was made to address this challenge.

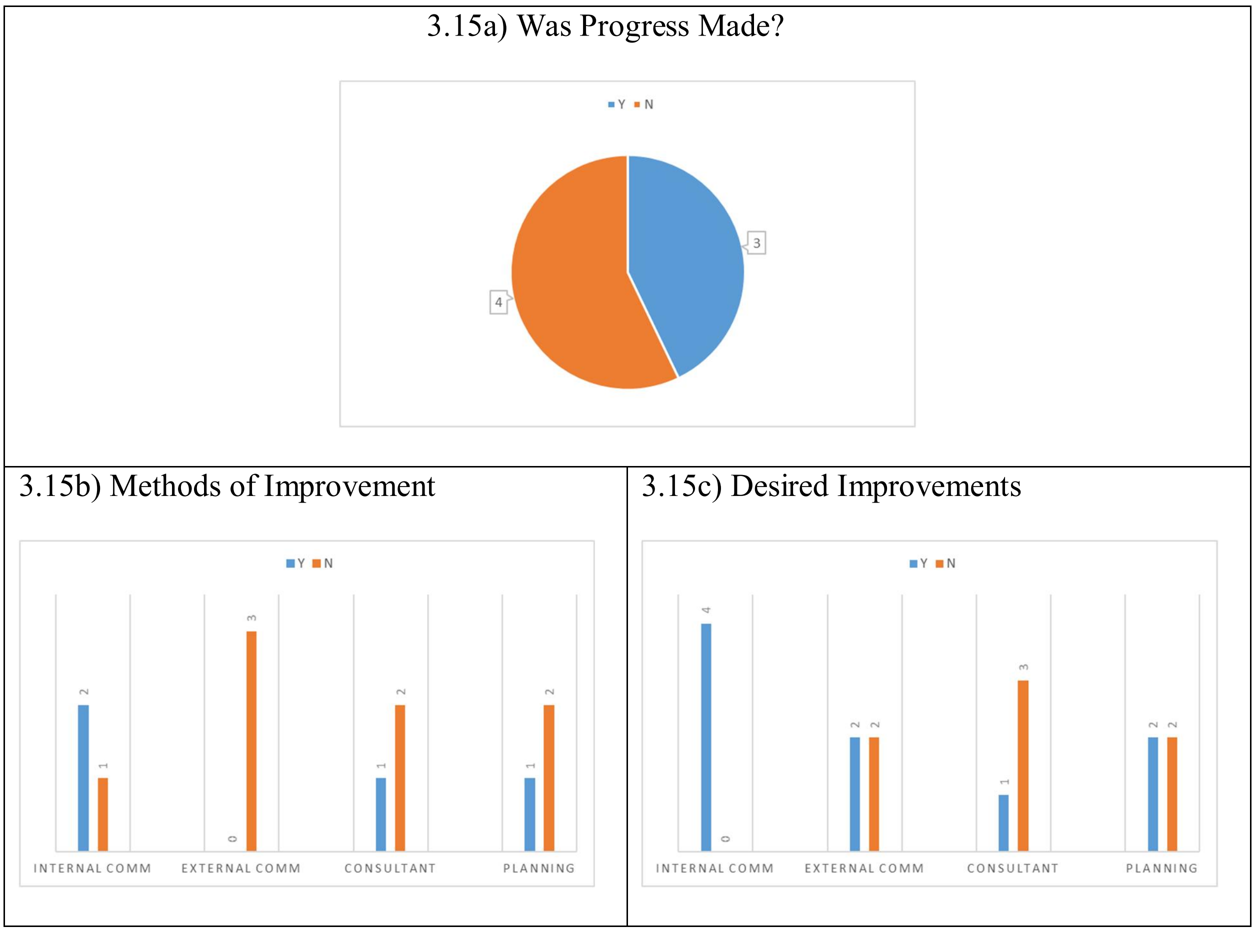


Figure 3.15: Management and Coordination Progress

Different groups seemed to favor different approaches to addressing their management and coordination challenges. Survey respondents from Peninsula and Phase I MS4s favored engaging stakeholders interested in managing GI. Survey respondents from Southside and Phase II MS4s showed stronger interest in recognizing and addressing challenges to cooperation between departments within their municipality. Statistically significant differences were observed between survey responses from Phase I and Phase II MS4s regarding interest in cooperation across jurisdictional boundaries, with a p-value of 0.0286. All three survey respondents from Phase II MS4s expressed interest in this method, compared to none of the respondents from Phase I MS4s. Figure 3.16 shows which actions would help address this challenge.

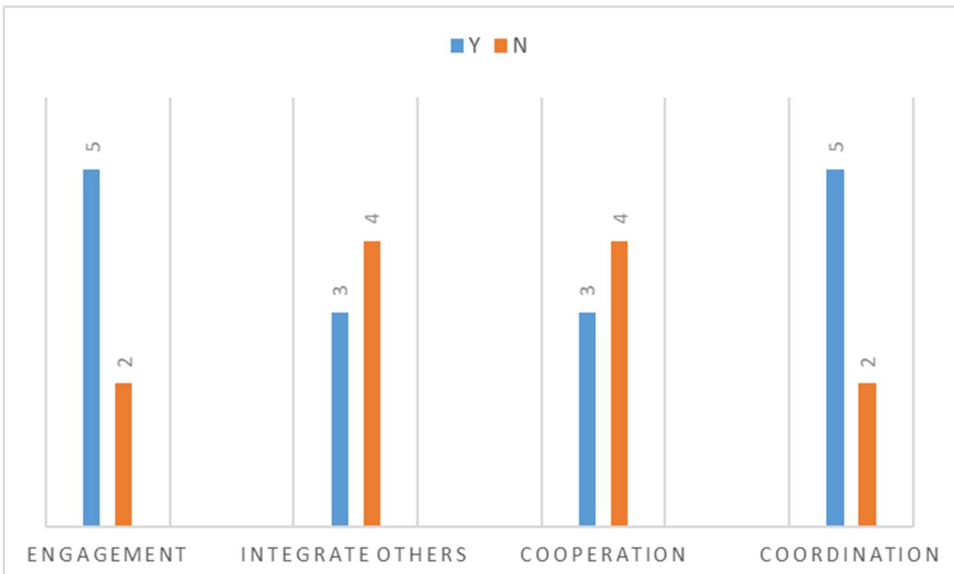


Figure 3.16: Actions to Improve Management and Coordination

3.2.2.5 Barrier 5: Residential Implementation

Five respondents selected the fifth most significant challenge, residential implementation, as one of their top three GI barriers. Three of these five chose to answer additional questions on the challenges of residential implementation of GI. Two respondents worked for Peninsula MS4s, and the other for a Southside MS4. Similarly, one participant worked in a Phase I MS4, while the other two worked for Phase II MS4s. Survey respondents from Peninsula MS4s ranked residential implementation as the fifth most significant barrier, compared to respondents from Southside MS4s ranking this challenge sixth. Phase I respondents ranked this challenge fifth, while Phase II ranked it fourth in a three-way tie.

Three components of the residential implementation challenge were found in the literature. The first recognizes that municipal authority over private land is limited, and all three respondents noted this challenge as highly significant. The second, difficulty in obtaining credit for GI practices installed on private property, was noted by the two respondents from Peninsula MS4s as highly significant. Third, incentivizing homeowners to adopt GI solutions was a highly significant challenge for all three respondents.

The longevity of residential implementation challenges was mixed, with two respondents noting residential implementation challenges to GI had only appeared within the last two or three years. The effects of residential implementation issues were also varied, though all three respondents recognized that they often prevented GI from being considered or approved. Both survey respondents from Peninsula MS4s noted that residential implementation challenges could impact inspection of GI.

None of the survey respondents stated that they had made positive progress in addressing the residential implementation of GI practices. Two believed that increasing communication with personnel and/or resources outside of their MS4 would lead to positive outcomes. The other highlighted the need for increased communication within their MS4 to address this challenge.

To address residential implementation challenges for GI, two activities were highlighted by two of the three survey respondents. The first was to engage with local communities to improve the maintenance of GI in residential areas. The second recommendation was engaging with residents to determine which incentives would be appropriate and effective.

3.2.2.6 Barrier 6: Public Education

The sixth most significant challenge was public education. While four respondents identified public education as among their top three challenges, only one chose to answer additional questions. The three components of public education challenges for GI from the literature included the need for expanded education and outreach efforts, the need for stronger public engagement to increase participation in the management of GI, and the role of negative public perceptions of GI. Of these, only public engagement to improve participation was ranked highly significant by survey respondents. Survey respondents from Peninsula MS4s ranked public education as the fourth most significant challenge, while respondents from Southside MS4s ranked it as their least significant challenge. Survey respondents from Phase I MS4s ranked this challenge sixth, while respondents from Phase II MS4s ranked it fourth in a three-way tie.

Survey respondents stated that public engagement challenges have persisted longer than five years in the region. While positive progress has not been made in addressing this challenge in each respondent's MS4, increasing communication within their MS4 was believed to be an important step toward making improvements. Survey respondents also favored developing a campaign explaining the connection between GI and public health benefits as an action their MS4 could take towards solving GI public education challenges.

3.2.2.7 Barrier 7: Training and Data

Only three respondents placed training and data issues in their top three challenges. All three chose to answer additional questions. It ranked as the seventh most significant challenge to GI implementation. Two respondents worked for Peninsula communities that are also Phase II

MS4s. The third worked for a Southside MS4 that is also a Phase I MS4. Peninsula respondents ranked training and data as their sixth most significant challenge, and Southside respondents ranked it seventh. Survey respondents from Phase I MS4s ranked this challenge seventh, while respondents from Phase II MS4s ranked it fourth in a three-way tie.

