2019

Green Infrastructure Initiative Plan

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GREEN INFRASTRUCTURE INITIATIVE PLAN

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Prepared for: Richmond Department of Public Utilities

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1. Introduction

1.1 Plan Purpose

This plan seeks to identify strategies to incentivize green infrastructure (GI) investments on privately owned land within three priority watersheds in Richmond, Virginia. The recommendations from this plan provide the City of Richmond Department of Public Utilities (DPU) with implementable policies that promote beneficial green infrastructure usage on privately owned property.

1.2 Client Description

DPU is a part of Richmond City Government. DPU manages stormwater and wastewater within city limits, but also manages the city's natural gas, drinking water, and electric street-lighting utilities. Funding for DPU comes from utility service fees. In the fiscal year 2017, approximately 8 million dollars were spent on operating costs for stormwater utilities. DPU manages Richmond's combined sewer system (CSS) of which 12,000 acres of Richmond is serviced. Richmond's wastewater treatment plant (WWTP) is also operated and managed by DPU.

1.3 Plan Implementation

The recommendations formulated from this plan may be directly implemented into DPU's stormwater utility policy. Recommendations involve DPU, landowners, and any potential stakeholders that might benefit from improved stormwater management. The quality of our water affects the entire regional environment, so everyone is ultimately affected by any improvements to the water quality and quantity drained into the James River. However, recommended incentives for stormwater management infrastructure will be focus area specific, and will need to cater to the needs of the community.

1.4 Plan Outline

This plan includes background information pertaining to existing stormwater regulations and practices in Richmond, and information on the effects of impervious surfaces and CSSs. This document also includes research on the impacts of green infrastructure and case studies from other cities to incentivize GI implementation. Lastly, methods for generating an incentive strategy for the three priority watersheds are outlined.

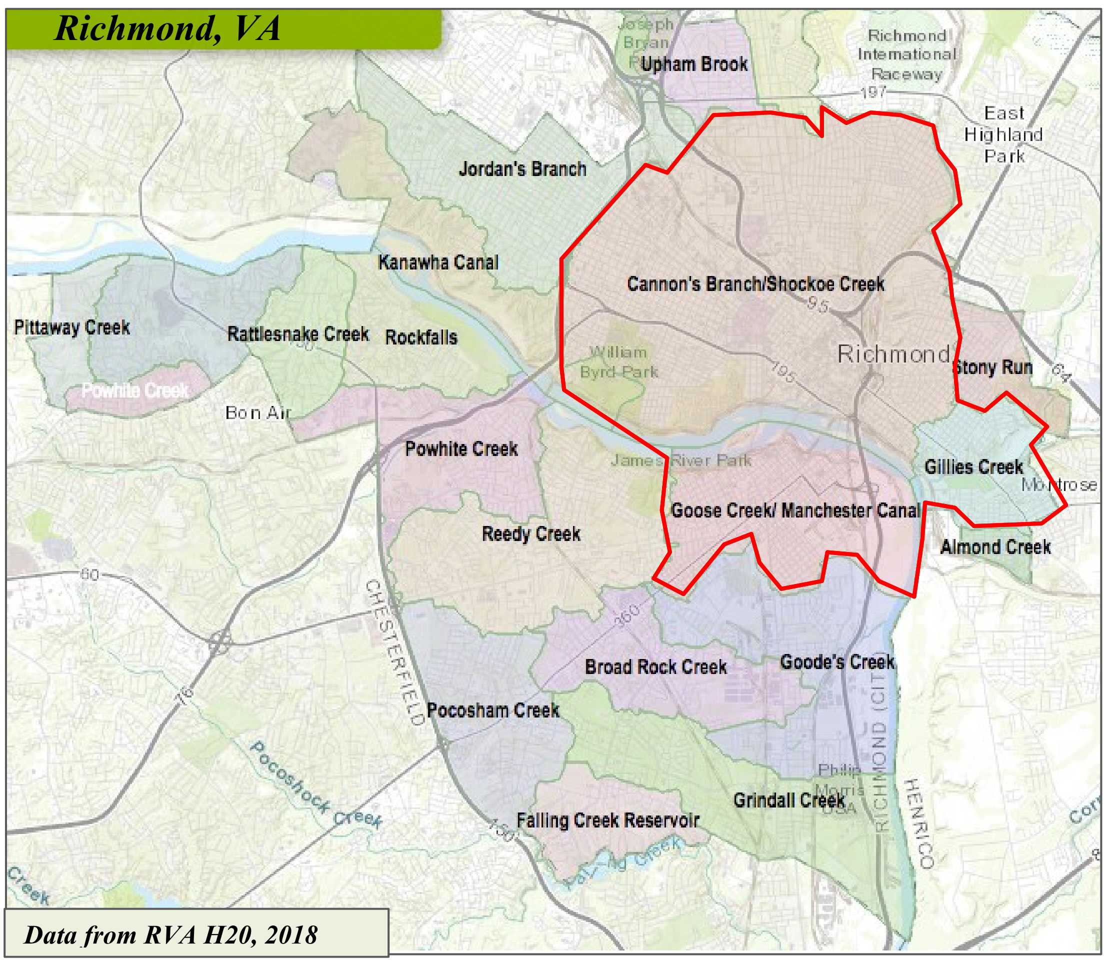


Figure 1-1: Three Priority Watersheds

2. Background

2.1 Plan Context

The City of Richmond is required to comply with federally mandated regulations issued by the U.S. Environmental Protection Agency (EPA) and the Clean Water Act (CWA). These regulations require Richmond's Department of Public Utilities (DPU) to adhere to permits granted to the city to allow responsible discharge of wastewater and stormwater into the Chesapeake Bay and other receiving water bodies. Under these permits, Richmond DPU must adopt several control measures to monitor and reduce pollutant levels into receiving waters.

In regards to stormwater management, DPU maintains Richmond's combined sewer system (CSS) and oversees the planning, infrastructure, and maintenance of the network of drainage systems that exist within the city. They are also tasked with creating solutions to reduce the negative effects of urban stormwater runoff into receiving bodies of water. This is done primarily through infrastructure construction/improvements, natural habitat conservation, impervious surface reduction, and public education.

Stormwater runoff that is exacerbated by urban environments leads to detrimental impacts on human and natural life. DPU uses the 2017 RVA Clean Water Plan to prioritize their efforts that will ultimately lead to cleaner receiving water bodies. Each objective, piece by piece, aims to confront Richmond's stormwater problems through improving water quality and adapting the urban environment to be more resilient to current conditions.

"Impervious surfaces are areas where the natural ground is covered in a surface that stormwater runs directly off. For example, roads, structures, sidewalks, and parking lots are all considered impervious, or impermeable, surfaces. These surfaces are problematic because they prevent rainwater from infiltrating into the soil, and runoff increases as a result. In addition, impervious surfaces create smooth and accelerated water flows for stormwater to travel quickly into existing drainage systems that are already overwhelmed with stormwater" (Virginia Stormwater Management Handbook, 2013). Impervious surfaces are seen everywhere in Richmond. Local roads, highways, buildings, and parking lots consist mainly of materials that are impenetrable to stormwater.

Efforts from Richmond City government have transformed some local roads and alleys into permeable surfaces, and other efforts, though so much impervious land surface remains. However, promoting best practices is difficult to accomplish when communities are not aware of the impacts every household has on stormwater management. This plan uncovers strategic and cost-effective green infrastructure initiatives within Richmond to help educate and incentivize the public to mitigate current stormwater water issues.

2.2 Existing Knowledge

There are several federal and state regulations that are aimed to limit the amount of pollutants discharged in our waterways. As discussed, the Clean Water Act was established by the federal government to help combat water quality issues. Richmond, like hundreds of other urban cities in the United States, use a CSS to assist stormwater drainage. CSS are systems that combine both surface runoff and sewage. In a CSS network when rainfall levels reach a certain point, the infrastructure designed solely for stormwater becomes overwhelmed and pipes that transport human, domestic, and industrial waste are then utilized to drain excess stormwater. "The city has the largest combined sewage system in all of Virginia, and approximately 12,000 acres-worth of sewage drains directly into the river during heavy rain" (Schmitt, 2017).

These events are called combined sewer overflows (CSOs). The example below depicts CSO events to the Great Lakes Basin, and Richmond's CSO network works much the same way.

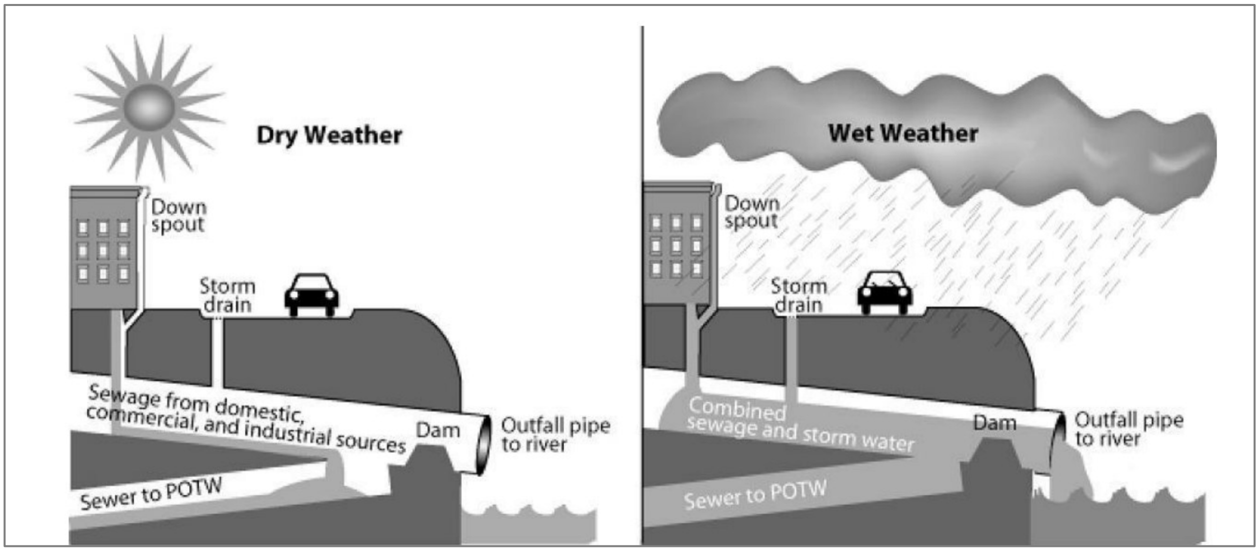


Figure 1-2: Typical Combined Sewer System

CSOs in Richmond cause devastating effects to the James River including increased prevalence of E. Coli in the water. "Fecal coliform counts are highest within the fall line stretch [of the James River] and 10 percent of all global cases of the fatal brain-eating Amoeba (Naegleria fowleri) are from the James River near Richmond" (Ettinger et. al 2002). The City of Richmond has made strides to combat stormwater management issues. DPU set out to educate the Richmond community about clean water in 2014 when it launched RVAH20.

2.21 Clean Water Plan

In 2017 DPU published the Clean Water Plan which was created to provide DPU with coherent goals and objectives that seek to restore and protect the waterways in the James River watershed through the development of stormwater management and CSS infrastructure improvement strategies that meet regulatory requirements.

The plan includes six elements: (1) stakeholder involvement, (2) watershed characterization, (3) strategy identification, evaluation, and selection, (4) program implementation, (5) progress measurement, and (6) adaptive management. Strategies and objectives are weighted to be in congruence of the priorities of the City and its stakeholders. Strategies incorporate riparian areas, green infrastructure in MS4 permit areas and within CSS areas, stream restoration, native and invasive plant species, tree canopies, land conservation, water conservation, pollution identification and reduction, and CSS infrastructure.

This plan will focus primarily on using the criteria set forth in the Clean Water Plan to help DPU implement new strategies to incentivize green stormwater infrastructure utilization for the communities within the Cannon's Branch/Shockoe Creek, Gillies Creek, and Goose Creek/Manchester Canal watersheds.

2.22 Green Infrastructure

The Clean Water Plan emphasizes use of green infrastructure to improve water quality in Virginia's waterways. The City of Richmond has implemented several green infrastructure initiatives such as rain gardens and planter beds. "Green infrastructure is a cost-effective, resilient approach to managing wet weather impacts that provides many community benefits.

Green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits" (EPA, 2018).

2.23 RVA Green: A Roadmap to Sustainability (2011)

This plan was developed for several facets of Richmond City government functions to include those related to environmental sustainability. One objective seeks to protect and enhance Richmond's water resources in part by reducing the percentage of impermeable surface area. This plan assessed the city to have 32 percent of surface area to be covered in impervious surface. The goal of this plan indicates a reduction in impermeable surface area to about 10 or 20 percent in order to minimize the effects of urban runoff pollutants into watersheds. This plan also serves to address the negative public perceptions of water quality of the James River. While treated water is deemed suitable for human consumption, many areas of the James River remain impaired due to pollutants. Public outreach and education on water quality and water consumption are an important piece of this plan's implementation.

2.3 Theoretical Framework

Rational Planning in wastewater and stormwater management preceded all other forms of thought in the 1950s through science and engineering. Planners today recognize that public involvement and public input is essential in plan development. This plan includes both advocacy planning and sustainability planning as the core theoretical frameworks that drive the goals and objectives.

2.31 Advocacy Planning

It is important to recognize the power of high modernism and rational planning in the historical context of stormwater because mechanisms such as the CSS and urban drainage serve their intended purposes. But strictly rational solutions and major engineering projects cannot meet the universal demands of an ecosystem. Today, the regional effects of pollutant runoff to receiving water bodies has become a universal issue for inhabitants in Richmond. Citizens need to be involved in this planning process. This plan places the planner in between the client and the landowners. The planner's role is to facilitate the process of land conversion in a way that benefits both the city's efforts and the other stakeholders' best interests. For public involvement and education on the topic of stormwater, it's important for everyone to understand their role as active participants in keeping the local waters clean. The goal is to encourage the community, who may not be fully educated on the negative effects of stormwater, to become involved in the implementation of this plan.

Advocacy planning theory is relevant due to the complexities of stormwater management. Many people do not understand what contributes to polluting the James River. Incorporating this theory into my plan will help to simplify the concepts in a way that make sense to people from various backgrounds and educations. The missing link is the lack of knowledge. DPU cites excessive water consumption as a significant issue to pollution of water bodies. DPU is currently undertaking large public outreach tactics to inform the public of day-to-day individual best practices to improve water quality. Many of these best practices are very simple, though their importance isn't emphasized. This means efforts from DPU should help the public understand the environmental effects related to runoff from their property, and to educate and deter people from excessive use of impermeable surfaces.

Incentives and deterrence measures need to be in place to push landowners and developers to reduce impervious surfaces, or minimize impervious surface area during development. Awareness may only scratch the surface to remedy a problem that requires drastic change. The only motive that exists for reducing imperious surfaces is a reduction in stormwater utility bills, which often goes unnoticed.

2.32 Sustainability

Urbanized cities face challenges related to environmental sustainability. Pollution from factories, transportation systems, garbage, and other means taint our air and water resources. To sustain the natural ecology in its original form while simultaneously developing is impossible. The goal of urban sustainability is to minimize the ecological footprint to conserve natural resources while destroying as little as possible.

In sustainability regarding urban runoff, the change will need to occur to reverse or retrofit existing infrastructure to diminish the negative effects. Richmond's stormwater infrastructure is efficient in water removal, but devastating to receiving water habitats. Richmond will need to undo the effects of work completed through vast projects that separated cities from nature during what Kavonen (2011) terms the "promethean era." During this era, city governments were encouraged to display the power of mankind and engineering through means that didn't agree with nature. It wasn't until immediately after these large projects that the effects of pollutants began to show themselves. But currently, ecological and urban sustainability efforts aim to replicate the original natural landscapes that existed prior to settlement. While Richmond cannot be totally razed and rebuilt, there are steps that should be taken to convert and retrofit existing infrastructure to more closely mimic a natural environment. These strategies include replacing impervious surfaces with permeable pavement, increasing tree canopy cover, creation of riparian buffers along streams, green roofing, and other low impact development (LID) means.

The problem of effective stormwater management originates not with poor design, but a historical lack of understanding. The emphasis on removal of stormwater and wastewater into receiving watersheds should be shifted to an emphasis on creating an urban environment that does not warrant a need for removal in the first place. Though a rebirth in Richmond's existing urban geography is not possible, procedures and policies that influence water usage and disposal can be altered to reduce consumption and improve the environment. Richmonders need to fully understand the effects of their water related choices, and equitable restrictions and pricing may assist awareness. Strategies to shape the physical geography to accommodate environmental sustainability must also be taken.

3. Methodology

3.1 Research Questions

Research suggests that creating incentivizing options for residential and commercial landowners to limit stormwater runoff from their properties are effective. "Green infrastructure reduces and treats stormwater at its source while also providing multiple community benefits such as, reducing localized flooding, improving community aesthetics, increasing property values, etc" (EPA, 2018). Richmond has a great need for improved stormwater infrastructure on both private residences and commercial property. Green infrastructure (GI) development and retrofitting can help mitigate the frequency of combined sewer overflow (CSO) events at a given CSO outfall and improve the water quality of the James River. GI has the ability to reduce the volume of stormwater that makes its way to the CSS. When stormwater volume that reaches combined sewer system (CSS) infrastructure is reduced to prevent a CSO event the overall water quality is improved because combined sewage will no longer flow into receiving waters. Prior research includes examples of successful strategies for green infrastructure investment incentives, however there are also stigmas and failures associated with past GI incentive programs in the research. The research questions for this plan will navigate the challenges and barriers that prevent landowners from utilizing GI, and creating a program that will encourage GI usage. DPU identifies Cannon's Branch/Shockoe Creek, Gillies Creek, and Goose Creek/Manchester Canal as priority watersheds for stormwater management improvement. According to the 2017 RVA Clean Water Plan, these three watersheds are of most concern due to the large CSS coverage area within, proximity to river related recreation, and their sensitivity to alterations in stormwater infrastructure. Green infrastructure when added to these watersheds will have the most impact on receiving waters. These watersheds will be the primary focus of this plan.

This plan seeks to identify strategies to incentivize green infrastructure investments on privately owned land within the Cannon's Branch/Shockoe Creek, Gillies Creek, and Goose Creek/Manchester Canal watersheds. Below are the research questions applied to help identify the most appropriate target areas to implement effective green infrastructure and policies to incentivize public action within these regions.

1. What are the current conditions of runoff associated with these regions?
2. To what extent do private landowners utilize existing stormwater credit programs for GI development?
3. Which combined sewer areas most negatively affect the water quality based on combined sewer overflow events?
4. What type of land coverage exists within the most problematic areas, and what kinds of properties should green infrastructure policies focus on?

Table 3-1. Research Questions and Information Sources

Research Questions	Information Sources	Purpose
Current Conditions	DPU data, DEQ's VEGIS datasets, DEQ TMDL Stress Report, CSO data	Measure current GI effectiveness, target pollutant types, designate appropriate GI solutions
Stormwater Credit Participation	DPU stormwater credit program participation data	Find gaps between actual program participation and opportunities for future participation
CSO regions with high impacts to receiving waters	CSO event frequency and volume data, impervious surface data	Identify regions with high levels of CSO impacts.
Potential GI in study area	Case studies, scientific research, existing VGEP land cover data	Pinpoint focus areas with characteristics best suited for potential green infrastructure programs

Green infrastructure takes several forms and each type is designed for specific physical conditions for the space they occupy. This plan identifies specific locations within Richmond where GI will most benefit receiving water quality in Richmond. Existing research on GI outputs were compiled in order to compare their potential volume reducing benefits.

3.2 Sources of Information

To examine the extent to which green infrastructure can mitigate stormwater runoff, an existing conditions analysis was conducted. The analysis included:

1. Data related to existing conditions, to include: total impervious surface land cover area, demographics, land use, CSO event frequency and severity, and existing GI.
2. Current participation and eligibility data for stormwater credit programs
3. Efficacy of GI techniques and standardized measures found in existing research

Research data was collected to evaluate the efficacy of modern GI implementation techniques in other regions. This included case studies involving past and current techniques to influence landowners to participate in GI development and retrofits. These sources served as a framework for understanding barriers and opportunities for Richmond stormwater incentive programs.

The Environmental Protection Agency (EPA) and Department of Environmental Quality (DEQ) have several published documents pertaining to best practices and guidance for GI and low impact development (LID) implementation. Materials include topics related to GI designs and policies, case studies, strategies, and resources for local governments and planners. Other sources including stormwater plans, case studies, scholarly articles, and online resources that refer to GI incentives and community outreach are referenced in this plan.

In order to identify areas of potential concentration, publically available land use data was used. This data helped develop target areas for the types of uses lacking GI. Data relating to future land uses was also collected for analysis.

In order to determine the quantity of stormwater runoff produced in the focus watersheds, data from DPU was assessed to locate problem areas within the watershed for further concentration. Geographic Information Systems (GIS) data gathered from DPU included impervious surface coverage, CSO area coverage, and CSO outfall locations. Data on existing GI infrastructure in the area was also used, and publicly available CSO event data was compiled.

Research suggests that stormwater is uniquely affected by local climate, soils, groundwater levels, and other site-specific parameters, all of which increase the complexity of design and construction (Copeland, 2016). Data involving these elements was analyzed to identify critical areas in the watershed region that would most benefit from GI implementation. Information sources related to the most impacted locations of the study area was collected from DPU and secondary sources.

3.3 Case Studies

Existing case studies are used to determine potential solutions that fit the unique needs of the study area. These case studies were examined to understand how their successes and downfalls could help shape the recommendations and implementation of this plan.

Portland:

Portland has been very successful in some of their green approaches to stormwater management. Their green infrastructure projects aim for regulatory compliance and public education and outreach. Much of their success comes from the aesthetic appeal of green projects, the multi-disciplinary approach of professionals involved, encouragement of community involvement, and the use of pilot programs on public property (LID Center, 2008).

Baltimore:

Property owners in Baltimore, MD pay a fixed stormwater fee based on the area of impervious surface on the property. The city incentivizes its property owners to become involved in stormwater management by reducing stormwater fees through implementation of approved stormwater BMPs, impervious surface reductions, and tree planting. Single-family properties can participate in public clean-up events for a stromwater fee credit, and eligible senior and low-income residents receive discounts on their fees (Baltimore City Department of Public Works, 2018).

Seattle:

Property owners in Seattle, WA benefit from credit and exchange incentives offered by Seattle Public Utilities. GI implementation such as permeable pavement, detention systems, and bioretention systems allow landowners to receive a credit on their stormwater utility bill (Seattle Public Utlities, 2018). Seattle uses a program called RainWise to inform property owners of the benefits of stormwater management, and instructions on how to properly build green stormwater techniques.

Washington DC:

Homeowners in DC can apply to become River Smart homeowners through the Department of Energy and Environment (DOEE). This program encourages homeowners to participate in GI development on their properties by offering free audits for GI construction. River Smart pay a copay on otherwise subsidized GI enhancements, and receive rebates on impervious surface reductions. Maintenance of the new infrastructure must be maintained by the homeowner following construction (DOEE, 2018).

3.4 Stakeholder Outreach Methods

Public participation in stormwater management can be increased through creative outreach programs. Currently, DPU has two programs that are geared to inform and incentivize the public to improve Richmond's water quality. The department has resources available for "presentations to community groups, neighborhood associations, schools, churches, etc" (RVA H20, 2018). Other programs include grade school education such as the rain barrel program where students can decorate rain barrels while learning about the negative consequences of stormwater pollution. The only homeowner incentive is the stormwater credit program where homeowners can get up to 50 percent off of their stormwater fees by implementing best practices. Currently, only 120 single-family residential properties, six commercial properties, and one multi-family residential property actively participate in the credit program.

A major concern of engaging stakeholder input from citizens is that most citizens are unaware of the water quality issues within the James River. This plan incorporated DPU's Community Outreach Coordinator goals to determine new educational resources in which water quality issues could be further communicated. The aim is to increase homeowner participation in order to improve water quality in the Cannon's Branch/Shockoe Creek, Gillies Creek, and Goose Creek/Manchester Canal watersheds.

3.5 Analytical Methods

In order to identify the target region within the watershed, GIS analysis was conducted. GIS layer data was utilized to accurately map out what extent surface areas are impervious. Data on the severity of CSO effects and frequency of CSO events was combined with impervious surface data to help identify the area of focus.

The Department of Public Utilities currently manages a stormwater utility credit program which enables eligible participants to receive reduced stormwater utility fees upon adherence with program regulation. Data relating to the credit and its participation was analyzed to identify gaps between those currently enrolled in the program and those that are eligible for enrollment. This gap in participation serves as a basis for understanding the opportunity of future incentive program participation.

Existing incentives from case studies of urbanized areas were considered and evaluated for suitable incentive options in the focus area. Recommendations from the EPA, DEQ, and reports from other cities with successful GI incentive programs have been analyzed for relevance to the focus area's social, physical, and political environment. Recommendations were centered on GI options and incentives to the landowners. An evaluation was conducted to examine existing stormwater incentive programs and stormwater fee calculations DPU currently maintains. Overlaying multiple forms of impervious surface area measurements has been found to be most accurate calculation method (Lee, Kim, & Lee, 2018). This plan analyzed DPU's current impervious surface calculation methods that determine stormwater utility fees, to prescribe recommendations for alteration.

Recommendations are based on a regional understanding of the area as it related to stormwater runoff improvement areas. These recommendations inform implementation of appropriate economic incentives for private landowners. Final recommendations are designed to incorporate DPU's realistic funding limitations.

4. Research Findings

4.1 Introduction

The purpose of this research is to identify regions of the three priority watersheds (see figure 1-1) that contribute the most to adverse water quality impacts to the James River. The results inform the Department of Public Utilities (DPU) where to focus efforts related to green infrastructure (GI) development/incentivizing policy programs. The methods used for this research allow for specific land uses as targets for further analysis and policy focus. This plan aims to present policy recommendations geared toward private property owners to increase GI production in areas of the most critical need. GI construction and improvements are beneficial in nearly all areas of the city, however this research locates the most crucial locations for new GI implementation based on findings related lack of existing GI in regions with particularly problematic stormwater runoff.

4.2 Methods

Combined sewer systems contribute largely to the adversity of receiving water quality. Using this approach, areas serviced by the combined sewer system were identified first. Data on the severity of combined sewer overflow (CSO) events was collected, and regions found with particularly severe CSO characteristics became the focuses for further study. Imperviousness was calculated for each region, as well as other land cover types, including tree canopy cover. The existing tree canopy cover, or urban tree canopy (UTC), was used as a proxy to existing (GI), as no reliable data on (GI) was available. Tree canopy cover was overlaid with land use parcel data, and tree canopy ratios per land use type were derived. Land uses with both significant surface areas and limited tree canopy surface ratios were identified as the most crucial to further analysis and policy recommendations.

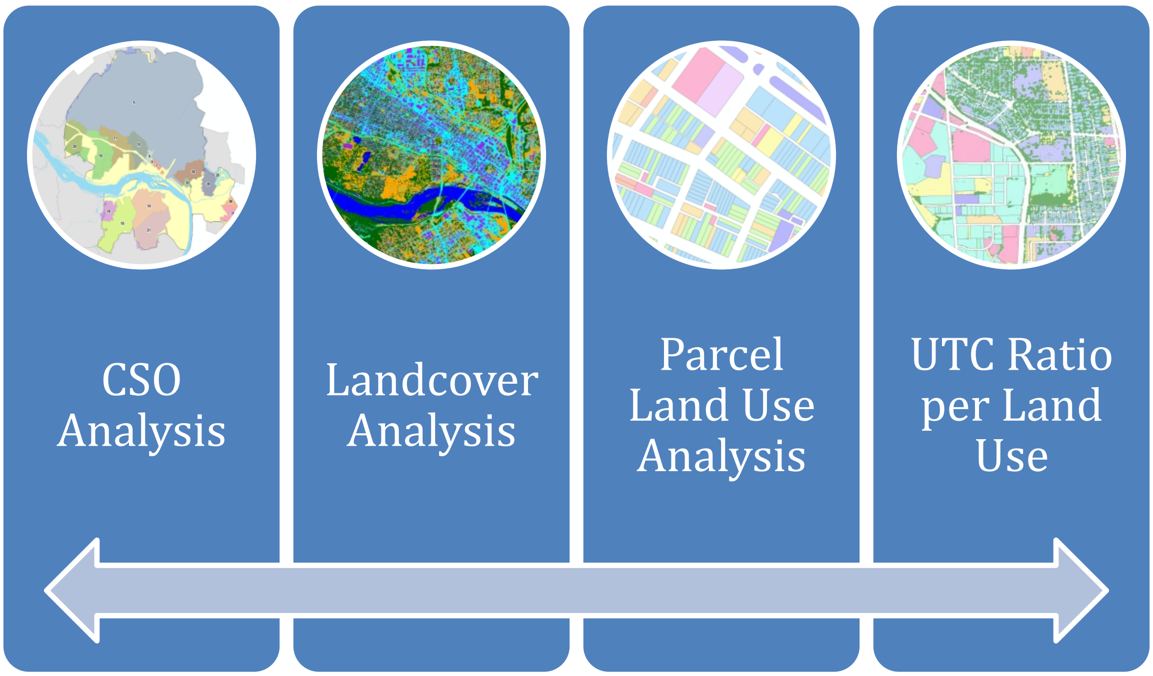


Figure 4-1: Methods

4.3 Priority Watersheds

Impervious surface area within the priority watersheds was calculated using Geographic Information Systems (GIS) software. Watershed feature data was retrieved from DPU, and reduced to only include the three watersheds of study: Cannon's Branch/Shockoe Creek, Gillies Creek, and Goose Creek/Manchester Canal. Publically available data from the City of Richmond was compiled to include existing water features, roads, other transportation surfaces, and structures.

Figure 4-2 below shows the impervious features overlaid onto the three watersheds within the study area. Between the three watersheds, 6,228 acres of the total 12,237 acres were found to be impervious. Overall, the three priority watersheds were found to be 50.89% impervious.