Three components of training and data challenges for GI implementation were identified from the literature. The first was the need for education and training opportunities for personnel, which was ranked as highly significant by the two survey respondents from Peninsula and Phase II MS4s. The second component identified was the need for better data on the performance and benefits of GI in Hampton Roads. This challenge was noted as highly or very highly significant by two respondents. The final component of training and data challenges for GI identified was the need for improved technical guidance materials on these practices. Two of the three survey respondents noted this challenge as highly significant.

All three survey respondents noted that GI training and data challenges were longstanding, having started over five years ago. All three survey respondents also noted that training and data challenges prevent GI from being considered or approved for implementation. In addition, two survey respondents noted that these challenges hinder the design of GI practices.

Two survey respondents recognized their MS4s for making positive progress in addressing training and data challenges for GI. Both respondents noted the role of increasing communication with personnel within their MS4 in the improvements that had been made. The other respondent showed interest in hiring a consultant to help address the GI training and data issues in their MS4.

All three survey respondents noted that providing training opportunities for developing GI design skills would be a helpful step toward addressing this challenge. In addition, two respondents showed interest in conducting studies on GI. One study would assess the performance of GI practices in improving water quality and quantity. The other study would seek to understand the benefits of GI implementation for the region.

3.2.2.8 Barrier 8: Laws and Regulations

The eighth most significant barrier for GI adoption was laws and regulations. Despite its standing as the least significant challenge, six respondents recognized it as one of their top three. All six answered additional questions related to the challenges of laws and regulations in GI implementation. Only one of these six survey respondents was from a Peninsula MS4. The remaining five survey respondents were from Southside MS4s. Survey respondents were split evenly between Phase I and Phase II MS4s. Respondents from Peninsula, Phase I, and Phase II MS4s all ranked laws and regulations as their least significant GI barrier. Meanwhile, survey respondents from Southside MS4s ranked this challenge as fifth. Table 3.7 shows all the calculated p-values associated with laws and regulations.

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Table 3.7: Laws and Regulations p-values

Question Subject	Response Choices	p-value Location	p-value Phase
Barrier Components	Conflicting/Confusing Legislation	X	1.0000
	Liability Concerns for GI Practices	X	1.0000
	Laws Limit/Restrict GI Implementation	X	1.0000
	Political Support for GI is Minimal	X	1.0000
Longevity		X	1.0000
Impacts	Prevents Consideration/Approval	X	1.0000
	Hinders Design	X	1.0000
	Delays Construction	X	1.0000
	Challenges Inspection	X	1.0000
Progress Made		X	1.0000
Progress Methods - If Yes	Internal Communication Improvement	X	X
	External Communication Improvement	X	X
	Hired Consultant	X	X
	Developed Action Plan	X	X
Desired Progress Methods - If No	Internal Communication Improvement	X	X
	External Communication Improvement	X	X
	Hire Consultant	X	X
	Develop Action Plan	X	X
Actions	Obtain Model Ordinances for GI	X	1.0000
	Conduct Audit of Existing Laws	X	0.4000
	Include Human Safety in GI Design Guidelines	X	1.0000
	Develop Education Program for Decision Makers	X	1.0000

Four components of legal and regulatory challenges for GI implementation were identified from the literature. The first of these, conflicting or confusing legislation regarding GI practices, was of low or moderate significance for all survey respondents. Concerns regarding liability for unforeseen consequences for GI implementation had low or moderate significance for four survey respondents. Legal restrictions on GI implementation were highly or very highly significant for four of the survey respondents, three of whom worked for Southside MS4s. Finally, political support for GI adoption was seen as having low or moderate significance in GI implementation for four respondents.

Four of the six survey respondents noted that legal and regulatory challenges have impacted GI implementation for over five years. Five respondents also noted that these challenges impact GI by preventing them from being considered or approved. Four of the five survey respondents from Southside also noted the role of legal challenges in hindering the design of GI. Figure 3.17 displays the challenge component, longevity, and impact of legal and regulatory challenges for GI.

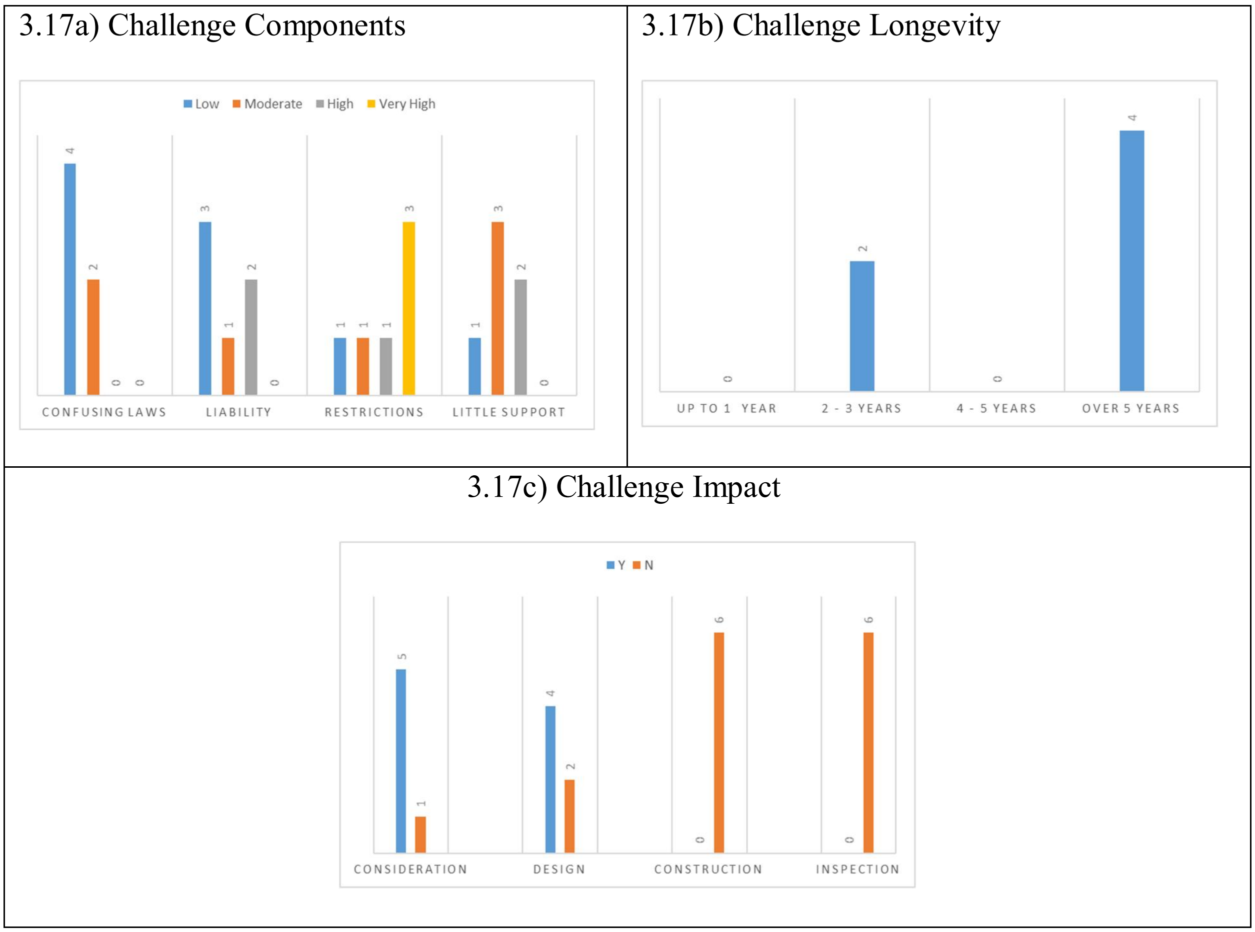

Figure 3.17: Legal and Regulatory Challenges

Only two survey respondents reported making positive progress toward addressing these challenges. The remaining four respondents all saw a need for increasing communication within their MS4 to make positive progress on this issue. Three of these four survey respondents also found potential value in addressing legal and regulatory challenges through developing an action plan for their MS4. Figure 3.18 shows if and how progress was made to address this challenge.