Data from City of Richmond and Richmond DPU, 2018

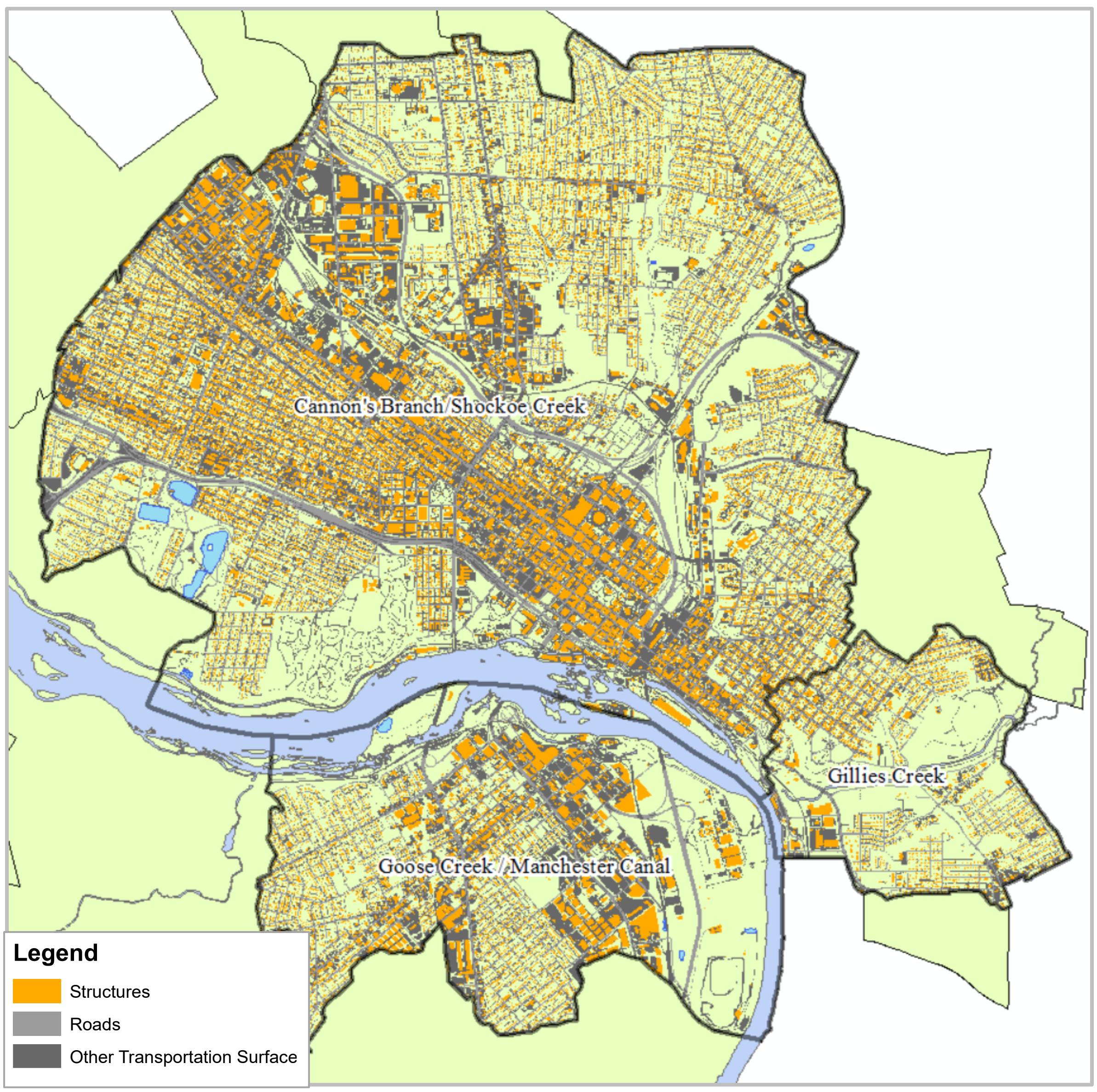


Figure 4-2 Impervious Surface Types

4.4 Combined Sewer System

Currently, 25 CSO outfalls exist within Richmond City limits. 22 of these outfalls are within the three priority watersheds. 12,000 acres of surface area within the city is serviced by the combined sewer system (see Figure 4-3). A majority of the land within the three priority watersheds is serviced by a CSO drainage area.

Richmond Department of Public Utilities, 2018

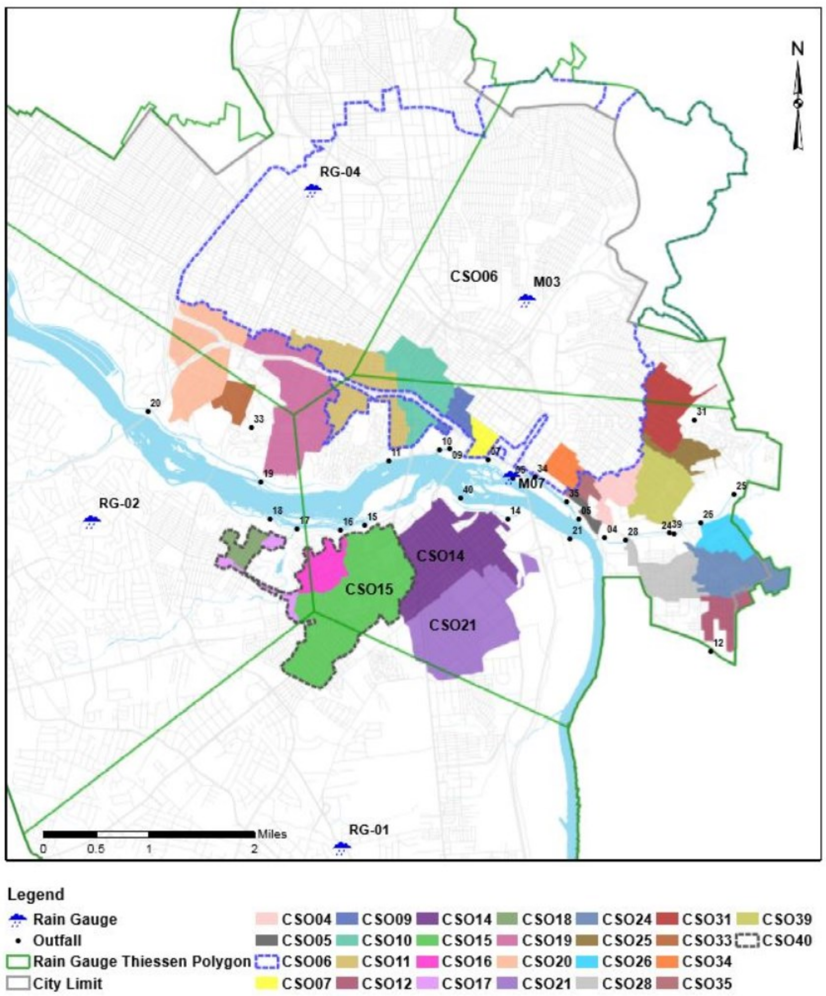


Figure 4-3: City of Richmond CSO Drainage Areas

GIS layer data for CSO drainage areas was retrieved from DPU's GIS department and used for this analysis. CSO areas were included in the analysis if a majority of the surface area fell within one of the three priority watersheds. Conversely, portions of CSO drainage areas that stretch beyond the limits of the three priority watersheds were also considered within the study. Data collected regarding CSO events and volumes encompass the entire drainage area as a whole, regardless of the watershed they fall within.

Data retrieved from DPU GIS Department

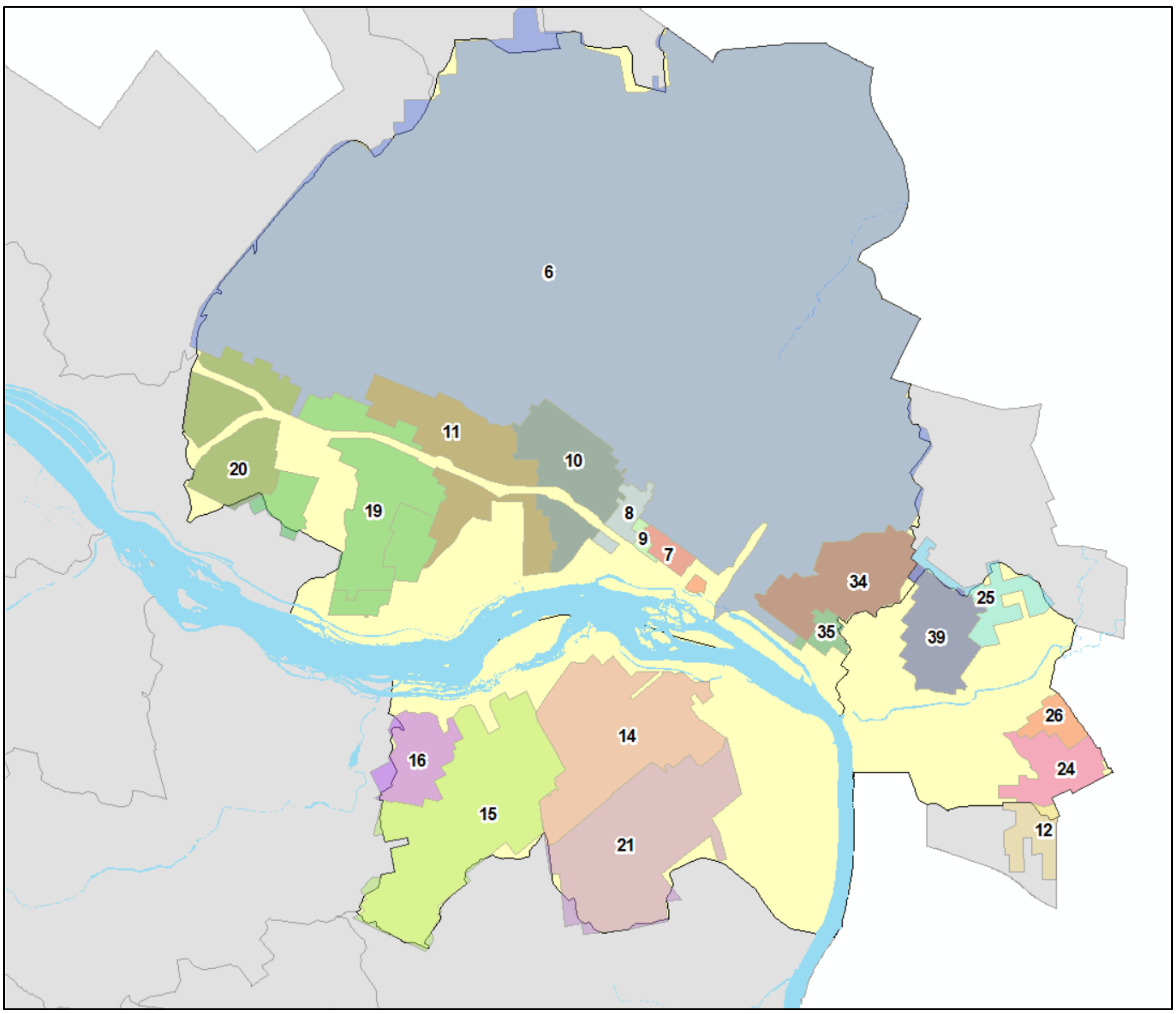


Figure 4-4: CSO Drainage Areas within Priority Watersheds

CSO event frequency data was combined with CSO drainage areas to determine where increased levels of CSO events occur within the area of study. The frequencies of CSO events do not reflect volumes of runoff entered into the CSO system. Rather, event frequencies provide insight as to how many times CSO outfalls are used to drain stormwater into the James River during rainfall events. Each CSO drainage area maintains a different threshold of rainfall prior to a CSO event. Reducing volume of stormwater runoff prior to reaching the CSO system is the quantity reduction goal of GI. Therefore, preventing a single CSO event from reaching the respective drainage area's threshold would result in significant benefits to the receiving James River's water quality impacts.

Data from Richmond Department of Public Utilities, 2018

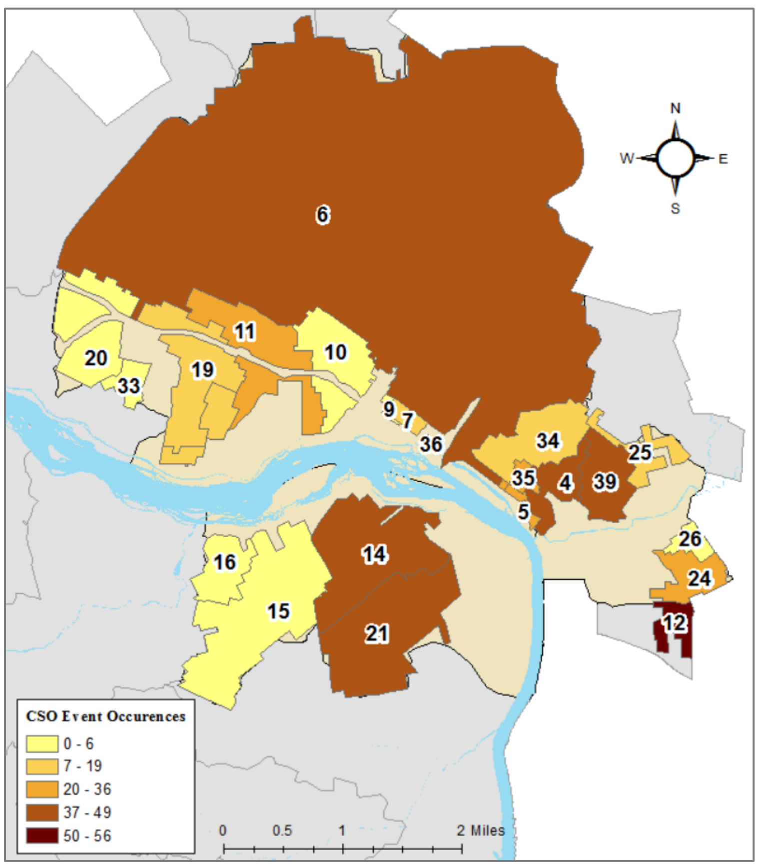


Figure 4-5: CSO Event Sums, December 2017 to November 2018

For this study, data was compiled from DPU's monthly CSO reports from December 2017 to November 2018. Each CSO outfall location was coded by month to indicate the number of CSO events that took place within that month (use figure 4-4 as reference). The chart below indicates the variation in CSO event frequency by month for all CSO outfalls located in Richmond.

Table 4-1: CSO Events: Dec '17 to Nov '18

CSO Number	***Dec '17***	***Jan '18***	***Feb '18***	***Mar '18***	***Apr '18***	***May '18***	***June '18***	***Jul '18***	***Aug '18***	***Sep '18***	***Oct '18***	***Nov '18***	*Total*
4	1	2	1	1	3	5	9	8	6	7	2	4	49
5	0	1	0	1	2	2	7	4	3	3	2	5	30
6	0	3	0	2	2	2	5	9	4	6	2	7	42
7	0	0	0	0	2	2	4	2	1	1	1	0	13
9	0	0	0	0	0	1	1	1	0	0	1	0	4
10	0	0	0	0	0	1	1	1	0	0	1	0	4
11	0	1	0	0	2	5	8	6	5	4	2	3	36
12	1	2	1	2	2	5	8	8	5	4	2	5	45
14	0	1	1	2	3	5	8	8	5	4	2	5	44
15	0	0	0	0	0	0	1	0	0	0	0	0	1
16	0	0	0	0	0	0	1	0	0	0	0	0	1
19	0	0	0	0	0	2	2	0	1	3	1	0	9
20	0	0	0	0	0	0	0	0	0	3	1	0	4
21	0	3	1	2	3	6	6	8	7	4	2	4	46
24	1	0	0	0	2	5	7	4	3	2	2	2	28
25	0	0	0	0	1	5	6	2	2	1	1	1	19
26	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	1	2	2	1	0	0	0	0	6
34	0	0	0	0	0	2	3	2	1	1	1	0	10
35	0	0	0	0	2	5	7	7	4	2	1	0	28
39	0	2	1	2	2	5	8	8	5	4	2	5	44
40	1	0	0	0	2	5	8	8	5	5	2	3	39
Month Totals	**4**	**15**	**5**	**12**	**29**	**65**	**102**	**87**	**57**	**54**	**28**	**44**	**502**

Data from Richmond Department of Public Utilities, 2018

During the timeframe observed, the results show CSO numbers 04, 21, and 39 to have experienced significant levels of CSO events, occurring more than 40 times. These three CSOs are located within relatively close proximity to one another, indicating a need for attention to stormwater infrastructure in that area. The findings also indicate increased levels of CSO event frequencies during the months of May, June and July of 2018. During the month of June alone, 116 CSO events occurred within the City and 92 of these events happened within the three priority watersheds (see figure 4-5). Within that single month, almost 750 million gallons of combined stormwater and sewer waste drained into the James River from the three watersheds (DPU, 2018). It is important to note that Richmond experienced record rainfall during the year of 2018, creating higher than average overflow volumes (Boyer, 2019).