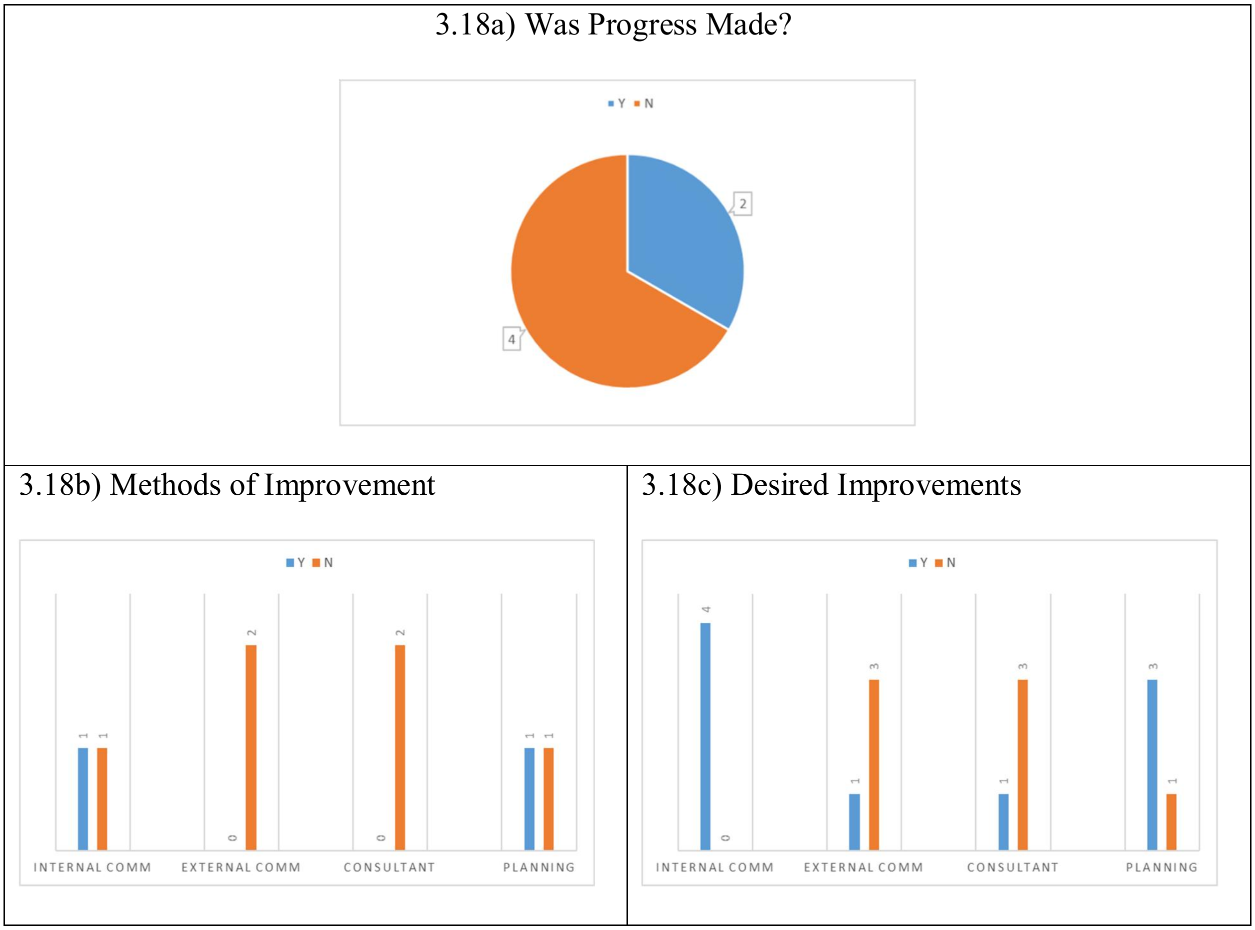

Figure 3.18: Laws and Regulations Progress

Respondents were mixed regarding actions their MS4 could take to address legal and regulatory challenges for GI implementation. Four of the five respondents from Southside MS4s showed interest in conducting legislative audits to assess to impact of existing legislation on GI implementation. All three survey respondents from Phase II MS4s selected this option. Figure 3.19 shows which actions would help address this challenge.

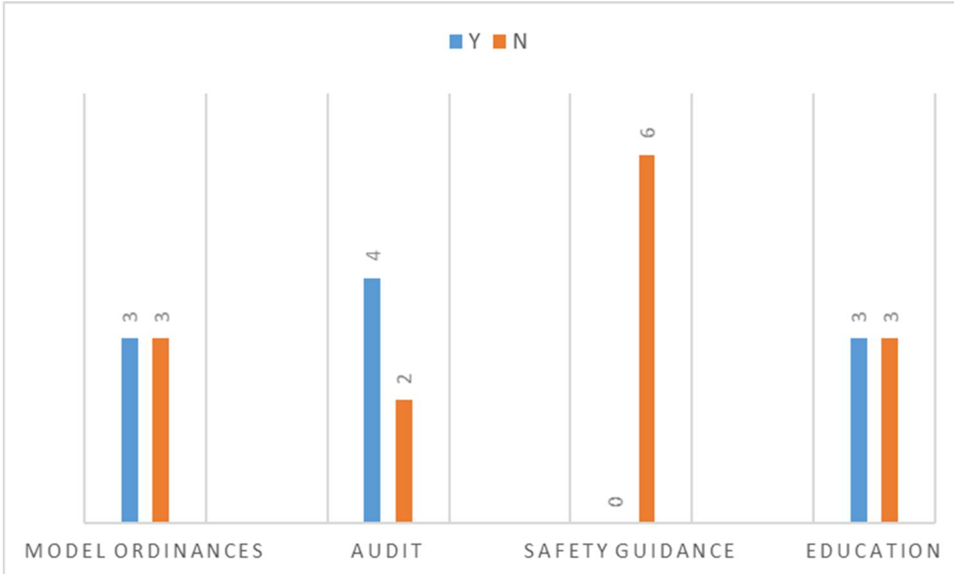

Figure 3.19: Actions to Improve Laws and Regulations

3.3 Interviews with Cooperative Extension

Potential VCE interview participants were selected for their familiarity with natural resource issues in the region. Ten respondents were chosen and invited to participate in the study, following which nine agreed to participate. Interviews were conducted throughout the summer of 2017 based on availability. All interviews were conducted in person and recorded. Transcriptions were created of each interview for this analysis.

3.3.1 Interview Introduction

The interviews with VCE personnel were divided into two parts. The first asked general questions regarding the Cooperative Extension programming of the interviewee. This included questions regarding level of experience, local water priorities, strengths and weaknesses of VCE programming, and partner agencies within the MS4. The second part focused on the role of VCE in GI and stormwater management. Topics included personal familiarity with GI practices, specific

VCE programs supporting these practices, and the perspective and actions of VCE on GI challenges in the region.

Part one of the interview began with assessing the level of experience of the interviewees. Extension personnel who participated in the interview process varied widely in experience. The most recently hired Extension Agent had only been with VCE within 4 months before the interview was conducted. The most experienced interviewee had been with VCE for over 17 years.

The next questions sought to identify water-related priorities of participants. Six of the nine Extension personnel interviewed perceive stormwater to be the most important water-related concern for their MS4. Rankings of water management challenges are shown in Table 3.8. In addition, only two of the nine interviewees dedicate less than 10% of their schedule to water management issues, as shown in Table 3.9.

Table 3.8: Water Issue Ranking

Rank	***Overall***	Peninsula	Southside	Phase I	Phase II
1	*Stormwater*	Stormwater	Stormwater	Stormwater	Groundwater
2	*Surface Water*	Surface Water	Drinking Water	Surface Water	Surface Water
3	*Groundwater*	Groundwater	Surface Water[1] (3)	Drinking Water	Stormwater
4	*Drinking Water*	Wastewater	Groundwater[1] (3)	Groundwater[1] (4)	Drinking Water
5	*Wastewater*	Drinking Water	Wastewater	Wastewater[1] (4)	Wastewater

1. Ranking calculations which resulted in a tie are indicated with their associated rank

Table 3.9: Time Dedicated to Water Management Challenges

Participant ID Number	**Percentage of Schedule**
073861	25%
110739	5%
117423	20-30%
136686	100%
319049	25%
392475	50-75%
655655	15%
907558	10-15%
927958	2-5%

For the next questions, participants were asked to identify the strengths and weaknesses of VCE programs in their municipality. A common strength noted by participants from four of the five Phase I MS4sis access to knowledgeable volunteers in the form of Master Gardeners to help facilitate stormwater programs. Participants from Phase II MS4s all highlighted the role of education in Extension programming as an important strength. Three of the four participants from Phase II MS4s recognized their access to knowledgeable personnel from Virginia Tech as another valuable strength. Where the identified strengths crossed geographic areas and MS4s, most of the weaknesses identified by interviewees were specific to their municipality. They included: not having enough volunteers to reach a large public, lack of awareness and/or participation of communities on water resource issues, lack of funding for new programs, lack of skilled personnel, and negative political influences on addressing water management concerns.

The final question in the first part of the interview asked participants to identify their major partners in their municipality for VCE programs. Three primary municipal partners for conducting VCE programs were identified from the interviews. The Public Works office was noted as an important partner for participants from four of the five Southside MS4s. The Stormwater department was the second major partner identified by interview participants, including all those Phase II MS4s. The Parks and Recreation department was the final municipal office recognized by four of the Extension personnel interviewed.

3.3.2 Green Infrastructure Assessment

Part two of the interview focused on GI and stormwater management with VCE. Interviewees were first asked questions related to their knowledge of these topics. The first question asked which municipal department was responsible for stormwater management in their MS4. Eight of the nine VCE personnel stated either the stormwater office or the public works office. The next question asked interviewees about their level of familiarity with the concepts of GI. All participants stated a level of familiarity with GI, though one stated they had no practical experience. Participants were asked to summarize the concept of GI in their own words. When providing their personal descriptions of GI, most of the interviewees noted the importance of plants and the environment in their definitions.

Next, interview participants were asked to identify past and present VCE programs involved in supporting GI. Six participants had previously conducted programs related to GI. Participants from four of these six highlighted rain barrel programs and activities, while another four participants highlighted rain garden activities. All four that conducted rain barrel programs in the past were from Southside and Phase I MS4s. Seven of the participants were currently conducting programs focused on GI practices. Four had rain barrel programs, with three of these four located in Phase I or Southside MS4s. Five participants had rain garden programs in their MS4s. Other past and present programs noted by interviewees addressed water management challenges outside green infrastructure that were specific to their municipality. These included turf seminars, tidal wetland programs, riparian buffer education courses, and water quality testing in wells.