Volumes for CSO drainage were coded and applied to the below map. Volume data were collected from December 2017 to November 2018. Volumes are measured by million gallons (MG) and represent a sum of the recorded timeframe. Only months in which a CSO event occurred will an overflow volume be recorded. If a CSO event did not occur within a given month for any particular CSO drainage area, the volume of overflow will be 0.00. Within the priority watersheds, CSO number 6 was by far the largest in terms of CSO volume with 1.83 billion gallons recorded. CSO drainage area 6 has significantly larger surface area than other drainage areas, which certainly contributed to the high volumes.

Richmond Department of Public Utilities, 2018

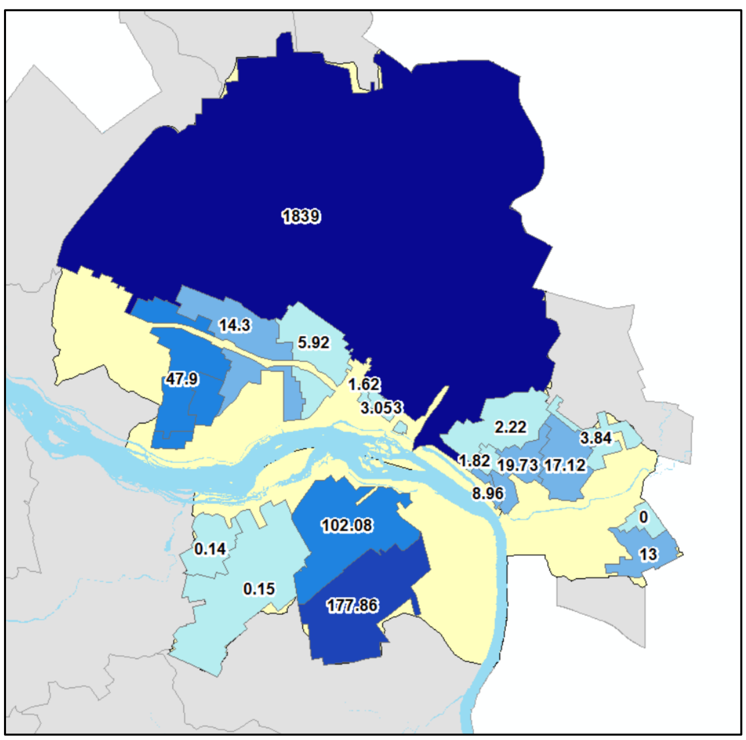


Figure 4-6: CSO Volumes in Million Gallons, Dec 2017-Sep 2018

Data from Richmond Department of Public Utilities, 2018

CSO Number	Dec '17	Jan '18	Feb '18	Mar '18	Apr '18	May '18	June '18	Jul '18	Aug '18	Sep '18	Oct '18	Nov '18	CSO Total
04	0.03	0.08	0.01	0.00	0.61	5.80	7.80	2.90	1.30	1.20	6.10	1.10	26.93
05	0.00	0.04	0.00	0.07	0.40	2.50	3.50	1.00	0.35	1.10	3.30	1.30	13.56
06	0.00	56.00	0.00	56.00	73.00	501.00	545.00	217.00	132.00	259.00	471.00	314.00	2,624.00
07	0.00	0.00	0.00	0.00	0.01	0.65	2.20	0.09	0.00	0.10	1.80	0.00	4.85
09	0.00	0.00	0.00	0.00	0.00	0.09	1.40	0.13	0.00	0.00	0.10	0.00	1.72
10	0.00	0.00	0.00	0.00	0.00	0.99	4.70	0.23	0.00	0.00	1.60	0.00	7.52
11	0.00	0.00	0.00	0.00	0.34	2.90	7.90	1.90	0.81	0.45	4.50	0.17	18.97
12	0.00	0.08	0.03	0.03	0.46	3.00	6.20	2.20	0.84	0.66	5.30	0.72	19.52
14	0.00	0.52	0.15	0.11	4.10	30.60	34.30	17.50	8.30	6.50	26.90	7.70	136.68
15	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.15
16	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.14
19	0.00	0.00	0.00	0.00	0.00	16.00	17.60	0.00	10.30	4.00	12.00	0.00	59.90
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.20	5.10	0.00	7.30
21	0.30	1.56	0.00	0.00	5.00	45.70	61.70	36.10	14.10	13.40	63.90	19.30	261.06
24	0.00	0.00	0.57	0.00	0.14	2.20	8.40	1.20	0.29	0.20	7.20	0.11	20.31
25	0.00	0.00	0.00	0.00	0.05	0.69	2.30	0.57	0.13	0.10	1.70	0.01	5.55
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.03	0.00	0.00	0.00	0.00	0.38
34	0.00	0.00	0.00	0.00	0.00	0.30	1.70	0.19	0.02	0.01	0.53	0.00	2.75
35	0.00	0.00	0.00	0.00	0.01	0.37	1.10	0.24	0.06	0.04	0.06	0.00	1.88
39	0.00	0.07	0.03	0.02	0.52	3.70	8.20	2.70	1.10	0.78	5.80	0.85	23.77
40	1.17	0.00	0.00	0.00	2.00	25.50	39.80	9.90	6.70	2.50	29.90	1.30	118.77
Month Totals	**1.50**	**58.35**	**0.79**	**56.23**	**86.64**	**642.34**	**754.09**	**293.88**	**176.304**	**292.24**	**646.79**	**346.56**	**3,355.71**

Table 4-2: CSO Volumes

Volume of stormwater was compared to the surface area of each respective combined sewer overflow drainage area, or combined sewer area (CSA). The CSAs were found to have varying levels of overflow volume per acre of surface area. CSAs 5, 21, and 6 were found to have significantly higher levels of volume per acre during the timeframe studied. The average volume of stormwater overflow that entered the combined sewer system (CSS) was 178,545 gallons per acre. CSA 5 was found to have the highest volume per acre with 700,000 gallons per acre. Next was CSA 21 with 530,000 gallons per acre, followed by CSA 6 with 430,000 gallons per acre.

Table 4-3: Volume per Acre

Volume Per Acre			
CSO Number	*Area (acres)*	*MG over 1 yr*	*MG per Acre*
04	116.62	26.93	0.23
05	19.39	13.56	0.70
06	6,165.75	2,624.00	0.43
07	28.58	4.85	0.17
09	11.02	1.72	0.16
10	233.58	7.52	0.03
11	327.02	18.97	0.06
12	70.83	19.52	0.28
14	463.64	136.68	0.29
15	591.10	0.15	0.00
16	132.17	0.14	0.00
19	328.82	59.90	0.18
20	273.87	7.30	0.03
21	490.14	261.06	0.53
24	116.99	20.31	0.17
25	95.68	5.55	0.06
26	45.86	0.00	0.00
33	58.40	0.38	0.01
34	229.54	2.75	0.01
35	28.15	1.88	0.07
39	170.55	23.77	0.14
40*	N/A	118.77	

**CSA encompasses other CSAs that mostly do not fall within priority watersheds*

4.41 Combined Sewer System Summary:

Stormwater drainage areas that utilize the combined sewer system in Richmond's three priority watersheds were mapped using GIS software. 12 months of combined sewer overflow frequency and volume data were coded and applied to each combined sewer drainage area (CSA) to identify CSAs with the highest overflow volume per area. CSAs 05, 21, and 06 were identified as having the highest ratio, respectively.

4.5 CSA Overview:

The three CSAs with the largest overflow volume per area were mapped using GIS software and used as a basis for further analysis. The three red CSAs indicated in the map below have significantly higher ratios of stormwater entering their respective combined sewer systems.

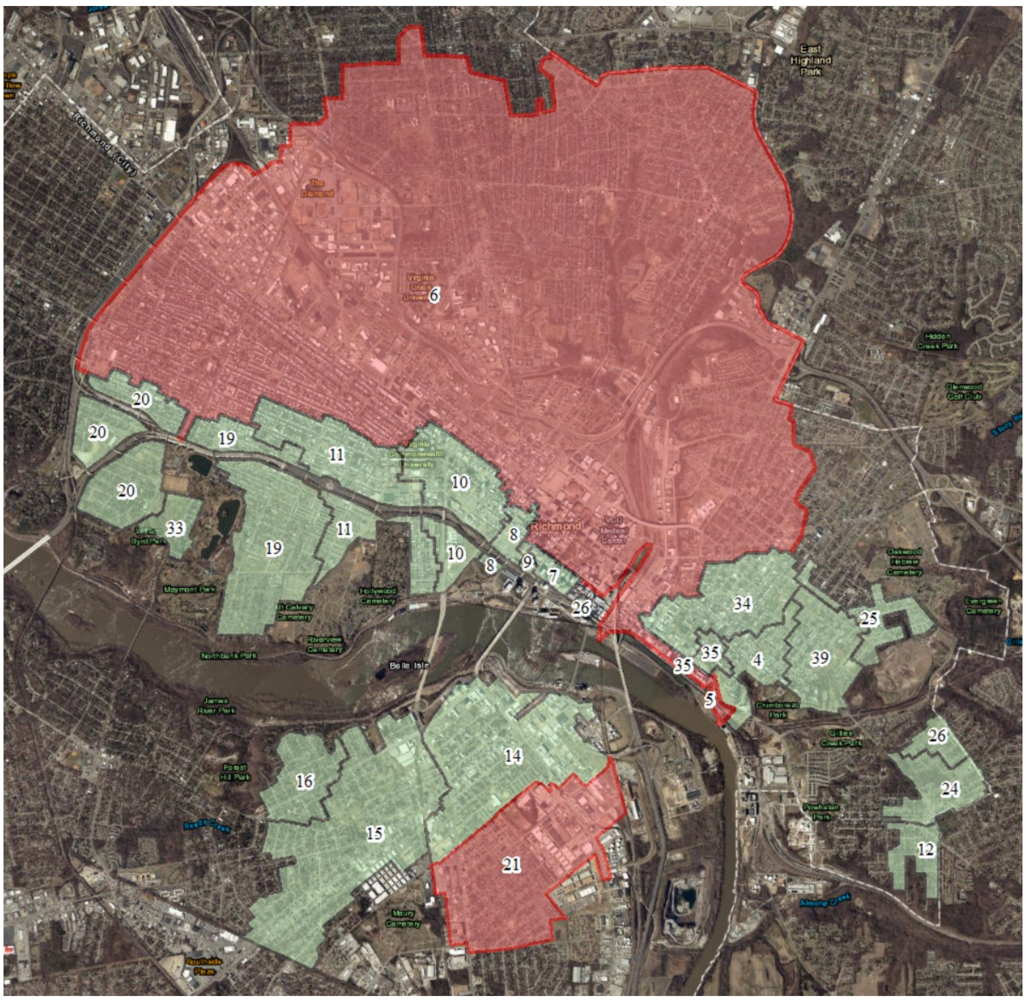


Figure 4-7: Three Highest Volume to Area Ratio CSAs

Further characteristics of the watershed were gathered and overlaid in tandem with CSO data to determine uniqueness of each high volume per area ratio CSAs. The data overlaid included impervious surface data received directly from Richmond Department of Public Utilities (DPU), as well as parcel land use and landcover data retrieved from the City of Richmond's public GIS data web portal. Each CSA is presented below individually and with each step of analysis described to include unique findings about the CSA. Below is the total acreage of the combined three priority watersheds, and broken down into land cover types.

Table 4-3: Total Land Cover

Landcover Type	**Area (acres)**	**Percent of CSA**
No Data	0.08	0.00%
Water	0.10	0.00%
Non-Building Impervious	3,206.43	32.07%
Non-Tree Vegetation	2,606.50	26.07%
Tree Canopy	2,458.79	24.59%
Building Impervious	1,725.65	17.26%
Total	***9,997.55***	***100.00%***

4.51 CSA 5:

CSA 5 located in close proximity to the James River has the highest ratio of CSO volume per acre, and the second smallest surface area covering only 19.39 acres. This region includes several loft apartment buildings that were once production factories. Included are paved roads and parking lots as well as a portion of rail line. One significant development is currently underway between Williamsburg Avenue and Dock Street.

Figure 4-8: CSA 5

Land cover types were overlaid and reduced to CSA 5 to analyze the degree to which each land cover type existed within that drainage area.

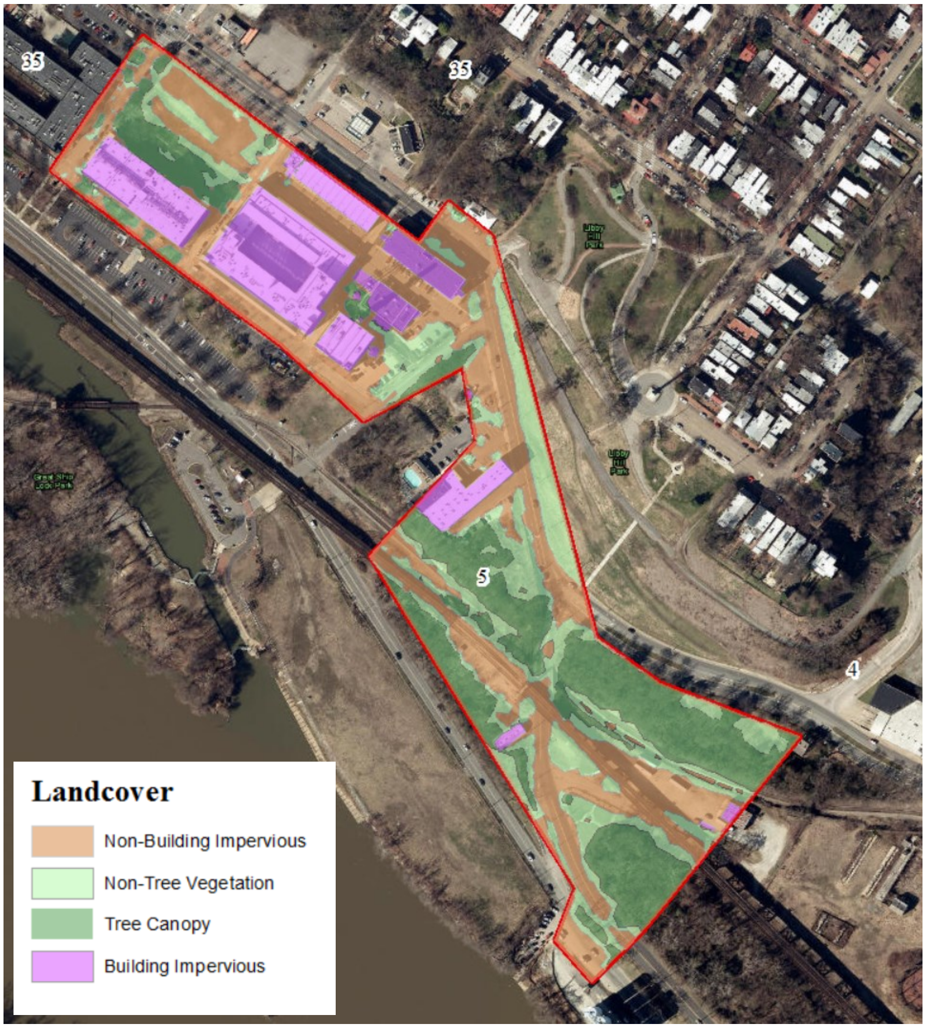


Figure 4-9: CSA 5 Landcover

The sum of each land cover type surface area was then divided by the surface area of the entire CSA to develop a percentage. Within CSA 5, non-building impervious land cover types compromised the largest portion of surface area. This mostly included transportation surfaces and parking lots. Tree canopy and non-tree vegetation together comprised of about 46 percent of the surface area, followed by over 16 percent land cover occupied by impervious building structures.