In the next part of the interview, VCE personnel were asked to rank the challenges to GI facing their municipality. The same challenge categories used in the survey were used here. As with the survey results, rankings were organized by challenge and averaged to determine an overall rank listing. Table 3.10 displays the barrier rankings according to the collected interviews

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Table 3.10: GI Barrier Ranking from Interviews

Rank	Overall	Peninsula	Southside	Phase I	Phase II
1	Costs and Funding	Costs and Funding	Costs and Funding	Costs and Funding	Costs and Funding
2	Maintenance	Maintenance[1] (2)	Maintenance	Maintenance	Maintenance[1] (2)
3	Residential Implementation	Residential Implementation[1] (2)	Public Engagement[1] (3)	Residential Implementation	Residential Implementation[1] (2)
4	Management and Coordination	Training and Data	Management and Coordination[1] (3)	Management and Coordination	Public Engagement[1] (4)
5	Training and Data	Laws and Regulations	Residential Implementation	Training and Data	Management and Coordination[1] (4)
6	Public Engagement	Management and Coordination	Training and Data	Public Engagement[1] (6)	Training and Data
7	Laws and Regulations	Climate and Land Features	Laws and Regulations	Climate and Land Features[1] (6)	Laws and Regulations
8	Climate and Land Features	Public Engagement	Climate and Land Features	Laws and Regulations	Climate and Land Features

1. Ranking calculations which resulted in a tie are indicated with their associated rank

Costs and funding was recognized by participants as the overall most significant challenge for Hampton Roads municipalities seeking to implement GI. This was the top ranking for participants from Peninsula, Southside, Phase I, and Phase II municipalities. Four participants highlighted different impacts of shrinking budgets on GI implementation. Smaller pools of funding may impact the perceived importance of GI when compared to other issues of immediate concern for the municipality. Less funding also reduces the ability of a municipality to evaluate and manage GI practices effectively. Four participants recognized a need for funding allocations to support maintenance activities for GI, given the labor needs associated with plantings. One of these four focused on GI installed on residential properties and the need for property owners to save for future maintenance costs.

The second overall ranked challenge to GI implementation noted by interview participants was maintenance. As with costs and funding, maintenance was ranked as second across the Peninsula, Southside, Phase I and Phase II municipalities. Four interviewees noted that maintenance challenges are associated with a lack of awareness or a need for education. One example provided by an interviewee is HOAs in their municipality who are unaware of their GI maintenance responsibilities and fail to allocate resources needed to address them. As previously mentioned, funding challenges from budget constraints have an important impact on GI maintenance.

The third overall ranked GI challenge identified by the interview participants was residential implementation. This challenge was tied for second most significant with maintenance by participants from Peninsula and Phase II municipalities, and ranked third by participants from Phase I MS4s, and fourth by participants from Southside municipalities. Four interviewees linked this challenge to a lack of knowledge of the responsibilities for GI and the need engage and educate the public. In addition, two participants recognized the need for homeowners to understand maintenance requirements for the practices installed on their land.

The fourth overall ranked challenge for GI identified was management and coordination. It was ranked fifth for participants from Peninsula municipalities, third for participants from Southside municipalities, and fourth for participants from Phase I and Phase II municipalities. Individual opinions on the importance of this challenge ranged from being of little to no concern for three participants to being the single most important challenge for one participant. One participant recognized the large quantity of water to manage through GI as a challenge, and another noted the potential for confusion regarding who is responsible for taking care of GI practices that are installed. Management was also noted to have multiple connections to other GI challenges.

Maintenance, training, residential implementation, public engagement and costs were each connected to GI management by a different interviewee.

The fifth overall ranked challenge to GI implementation was training and data. It was ranked fourth by participants from Peninsula municipalities, sixth by participants from Southside municipalities, fifth by participants from Phase I municipalities, and sixth by participants from Phase II municipalities. Several components of this challenge were identified, including a need for more active data gathering, the need for training time and resources, and the need to engage local communities with training opportunities. In addition, one participant noted that structures installed in their municipality were not evaluated for their performance. However, two participants saw little need to focus on training, noting that their municipalities had both strong interest in and multiple avenues for training available. Training and data challenges for GI were also linked to management and costs and funding concerns.

The sixth overall ranked challenge was public engagement. It was ranked eighth by participants from Peninsula municipalities, third by participants from Southside municipalities, sixth by participants from Phase I municipalities, and fourth by participants from Phase II municipalities. Perspectives on the importance of this challenge varied widely among participants. Two of those interviewed noted the role VCE already plays in educating the public, stating that public education was a focus for Cooperative Extension and was therefore not a significant concern for GI. Two others stated that public buy-in and education were necessary to encourage GI adoption. Another stated that GI should be implemented prior to public engagement efforts. Level of interest from the public in GI also varied. One participant stated that lack of funding was preventing action on GI even though it has already received interest from the public. Another noted the difficulty in advertising for events due to rising costs and decreasing public interest in VCE programs.

The seventh overall ranked challenge was laws and regulations. It was ranked fifth by participants from Peninsula MS4s, seventh by participants from Southside, MS4s, eighth by participants from Phase I MS4s, and seventh by participants from Phase II MS4s. This ranking was relatively consistent, regardless of program scale or location. Five participants agreed that laws and regulations had little impact on GI implementation and was therefore not a significant challenge.

The eighth overall ranked challenge was climate and land features. It was ranked seventh by participants from Peninsula municipalities, eighth by participants from Southside municipalities, seventh by participants from Phase I municipalities, and eighth by participants from Phase II municipalities. Perspectives on this challenge also varied by participant. Three noted the important effect of the landscape of the region on GI installation, recognizing the flat topography as an impediment for GI. However, three participants stated that the topography and climate of Hampton Roads would work well with GI practices. One participant regarded climate and land features as unimportant since they could not be changed. Another stated that GI was better suited for urban contexts and would provide rural land with few benefits.

After ranking and discussing GI challenges, the participants were asked if Cooperative Extension dedicates time and resources to addressing the three most significant challenges they identified. Two participants stated that VCE was not involved in addressing any of these issues, and one other stated that its actions were limited by the role of VCE as an educational organization. Therefore, it could not be involved in addressing GI issues unless it was through educational programming.

Those who did address GI implementation challenges in their municipalities noted a variety of methods for doing so. VCE offices held fundraisers to facilitate events focused on GI practices and provided resources to reduce total event costs. Extension also supported GI adoption through topic specific educational programs and events including demonstrations, speaking engagements, and training classes. VCE also provided manpower to aid with GI challenges through knowledgeable Master Gardeners at various events and projects. Participants also identified VCE specialists as an important resource for addressing major GI challenges. Their specialized knowledge could be applied in various way to improve GI in the region and disseminate new information to the public.

Chapter 4. Discussion

4.1 Regional Challenges in Hampton Roads to Green Infrastructure

The first goal of this study was to understand the current state of green infrastructure implementation in Hampton Roads. As seen in the document reviews, every municipality in the region has encouraged the adoption of GI practices. This was mainly observed in the form of educational activities and programs. Limitations in available data prevented a full understanding of the number of GI practices installed during the period of interest. However, assessment of James City County as the best-case scenario in the region for GI adoption indicated that traditional practices such as detention ponds and retention ponds treated much more land than GI practices. This likely applies to the entire Hampton Roads region. This conclusion is supported by the recent work of Johnson and Sample (2017), whose analysis of stormwater control measure applicability in Virginia Beach indicated the limitation of infiltrative GI practices in coastal Virginia.

The second goal was to identify and characterize the barriers to implementing green infrastructure practices in Hampton Roads. In analyzing survey and interview responses, two GI barriers were identified and ranked consistently across locations, MS4s, and stormwater and VCE personnel. The first of these barriers was limited GI funding and unknown GI costs. The second barrier was unfamiliarity and lack of resources for GI maintenance. The widespread acknowledgement of these challenges indicates their important role in the hindering of green infrastructure implementation in the region and represents an opportunity to focus on targeted solutions.

The survey portion of the study was designed to characterize GI challenges individually. However, observing responses in the aggregate led to a deeper understanding of barriers to GI adoption regionally. Ignoring the challenge to which they applied, 77.4% of survey responses noted that barriers had impacted GI adoption for at least 5 years. In addition, 83.9% of survey responses stated that the identified challenges to GI adoption prevented them from being considered or approved. These results show that financial and maintenance challenges are persistent in the region. To successfully implement GI practices in Hampton Roads, designers and decision makers will need to accurately predict installation and maintenance costs in order to consider them in the early planning and design stages. Funding sources and maintenance resources will also need to be identified early to increase the likelihood of a GI practice being considered and/or approved.

Aggregated survey responses also reveal the preferred method for addressing GI implementation challenges in Hampton Roads. Approximately 75% of survey responses, regardless of the GI challenge, either increased or sought to increase internal communications with relevant personnel as a strategy to address GI implementation challenges, compared to 40% of survey responses for developing a plan or strategy to address their GI challenges, 38.3% of survey responses for increasing communication with those outside of their MS4, and just 18.3% of survey responses expressing interest in hiring a consultant for assistance. Interdepartmental communication within a municipality plays an important role in GI development, given the interdisciplinary nature of these practices. Improving internal communication channels within a municipality between its various offices should have an important positive impact on GI support and adoption. However, increasing the implementation of GI in the Hampton Roads region may require local MS4 communities to adopt additional methods to supplement the continual improvement in interdepartmental cooperation for GI projects.

4.2 Cooperative Extension as a Good Fit for Green Infrastructure

The third goal of this study was to determine how VCE personnel and offices in the Hampton Roads region can help municipalities address their GI challenges. The study data show that MS4s and VCE personnel recognize and prioritize GI implementation challenges similarly. This is a starting point for discussion between the two groups. Understanding the unique factors of each municipality (VCE personnel experience and familiarity with GI, available funding and volunteer resources, and community priorities) and how these factors fit into the broader mission of Cooperative Extension will also provide a starting point. Hampton Roads VCE offices can open communication, share experience and programs, and potentially pool resources to meet the needs of Hampton Roads MS4s.

VCE is well suited and positioned to address the top ranked regional challenges to GI implementation in Hampton Roads. The interviews data showed Extension personnel have familiarity with GI, are strongly interested in stormwater management, and are aware that it is a primary concern in their municipality. In addition, all Extension personnel interviewed were already engaged with their respective MS4, with several partnerships already focused specifically on stormwater management issues. Most interview participants had or were currently conducting educational programs focused on GI. These programs mainly focused on rain barrels or rain gardens for on-site for on-site stormwater collection and management.

Extension participants also noted unique resources that would be helpful in raising awareness and facilitating implementation of GI throughout the Hampton Roads region. Local VCE offices train Master Gardener and Master Gardener Water Steward volunteers, who then utilize their expertise in their communities by participating in local projects and providing volunteer services. These volunteers conduct rain barrel and rain garden educational presentations and demonstrations. They provide water related programs to schools and local groups and participate in field days, festivals, tours, and other community events. Their information is research based and is provided through Virginia Tech.

The Virginia Tech Hampton Roads Agricultural Research and Extension Center (AREC) is another important asset noted by interviewed Extension personnel. This research center is one of twelve in the university operates across Virginia. This particular AREC's research focuses on urban landscape issues, including stormwater management. It is located in Virginia Beach (Southside) and houses seven university research and extension specialists who provide a strong network of support for VCE offices. This direct connection between VCE and university personnel and resources can play an important role in supporting GI implementation efforts. Virginia Tech can conduct research and provide data that can then be utilized by MS4s or disseminated through VCE to raise awareness and influence GI implementation.

4.3 Engaging Cooperative Extension in Green infrastructure

VCE is an educational organization focused on providing knowledge to the public in order to improve lives and communities. VCE's core strength is its connection to unbiased university-based scientific research which is disseminated through various means. It has a critical role to play in improving GI adoption in Hampton Roads. The following are recommendations and opportunities emphasize for Cooperative Extension in addressing GI challenges in Hampton Roads.

4.3.1 Conducting Green Infrastructure Cost and Maintenance Studies

Municipal survey responses to the most significant GI challenges highlighted a strong interest in addressing information gaps. Understanding GI lifecycle costs, comparing the costs of

GI to gray infrastructure stormwater solutions, and understanding GI maintenance costs were among the most highly desired actions selected by municipal personnel. VCE, through its connection to university resources and personnel, is well suited to facilitate these studies. The knowledge gained from these studies could lead to improved understandings of the many uncertainties of GI, including: overall costs of specific GI practices, costs of specific GI practices compared to traditional practices, costs of specific maintenance tasks, maintenance timing and life expectancy of GI practices, etc. Knowledge sharing is another important role for Cooperative Extension to support GI adoption. Locally relevant information gained in these studies can be disseminated to stormwater designers, contractors, and decision makers in the region through educational events organized by VCE. Applications of this new shared knowledge could have significant positive impacts on decisions regarding GI selection, location, implementation, and long term functionality in Hampton Roads.

It is important to note the need for improved GI pollutant removal data. Understanding GI costs and associated maintenance requires knowledge of GI pollution reduction performance, which is largely absent in the coastal plain. Cost and maintenance studies performed to better understand GI implementation in Hampton Roads should include pollutant removal performance evaluations specific to the Hampton Roads region. This improved knowledge could lead to better decisions in GI selection and application to meet pollutant reduction needs throughout Hampton Roads.

4.3.2 Providing Maintenance Training Opportunities

Municipal survey respondents also showed a strong interest in finding GI maintenance training programs. Proper maintenance is necessary to preserve the functionality of GI and to meet or extend the life expectancy of the practice. As an educational organization, VCE could play in important role in providing GI maintenance training services to Hampton Roads municipal personnel, stormwater engineers, designers, and landscape contractors. VCE could develop training programs or partner with other organizations to facilitate training. VCE could provide general of topic specific training, especially on maintenance practices and vegetation selection and management. They could provide training venues, hands on demonstrations, and actual examples of installed GI practices. VCE could also provide public education and promote engagement and participation. Conducting training workshops at nearby venues with local Extension personnel would provide municipalities with an important workforce development partner for new GI practices. In addition, access to Master Gardener volunteers would allow for knowledgeable community members to aid in training sessions.

This solution is especially feasible given VCE's current level of involvement in GI training in the Chesapeake Bay. The interview data showed that several VCE offices had or currently have rain barrel and rain garden programs. Additionally, several VCE offices and the Hampton Roads AREC have demonstration GI practices in the landscape available for visitors to observe. Mot VCE offices have trained Master Gardener Water Stewards who conduct a variety of water education programs. Also, Dr. Laurie Fox, an Extension Specialist at the Hampton Roads AREC, has been involved with developing the new Chesapeake Bay Landscape Professional certification program (https://cblpro.org/). Level 1 of the certification targets landscape contractors and is focused on stormwater management practice maintenance. Level 2 is focused on design and installation of those practices. Opportunities exist for VCE to refine, expand, and collaborate on GI related programs.

4.3.3 Partnerships for Green Infrastructure Funding

To help offset the costs of GI implementation and encourage its adoption, various sources of funding have become available in recent years. MS4s with an interest in obtaining funding for GI projects could benefit from partnering with Cooperative Extension. Some funding sources require an outreach, education or public engagement component, which Extension could provide. Partnering with Extension could make MS4s eligible for new sources of funding for GI projects that were previously not accessible.

The Rutgers Cooperative Extension Water Resources Program (RCEWRP) in New Jersey is an example of Extension's role in successfully funding GI implementation initiatives through various funding sources. RCEWRP's work with Camden City to promote GI design and implementation began with grant support from the Camden County Municipal Utilities Authority. The success of that program led to further grant funding from the New Jersey Department of Environmental Protection, low interest loans with 50% principal forgiveness for GI projects from the New Jersey Environmental Infrastructure Trust, and private funding from the Surdna Foundation to expand the program to other municipalities (Obropta, 2017).

4.4 Challenges to Extension Involvement in Green Infrastructure

The opportunities identified above would have a significant impact on GI implementation in the Hampton Roads region, as they address the major challenges identified by municipal personnel. However, there are some factors that could limit the scope of Cooperative Extension's involvement in GI implementation.

First, while stormwater management is an important issue for Extension in Hampton Roads, it is not the only or even primary focus for many offices. As with any organization, personnel numbers and workload, existing obligations, and shrinking budgets could limit Extension's level of engagement.

Second is the uniqueness of each municipality in Hampton Roads. Extension offices are customized to address and support specific local and community needs, which drives where and how their resources are allocated. This was reflected in the data in that every Extension interviewee prioritized stormwater differently. Municipalities throughout Hampton Roads have different stormwater concerns, different levels of resources, and different histories with Extension. This could make improving GI implementation on a regional scale more difficult.

Third is the different perspectives of municipal and Extension personnel on GI. Most municipal survey participants understand GI as engineered practices to manage stormwater. Conversely, the Extension personnel interviewed emphasized a horticultural or ecological understanding of GI, noting stormwater management as one of several potential applications for the practices. This perspective difference could lead to confusion between municipal and Extension personnel when interacting on GI in the region. This difference just as easily become a strength, providing both groups a well-rounded broader perspective for GI programming.

Fourth and finally, municipal offices and Cooperative Extension have different missions and goals relative to GI. Some of these differences were reflected in the major GI challenges identified by both groups. These differences must be understood and respected for strong partnerships to form and for successful GI programming that benefits everyone to be achieved.

Chapter 5. Conclusion

Green infrastructure has an important role to play in helping to manage the water quality and quantity challenges in Hampton Roads. However, its implementation throughout the region has been largely hindered by funding limitations, knowledge gaps regarding GI costs, limited resources to support maintenance activities, and lack of knowledge around maintaining GI practices. The physiographic and topographic features of Southside Hampton Roads also limit the applicability of GI. As a result, these practices are often prevented from being approved or considered by decision makers.

Virginia Cooperative Extension is uniquely suited to help Hampton Roads municipalities address these barriers to GI implementation, with knowledgeable personnel who are experienced in promoting GI through public education events and activities. In addition to internal experience, VCE has access to university personnel and specialists familiar with Hampton Roads and GI from Virginia Tech, as well as its own trained Master Gardener and Water Steward volunteers who are familiar with water management issues. These resources would allow VCE personnel to support Hampton Roads MS4s by: facilitating learning around local GI costs; training and educating municipal personnel in GI maintenance; partnering with municipalities to pursue various funding opportunities for GI implementation and education; and fostering communication to spread and share knowledge about GI. VCE is already supporting GI adoption in Hampton Roads communities through various public education events. By adopting a collaborative and regional approach to address these GI barriers, Hampton Roads municipalities can tap into the many strengths and resources of VCE to improve decision-making in the region with respect to GI and help solve the pressing water challenges of Hampton Roads.

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Appendix A. Recruitement Materials

Municipality Invitation Letter

VirginiaTech
College of Agriculture and Life Sciences

Hampton Roads Agricultural Research and Extension Center
1444 Diamond Springs Road
Virginia Beach, VA 23455
Phone: 757-363-3900 Fax: 757-363-3950
http://arecs.vaes.vt.edu/hampton

April 3, 2017

Good morning,

My name is Daniel Robinson and I am currently a master's student in the Biological Systems Engineering department at Virginia Tech. I am reaching out to you today to invite you to participate in the Virginia Tech Hampton Roads Green Infrastructure Study, developed in partnership with the Hampton Roads Planning District Commission and conducted through the Virginia Tech Agricultural Research and Extension Center in Virginia Beach.

Flooding and water pollution continue to be significant urban issues around the country. Hampton Roads is especially sensitive to these challenges due to Chesapeake Bay TMDL requirements and sea level rise concerns. New technologies and development strategies now exist to address these problems more effectively, such as green infrastructure (GI) and low impact development (LID). However, several studies have indicated that the adoption of these newer stormwater management practices has been slowed by various barriers.