Table 4-4: CSA 5 Land Cover

Landcover Type	**Area (acres)**	**Percent of CSA**
No Data	0.00	0.00%
Water	0.00	0.00%
Non-Building Impervious	7.20	37.13%
Non-Tree Vegetation	4.26	21.97%
Tree Canopy	4.70	24.24%
Building Impervious	3.23	16.66%
Total	***19.39***	***100.00%***

The next characteristic of study for CSA 5 included an analysis of existing parcels within the CSA. GIS data was clipped from the CSA 5 shapefile to contain only land uses within. Area composition of each land use type was summed to determine the overall makeup of the area.

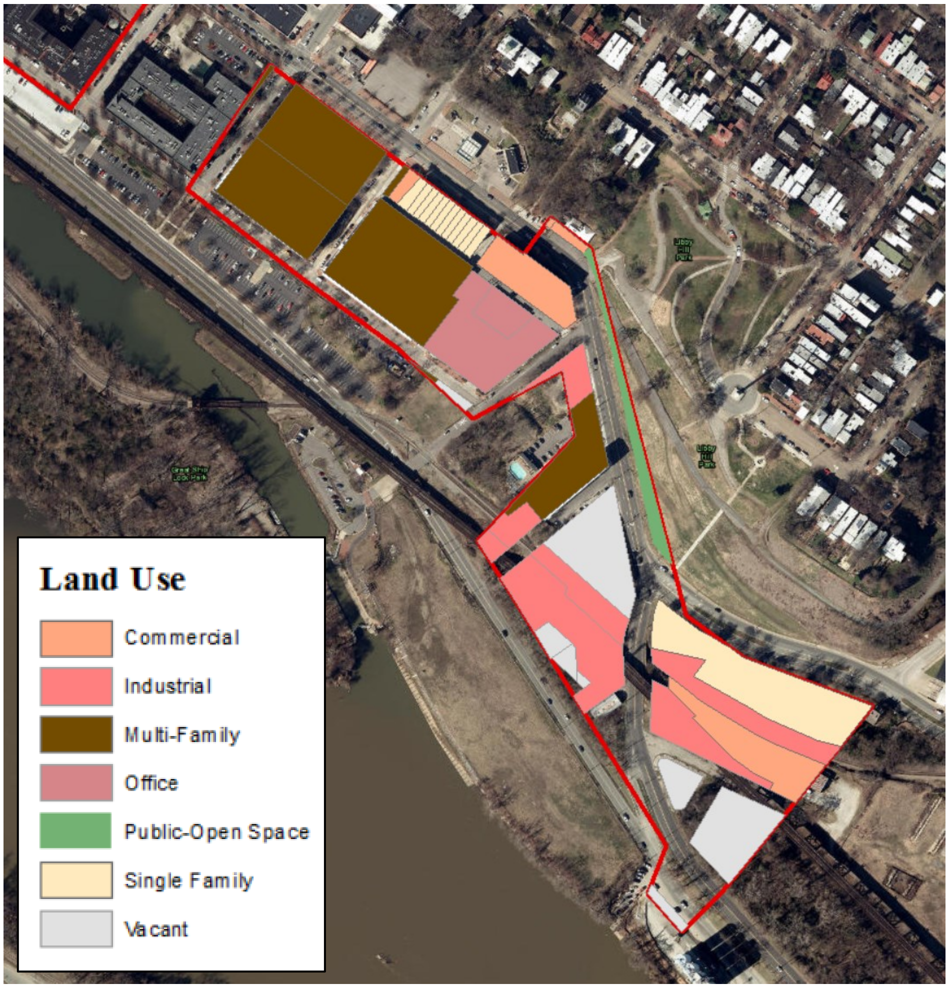


Figure 4-9: CSA 5 Land Use

The industrial and multi-family residential make up large portions of land within CSA 5. The large loft apartments on the Northwestern side of the region are of particular interest to this study. Multi-family properties alone occupy greater than one-quarter of the surface land within this region. Polies and incentives regarding the implementation of increased (GI) within this target are will need to be geared toward the property owners of commercial, industrial, and multifamily properties. One single-family parcel in the Southeast corner of the CSA totals roughly 1.3 acres of land individually, though from the land cover area comparison, most of that property appears to already have significant beneficial tree-canopy cover. Incentives directed toward single-family residential land owners will not provide significant benefits to reducing combined sewer overflow events or volume due to the limited number and impervious area of those parcels.

Table 4-5: CSA 5 Land Use Parcels

Land Use	Number of Parcels	Area (acres)	Percent of Total CSA
Commercial	5	1.28	6.6%
Industrial	7	2.69	13.9%
Office	2	1.10	5.7%
Public Open Space	1	0.34	1.8%
Vacant	8	1.83	9.4%
Multi-Family Residential	9	5.19	26.8%
Single Family Residential	13	1.71	8.8%

Tree canopy cover was overlaid onto the parcel map of CSA 5. Each parcel was clipped individually to withdraw tree canopy surface areas from the different parcels. Surface area was converted to acreage, and measured against the surface area of the entire parcel types.

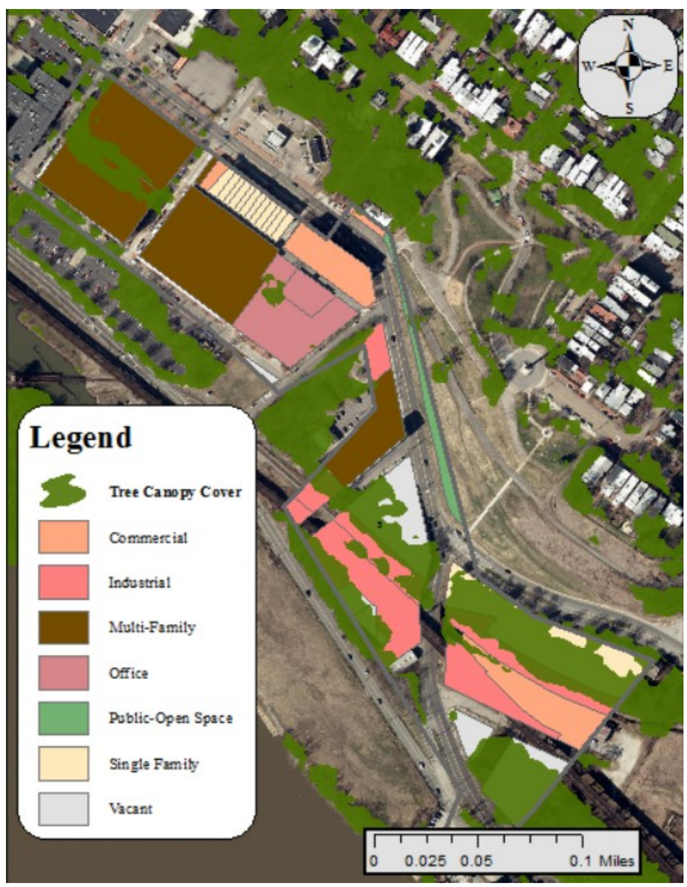


Figure 4-10: CSA 5, UTC per Parcel

The land uses of particular interest are those with both low levels of urban tree canopy (UTC) cover as well as those that contain significant portions of the CSA's total area. Multi-family parcels in CSA 5 fit both criteria. Only 9.39 percent of all multi-family parcels contain tree canopy cover.

Table 4-6: CSA 5, UTC Percentage of Land Use

Land Use	*Total Acres*	*Percent of Total CSA*	*UTC area (acres)*	*UTC percent cover*
Vacant	1.83	9.44%	1.17	64.16%
Single Family	1.71	8.82%	1.06	62.24%
Industrial	2.69	13.87%	0.87	32.38%
Multi-family	5.19	24.19%	0.49	9.39%
Office	1.10	5.67%	0.07	6.43%
Commercial	1.28	6.60%	0.04	3.49%
Public Open Space	0.34	1.75%	0.01	2.21%
Duplex	0.00	0.00%	0.00	0.00%
Government	0.00	0.00%	0.00	0.00%
Institutional	0.00	0.00%	0.00	0.00%
Mixed Use	0.00	0.00%	0.00	0.00%

4.52 CSA 5 Summary:

Though the 5th combined sewer drainage area is very small in physical size, high levels of combined sewer overflow volumes drain from it. Any incentives for private landowners to limit stormwater flows or impervious surfaces from their properties will on its own require a very tailored and case-by-case approach. CSA 5 currently has a fair portion of land devoted to vegetation of some kind; however, site visits to the area indicate development between Williamsburg Road and Dock Street that are not reflected in the land cover data. Despite this discrepancy, the data reflected in the analysis appear otherwise accurate. Because of its small size, incentives directed toward this CSA may need to be influenced primarily by incentives directed toward CSAs 6 and 21 which contain far greater surface area and diversity in land uses.

4.53 CSA 21:

CSA 21 is located within the Goose Creek/Manchester Canal watershed and includes a portion of the Manchester Neighborhood. Over 261 million gallons of stormwater combined sewer overflows drained from this CSA alone during the period of analysis. CSA 21 has a total surface area of over 490 acres and is the third largest CSA within the three priority watersheds.

Land cover with any filtration properties is virtually nonexistent in large portions of this region where large industrial structures occupy tight blocks. Observational data taken from region confirm the degree of limited greenery particularly in the Northeastern portion of the region.

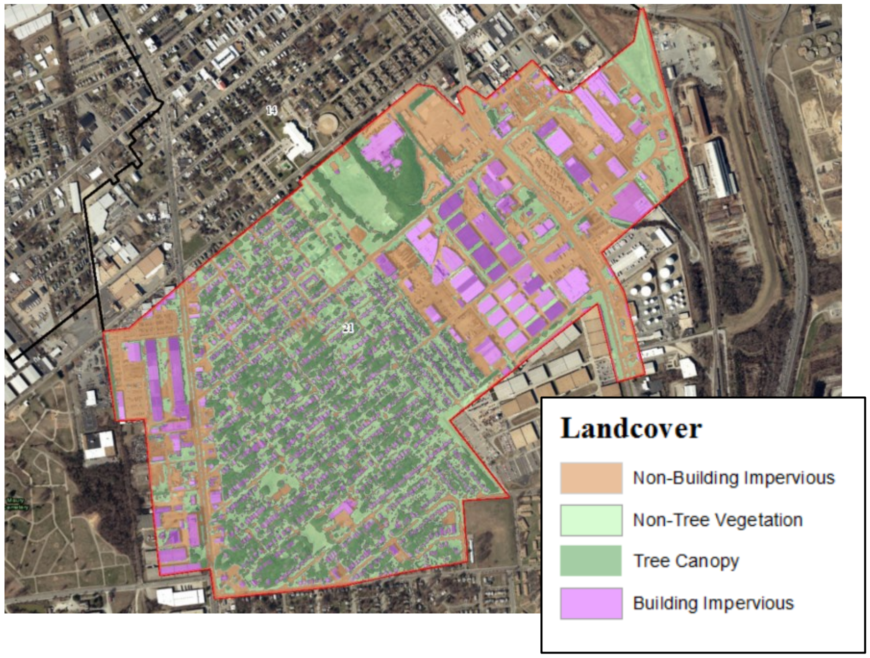


Figure 4-11: CSA 21 Land Cover

High levels of imperviousness inhabit CSA 21. Between non-building impervious and building impervious areas, over 50 percent of the region is considered to have no stormwater infiltration or retention properties.

Table 4-6: CSA 21 Land Cover

Landcover Type	Area (acres)	Percent of CSA
No Data	0.00	0.00%
Water	0.00	0.00%
Non-Building Impervious	160.10	32.66%
Non-Tree Vegetation	161.20	32.89%
Tree Canopy	81.13	16.55%
Building Impervious	87.72	17.90%
Total	***490.15***	***100.00%***

Land cover for each CSA was calculated similarly using ArcGIS functions. Overlaid data was categorized and colored to match grid codes associated with land cover types. Data was collected using aerial photography and distributed publicly on the City of Richmond's GIS website. Surface area was then calculated to include a measurement using U.S. acres, and a statistical sum was realized and recorded into a table for each land cover type.

Figure 4-12: Land Cover Calculation

Land use data was collected and overlaid onto the map of existing CSAs to further analyze the composition of each. CSA 21 differed greatly from CSA 5 in that large separated portions of parcels were devoted to mostly residential and industrial uses. Findings indicate limited public green space which likely contributes to the accelerated occurrences and volumes of CSOs.