The goal of this study is to identify key barriers to GI implementation in Hampton Roads. The insights of you and other stormwater leaders in the region are critical for understanding local challenges for GI adoption, and your participation would be greatly appreciated. In addition, data from survey responses will be paired with a parallel assessment of Virginia Cooperative Extension (VCE) offices in Hampton Roads, where current and desired levels of VCE participation in stormwater management activities will be identified. The subsequent report will combine the results of both assessment to provide VCE and municipal personnel with targeted joint solutions to the challenges identified. Study results may also be published and used in master's thesis.

We hope you choose to apply your expert knowledge to our study. If you choose to participate, please note that all participants will remain anonymous. The total survey time is estimated at 20 minutes, and the survey response deadline is May 5th. If you have any questions, please feel free to contact me using the information below. Thank you for your consideration!

Sincerely,

Daniel J. Robinson
(678) 925-5996
djr91@vt.edu

Virginia Cooperative Extension Invitation Letter

VirginiaTech
College of Agriculture and Life Sciences

Hampton Roads Agricultural Research and Extension Center
1444 Diamond Springs Road
Virginia Beach, VA 23455
Phone: 757-363-3900 Fax: 757-363-3950
http://arecs.vaes.vt.edu/hampton

April 3, 2017

Good morning,

My name is Daniel Robinson and I am currently a master's student in the Biological Systems Engineering department at Virginia Tech. I am reaching out to you today to invite you to participate in the Virginia Tech Hampton Roads Green Infrastructure Study, developed in partnership with the Hampton Roads Planning District Commission and conducted through the Virginia Tech Agricultural Research and Extension Center in Virginia Beach.

Flooding and water pollution continue to be significant urban issues around the country. Hampton Roads is especially sensitive to these challenges due to Chesapeake Bay TMDL requirements and sea level rise concerns. New technologies and development strategies now exist to address these problems more effectively, such as green infrastructure (GI) and low impact development (LID). However, several studies have indicated that the adoption of these newer stormwater management practices has been slowed by various barriers.

Virginia Cooperative Extension has a history and expertise that is uniquely suited to help municipalities promote and implement green infrastructure. With the insights and you and other agents and personnel, I hope to identify the current and desired role of local VCE offices in supporting the implementation of GI in Hampton Roads. Using data collected through one-on-one in-person interviews, a report will be developed combining these responses with a parallel municipal survey identifying GI barriers. This report will provide VCE and stormwater personnel with solutions to the challenges identified. Study results may also be published and used in master's thesis.

We hope you choose to apply your expert knowledge to our study. If you choose to participate, please contact me to schedule an interview time using the information below. The identity of all study participants will remain confidential. The total interview time is estimated at 30 to 45 minutes, and all interviews will be audio recorded. Study responses will be pooled, analyzed and summarized, with a copy sent to you. If you have any questions, please feel free to contact me. Thank you for your consideration!

Sincerely,

Daniel J. Robinson
(678) 925-5996
djr91@vt.edu

Appendix B. Municipal Survey

Hampton Roads Green Infrastructure Survey

Intro

Hello and welcome to the Virginia Tech Hampton Roads Green Infrastructure Survey, developed in cooperation with the Hampton Roads Planning District Commission. This survey is part of a graduate research project in the Biological Systems Engineering Department at Virginia Tech, conducted through the Hampton Roads Agricultural Research & Extension Center in Virginia Beach.

The Hampton Roads region is incredibly connected to its local water resources. These connections come in various forms, including a large coastal economy, military interests through the largest naval base in the world, and legal requirements for the protection of both local water bodies and the Chesapeake Bay. New technologies and development strategies now exist to protect these water resources interests and others more effectively. However, several studies have indicated that municipal adoption of some water management practices has been slowed by a variety of barriers.

The goal of this survey is to identify challenges and potential solutions to the implementation of green infrastructure to manage urban runoff in Hampton Roads municipalities. In the context of this survey, the term "green infrastructure" refers to the following stormwater engineering practices and techniques:

Bioretention Cells/Rain Gardens
Grass Channels and Swales
Infiltration Basins and Trenches
Constructed Wetlands
Vegetated Roofs
Permeable Pavements
Rainwater Harvesting Techniques
Low Impact Development Strategies

Once identified, challenges and potential solutions determined through this survey will be paired with responses from parallel interviews with Virginia Cooperative Extension (VCE) offices in the region. Current and desired levels of VCE participation in stormwater management activities will be identified to determine the potential for VCE to support Hampton Roads MS4s in their mission to protect water resources in the region. Specific solutions will be recommended in a subsequent report combining information gained from both surveys and interviews. Results from report may also be published and used in master's thesis.

The total survey time is estimated at 20 minutes. Participants will remain anonymous. The survey response deadline is May 3rd, 2017. If you have any questions, please contact Daniel Robinson by email at djr91@vt.edu. Thank you for your participation, we greatly appreciate your input! Should you have any questions or concerns about your rights as a research subject, you may contact the VT IRB Chair, Dr. David M. Moore at moored@vt.edu.

Q1 Please identify your municipality as a Phase I or Phase II MS4
Phase I (1)
Phase II (2)

Q2 How long have you been in your current position?
0-3 years (1)
4-6 years (2)
7+ years (3)

Q3 How long have you been in the stormwater field?
0-6 years (1)
7-14 years (2)
15+ years (3)

Q4 How are you familiar with Virginia Cooperative Extension (VCE)? (Select all that apply)
Working relationship with local VCE office (1)
Knowledge of local VCE programs/activities (2)
Knowledge of VCE outside my municipality (4)
Not familiar with VCE (3)

Q5 Please organize (drag and drop) the following barriers to green infrastructure (or GI) in your municipality from greatest (#1) to least (#8):
______ Laws and Regulations (1)
______ Training and Data (2)
______ Management and Coordination (3)
______ Costs and Funding (4)
______ Climate and Land Features (5)
______ Maintenance (6)
______ Public Education and Engagement (7)
______ Residential Implementation (8)

Info Notice: The remainder of the survey will focus only on the top three challenges selected.

LR1 Please indicate the level of significance of the following barriers to GI in your municipality:

	Low (1)	Moderate (2)	High (3)	Very High (4)	N/A (5)
Legislation relevant to GI is conflicting or confusing (1)					
Concerns exist for liability due to unintended consequences of GI (2)					
Existing laws limit and/or restrict the implementation of GI (3)					
Political support for GI implementation is lacking (4)					

LR2 About how long have legal and/or regulatory challenges been a barrier for the implementation of GI in your municipality?

1 year or less (1)
2 - 3 years (2)
4 - 5 years (3)
More than 5 years (4)

LR3 How do legal and/or regulatory challenges impact the implementation of GI practices in your municipality? (Select all that apply)

Prevents the practice from being considered or approved (1)
Hinders the design process of the practice (2)
Delays the construction of the practice (3)
Causes challenges for practice inspection (4)

LR4 Has your municipality made positive progress toward addressing this barrier to GI implementation?

Yes (1)
No (2)

Display This Question:
Has your municipality made positive progress toward addressing this barrier to GI implementation? Yes Is Selected

LR4Y What changes were made to start addressing this challenge? (Select all that apply)

- Increased communication with relevant personnel inside our municipality (1)
- Increased communication with relevant personnel outside our municipality (2)
- Hired a consultant to help address this challenge (3)
- Developed a plan to address this challenge (4)
- Other (5) ____________________

Display This Question:
Has your municipality made positive progress toward addressing this barrier to GI implementation? No Is Selected

LR4N What changes have you already made or would like to make to start addressing this challenge? (Select all that apply)

- Increase communication with relevant personnel inside our municipality (1)
- Increase communication with relevant personnel outside our municipality (2)
- Hire a consultant to help address this challenge (3)
- Develop a plan to address this challenge (4)
- Other (5) ____________________

LR5 Which of the following activities would be most useful to your municipality in working toward a solution to this challenge? (Select all that apply)

- Obtaining model ordinances and legislation from regions that embrace GI and LID practices (1)
- Conducting an audit of existing legislation and ordinances that impact green infrastructure (2)
- Including human safety considerations in existing GI design guidelines (3)
- Developing an education program for legislators and decision makers on importance of GI (4)
- Other (5) ____________________

TD1 Please indicate the level of significance of the following barriers to GI in your municipality:

	Low (1)	Moderate (2)	High (3)	Very High (4)	N/A (5)
Need for increased or modified personnel education and training opportunities (1)					
Need for improved data on GI performance and benefits in Hampton Roads region (2)					
Need for updated or new technical guidance materials focused on GI (3)					

TD2 About how long have training and data challenges been a barrier for the implementation of GI in your municipality?

1 year or less (1)
2 - 3 years (2)
4 - 5 years (3)
More than 5 years (4)

TD3 How do training and data challenges impact the implementation of GI practices in your municipality? (Select all that apply)

Prevents the practice from being considered or approved (1)
Hinders the design process of the practice (2)
Delays the construction of the practice (3)
Causes challenges for practice inspection (4)

TD4 Has your municipality made positive progress toward addressing this barrier to GI implementation?

Yes (1)
No (2)

Display This Question:
Has your municipality made positive progress toward addressing this barrier to GI implementation? Yes Is Selected

TD4Y What changes were made to start addressing this challenge? (Select all that apply)

- Increased communication with relevant personnel inside our municipality (1)
- Increased communication with relevant personnel outside our municipality (2)
- Hired a consultant to help address this challenge (3)
- Developed a plan to address this challenge (4)
- Other (5) ____________________

Display This Question:
Has your municipality made positive progress toward addressing this barrier to GI implementation? No Is Selected

TD4N What changes have you already made or would like to make to start addressing this challenge? (Select all that apply)

- Increase communication with relevant personnel inside our municipality (1)
- Increase communication with relevant personnel outside our municipality (2)
- Hire a consultant to help address this challenge (3)
- Develop a plan to address this challenge (4)
- Other (5) ____________________

TD5 Which of the following activities would be most useful to your municipality in working toward a solution to this challenge? (Select all that apply)

- Identifying locally accepted professional certification in GI design and implementation (1)
- Providing training opportunities for critical GI design skills (2)
- Conducting studies on performance of GI in improving water quality and quantity (3)
- Conducting studies on local benefits of GI implementation (4)
- Other (5) ____________________

MC1 Please indicate the level of significance of the following barriers to GI in your municipality:

	Low (1)	Moderate (2)	High (3)	Very High (4)	N/A (5)
Inclusion of community stakeholders in GI management is limited (1)					
Cooperation across municipal boundaries to support GI is limited (2)					
Coordination between various municipal offices involved in GI is limited (3)					

MC2 About how long have management and coordination challenges been a barrier for the implementation of GI in your municipality?

1 year or less (1)
2 - 3 years (2)
4 - 5 years (3)
More than 5 years (4)

MC3 How do management and coordination challenges impact the implementation of GI practices in your municipality? (Select all that apply)

Prevents the practice from being considered or approved (1)
Hinders the design process of the practice (2)
Delays the construction of the practice (3)
Causes challenges for practice inspection (4)

MC4 Has your municipality made positive progress toward addressing this barrier to GI implementation?

Yes (1)
No (2)

Display This Question:
Has your municipality made positive progress toward addressing this barrier to GI implementation? Yes Is Selected

MC4Y What changes were made to start addressing this challenge? (Select all that apply)

- Increased communication with relevant personnel inside our municipality (1)
- Increased communication with relevant personnel outside our municipality (2)
- Hired a consultant to help address this challenge (3)
- Developed a plan to address this challenge (4)
- Other (5) ____________________

Display This Question:
Has your municipality made positive progress toward addressing this barrier to GI implementation? No Is Selected

MC4N What changes have you already made or would like to make to start addressing this challenge? (Select all that apply)

- Increase communication with relevant personnel inside our municipality (1)
- Increase communication with relevant personnel outside our municipality (2)
- Hire a consultant to help address this challenge (3)
- Develop a plan to address this challenge (4)
- Other (5) ____________________

MC5 Which of the following activities would be most useful to your municipality in working toward a solution to this challenge? (Select all that apply)

- Identify and engage with stakeholders interested in GI management (1)
- Integrate stakeholders into planning and implementation of GI practices (2)
- Identify barriers to cooperation across municipal boundaries and resolve them (3)
- Recognize challenges for cooperation between municipal departments (4)
- Other (5) ____________________

CF1 Please indicate the level of significance of the following barriers to GI in your municipality:

	Low (1)	Moderate (2)	High (3)	Very High (4)	N/A (5)
Funding for GI implementation is limited or unavailable (1)					
Information on GI implementation costs is unfamiliar or unknown (2)					

CF2 About how long have cost and funding challenges been a barrier for the implementation of GI in your municipality?

1 year or less (1)
2 - 3 years (2)
4 - 5 years (3)
More than 5 years (4)

CF3 How do cost and funding challenges impact the implementation of GI practices in your municipality? (Select all that apply)

Prevents the practice from being considered or approved (1)
Hinders the design process of the practice (2)
Delays the construction of the practice (3)
Causes challenges for practice inspection (4)

CF4 Has your municipality made positive progress toward addressing this barrier to GI implementation?

Yes (1)
No (2)

Display This Question: Has your municipality made positive progress toward addressing this barrier to GI implementation? Yes Is Selected

CF4Y What changes were made to start addressing this challenge? (Select all that apply)

Increased communication with relevant personnel inside our municipality (1)
Increased communication with relevant personnel outside our municipality (2)
Hired a consultant to help address this challenge (3)
Developed a plan to address this challenge (4)
Other (5) ____________________

Display This Question:
Has your municipality made positive progress toward addressing this barrier to GI implementation? No Is Selected

CF4N What changes have you already made or would like to make to start addressing this challenge? (Select all that apply)

Increase communication with relevant personnel inside our municipality (1)
Increase communication with relevant personnel outside our municipality (2)
Hire a consultant to help address this challenge (3)
Develop a plan to address this challenge (4)
Other (5) ____________________

CF5 Which of the following activities would be most useful to your municipality in working toward a solution to this challenge? (Select all that apply)

Identify new sources of funding for green infrastructure (1)
Develop new methods of generating revenue for green infrastructure (2)
Conduct life-cycle cost analyses of green infrastructure practices (3)
Conduct comparative economic analyses of gray vs green infrastructure (4)
Other (5) ____________________

CL1 Please indicate the level of significance of the following barriers to GI in your municipality:

	Low (1)	Moderate (2)	High (3)	Very High (4)	N/A (5)
GI may not adequately address impacts from changing weather patterns (1)					
Characteristics of the physical landscape limit GI implementation (2)					
Space for GI practice implementation is limited (3)					

CL2 About how long ago did your municipality recognize GI challenges related to weather and/or land features?

Within the last year (1)
2 - 5 years ago (2)
6 - 8 years (3)
More than 8 years ago (4)

CL3 How do climate and land feature challenges impact the implementation of GI practices in your municipality? (Select all that apply)

Prevents the practice from being considered or approved (1)
Hinders the design process of the practice (2)
Delays the construction of the practice (3)
Causes challenges for practice inspection (4)

CL4 Has your municipality made positive progress toward addressing this barrier to GI implementation?

Yes (1)
No (2)

Display This Question:
Has your municipality made positive progress toward addressing this barrier to GI implementation? Yes Is Selected

CL4Y What changes were made to start addressing this challenge? (Select all that apply)

Increased communication with relevant personnel inside our municipality (1)
Increased communication with relevant personnel outside our municipality (2)
Hired a consultant to help address this challenge (3)
Developed a plan to address this challenge (4)
Other (5) ____________________

Display This Question:
Has your municipality made positive progress toward addressing this barrier to GI implementation? No Is Selected

CL4N What changes have you already made or would like to make to start addressing this challenge? (Select all that apply)

Increase communication with relevant personnel inside our municipality (1)
Increase communication with relevant personnel outside our municipality (2)
Hire a consultant to help address this challenge (3)
Develop a plan to address this challenge (4)
Other (5) ____________________

CL5 Which of the following activities would be most useful to your municipality in working toward a solution to this challenge? (Select all that apply)

Determine impact of changing weather patterns on GI effectiveness (1)
Use modeling to determine ideal GI placement based on landscape characteristics (2)
Develop new strategies to implement GI in difficult spaces (3)
Develop new GI practices to take advantage of local characteristics (4)
Other (5) ____________________

M1 Please indicate the level of significance of the following barriers to GI in your municipality:

	Low (1)	Moderate (2)	High (3)	Very High (4)	N/A (5)
Maintenance practices and costs for GI are unfamiliar (1)					
Resources to support maintenance activities for GI are limited (2)					

M2 About how long have maintenance challenges been a barrier for the implementation of GI in your municipality?

1 year or less (1)
2 - 3 years (2)
4 - 5 years (3)
More than 5 years (4)

M3 How do maintenance challenges impact the implementation of GI practices in your municipality? (Select all that apply)

Prevents the practice from being considered or approved (1)
Hinders the design process of the practice (2)
Delays the construction of the practice (3)
Causes challenges for practice inspection (4)

M4 Has your municipality made positive progress toward addressing this barrier to GI implementation?

Yes (1)
No (2)

Display This Question: Has your municipality made positive progress toward addressing this barrier to GI implementation? Yes Is Selected

M4Y What changes were made to start addressing this challenge? (Select all that apply)

Increased communication with relevant personnel inside our municipality (1)
Increased communication with relevant personnel outside our municipality (2)
Hired a consultant to help address this challenge (3)
Developed a plan to address this challenge (4)
Other (5) ____________________

Display This Question: Has your municipality made positive progress toward addressing this barrier to GI implementation? No Is Selected

M4N What changes have you already made or would like to make to start addressing this challenge? (Select all that apply)

Increase communication with relevant personnel inside our municipality (1)

Increase communication with relevant personnel outside our municipality (2)

Hire a consultant to help address this challenge (3)

Develop a plan to address this challenge (4)

Other (5) ____

M5 Which of the following activities would be most useful to your municipality in working toward a solution to this challenge? (Select all that apply)

Develop or identify training programs to improve GI maintenance knowledge (1)

Conduct study on lifecycle maintenance costs of local GI practices (2)

Involve stakeholder groups and the public in GI maintenance tasks (3)

Identify new sources of funding for GI maintenance tasks (4)

Other (5) ____

PE1 Please indicate the level of significance of the following barriers to GI in your municipality:

	Low (1)	Moderate (2)	High (3)	Very High (4)	N/A (5)
Public education and outreach efforts supporting GI should be expanded (1)					
Public engagement efforts should expand to increase participation in GI management (2)					
Negative public perceptions of GI discourage implementation efforts (3)					

PE2 About how long have public education and engagement challenges been a barrier for the implementation of GI in your municipality?

1 year or less (1)
2 - 3 years (2)
4 - 5 years (3)
More than 5 years (4)

PE3 How do public education and engagement challenges impact the implementation of GI practices in your municipality? (Select all that apply)

Prevents the practice from being considered or approved (1)
Hinders the design process of the practice (2)
Delays the construction of the practice (3)
Causes challenges for practice inspection (4)

PE4 Has your municipality made positive progress toward addressing this barrier to GI implementation?