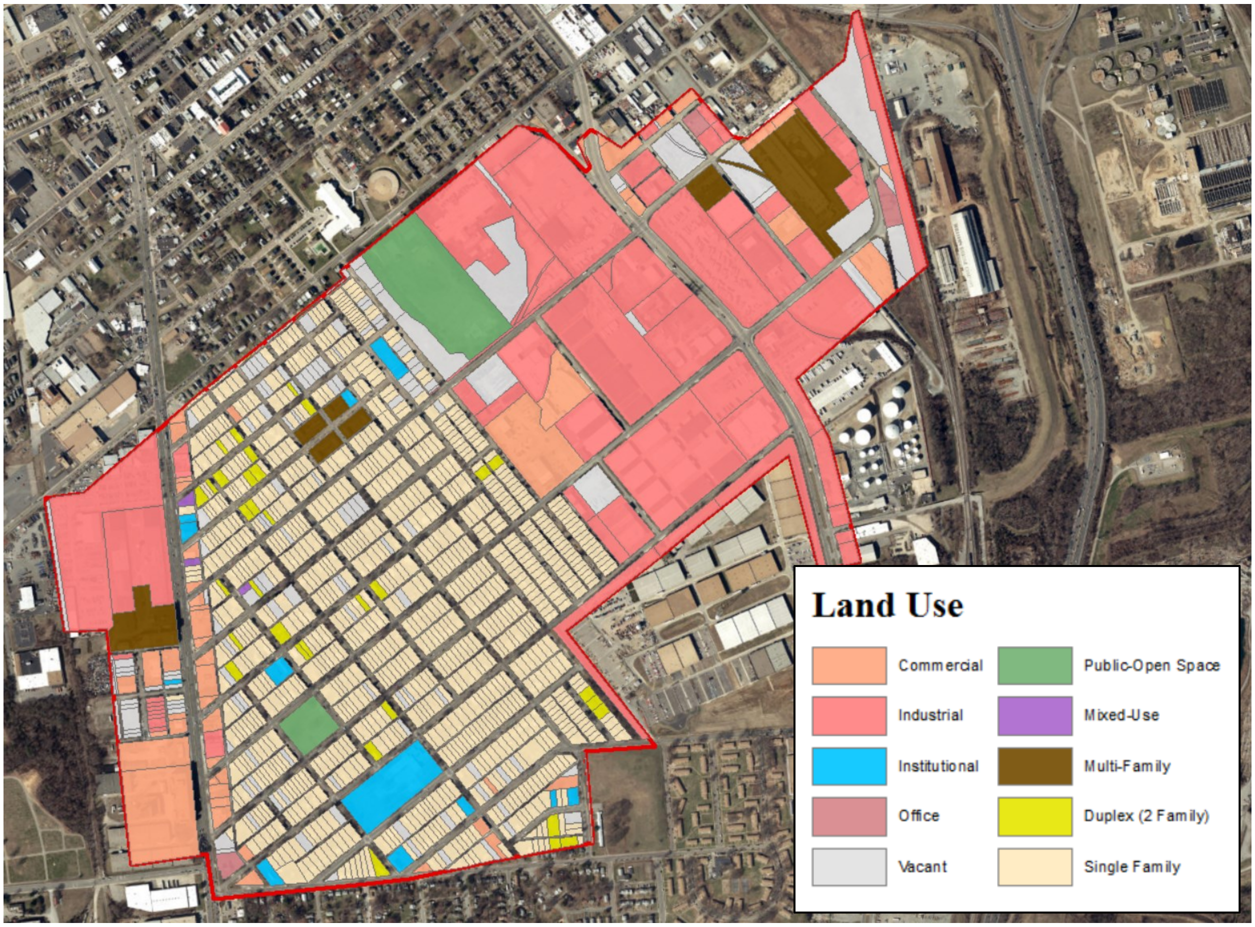


Figure 4-13: CSA 21 Land Use

Among parcels dedicated to residential land uses, single-family and multi-family parcels make up 38 percent of the surface area combined. Combined with duplexes, a total of 988 residential parcels exist within CSA 21. Industrial parcels make up another significant portion of land uses covering almost 29 percent of the region alone. Followed by commercial properties which make up 11.7 percent of the surface area.

Table 4-7: CSA 21 Land Use Parcels

Land Use	Number of Parcels	Area (acres)	Percent of Total CSA
Commercial	56	57.40	11.7%
Industrial	62	141.31	28.8%
Government	0	0.00	0.0%
Institutional	12	8.56	1.7%
Office	3	2.01	0.4%
Vacant	157	38.86	7.9%
Public Open Space	2	14.50	3.0%
Mixed-Use	3	0.43	0.1%
Multi-Family Residential	24	62.47	12.7%
Duplex	34	5.58	1.1%
Single Family	930	124.25	25.3%

Tree canopy cover was overlaid onto the parcel map to determine which land use types lacked tree canopy coverage, and which land use types had high proportions of tree canopy coverage. CSA 21 was particularly dichotomous in tree canopy locations. Clusters of tree canopy coverage appear primarily within the residential regions of the CSA, and are virtually non-existent among the industrial, commercial, and multi-family parcels.

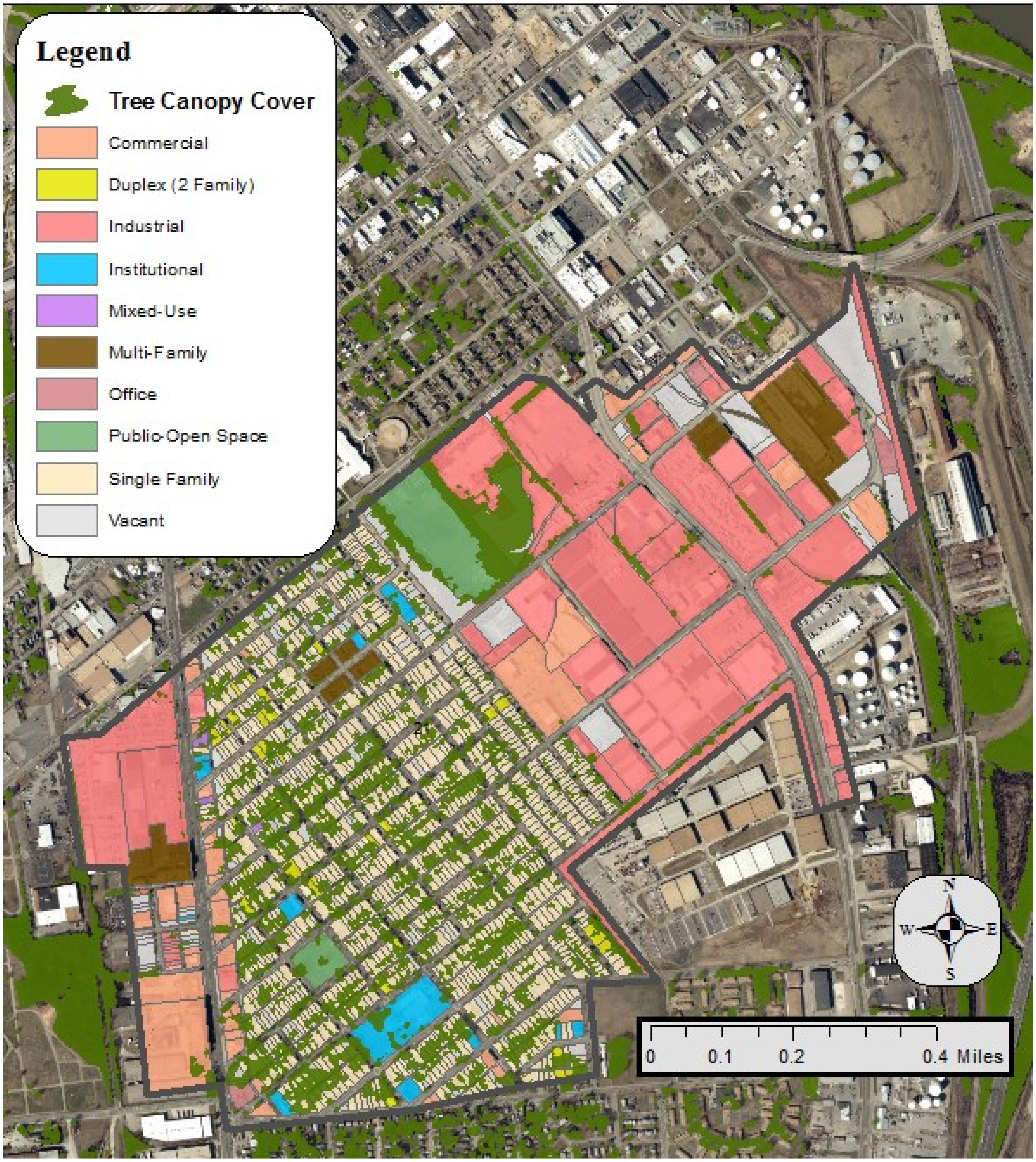


Figure 4-14: CSA 21, UTC per Parcel

Multi-family, industrial, and commercial parcels each have low levels of UTC coverage and each make up a significant portion of the entire CSA. Combined, these parcels make up

53.29 percent of the surface area of CSA 5, and only contain a combined 7.57 acres, or roughly 7 percent of the surface area of those three parcel types. Tree canopy is especially noteworthy among multi-family parcels whose coverage totals less than 0.3 percent.

Table 4-8: CSA 21, UTC Percentage of Land Use

Land Use	*Total Acres*	*Percent of Total CSA*	*UTC area (acres)*	*UTC percent cover*
Duplex	5.58	1.14%	1.92	34.38%
Single Family	124.25	25.35%	38.97	31.37%
Public Open Space	14.50	2.96%	4.09	28.22%
Vacant	38.86	7.93%	10.91	28.07%
Institutional	8.56	1.75%	1.31	15.35%
Mixed-Use	0.43	0.09%	0.06	13.04%
Industrial	141.31	28.83%	5.97	4.22%
Office	2.01	0.41%	0.06	2.92%
Commercial	57.40	11.71%	1.43	2.49%
Multi-family	62.47	12.75%	0.17	0.27%
Government	0	0%	0	0%

4.54 CSA 21 Summary:

GI initiatives related to the characteristics of CSA 21 will be most beneficial if directed toward private property owners of multi-family residential, industrial, and commercial properties. An extremely large portion of imperviousness exists within the areas of this region allotted to industrial and commercial uses. Tree canopy cover is virtually non-existent in the Northeastern half of the CSA.

4.55 CSA 6

CSA 6 is the largest CSA in Richmond in terms of both surface area and overall volume. Over 2.6 billion gallons of stormwater ran through this CSO system during the 12-month period analyzed. This region encompasses almost 20,000 parcels with several different neighborhoods and high levels of imperviousness due to roads, parking surfaces, and structures.

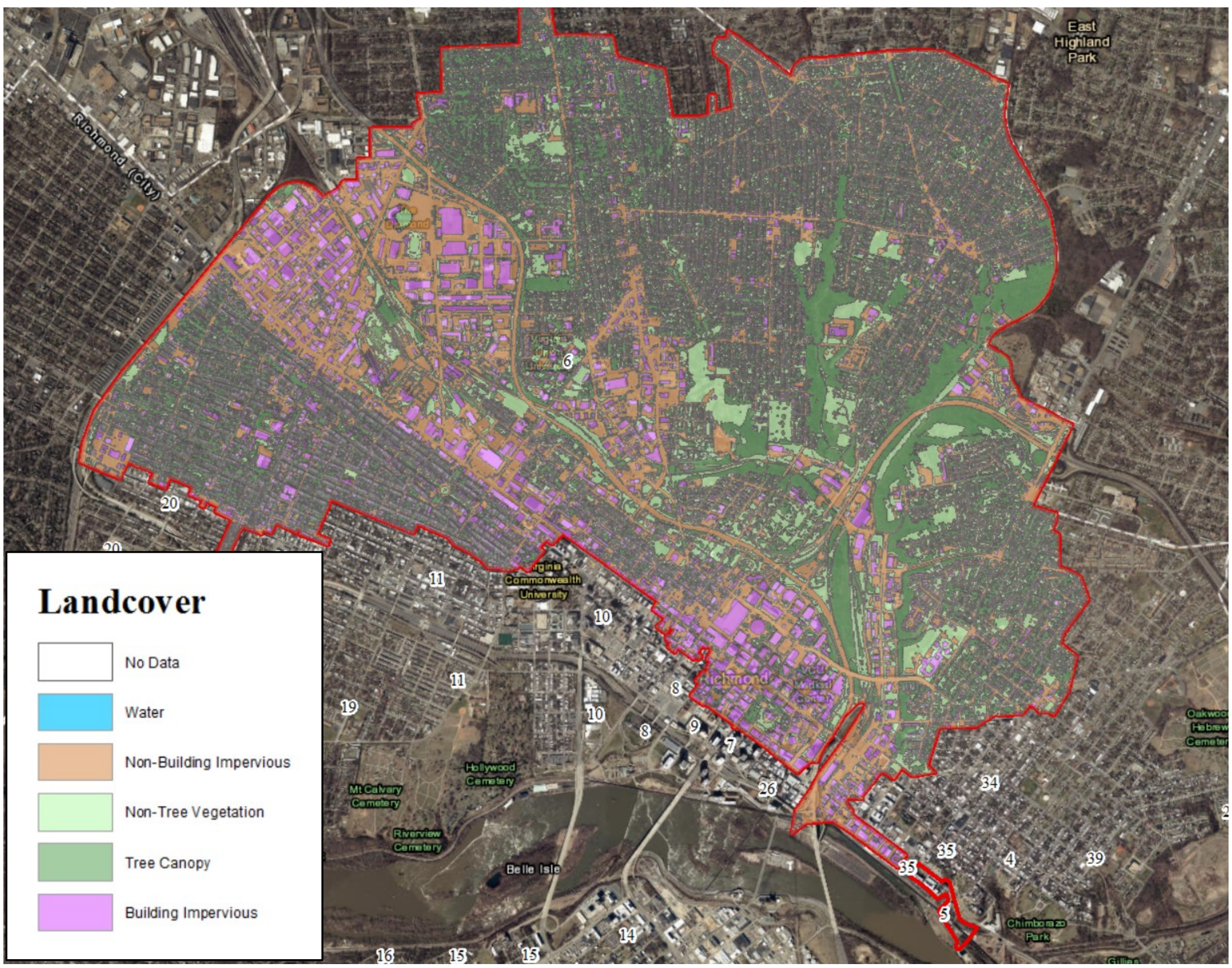


Figure 4-15: CSA 6 Land Cover

Non-building and building impervious surface areas combined show that CSA 6 has over 50 percent of its coverage deemed impervious. Tree canopy coverage constitutes 24.3 percent, and 25.5 percent non-tree vegetation for the land. Areas with clustered industrial and commercial properties such as the region known as Scott's Addition have dramatic need for increased GI. Riparian buffers and forestation along Shockoe Creek constitute the majority of green coverage in the region. Some residential neighborhoods with increased parcel areas have higher levels of tree canopy cover than tight blocks such as those in the Fan and City Center districts.

Table 4-9: CSA 6 Land Cover

Landcover Type	**Area (acres)**	**Percent of CSA**
No Data	0.08	0.00%
Water	0.10	0.00%
Non-Building Impervious	2,043.92	33.14%
Non-Tree Vegetation	1,574.63	25.53%
Tree Canopy	1,499.46	24.32%
Building Impervious	1,048.55	17.00%
Total	***6,166.74***	***100.00%***

Residential land uses constitute the largest portion of coverage within CSA 6. Single-family residential, duplexes, and multi-family properties make up over 53 percent of the surface area. 38 government parcels cover over 111 acres in the region, and 362 mixed-use parcels cover more than 35 acres. Combined, these parcels create an area larger than the entire CSA 5. But their area within CSA 6 only makes up 2.4 percent of the land cover and would be insignificant for particular focus on GI incentivizing policies. Practical and meaningful policies will focus on areas with high concentrations of residential properties, and those areas in which are primarily designated to industrial and commercial properties.

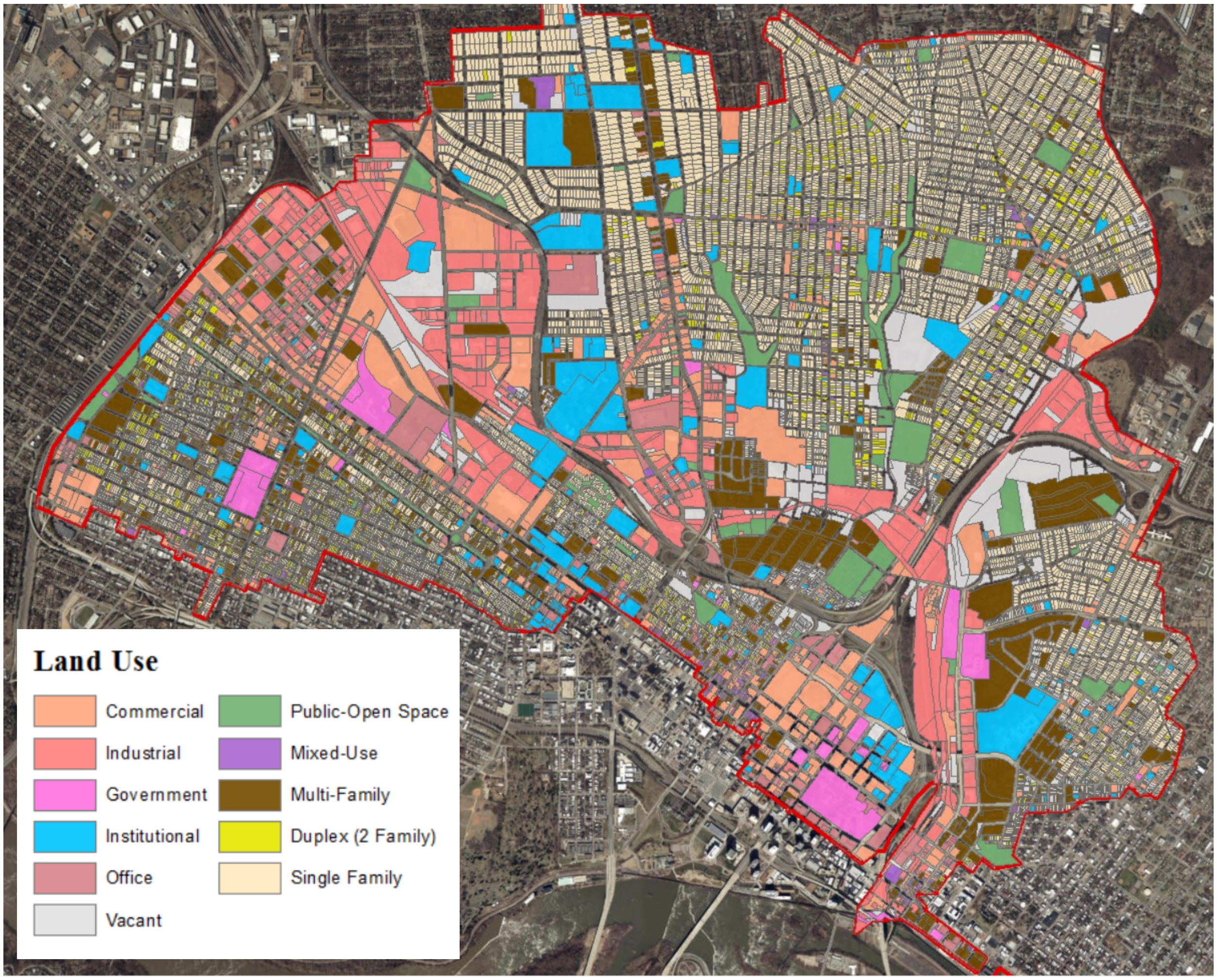


Figure 4-15: CSA 6 Land Use

Table 4-10: CSA 6 Land Use Parcels

Land Use	*Total Acres*	*Percent of Total CSA*	*UTC area (acres)*	*UTC percent cover*
Vacant	431.45	7.00%	209.24	48.51%
Single Family	1478.29	23.98%	478.48	32.37%
Public Open Space	212.06	3.44%	66.14	31.19%
Duplex	178.62	2.90%	54.18	30.33%
Institutional	365.82	5.93%	56.15	15.35%
Government	111.21	1.80%	16.57	14.90%
Office	176.14	2.86%	18.75	10.64%
Industrial	585.38	9.49%	58.46	9.99%
Mixed Use	35.15	0.57%	2.48	7.05%
Multi-family	1623.65	26.33%	114.03	7.02%
Commercial	639.60	10.37%	40.28	6.30%

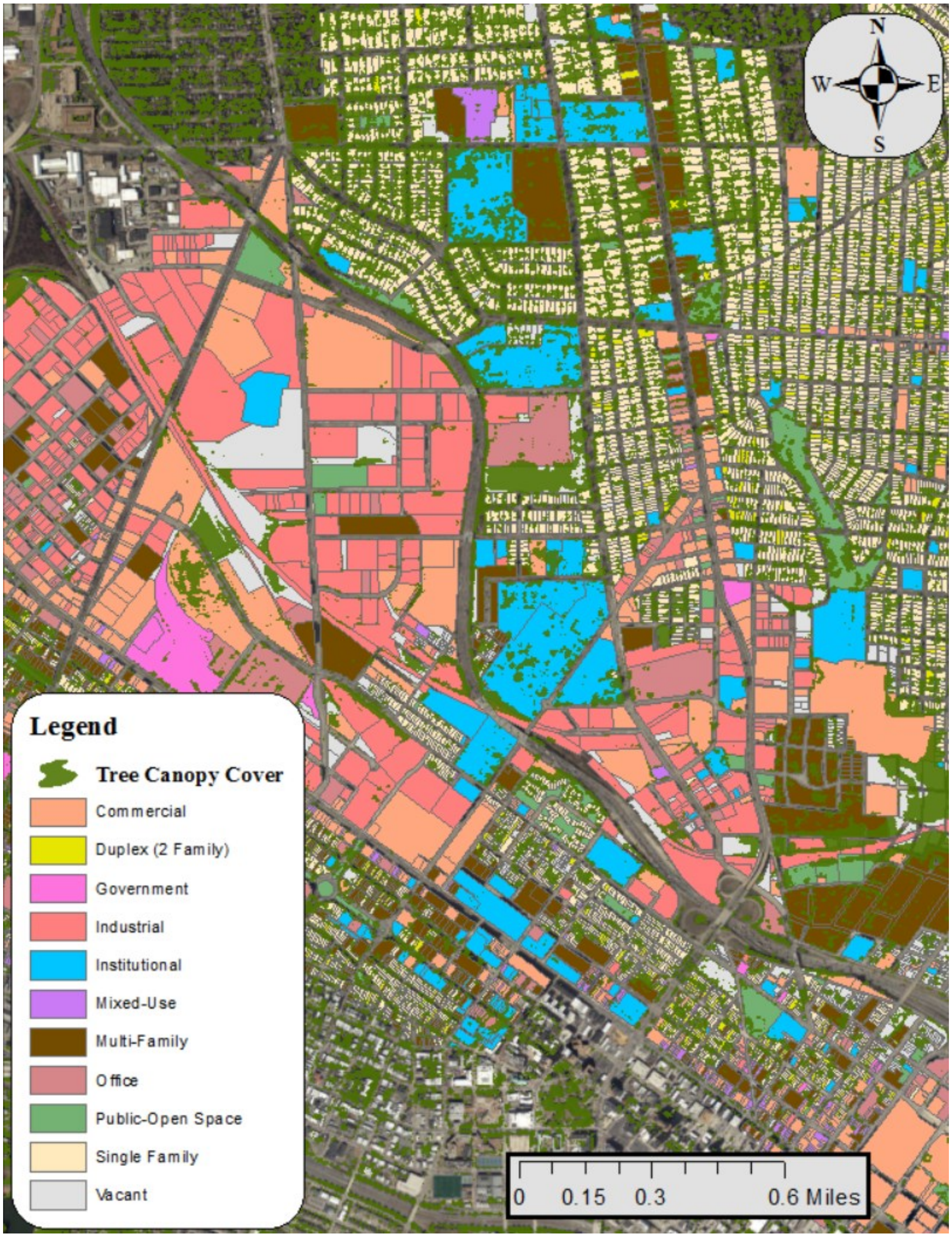


Figure 4-16: CSA 6, UTC per Parcel

Multi-family and commercial parcels make up significant total surface areas as well as low levels of UTC coverage ratios. Multi-family parcels make up over one quarter of the entire CSA in terms of surface area with over 1,600 acres, making it the largest portion of land use compared to any other in the region. However, only 7.02 percent of those parcels contain tree canopy cover within. This finding indicates a need for more attention to improving tree canopy/GI for multi-family and commercial properties within CSA 6. Industrial parcels should additionally receive attention as these land uses fit both the target criteria: significant portion of surface area (9.49 percent of CSA) and a low ratio of UTC cover (9.99 percent).

Table 4-11: CSA 6, UTC Percentage of Land Use

Land Use	*Total Acres*	*Percent of Total CSA*	*UTC area (acres)*	*UTC percent cover*
Vacant	431.37	7.00%	209.24	48.51%
Single Family	1478.22	23.98%	478.48	32.37%
Public Open Space	212.06	3.44%	66.14	31.19%
Duplex	178.62	2.90%	54.18	30.33%
Institutional	365.82	5.93%	56.15	15.35%
Government	111.21	1.80%	16.57	14.90%
Office	176.14	2.86%	18.75	10.64%
Industrial	585.35	9.49%	58.46	9.99%
Mixed Use	35.15	0.57%	2.48	7.05%
Multi-family	1623.53	26.33%	114.03	7.02%
Commercial	639.58	10.37%	40.28	6.30%

4.56 CSA 6 Summary:

This CSA is by far the largest in terms of surface area. Findings associated with the existence of proportional tree canopy cover indicate a marked need for improvement among the multi-family residential, commercial, and industrial land uses. Emphasis for GI improvement should target these properties because they are the largest contributors to stormwater runoff entering into the combined sewer system.

4.57 CSA Analysis Summary

Each CSA of study differs largely in total surface area and overflow volume. The top three CSAs studies were identified based on their high ratios of CSO volumes compared to the measured area. This method provides insight to identify CSA specific reduction strategies for CSO event frequencies and volumes. CSA characteristics were investigated using land cover data, impervious surfaces, and land use composition. Land cover data was assessed to identify existing green spaces that included tree canopy coverage. For this research, the existence of data on GI in Richmond is limited, therefore tree canopy cover was used as a proxy to GI. Parcel land use data was overlaid to determine the acreage of each classification of land use to better understand portions of land most likely creating negative stormwater effects.

CSA 6 (Shockoe) is by far the largest combined sewer area within Richmond spanning across roughly 6,166 areas of the city. Volume of combined sewer overflows were calculated to be about .43 million gallons (MG) per acre. This was the third highest ratio behind CSA 5 (Peach St) at .7 MG per acre, and CSA 21 (Gordon Ave) at .53 MG per acre (see table 4-2).

Land coverage data was applied and classified to each CSA to determine proportions of tree canopy cover, non-tree vegetation, building impervious, and non-building impervious surface coverage. Water body area and portions of uncollected data were recorded, though the area of each were too insignificant for study. CSA 5 was found to have the largest ratio of non-building impervious coverage at 37.1 percent of the total area. CSA 21 was found to have significantly less tree canopy cover than CSAs 5 and 6, at only 16.6 percent. Though CSA 21 had slightly higher non-tree vegetated coverage at 32.9 percent.

Parcel land use data was applied using a similar technique. Parcels were counted by type in each CSA and the area of each parcel type was summed to display a ratio of the entire CSA acreage. Residential parcel surface area was particularly significant in CSA 6, with greater than half of the entire surface area delegated to residential land uses. Residential property areas in CSAs 5 and 21 were also significant, with 35.6 percent and 39.2 percent respectively. Commercial and industrial properties were especially notable in CSA 21, where 40.5 percent of the land area consisted of those two types. Additionally, areas within all three CSAs where clustered industrial and commercial properties persist, increased levels of imperviousness are prevalent.

Finally, within each CSA, tree canopy cover was calculated as a proportion of each land use parcel type. Land uses with both significant proportional surface area as well as low tree canopy coverage ratios were identified. Among each CSA studied the results were largely consistent. Multi-family residential and commercial parcels fit both criteria in all three CSAs of study, and industrial parcels were also targeted in CSA 6 and 21.

4.58 Discussion:

These findings highlight areas to target for improvement in GI in order to reduce the harmful effects of stormwater runoff. This research focuses exclusively on the areas serviced by the combined sewer system within the three priority watersheds (see figure 4-7). The aim of this plan is to improve the quality of receiving water bodies in the city through policies that will engage private landowners to engage in GI implementation.

This research indicates specific parcel types that should be the focus of further incentivizing programs for GI development. Multi-family residential and commercial properties within the areas serviced by combined sewer drainage areas 5, 21, and 6 contribute the most to increased combined sewer overflow events. Additionally, industrial parcels in drainage areas 21 and 6 contribute significantly to overflow events. These properties should be the first to receive consideration for further GI improvements. Any strategy to reduce imperviousness and increase water retaining GI will reduce the adverse effects that these parcels contribute to the overall water quality of the James River.

4.6 Green Infrastructure Techniques

Using measures from existing research and external case studies, data was compiled to compare the cost of installation for the major types of GI forms to be used in residential and commercial properties. Several measurement techniques were applied to derive a singular cost (or cost range) of each form. Therefore, some cost estimates may not accurately reflect regional labor cost, material cost, and availability of service for within the Richmond area. See table 4-12 for the cost estimate findings.

Table 4-12: GI Costs

Type	Build Cost ($/sq.ft)
Tree canopy cover	0.80 (10-ft canopy radius)
Permeable Pavements	7.10
Rain Gardens	9.00 - 32.00
Bioswales	7.10
Vegetated Swales	4.50-20.00 (per linear foot)
Infiltration Trenches	11.77
Green Roofs	15.75
Rain Barrels	120.00 (55 gallon)
Cistern (underground with pump)	1,500.00 (1,500 gallon)
Cistern (above ground)	5,000.00 (1,000 gallon)

4.7 Stormwater Utility Fees:

Richmond's Department of Public Utilities charges stormwater utility fees to finance infrastructure, flood mitigation, stream bank protection, and other stormwater related efforts. Payers into this system are owners of developed parcels within the city. The fee calculation is based on impervious surface area of the property. As the square footage of impervious surface area increases on a property in increments of 1,000 square feet, the monthly fee also increases. See table 4-13 for the specific cost for single family residential (SFR) properties. For parcels other than SFR, the cost is slightly higher (see table 4-14). Under DPU's policy, undeveloped property is exempt from the fee (DPU, 2018).

Table 4-13: Developed Residential Stormwater Rates for Single Family Residential (SFR) Parcels

SFR Parcel Size	Cost per month
Between 1 and 1,000 square feet	$2.14
Between 1,001 and 2,000 square feet	$3.94
Between 2,001 and 3,000 square feet	$6.41
Between 3,001 and 4,000 square feet	$9.14
Greater than 4,000 square feet	$13.25

City of Richmond Department of Public Utilities, 2019

Table 4-14: Developed Non-Residential Rates per 1,000 square feet of impervious surface area

Property Type	Cost per Month	Cost per Quarter	Cost per Year
Non-Single Family Residential (i.e., multifamily)	$2.65	$7.95	$31.80
Non-Residential (including commercial and industrial)	$2.65	$7.95	$31.80

City of Richmond Department of Public Utilities, 2019

4.8 DPU Stormwater Credit

DPU currently manages two types of stormwater credit programs, a program for both non-residential and multifamily properties as well as for single-family residential properties. The credit is applied based on the square footage of impervious surface on the property. In order to receive the credit, single-family residential property owners must adhere to specific size requirements for on-site GI implementation. The credit offers a maximum of 50 percent off the total stormwater utility bill. Property owners must pay for initial installation and ongoing maintenance (DPU, 2018)

For non-residential and multi-family properties, up to a 50 percent credit applied to the stormwater utility fee may be applied. For industrial properties that obtain a Virginia Pollutant Discharge Elimination System (VPDES) permit, up to 100 percent of the stormwater utility fee may be applied (DPU, 2018)

At the time of this writing, only 120 properties are currently enrolled in the single-family residential credit program. Six commercial properties and one multi-family property are actively participating. On average, two to three applications for the credit are disapproved annually, typically for not adhering to GI build guidelines closely enough.