Yes (1)
No (2)

Display This Question: Has your municipality made positive progress toward addressing this barrier to GI implementation? Yes Is Selected

PE4Y What changes were made to start addressing this challenge? (Select all that apply)

- Increased communication with relevant personnel inside our municipality (1)
- Increased communication with relevant personnel outside our municipality (2)
- Hired a consultant to help address this challenge (3)
- Developed a plan to address this challenge (4)
- Other (5) ____________________

Display This Question: Has your municipality made positive progress toward addressing this barrier to GI implementation? No Is Selected

PE4N What changes have you already made or would like to make to start addressing this challenge? (Select all that apply)

- Increase communication with relevant personnel inside our municipality (1)
- Increase communication with relevant personnel outside our municipality (2)
- Hire a consultant to help address this challenge (3)
- Develop a plan to address this challenge (4)
- Other (5) ____________________

PE5 Which of the following activities would be most useful to your municipality in working toward a solution to this challenge? (Select all that apply)

- Create campaign to explain links between GI practices and public health benefits (1)
- Engage with stakeholders to determine how GI can address community priorities (2)
- Provide incentives for public engagement in GI implementation and maintenance (3)
- Other (4) ____________________

RI1 Please indicate the level of significance of the following barriers to GI in your municipality:

	Low (1)	Moderate (2)	High (3)	Very High (4)	N/A (5)
Municipal authority to manage GI on private land is limited (1)					
Obtaining credit for GI on private property is difficult (2)					
Incentives to promote homeowner adoption of GI practices are limited (3)					

RI2 About how long have residential implementation challenges been a barrier for the implementation of GI in your municipality?

1 year or less (1)
2 - 3 years (2)
4 - 5 years (3)
More than 5 years (4)

RI3 How do residential implementation challenges impact the implementation of GI practices in your municipality? (Select all that apply)

Prevents the practice from being considered or approved (1)
Hinders the design process of the practice (2)
Delays the construction of the practice (3)
Causes challenges for practice inspection (4)

RI4 Has your municipality made positive progress toward addressing this barrier to GI implementation?

Yes (1)
No (2)

Display This Question:
Has your municipality made positive progress toward addressing this barrier to GI implementation? Yes Is Selected

RI4Y What changes were made to start addressing this challenge? (Select all that apply)
- Increased communication with relevant personnel inside our municipality (1)
- Increased communication with relevant personnel outside our municipality (2)
- Hired a consultant to help address this challenge (3)
- Developed a plan to address this challenge (4)
- Other (5) ____________________

Display This Question:
Has your municipality made positive progress toward addressing this barrier to GI implementation? No Is Selected

RI4N What changes have you already made or would like to make to start addressing this challenge? (Select all that apply)
- Increase communication with relevant personnel inside our municipality (1)
- Increase communication with relevant personnel outside our municipality (2)
- Hire a consultant to help address this challenge (3)
- Develop a plan to address this challenge (4)
- Other (5) ____________________

RI5 Which of the following activities would be most useful to your municipality in working toward a solution to this challenge? (Select all that apply)
- Examine model programs that successfully credit GI practices on private land (1)
- Engage with communities to improve residential GI maintenance (2)
- Engage with residents to determine appropriate incentives for GI adoption (3)
- Other (4) ____________________

C1 Briefly identify another one or two major challenges your municipality is facing with respect to the implementation of green infrastructure.

C2 For the problem(s) identified above, please provide a solution you believe would be valuable to improve GI implementation in your municipality.

C3 Is your municipal office willing to share its progress on addressing its GI implementation challenges with other municipalities in the Hampton Roads region?
- Yes (1)
- Maybe (2)
- No (3)

Thank you Thank you for your participation in this survey! If you have any questions or comments, please contact Daniel Robinson at djr91@vt.edu.

Appendix C. VCE Interview

Intro

How long have you been in your current position with Virginia Cooperative Extension?

Rank in order of importance the water management priorities in the municipality your Extension office serves.

- Wastewater treatment
- Drinking water treatment and delivery
- Surface water resources protection
- Groundwater resources protection
- Stormwater management
- Other

In your current position, approximately what % of your time do you devote to water related responsibilities?

What % specifically to stormwater issues?

What are your office's greatest strengths and resources in supporting the municipality's water management efforts?

What are the weaknesses?

Which municipal office(s) do you primarily engage with on water management issues?

- Stormwater
- Planning
- Public Works
- Parks & Recreation
- Other

Stormwater and GI

Which municipal office is responsible for stormwater management?

How familiar are you with the concept of green infrastructure (GI)? (Definition will be provided)

- Very familiar
- Somewhat familiar
- A little familiar
- Not at all familiar

Have you conducted VCE programs focused on GI in the past?

Are there any current VCE programs on GI in your municipality? If so, please list them.

From your perspective, rank the following challenges to GI from greatest to least according to their level of significance in your municipality.

Laws and Regulations
Training and Data
Management and Coordination
Costs and Funding
Climate and Land Features
Maintenance
Public Education and Engagement
Residential Implementation

Does your VCE office currently devote time to addressing the top three challenges you identified?

Challenge 1: ______________________
Challenge 2: ______________________
Challenge 3: ______________________

What VCE resources have been devoted to these challenges?

Challenge 1: ______________________
Challenge 2: ______________________
Challenge 3: ______________________

What additional challenges to GI implementation can you identify?

What resources are needed for VCE to address these challenges?

Appendix D. VCE Consent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants
in Research Projects Involving Human Subjects

Title of Project: Addressing MS4 Stormwater Needs Through Cooperative Extension

Investigator(s): **Daniel Robinson (678-925-5996)** **djr91@vt.edu**

David Sample **dsample@vt.edu**

I. Purpose of this Research Project

Stormwater management is a priority in urban areas for practical and regulatory reasons. In recent years, the U.S. Environmental Protection Agency (USEPA) and others have promoted the implementation of new stormwater technologies and practices that improve runoff quantity and quality by infiltration, filtration, evapotranspiration, and treatment. Collectively, these strategies are known as green infrastructure (GI) and/or low impact development (LID); in contrast with conventional stormwater management which is known as gray infrastructure. The implementation of GI and LID is thought by many experts to be more holistic than gray infrastructure and provides a variety of co-benefits. Despite support for these new approaches to stormwater management, their adoption by municipalities has been slow.

Several states (other than the Commonwealth of Virginia) have seen their local Cooperative Extension Service offices take on several tasks that support and encourage the adoption of these new stormwater practices. These include developing training and certification programs for professionals, conducting research to determine their effectiveness, assisting communities in watershed planning, and developing educational materials for the public. The goal of this study is to identify challenges to implementing GI in Hampton Roads, assess local Virginia Cooperative Extension offices for their capacity to help meet these challenges, and to provide recommendations that support municipal adoption of GI through Virginia Cooperative Extension.

Study results may be published and used in a master's thesis.

II. Procedures

Should you agree to participate, you will be asked to participate in a 30-45-minute audio-recorded interview. Interviews will take place in a mutually agreed upon location between you and the interviewer, as determined through initial contact and interview scheduling.

III. Risks

Potential risks include being penalized within your place of work for statements and opinions given during this interview, possibly resulting in negative impacts to economic stability, emotional state, and/or personal dignity. To reduce this risk, your identity as a participant will remain confidential.

IV. Benefits

Benefits of the study include formally identifying barriers to addressing a challenge of regional importance in local flooding and water quality control, identifying potentially viable solutions to these challenges, and obtaining a range of opinions on identified problems and solutions from local stormwater professionals.

No promise or guarantee of benefits has been made to encourage you to participate.

V. Extent of Anonymity and Confidentiality

Data collected during this interview will include identifying information in the form of a signature in this consent form. In order to protect your identity, identification codes will be used, with a key being developed linking code to participant name. This key will be digitally created, encrypted, and kept on a separate removable hard drive. Only the interviewer will have access to this encrypted document.

At no time will the researchers release identifiable results of the study to anyone other than individuals working on the project without your written consent.

The Virginia Tech (VT) Institutional Review Board (IRB) may view the study's data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research.

VI. Compensation

There is no compensation provided for study participants.

VII. Freedom to Withdraw

It is important for you to know that you are free to withdraw from this study at any time without penalty. You are free not to answer any questions that you choose or respond to what is being asked of you without penalty.

Please note that there may be circumstances under which the investigator may determine that a subject should not continue to participate.

VIII. Questions or Concerns

Should you have any questions about this study, you may contact one of the research investigators whose contact information is included at the beginning of this document.

Should you have any questions or concerns about the study's conduct or your rights as a research subject, or need to report a research-related injury or event, you may contact the VT IRB Chair, Dr. David M. Moore at moored@vt.edu or (540) 231-4991.

IX. Subject's Consent

I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

____ Date__________
Subject signature

____
Subject printed name

Virginia Tech Institutional Review Board Project No. 17-044
Approved April 10, 2017 to April 9, 2018

Appendix E. IRB Approval Forms

Office of Research Compliance
Institutional Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: April 10, 2017

TO: David J Sample, Daniel Joseph Robinson

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)

PROTOCOL TITLE: Addressing MS4 Stormwater Needs Through Cooperative Extension

IRB NUMBER: **17-044**

Effective April 10, 2017, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**April 10, 2017**
Protocol Expiration Date:	**April 9, 2018**
Continuing Review Due Date*:	**March 26, 2018**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution

Date*	OSP Number	Sponsor	Grant Comparison Conducted?

* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.

VIRGINIA TECH.

Office of Research Compliance
Institutional Review Board
North End Center, Suite 4120
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-3732 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: March 30, 2018

TO: David J Sample, Daniel Joseph Robinson

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)

PROTOCOL TITLE: Addressing MS4 Stormwater Needs Through Cooperative Extension

IRB NUMBER: **17-044**

Effective March 30, 2018, the Virginia Tech Institution Review Board (IRB) approved the Continuing Review request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

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(Please review responsibilities before the commencement of your research.)

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