4.9 Summary of Findings

Overall, these research findings provide insight into the specific problem areas within Richmond associated with stormwater runoff. In order for Richmond City government to make measurable improvements to public participation in reducing stormwater volumes, private landowners must take part in the process. Policy changes should be geared toward CSAs 5, 21, and 6 and especially within the commercial, multi-family, and industrial parcels to create effect reductions of CSO event frequencies and runoff volumes. Changes in development requirements, stormwater fees and other funding from DPU, as well as changes in the behavior of landowners and developers may bring about meaningful change in the effort to clean up the James River.

5. Recommendations

Recommendations are organized to include three major *goals* to work toward in relation to the research findings. Each goal is broken down into subsequent *objectives*, and then further into *actions*. Actions are specific recommended items the Department of Public Utilities may take to improve the future of stormwater quality.

5.1 Goals, Objectives, and Actions

Goal 1: Increase education about stormwater management

There are several benefits to stormwater management to private landowners outside of potential fee reductions including increased property values. Informing the public about stormwater management is a cost effective practice that allows private land owners to take part in long-term investments on their own accord.

Objective 1.1: Educate the public on the impacts of stormwater management

Water quality improvement is dependent on individual behavior changes. In order to create lasting change, the public must understand the significance of their actions. Through community outreach and educational campaigns people can make the connection between their individual choices and water quality. The goal is to bring awareness to the issue through repetition and redundancy in highly visible educational material.

- Action 1.1.1: Become a vendor at all major Richmond City Festivals to increase public exposure to stormwater issues in Richmond.

- Action 1.1.2: Create an educational campaign for selected areas within CSAs 5, 6, and 21 to teach property owners about their effects to Richmond's overall stormwater drainage system.

Objective 1.2: Educate commercial, multi-family, and industrial property owners and developers on their roles in improving water quality

Commercial and industrial property owners are found to disproportionately contribute to CSO events adversely impacting receiving water quality. Those with the authority to alter the ground cover of these properties would benefit from increased knowledge on the stormwater management techniques.

- Action 1.2.1: Create a comprehensive guidebook for stormwater GI and BMP costs and implementation that allows property owners to make informed decisions about techniques that would allow them to receive fee reductions.
- Action 1.2.2: Increase stakeholder participation through focus group development with targeted land owners to develop optimal solutions GI implementation.

<u>Goal 2: Commit to policy changes that will create assessable improvements to reducing runoff volumes</u>

Creating stormwater friendly retrofits for existing properties can be costly. Requiring significant infrastructure to capture or slow stormwater flows upon the development will reduce the burden of retrofitting properties and structures to stringent stormwater policies.

Objective 2.1: Require all new developments to participate in enhanced stormwater control measures

Creating a policy that requires all parcels to participate in drastic structural change to meet stormwater quality/quantity needs would not be feasible. Requiring new developments to participate in specific minimum stormwater controls allows for a change in the culture and would force a new stormwater focus in the region.

- Action 2.1.1: Require Leadership in Energy and Environmental Design (LEED) building certifications of new developments to assist in reducing adverse effects of less environmentally mindful options for developments other than affordable housing.
- Action 2.1.2: Require at least 20 percent tree canopy cover or green infrastructure area on each commercial, industrial, and multi-family parcel within CSA 5, 6, and 21 to reduce stormwater runoff from those properties.

Objective 2.2: Incorporate rainwater harvesting in future developments

Rainwater harvesting strategies use collected water from rainfall for recycle in non-potable uses. Harvesting rainwater captures water that would otherwise drain into the stormwater drainage system, and potentially contribute to the onset of a CSO event. Using cisterns, tanks, and rain barrels, new developments can construct means to collect and reuse water drained from impervious surfaces on their property.

- Action 2.2.1: Establish density thresholds for multi-family properties to require non-potable water reuse.
- Action 2.2.2: Require some form of rainwater harvesting on each new development, regardless of land use, to include small residential rain barrels.

Objective 2.3: Adjust stormwater utility fees to be more conducive to reducing impervious surfaces on critical properties

Stormwater fees provide DPU with the funding required to maintain stormwater infrastructure in Richmond. With growing obligations to improving water quality, DPU may increase stormwater fees for property owners that disproportionately affect water quality.

- Action 2.3.1: Create a more comprehensive stormwater utility fee calculation that incorporates percent impervious, as well as specific property impacts to CSOs.
- Action 2.3.2: Provide design recommendations to large commercial, industrial, and multi-family property owners that may reduce runoff and provide credits to landowners.

Goal 3: Create incentives that actuate real change in behavior

The research within this plan has identified key areas in Richmond that should be targeted for stormwater improvements. Measurable outcomes to stormwater runoff volumes are achievable if change occurs within smaller, more specified regions.

Objective 3.1: Develop policies to reward participation in green infrastructure development.

Stormwater gets little spotlight in public policy, but warrants more attention. Increased awareness and fee-reducing options for fee-payers may influence property owners to take part in reducing stormwater runoff from their properties. Increased participation of GI production will also create a growing market for GI services and suppliers.

- Action 3.1.1: Develop green roof rebate program where a portion of the initial cost of green roof construction is reimbursed through DPU.
- Action 3.1.2: Establish 1:1 rain garden plant grant, where for each plant purchased (maximum one per square foot), DPU supplements one additional plant to encourage GI retrofits.
- Action 3.1.3: Create and continually update public dashboard of ongoing GI projects to promote GI construction, and to compare costs and benefits.

Objective 3.2: Create an environment that promotes green infrastructure development through public support

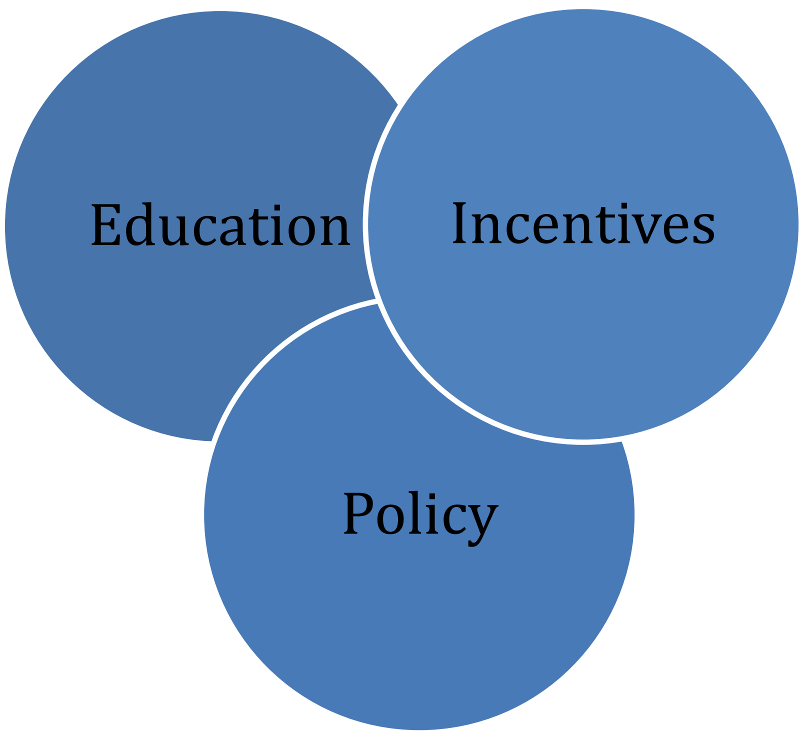
Private landowners are more likely to participate in GI and other LID projects if their local department of public utilities is highly supportive. People tend to be incredulous of the benefits

GI provide. With open support and high visibility of GI projects on public property, landowners may understand its success and benefits to the community.

- Action 3.2.1: Employ individual parcel assessors to determine accurate stormwater fee calculations and simultaneously promote GI and LID developments, to increase physical presence and awareness to stormwater issues.
- Action 3.2.2: Continue developing public GI projects to allow the public to become familiar with GI, and to promote its successes.
- Action 3.2.3: Create and update ongoing GIS-based data inventory to include base data, data on existing GI and LID projects, and data on potential sites for implementing new BMPs to continually assess future potential options for GI development.

6. Implementation

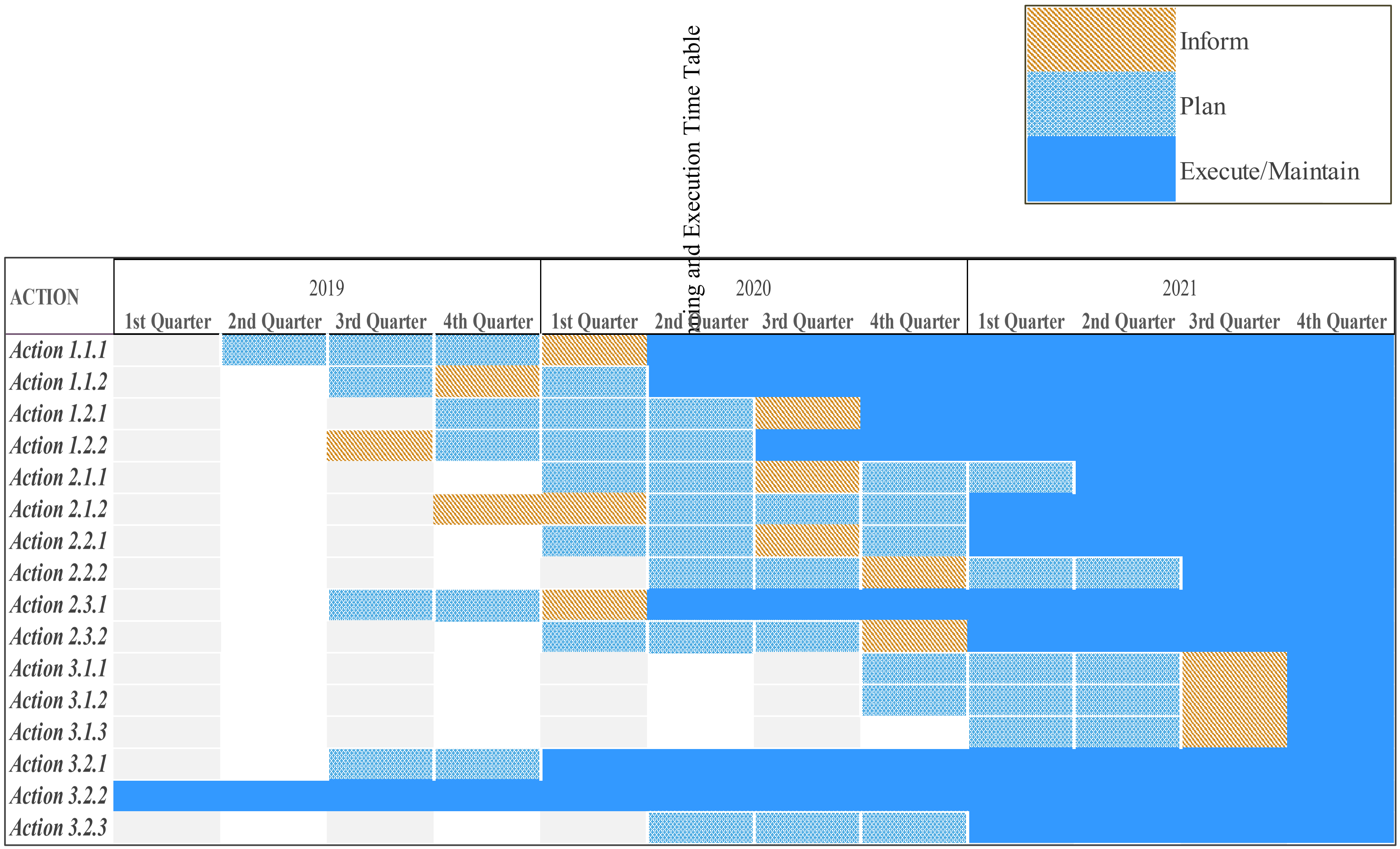
The implementation section is designed to aid the Richmond Department of Public Utilities in positioning themselves to carry out the above recommendations. This includes research and planning resources that may be referenced to assist in decisionmaking as it relates to recommended actions. The Green Infrastructure Initiative Plan focuses on three primary goals, education, incentives, and policy.



6.1 Recommended Actions Time Table

The table below (Table 6-16) displays a recommended timetable for each action to begin. Phases include *inform, plan, and execute/maintain. Inform* involves actions taken to warn and post public information to relevant audiences to allow the public to prepare for upcoming policy changes. Recommended actions such as Action 2.1.2 and Action 2.1.3 require existing property owners to make changes to their properties that may take time to prepare for. The *plan* period includes preparing, researching, and refining the implementation of each action. No single action should be implemented without an extensive understanding of exterior consequences. The *execute/maintain* period marks the actual occurrence of each action, and each action should be assessed and refined as unexpected hurdles and events are inevitable.

nning and Execution Time Table



6.2 Potential Funding Opportunities

Several federal and state agencies offer potential funding to green infrastructure development projects dependent on eligibility and availability of funds. Agencies which have historically contributed to GI programs include the U.S. Environmental Protection Agency (EPA), U.S. Housing and Urban Development (HUD), Federal Emergency Management Administration (FEMA), U.S. Department of Transportation, U.S. Department of Agriculture, U.S. Department of the Treasury, U.S. Department of Energy, and the National Park Service, and the U.S. Department of Commerce. As the Richmond Department of Public Utilities expands their scope of GI programs, these federal agencies should be considered for potential funding opportunities.

The funding program below indicates criteria most closely associated with the Green Infrastructure Initiative plan as well as related eligibility requirements:

HUD Community Development Block Grant Program

Local governments seeking to provide affordable housing, suitable living conditions, and economic development may be eligible for this grant. Suitable living conditions by definition for this grant include conditions related to the environmental cleanliness and flood mitigation. The scope of this grant may be narrowed to the three combined sewer drainage areas identified in the Green Infrastructure Initiative Plan. Criteria for the use of this grant program needs to cater to residents with lower incomes and poorer living conditions.

6.3 Educational and Funding Resources for Private Landowners

Local to the Richmond area, private landowners have several resources at their disposal to learn more and become a part of effort to reduce stormwater runoff and improve overall environmental quality. The Department of Public Utilities should take full advantage of these resources as the goals of some non-profit and private organizations have many congruencies. Programs specifically geared toward the goals in the Green Infrastructure Initiative Plan include:

Restoring the Environment and Developing Youth (READY), *Alliance for the Chesapeake Bay*

READY helps young people with job skills in the stormwater control field. Participants receive training on the construction and maintenance of stormwater control measures and also become informed on local environmental problems. The project is twofold, to help raise awareness and emphasis on the importance of stormwater controls and the growing need for a job market in this field, and also to provide underprivileged youth with job training.

Online Yard Design Tool, *Alliance for the Chesapeake Bay*

This tool provides specific instructions for landowners interested in constructing green infrastructure on their property. The tool asks a series of questions on GI preferences and lot dimensions to include existing spaces. Following the questions the user is exposed to several resources neatly embedded to allow the property owner to become her own GI builder.

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